

*PRODUCTION/INVENTORY
MANAGEMENT IN A
FLOW PRODUCTION
ENVIRONMENT*

BY

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*PRODUCTION/INVENTORY MANAGEMENT
IN A FLOW PRODUCTION ENVIRONMENT*

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*Submitted in fulfillment of the requirements
for the degree of*

MASTER OF COMMERCE

in the Department of

BUSINESS ADMINISTRATION

UNIVERSITY OF NATAL

SUPERVISOR : MR J D MACDONALD

1991

I declare that "Production/Inventory Management in a Flow Production Environment" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged.

V HERMELIN

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A B S T R A C T

A modular model named "Total Inventory Planning and Flow Control" is developed to better plan and control a manufacturing environment.

The research into the philosophies, ideas and tools used by two apparently conceptually different manufacturing systems - Manufacturing Resource Planning and Just-In-Time - shows that:

- * The main goals of Manufacturing Resource Planning and Just-In-Time are very similar;
- * There appears to be different tools used by the two systems, Manufacturing Resource Planning and Just-In-Time;
- * The two systems have different approaches to some of the manufacturing factors;
- * Both, Manufacturing Resource Planning and Just-In-Time, have "blind spots" in their system;
- * By combining selected complementary philosophies, ideas, concepts and tools from the two systems, a synergistic affect is created that overcomes the differences between the systems and covers the "blind spots" which occur in each system separately.

ACKNOWLEDGEMENTS

I wish to express my gratitude to :

- Mr D. J. MacDonald for his advice, guidance and encouragement while writing the dissertation.
- Toyota S.A - Quality department for supplying me with information about their manufacturing systems.
- Miss S. Wagner for her assistance in the editing of the dissertation.
- Mrs S. Naidoo for assisting with the typing of the dissertation.

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Chapter 1. THE IDENTIFICATION AND STATEMENT OF THE PROBLEM.

1.1 Introduction

=====

Consideration of the current situation in the South African Textile Industry in Natal has made it clear that there is a need for a more effective form of inventory planning and flow control. A study of the literature has revealed that there are two different approaches to the management of manufacturing industry; *Manufacturing Resource Planning* and *Just-In-Time*. It would appear that significant benefits can be obtained from the integration of the two systems.

1.2 Statement of The Problem

=====

Two main systems have been developed and used in advanced companies in a variety of industries, backed by different approaches, philosophies and techniques. *Manufacturing Resource Planning* has had considerable success in those companies where all the necessary disciplines and infrastructure are in place. *Just-In-Time* requires an environment with certain definable characteristics if it is to be successfully implemented. A suitable environment for *Just-In-Time* exists predominantly in repetitive production systems. Failure to appreciate the importance of the production

environment in determining the choice of system to be used has led to:

- * Uncertainty and disagreement as to which system to apply in the different industrial environments.
- * Difficulties and disagreements by management in identifying the reasons for the incomplete achievement of the anticipated benefits from either of the systems.
- * The *Just-In-Time* system was implemented mainly in Japan.
- * Both systems have "blind spots" in their conceptual and philosophical base which creates the possibility of achieving significant benefit by integration of features from both systems to overcome the blind spot. It is from this last statement that the purpose of the research arises.

1.3 The Purpose of the Research

=====

The research purpose is to develop an integrated model combining two existing philosophies; *Manufacturing Resource Planning* and *Just-In-Time* that will overcome contradictions between the systems and exploit the synergistic effects which can be gained from their integration.

1.4 Relevance of The Research.

=====

There is a move taking place in manufacturing from high volume, process related, operations to complex make-to-order operations. These require that the management of organisations affected in this movement adopt an appropriate manufacturing management system. A decision to adopt the *Just-In-Time* system might cause disappointment, because a make-to-order environment is potentially opposed to optimal use of the *Just-In-Time* system. *Manufacturing Resource Planning* is orientated towards a batch production type of environment and it would therefore, appear to be the most appropriate system for use in a make-to-order environment. However, *Manufacturing Resource Planning* is designed to operate optimally in a relatively active demand situation, implying a degree of rigidity which is not acceptable in a very volatile demand situation such as that found in a make-to-order

environment. What is needed is a flexible and less rigid model, which combines the best characteristics of both systems. Such a model can lead the manufacturing processes to the desired goal. A secondary reason driving the research is illustrated by the motto "Let your great objective be Victorious". Any model or system which can assist management to achieve and maintain higher levels of manufacturing performance, should be welcomed. It would be even more acceptable if the new model is a combination of all or some of the methodologies and techniques in the existing body of knowledge, expanding the use of skills, in order to integrate all manufacturing efforts towards the same goal.

1.5 Hypotheses.

=====

The initiation of the research was based on two main hypotheses which will be validated during the course of the research.

The first hypothesis is that it is possible to overcome the apparent conflicts between *Manufacturing Resource Planning* and *Just-In-Time*, as there is nothing in either system that precludes using the other.

The second hypothesis is that the merger of *Manufacturing Resource Planning* and *Just-In-Time* will create a synergistic affect.

1.6 The Structure of The Dissertation.

=====

- * *Chapter 1* Identifies the aim of the research and states the problem.
- * *Chapter 2* Introduction to production planning and inventory control.
- * *Chapter 3* A study of the *Manufacturing Resource Planning* system.
- * *Chapter 4* A study of the *Just-In-Time* system.
- * *Chapter 5* An analysis of and comparison between, *Manufacturing Resource Planning* and *Just-In-Time*. Development of a strategy to be used in the solution to the problem.
- * *Chapter 6* The proposed Model.
- * *Chapter 7* Summary and conclusions of the research.

1.7 The Limitations of The Research.

=====

It is accepted that certain aspects are external to the system and not within the scope of the research. These limitations are:

- * The research will not refer to the following aspects in the model: Marketing, Purchasing, Cost accounting and Customer service.
- * The research will not attempt to develop a fully

detailed model, but to structure and emphasise the main points and ideas in practice. Each implementation will have to tailor more details to the main structure in order to succeed in the individual attempt.

- * The research will not attempt to apply the model to a specific organisation or industry, but will try to prove viability to industry in general operating in a realistic environment.

Chapter 2. INTRODUCTION TO THE BASIC PRINCIPLES AND TECHNIQUES
OF PRODUCTION PLANNING AND INVENTORY CONTROL
SYSTEMS.

2.1. Introduction to Production Planning and Inventory
Control Systems.

After World War II, American and Japanese
manufacturers, although operating under totally
different circumstances, started to search for
improved ways to plan production inventories. They
strove to satisfy the customer and still make money
- the goals for the survival of every industry.

America emerged from the war as the industrial leader
of the world and sought more scientific systems to
improve production and control inventories. Although
some "scientific management" methods had already been
developed by Taylor, Galbraith and Ford in the
beginning of the century and fifties for application
in assembly lines, management needed to look for a
complete system to manage and control orders from
booking to despatch. Industrial engineering and
process improvement issues had already been tackled
and attention then turned to improving the systems for
planning and scheduling work flow and the control of
inventories and production. The new approach
stimulated the development of the operations research
concept and drew scientists from a wide range of

disciplines into problem solving. Out of a chaotic production environment, driven by the needs of war, a variety of techniques emerged of which some are shown in table 1.

Name of Technique	Abbreviation
Re-order Point	- <i>ROP</i>
Economic Order Quantity	- <i>EOQ</i>
Lot Sizes	- <i>LS</i>
Material Requirement Planning	- <i>MRP I</i>
Capacity Requirement Planning	- <i>CRP</i>
Shop Floor Control	- <i>SFC</i>

Table 1 Production and inventory control techniques and their abbreviations. (Source: various authors)

The combination of these techniques led the Western World to develop Manufacturing Resource Planning which will be discussed in detail in chapter 3. While the Western World was implementing these various techniques, Japan was developing different areas and focusing on Automation, Group Technology and Statistical Quality Control. These areas of focus can be defined as follows:

- * *Automation* - A concept applied in industry to reduce the use of human labour in the manufacturing process to the minimum;

- * *Group Technology* - A technique to eliminate waste in order to reduce inventory. Group Technology is a special layout of machines rearranged so as to be dedicated to a certain family of parts. A work centre is not identified by the nature of machines e.g drill; lathe; grinder, but by the kind of product produced in the work centre, for example Cylindrical parts between 5 and 15 cm in length;

- * *Statistical Quality Control* - Uses statistical sampling and frequency distribution to monitor the level of quality in the production process.

Japan, led by Toyota, was working on a manufacturing strategy to be known as Just-In-Time (JIT) production. The Just-In-Time system utilises a selection of specific techniques to be discussed in chapter 4.

The objective of this dissertation is to establish the degree to which these two apparently disparate approaches to the problem of managing a productive system, can be integrated creating a synergistic affect. Before the possibility of integration can be discussed, it is necessary to discuss the individual

systems in some detail. Manufacturing Resource Planning will be discussed in chapter 3, and Just-In-Time in chapter 4.

CHAPTER 3. MANUFACTURING RESOURCE PLANNING - MRP II

3.1 Introduction

=====

The initial thinking which eventually led to the development of Manufacturing Resource Planning was the work of Orlicky(1975) and Wight(1981). Orlicky concentrated on the development of the concept of independent and dependent demand and the extension of this concept to the time-phased order point resulting in a set of techniques called Material Requirements Planning. Wight's main contribution was to adopt the Material Requirements Planning approach, extend it to Capacity Requirement Planning, and ultimately integrate it with all the associated functions to yield Manufacturing Resource Planning. Because of the seminal nature of the work of Orlicky and Wight and the extent to which they later became involved in publicising the concepts of Manufacturing Resource Planning, it is inevitable that much of this chapter will be based on their work.

Manufacturing Resource Planning (MRP II) was developed as a set of modules [Figure 3.1] which together make up the system. The modular nature of the system ensures its flexibility and its adaptability to all kinds of manufacturing.

MANUFACTURING RESOURCE PLANNING (MRP II)

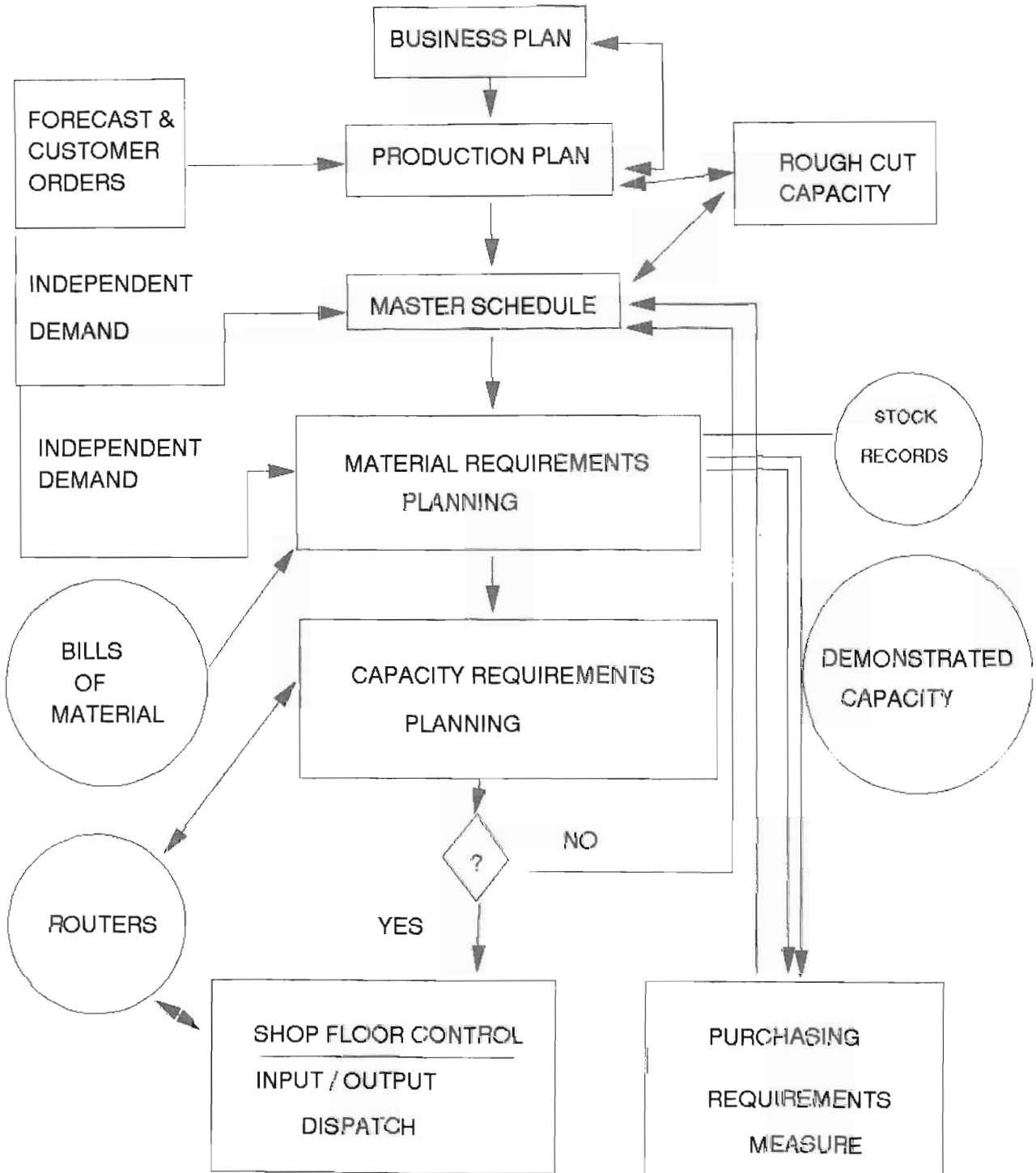


FIGURE 3.1 MANUFACTURING RESOURCE PLANNING (MRPII)

OLIVER WIGHT EDUCATION ASSOCIATES, INC

CLASS "A" education: MRPII (revision)page oww 19.

The concept of Manufacturing Resource Planning is based on the three underlying techniques:

* *Material Requirements Planning - MRP I*

The objective of Material Requirements Planning is to determine gross and net requirements in discrete time periods of demand for each item of inventory so as to be able to generate the information needed for correct inventory order action. Another simple way of expressing the objective of Material Requirements Planning is that it aims to answer the basic questions:

- *What to order (or produce)?*
- *How much to order (or produce)?*
- *When to order (or produce)?*
- *When to schedule delivery?*

* *Capacity Requirements Planning - CRP*

The objective of Capacity Requirements Planning is to determine how much capacity is needed and when, and if enough capacity can be acquired. Capacity Requirement Planning is the module that looks at the shop schedule - which represents the schedule of jobs on the shop floor - and uses the routings of each product and all products together to determine the amount of standard hours required to complete the production of all products.

* *Shop Floor Control*

- *SFC*

The objective of Shop Floor Control is to give the system information and control over what is happening on the shop floor. It is a set of documentation originating on the shop floor stating what has been done in each work centre, and how much inventory is available in the various intermediate stores. The data is fed into a computerised system for comparison against plans to create correction factors for the next shop schedule.

Because of the seminal nature of the work of Orlicky and Wight and the extent to which they later became involved in publicising the concepts of Manufacturing Resource Planning, it is inevitable that much of this chapter will be based on their work.

3.2 The Manufacturing Resource Planning System

=====

In order to understand the complexity of the Manufacturing Resource Planning system and the various modules, it is necessary to briefly explain the main modules as shown in figure 3.1 which represent the full Manufacturing Resource Planning system. In order to keep a completely clear picture of the system some degree of repetition of the previous chapter will occur in this chapter in the exploration of the system modules and the connections between them. The main modules of the system are:

Business plan - The Business plan is a process in which management establish where the company is, and where it should be. Management set objectives and establish accountability and policies.

Production plan - In this stage production rates, the control inventory levels and purchasing rates are set.

Master schedule - The Master Schedule controls the overall mix of the above rates.

Material requirements planning - Breaks the mix of rates into detailed schedules for raw materials and components.

Capacity requirement planning - Breaks the schedule into standard hours required to achieve the production plan.

Shop floor control - Generates reports that monitor the output and inventory against capacity plans.

3.2.1 Business Plan

Companies must develop business plans that will guide all the departments towards the same final goal. The business plan as defined by Wight[67: 55,254] should cover the following aspects:

Define the market the company serves - what markets or market niche the company wants to serve. Develop long range strategic plans for market development which may involve changes in the target population, discontinuation of a line of products or move to a new line of products.

Establish product development policies including the development of current products in order to improve processes, service or sales. Development of new products to enter into new markets or as replacements to existing ones.

Establish strategic plans for manufacturing resources such as machinery, workforce and raw materials.

Define financial resources including loans from banks, raising funds through the stock market and investment

of funds from the stakeholders.

It is also necessary to *establish goals of quantity and timing* for sales volumes, investments and profits as well as *guidelines and policy* for production planning and measurement criteria.

3.2.2 The Production Plan

Wight[67: 145,158] defines the production plan is a sub-system used to establish manufacturing rates to provide support for sales while taking into consideration constraints of financial resources and engineering support capacity. The production plan states a production rate, usually in terms of units, but sometimes in terms of money, or even in terms of other general measures. The purpose of the production plan is to give management a broad planning view and it is usually made over a two or three year period. The production plan provides the basis for monitoring actual sales, production, and the resulting inventory. The connection between the elements is well illustrated in figure 3.2 .

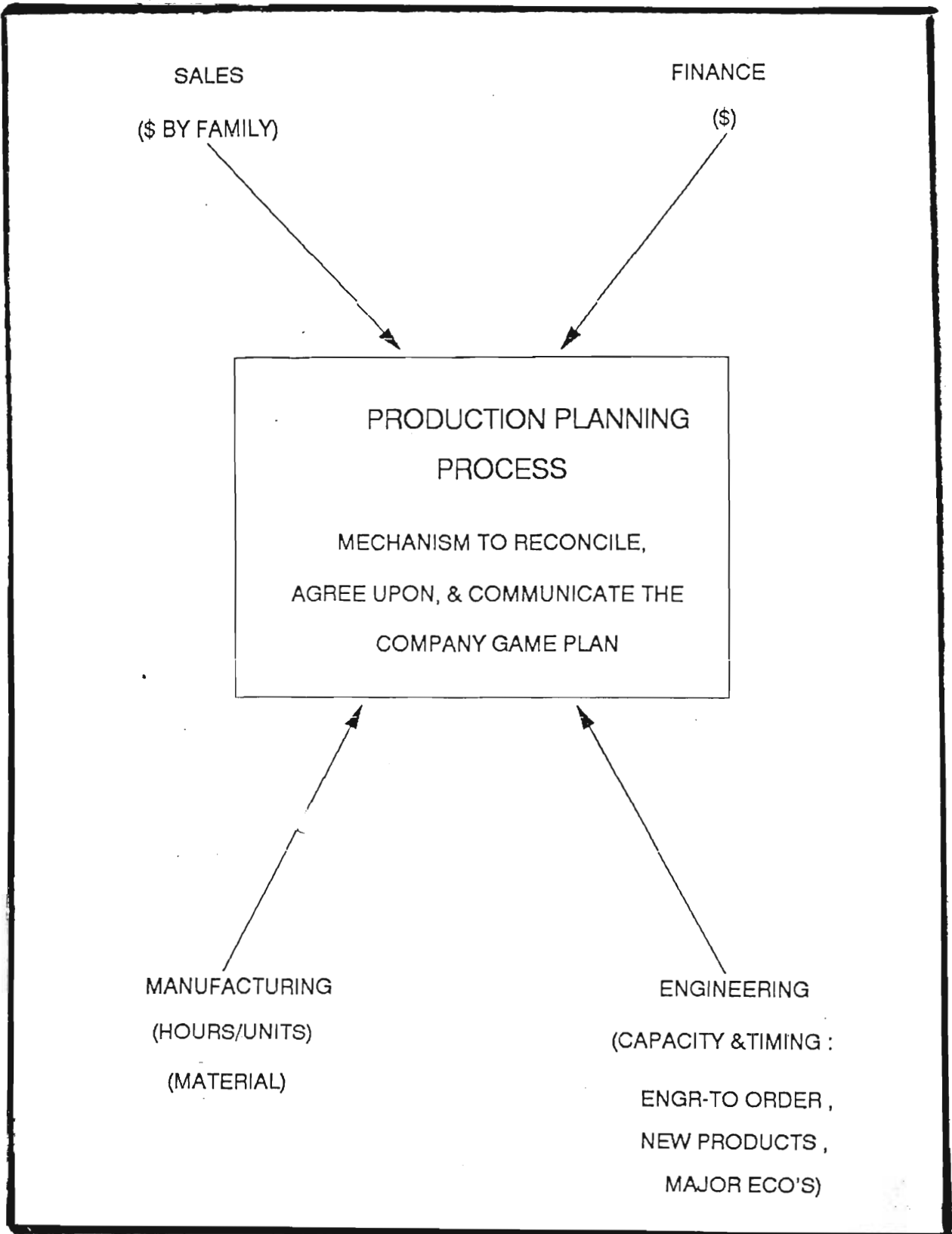


Figure 3.2 THE PRODUCTION PLANNING PROCESS

(Source: Wight [70:14]).

3.2.3 Master Production Schedule (MPS)

"The master production schedule is a statement of what will be produced. It takes management policy, as expressed in the production plan, and breaks it down to the detailed level" Wight[67: 165,199]. The master production schedule anticipates how the information schedule is to be developed and consists of firm planned orders for certain end items, components, and finished goods. The master production schedule is usually stated as specific item numbers, specific quantities and specific dates. The master production schedule is prepared and thereafter at regular intervals, weekly or monthly, a new increment is to be adjusted into the basic one. The master production schedule converts the production plan into days and weeks in order to generate priority plans which must be stated in terms of these periods. The master production schedule can be changed if sales do not meet their forecast for a certain period, when there are machine breakdowns or when vendor delivery problems occur.

3.2.4 Rough Cut Capacity Planning

Rough Cut Capacity Planning is the module which originates a report stating, in standard hours by time period, what capacity will be required at each work

centre to make the production plan achievable. Wight [67:199] defines the purpose of Rough Cut Capacity Planning as:

- " 1. Size capacity requirements of the production plan prior to master scheduling.*
- 2. Size capacity requirements of the master production scheduling prior to detailed material planning."*

In order to generate the rough cut capacity report the master schedule must be run against the routings and the list of work centres available. The routings specify the sequence of operations to be processed and the standard time required for each operation. The work centre list is a list of possible work centres. A work centre can be a machine, a group of machines, a person, or a group of people with the same production capacity.

3.2.5 Bill Of Material (BOM)

The Bill Of Material according to Wight[67: 276,283] is a fully centralised schedule detailing the structure and quantities of the components, sub-assemblies, assemblies, as well as providing the detailed interrelation between them for each product made. It is used by engineering, costing, manufacturing and planning. Figure 3.3 provides an illustration of the hierarchical levels, quantities of

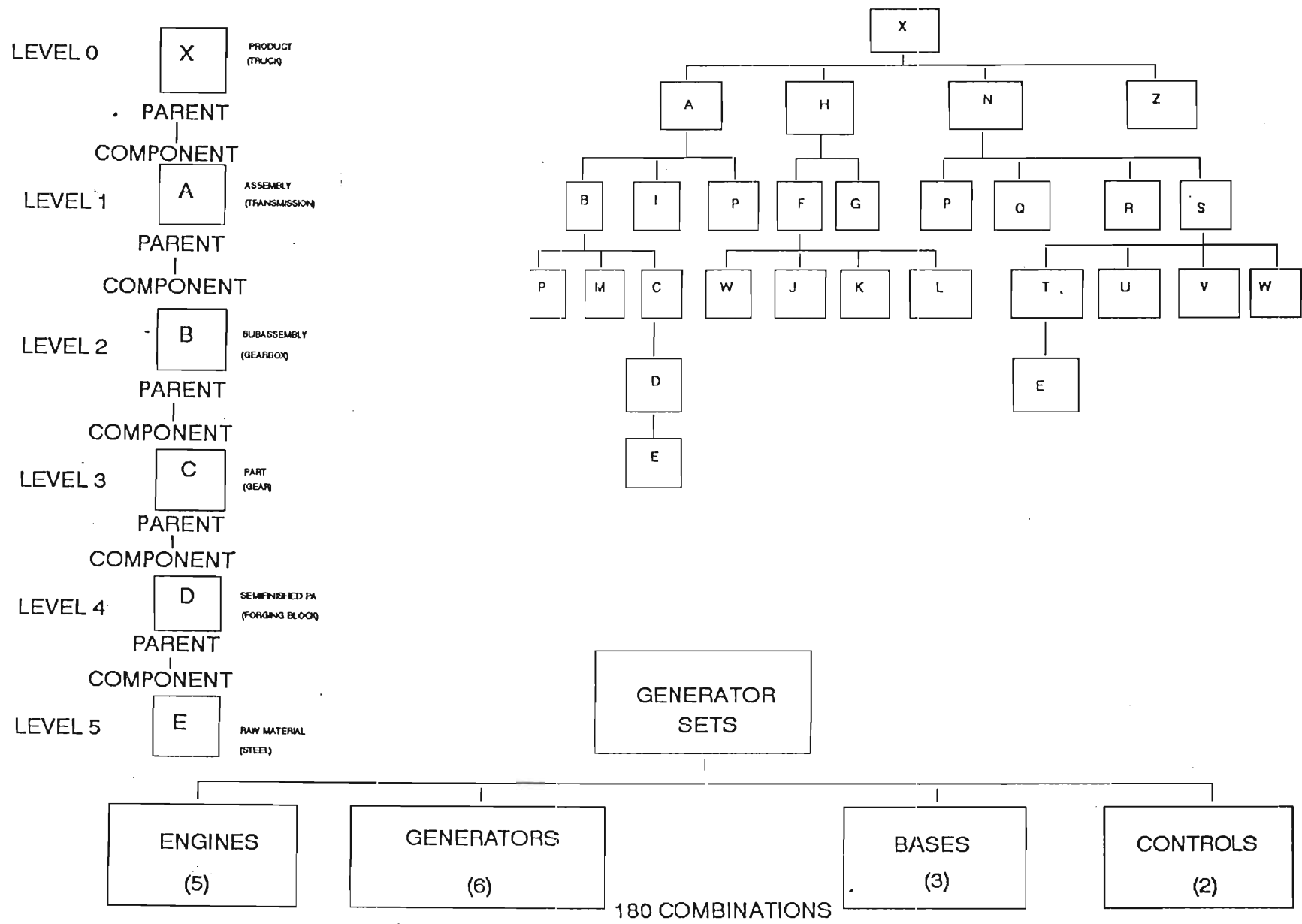


FIGURE 3.3 HIERARCHY OF BILL OF MATERIAL AND PARENT COMPONENT RELATIONSHIP

parts and sub-assemblies that make up the Bill Of Material.

3.2.6 Material Requirement Planning (M.R.P I)

According to Wight and Orlickey [67:200] Material Requirement Planning is based mainly on stock inventories and manufacturing orders. As inventories have a major role in the system a set of inventory system categories should be established. Inventory is defined as follows :-

Raw material - usually raw material purchased from a supplier and used as a basic material to produce parts;

Semi-finished component parts - raw materials that have been processed but still have to undergo more processes before they can be called a finished part;

Finished component parts - components gone through all the routed processes and available for assembly;

Sub-assemblies - amounts of components assembled together, but not yet a final product;

Component parts in process - raw materials in one of the processes to become a component part;

Sub-assemblies in process - sub-assemblies in one of the processes that will combine sub-assemblies to make the final product.

Inventory management comprises of the functions as shown in table 3.1.

1. Planning
 - 1.1 Inventory policy
 - 1.2 Inventory planning
 - 1.3 Forecasting
2. Acquisition
 - 2.1 Positive order action
 - 2.2 Negative order action
3. Stock keeping
 - 3.1 Receiving
 - 3.2 Physical inventory control
 - 3.3 Inventory accounting
4. Disposition
 - 4.1 Scrap and write off of obsolete items
 - 4.2 Delivery-on-demand services.

Table 3.1 Inventory management
(Source: Orlicky[45:17])

In addition to the full inventory system the following sub-systems and assumptions must be made to form a complete Material Requirement Planning (MRP I) system:

A Master Production Schedule should exist, in other words, what is to be produced must be known. All inventory items should be uniquely identifiable, meaning that each of the inventory items is defined in such a way that it is unique to that specific part only.

A Bill of Material exists; the levels, parts and sub-assemblies that together make the final product are known. Individual item lead times and standard manufacturing times are known. Discrete usage of component materials, the exact amount of each part component used to make a sub-assembly or the final product is known.

The routing of each raw material, sub-assembly and part component in the process is set and identified.

These modules, create the first layer of the total system and their interrelations are demonstrated in figure 3.4 .

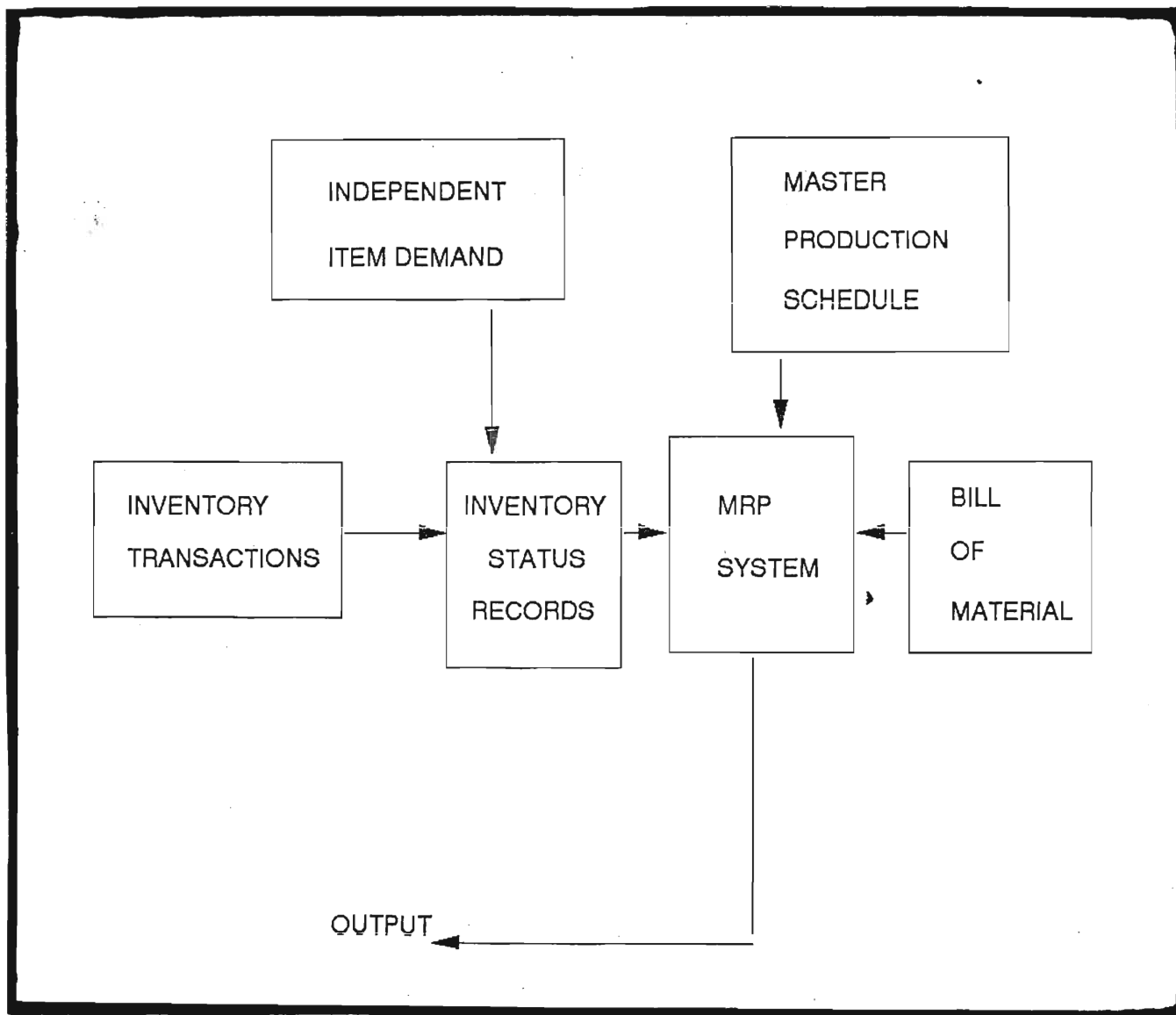


Figure 3.4 Material Requirement Planning system: input output relationships. (Source: Orlicky [45:13]).

3.2.7 Capacity Requirements Planning

The objective of Capacity Requirements Planning is to determine the need to;

* *Work overtime* when the number of operator hours required to produce the planned output is more than the amount of hours worked in normal time.

* *Transfer work from one department to another* - in order to balance the load on operators or machines, some of the work should be transferred to under-loaded areas. Transfer an operator from one area to another to balance the load on operators.

* *Subcontract work* - if the number of hours needed to complete the job exceeds the normal working hours and overtime is not allowed then the help of outside contractors must be used.

* *Hire more people* - in case the hours needed to perform the work are insufficient and no contractors are available, increasing the complement of operators can be considered.

* *Start new work* - if the capacity of the machines and operators exceeds the amount of work presently performed then new work should be considered.

Capacity Requirements Planning is the tool that validates the load projection. Calculation of loads and capacities is done on a work centre level. While a work centre can be a machine or operator, the dominant capacity will be determined by the relative connection between them. For example - when several operators are working on one machine at the same time or one operator operates several machines at the same time, the dominant capacity in the above cases will be the machine capacity. In case where one operator operates one machine or one operator performs a specific task not related to a machine, then the operator capacity will dominate.

3.2.8 Shop Floor Control

Shop Floor Control is a set of techniques that gives the system information about, and control over, shop floor performance. In order to achieve the required control, information must be fed back regularly from the shop floor. This requires the establishment of a formal system which collects and analyses data from the shop floor to paint a coherent picture on which management decisions can be based. Such a system frequently includes reports such as an input control report (figure 3.5a), an output control report (figure 3.5b), an anticipated delay report (figure 3.6) and a valuing work-in- process report (figure 3.7).

INPUT/OUTPUT CONTROL

WORK CENTRE NUMBER: 40	DATE: 2/22
DEPARTMENT NUMBER: M	
WORK CENTRE DESC: DRILL	ACTION MESSAGE : INPUT UNDER/OVER

A.

INPUT

WEEK	-4	-3	-2	-1	THIS WEEK	2/27	3/6	3/13	3/20	3/27	4/3	4/10
PLAN IN	115	115	115	115	115	115	115	115	115	115	115	115
ACTUAL IN	100	125	80	132								
CUM.DEV.	15	-5	-40	-23								

TOLERANCE : 30 HOURS

B.

OUTPUT

CORRECTIVE ACTION: WORK WEEKENDS

WEEK	-4	-3	-2	-1	THIS WEEK	2/27	3/6	3/13	3/20	3/27	4/3	4/10
PLAN OUT	115	115	115	115	115	115	115	115	115	115	115	115
ACTUAL OUT	120	95	90	90								
CUM.DEV.	+5	-15	-40	-65								

TOLERANCE: 30 HOURS

PLANNED Q 50 HOURS

ACTUAL Q 105 HOURS

Figure 3.5 (a & b) INPUT / OUTPUT CONTROL.
 (Source: Wight [70;(spc 17)]).

Figure 3.5(a) records the actual input into a work centre against the planned input. A relevant performance history of the work centre and an accepted tolerance which does not effect the full plan are also found in the report. Figure 3.5(b) records the actual output of the work centre with a performance history and acceptable tolerance.

The anticipated delay report, an example of which is shown in Figure 3.6, is designed to bring an anticipated delay in the production of an item at a particular work centre to the notice of management. Parts which are anticipated to be delayed are detailed by shop order numbers, the original due date, the reason for the anticipated delay, the action to be taken to minimise the effect and the new date anticipated for delivery.

ANTICIPATED DELAY REPORT					
WORK CENTER 40					
DATE 2/17					
SHOP ORDER	PART NO.	DUE DATE	CAUSE	NEW DATE	ACTION
145	4422	2/20	FIXTURE BROKE	3/2	

Figure 3.6 ANTICIPATED DELAY REPORT
(Source: Wight [70,(spc 20)]).

The Anticipated Delay Report is designed to bring an anticipated delay in the production of an item at a particular work centre to the notice of management.

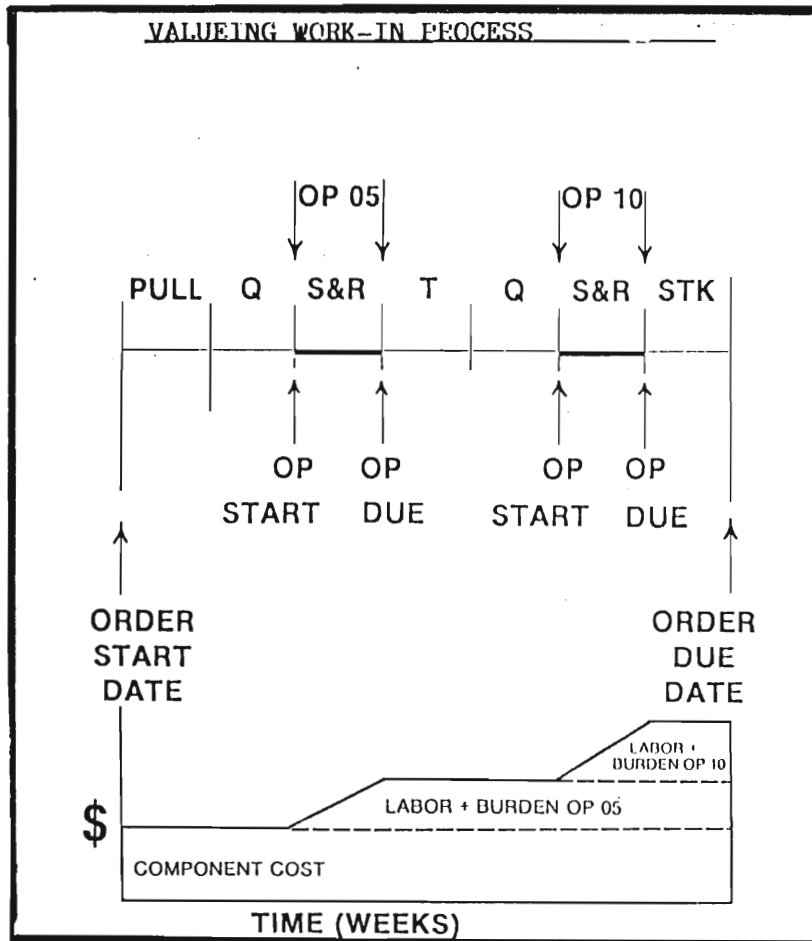


FIGURE 3.7 VALUEING WORK-IN-PROGRESS

(SOURCE : WIGHT [70, (spc 21)]).

Figure 3.7 VALUEING WORK-IN-PROGRESS

(Source: Wight [70,(spc 21)]).

The valuing work-in-progress report charts the values of the work-in-progress of an order in each process through the time scale. It indicates the amounts (in money value) allocated to the cost of the component for labour in each of the processes of that operation. The integration between Capacity Requirements Planning and Shop Floor Control is illustrated in figure 3.8 . The figure shows that the Master Schedule incorporated with Rough Cut Capacity, Material Requirements Planning and in conjunction with the work-in-process, drive the Capacity Requirements Planning. The Capacity Requirements Planning elements such as routes and standards, Work Centre Capacity Report and detailed Capacity Plan are the basis for the generating of job orders to the shop floor. After the jobs had been carried out, the shop floor sends back data which is essential for the generation of the Shop Floor Control reports such as Input/Output Control, Despatch Lists and Anticipated Delay Report. These reports will ensure that the next rescheduled production plans are based on more accurate data. These last two modules when added to the first module of the system (MRP I) close the loop between planning and the shop floor.

CAPACITY REQUIREMENTS PLANNING AND SHOP FLOOR CONTROL OVERVIEW

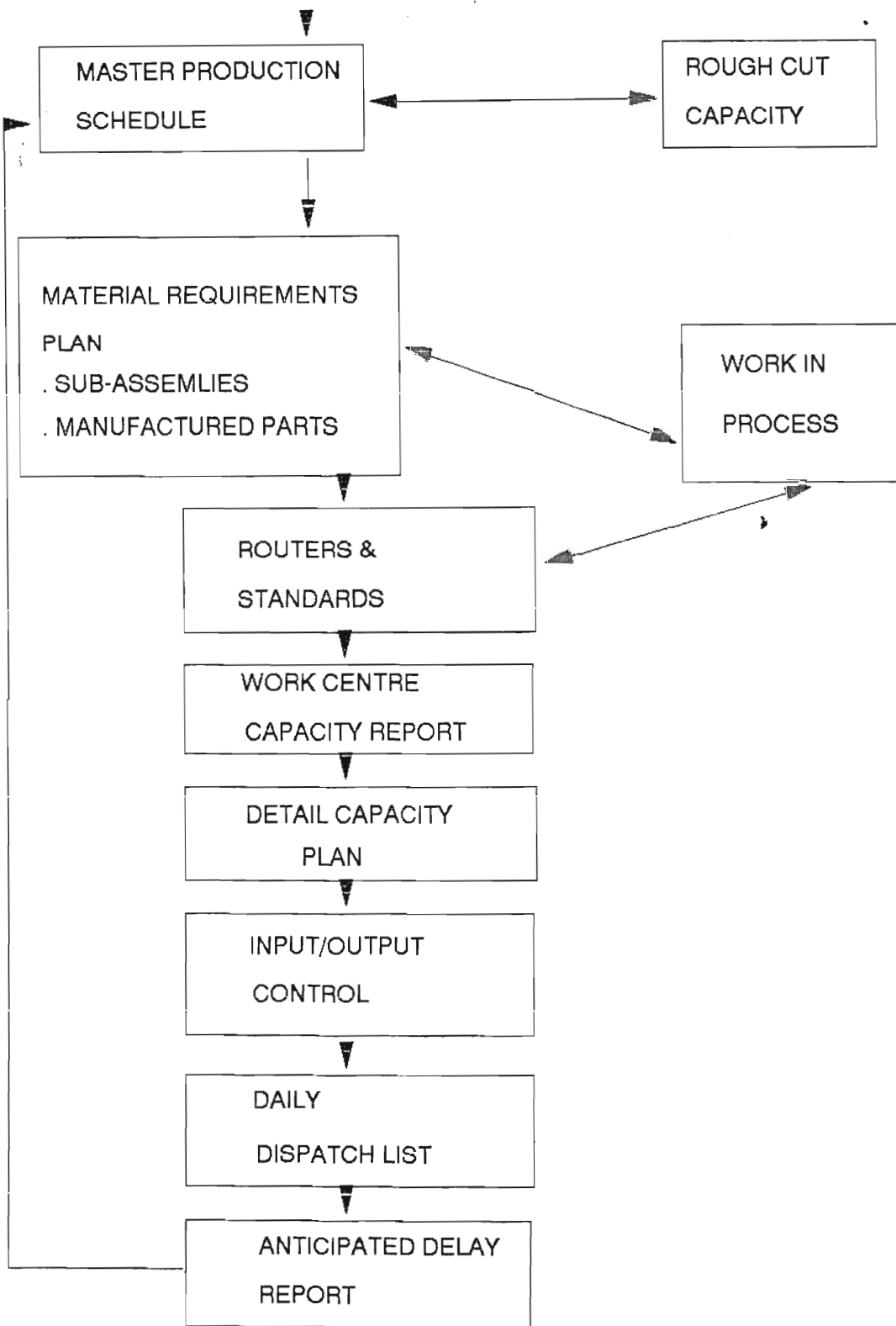


Figure 3.8 Capacity Requirements Planning and Shop Floor Control (Source: Wight [70,(crp 4)]).

3.2.9 Purchasing

The purchasing operation in the system makes sure that the raw materials and component parts needed for production will be available at the right time in the correct quantities. The steps performed for purchasing are as follows:

Negotiations with suppliers - purchasing must negotiate with various suppliers on price, quality of the items supplied, lead times and other conditions that may have an effect on the final product or the operation;

Capacities of suppliers - purchasing should establish the capacity of the supplier, can the supplier adhere to his commitment and what will happen should the orders be increased;

Material availability - check availability of raw material, check for substitute in case of shortage, check stocks on hand;

Order placement - after the selection of the most suitable supplier, and the establishment of the quantities needed and delivery times, an order must be placed with that supplier;

Follow up - It is the duty of purchasing to ensure that deliveries are made on time, that pricing is correct and that all documentation is up to date.

3.3 Summary

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Following the presentation of the modules and examination of the sub-systems including their interactions, it can be stated that "Manufacturing Resource Planning" is about managing production, purchasing, inventories, cash flow, and return on investment. Wight[67: xiii] summarises "Manufacturing Resource Planning" as follows:

"It is about tying marketing planning, manufacturing planning and financial planning into a company plan that can be executed and monitored. It is about improving the effectiveness of engineering and marketing and delivery performance"

It was pointed out in chapter 1 that the objective of this dissertation is to develop a model intergrating Manufacturing Resource Planning with the Just-In-Time system of production and inventory management.

Having discussed Manufacturing Resource Planning in the current chapter the next chapter will discuss the Just-In-Time system.

CHAPTER 4. JUST-IN-TIME

4.1 Introduction

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After World War II Japan was faced with tremendous problems forcing them to establish a set of strategies to try and overcome the problems as soon as possible. Loebel [39: 152,154] summarises the reasons and the steps taken by the Japanese to overcome their problems as follows;

On the human relations side they attempted to eliminate unemployment through industrialisation, the goal being to attain full employment within a happy working environment;

On the industrial side the Japanese recognised that they were at a disadvantage in some areas, in particular;

- a lack of raw materials
- little space
- quality problems
- productivity problems.

The low quality of Japanese products was the first issue to be addressed. Because of quality problems the label "Made in Japan" was a cause for concern. The

United States of America, a potentially important market, insisted on the display of the origin of every imported product on the packaging so that Japanese products could be easily identified. Japanese companies like Toyota resolved to address the quality problem. They decided to implement quality standards which would enable them to produce a product of such quality and reliability, that it could not be matched by their competitors.

The Japanese recognised that low cost and higher productivity go hand in hand. Therefore, the next issue to be resolved was low productivity. Japan's most talented engineers, together with employees from the lowest levels and upwards, were trained in Industrial Engineering. These teams recognised that stability of manufacturing and a balanced work load are major contributors to an increase in productivity. Finally, as Japan had neither time nor money to spend on technological development, they entered licensing agreements to import the required technologies and machinery to manufacture products for the markets they had decided to dominate.

Driven by these decisions and strategies, Japanese manufacturers embraced a different approach from that of American manufacturers. They combined all the technical manufacturing skills, that is:

Production ; Inventory control ; Quality Control ; Manufacturing Process ; Engineering ; Industrial Engineering ; Material Handling and Purchasing. In this way they established a new system to resolve their problems and to drive them towards first-class manufacture.

These leading teams considered the reduction of manufacturing costs as an equally important goal. This guided them towards basic concepts such as;

- elimination of waste;
- production of items that are ready when they are needed;
- use of balanced "Assembly Lines" as the most efficient way to produce.

The above concepts were put into practice, making use of a systematic approach. A set of guidelines was developed to assist management to implement the concepts such as; use of the 'pull' method instead of 'push' method, elimination of queues and material handling. A detailed list of the guidelines is given in table 4.1.

It was imperative for the Japanese manufacturers to ensure a highly reliable, low cost and good quality product in order to change customer attitudes and

generate customer satisfaction. To achieve this, each activity within the company was strongly related to quality assurance. Every phase from product planning, design and manufacturing to sales and after sales service, was involved with quality.

This introduction discussed Just-In-Time as an overall philosophy. It is now necessary to discuss the manufacturing system based on this philosophy.

- (1) Avoid interrupted work flow
 - (1.1) Control quality at source
 - (1.2) Decrease set-up time to minimum
 - (1.3) Decrease machine breakdown to minimum
- (2) Eliminate material handling and stocks
 - (2.1) Reduce space between operations
 - (2.2) Eliminate stocking points and deliver straight to next operation
 - * Extend Routings
 - * Reduce levels in the Bill Of Material
 - (2.3) Arrange equipment according to product flow (Group Technology, Flexible Manufacturing cell etc.)
- (3) Switch to 'pull' scheduling instead of the common known 'push' scheduling. Replacement of assembly must be made only if there is an immediate need of it; the 'kanban' technique was developed
- (4) Synchronised Manufacturing
 - (4.1) Cross-trained operators (Flexible moving, multi-task operators)
 - (4.2) Match machine speeds to master schedule (Uniform plant loading)
 - (4.3) Master schedule each sold item for a given period
 - * Smooth out gross requirement by making only what is needed
 - * Eliminate any differences between requirements and orders by lot sizing and synchronisation of production
 - (4.4) Eliminate queues (Zero lead time)
 - (4.5) Work with tenders so they deliver more frequently and at the time needed. (Co-operative purchasing)
- (5) Zero defects or Total Quality Assurance

Table 4.1 THE LOGIC OF THE JAPANESE MANUFACTURING SYSTEM
BASED ON SCHONBERGER [56] AND YASUHIRO [42]

4.2 Just-In-Time manufacturing system

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In order to fully understand how Just-In-Time works, an exploration of the interrelation and correlation between all the elements involved, is needed. Figure 4.1 gives an overview of the main elements in the system: Production, Quality, Cost, and Respect for humans.

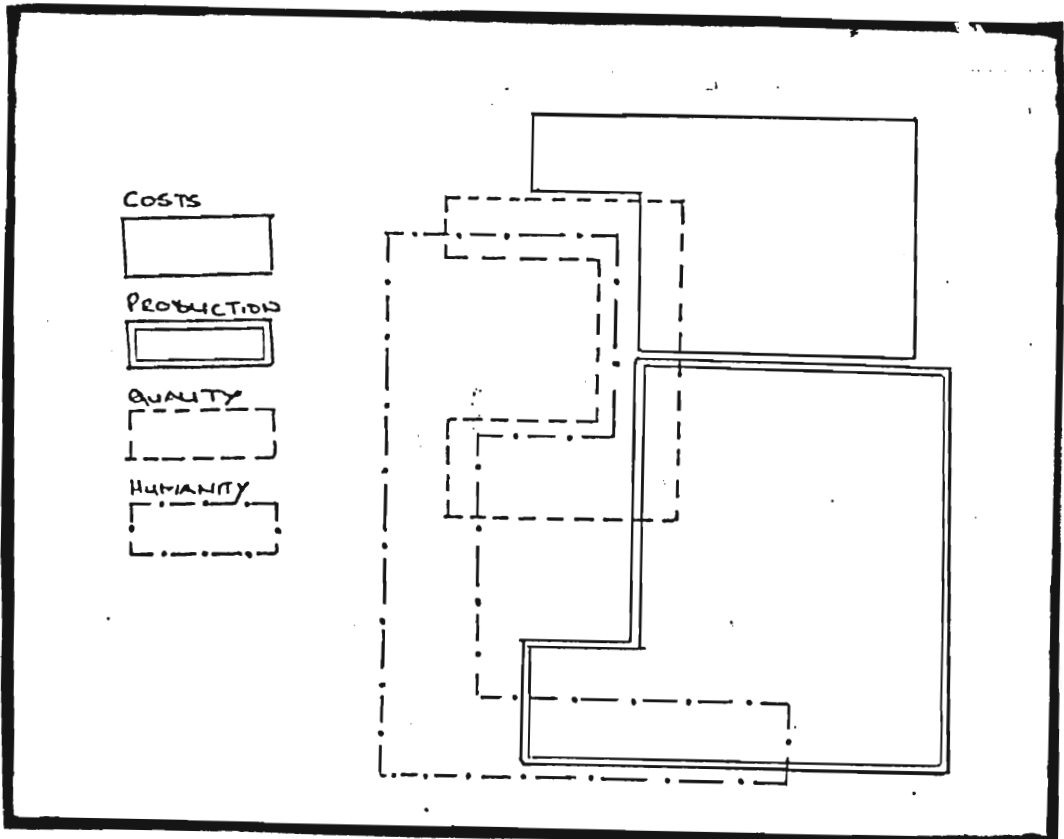


Figure 4.1 The Four Main Elements In the JIT System And Their Interrelationship. (Source: YASUHIRO[42:3].)

4.3 Just-In-Time Production

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The production of the right product in the necessary quantities at the correct time is the goal of Just-In-Time production. In order to operate accordingly, the following techniques should be a part of the system:

- (*) *Kanban* - The use of signs and indicators to help production control.
- (*) *Smoothing of production* - The idea behind this technique is to plan production in a constant speed and fixed minimum quantities to adapt to demand change.
- (*) *Reduction of set-up time and lead time* to the minimum possible as they are processes which, add no value to the product.
- (*) *Shojinka*-Design of machine layout, multi-function worker, flexible workforce and capacity balancing.
- (*) *Standardisation of operation* implies to determine the standard hours required to produce one unit.
- (*) *Improvement of activities* through Quality Circle - The use of Quality Circles to stimulate innovative ideas to improve activities.

4.3.1 The "KANBAN"

The direct translation of the word 'Kanban' is "sign" or "indicator", but in the process line 'Kanban' is a technique - a system of information for harmonious control of production quantities in every process. According to SHINGO, SHIGEO [57] and YASUHIRO [42: 14] two main "Kanban" are used which are:

- * *Withdrawal Kanban* - details of the quantity which the subsequent process should withdraw (figure 4.2).
- * *Production ordering Kanban* - the quantity which the preceding process should produce (figure 4.3).

Store Shell No. <u>5E215</u> Item Back No. <u>A2-15</u>			Preceding Process: <u>FORGING</u> <u>B-2</u>
Item No. <u>35670S07</u>			
Item Name <u>DRIVE PINION</u>			Subsequent Process: <u>MACHINING</u> <u>M-6</u>
Car Type <u>SX50BC</u>			
Box Capacity	Box Type	Issued No.	
<u>20</u>	<u>B</u>	<u>4/8</u>	

Figure 4.2 Withdrawal Kanban
(Source: Monden, Yasuhiro[42:15].)

Store Shell No. <u>F26-18</u> Item Back No. <u>A5-34</u>		Process: <u>MACHINING</u> <u>SB-8</u>
Item No. <u>56790-321</u>		
Item Name <u>CRANK SHAFT</u>		
Car Type <u>SX50BC-150</u>		

Figure 4.3 Production-ordering Kanban
(Source: Monden, Yasuhiro[42:15].)

The flow of Kanban is illustrated in Figure 4.4. Suppose products (A)(B)and (C) are assembled at the assembly line (O). Parts (a) and (b) which are produced by the machine line (P) and stored behind the line are necessary to produce these products. A "withdrawal Kanban" will be made at assembly line (O) to withdraw the right amount of parts (a) and (b) from the store to assemble the products (A)(B) or (C). If the intermediate store is short of one of the parts (a) or (b), a "production ordering Kanban" will be issued by stores to the machine line (P) to produce the necessary quantity part (a) or (b) or for both of them.

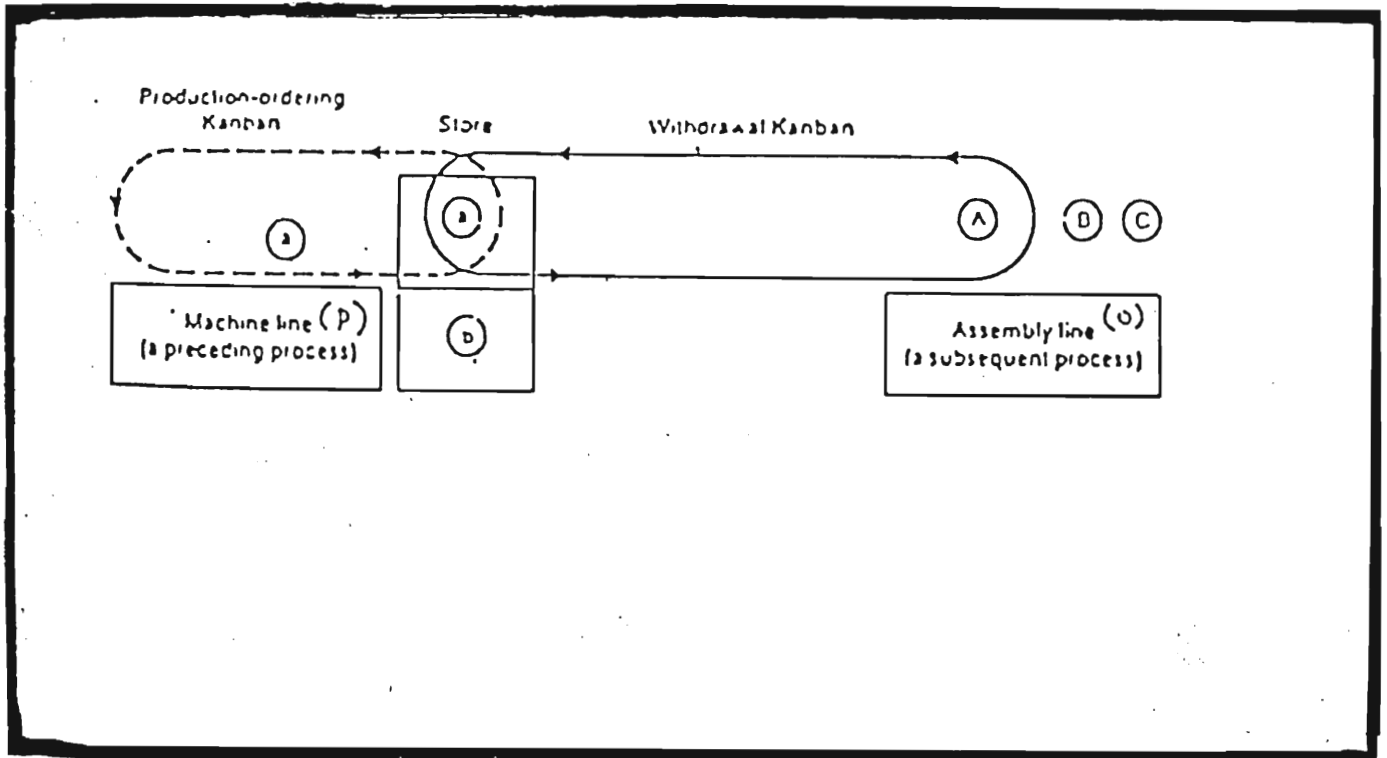


Figure 4.4 The flow of two Kanbans.
(Source: Monden, Yasuhiro[42:19].)

Each of the two main Kanbans, "production ordering" and "withdrawal", are divided into two sub-Kanbans. The "production-ordering Kanban" sub-Kanban are "Ordinary production Kanban" and "signal Kanban". The "withdrawal Kanban" sub-Kanban are: "interprocess withdrawal Kanban" and "supplier Kanban" the relationships between these Kanbans and Sub-Kanbans are illustrated in figure 4.5.

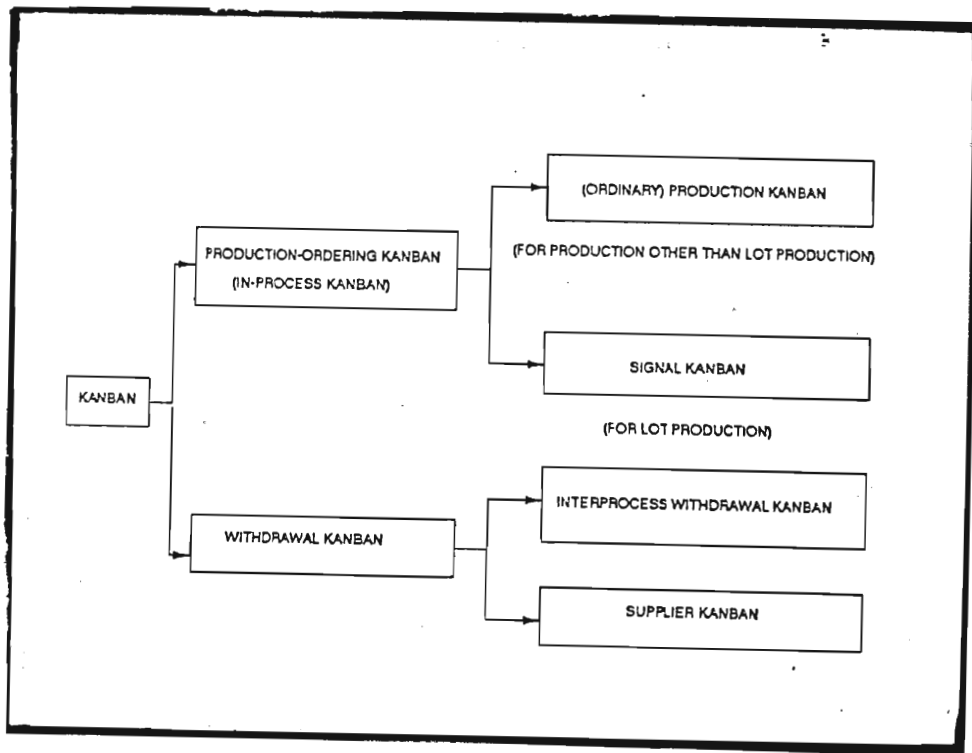


Figure 4.5 Framework of the main types of Kanbans.
(Source: Monden, Yasuhiro[42:19].)

4.3.2 SET-UP AND LEAD TIME REDUCTION

The process of reducing lead time is important to the prompt and timeous production of various kinds of parts and products. In order to succeed in lead time reduction a special effort must be made to shorten the set-up time to the minimum. A survey carried out to establish time consuming set-ups revealed two kinds of operation in every set-up.

(*) Internal set-up

(*) External set-up

Internal set-up operations are such actions that can only be done while the machine is stopped. For example the attachment of dies and tooling to the machine. External set-up operations are actions connected to the set-up, that can be carried out while the machine is in operation. For example, tools, materials, parts, proposed sub- assemblies of the set-up can be prepared, brought to and taken from, the working area before the machine stops or after the machine is back in operation.

In order to succeed in the reduction of set-up time, every operation should convert as much as possible of the internal set-up to external set-up. Figure 4.6 shows detailed steps to be considered when aiming for reduction in lead time, and also charts the connection between reduction in lead time and production

smoothing.

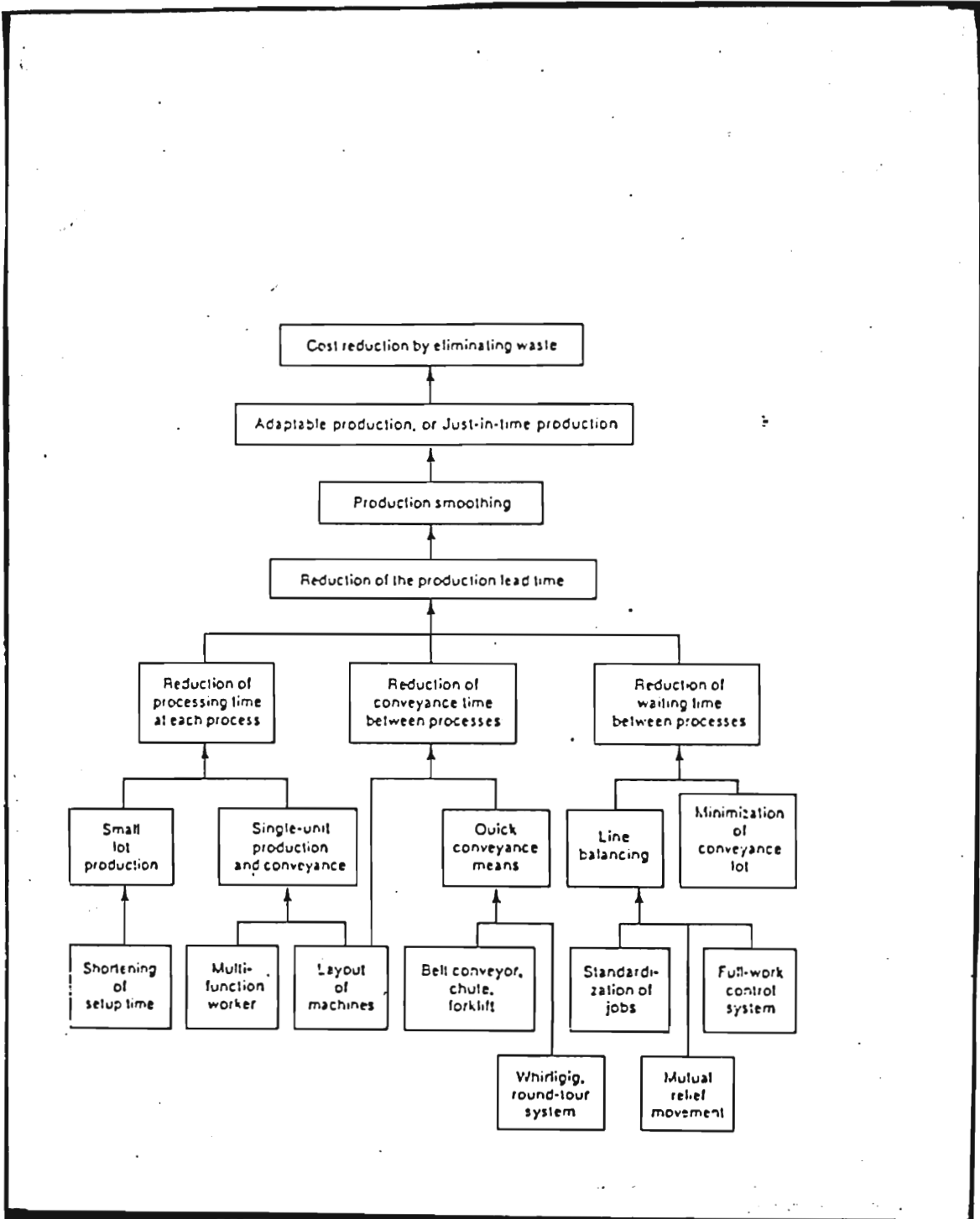


Figure 4.6 Framework for reducing the lead time.

(Source: Monden, Yasuhiro[42:69].)

4.3.3 SHOJINKA

Shojinka means increasing productivity by adjusting and rescheduling human resources, in other words, ensuring flexibility in the number of workers at a production point to adapt to demand changes. Because the main goal is productivity and cost effectiveness, flexibility means a minimum number of workers for the new calculated load of that production point.

In order to successfully achieve Shojinka, the following concepts should be adopted:

- * *Proper design of machine layout* - A proper layout of machines on the shop floor is the first step in increasing productivity. It facilitates the better flow of material and effects reduction in the walking distances of the operator while moving from one work station to another. To be in a position to move workers from one station to another and to adapt to changes in demand, the 'U' shape layout (figure 4.7) is sometimes adopted.

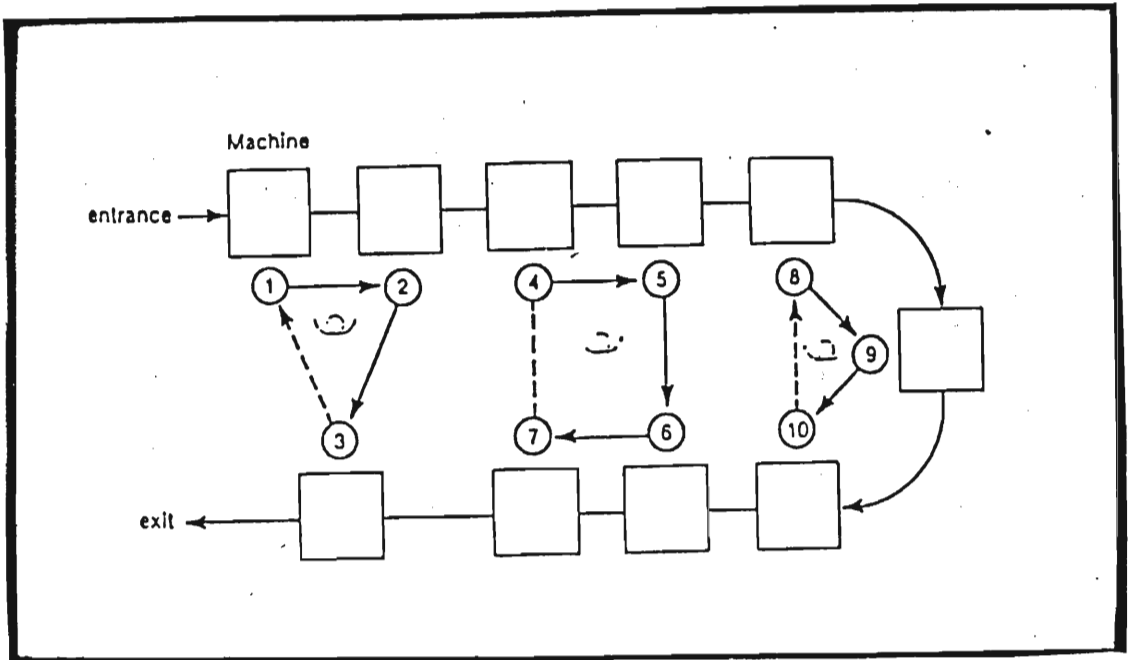


Figure 4.7 U-form layout
(Source: Monden, Yasuhiro[42:101].)

The 'U' shape gives one operator the control of incoming and outgoing parts in the line by being the operator of the first and last process. That way, work in progress is kept constant in the line while unbalanced operations within the other work stations in the "U" shape will immediately be identified and, with team effort, resolved.

To make layouts even more flexible Toyota combined some 'U' shape sub-lines in a major line so that operators could be moved from one sub-line to another, increasing the flexibility in response to changes in demand. Figure 4.8 is an example of combined lines.

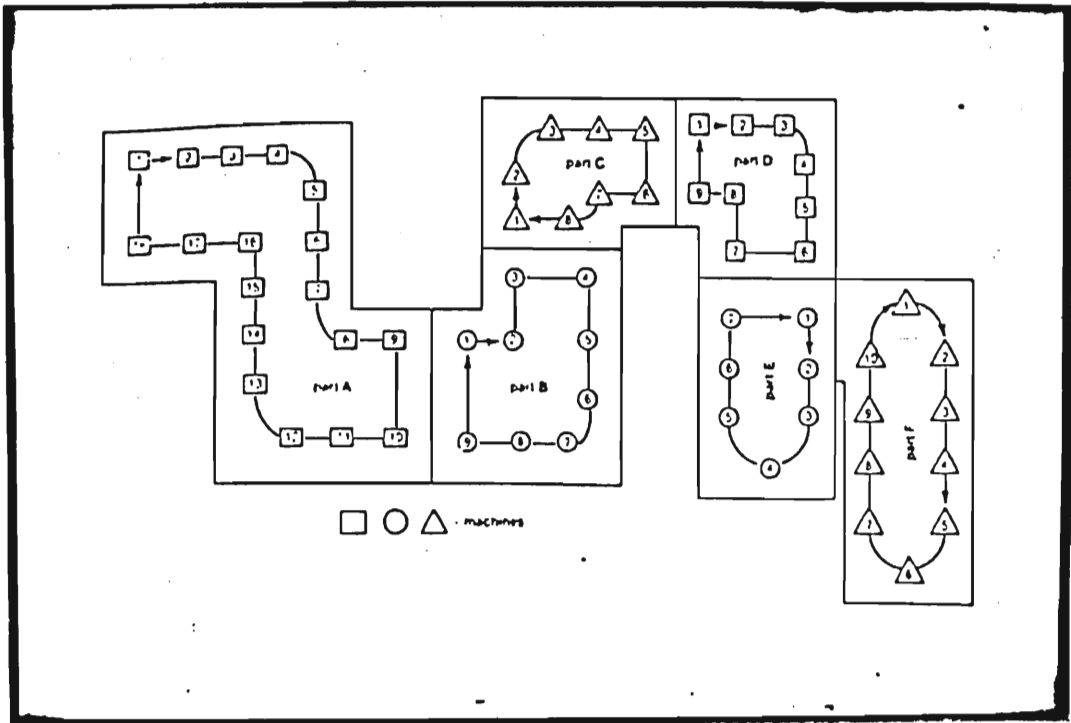


Figure 4.8 Combined line for making six kinds of parts.

(Source: Monden, Yasuhiro [42:101].)

* *Multi-function operator or versatile operator.* - The 'U' shape layout where the operator's walking distance from one work station to the other is short and the material can flow easily is not enough to fulfil Shojinka, as it does not qualify the operator of one of the work station to operate the other work stations in the 'U' shape layout successfully.

The most important step in achieving Shojinka is to have multi-function operators. Operators must be trained in the skills to carry out any type of job, at any process, at any time.

One way of training operators to become multi-functional is through job rotation. In order for job rotation to be successful, it should be introduced in three stages.

Stage one is *Rotation of Supervisors*. Establishing the desired attitude in the workplace requires that management, from the top down through to the supervisory level, provides the required leadership, showing through example the advantages of a multi-functional workforce. As this process takes a long time it must be part of a long range planning programme.





Stage two is *Rotation of Workers* within each shop. This process takes a very long time to accomplish and in order to control the process and evaluate it as time goes on, a job training plan must be scheduled for every worker. Figure 4.10 represents a good example of a training plan for an operator within an assembly line. In order to promote and stress the importance of the multi-functional operator, a rating should be established for each shop (a group of processes) in order to indicate the flexibility of the shop. The formula to calculate the rating is:

n Number of processes each Worker(t) now masters

 $t=1$ Total number of processes $\times n$
 n is total number of workers in shop

The actual time for training a worker to master a job varies from worker to worker and from job to job depending on the complexity of the job and the ability of the worker. At Toyota the range of time varied from days to weeks.

Job Training Plan Sheet
(shop no. 523)

 planned to train this year
 in training
  trained already

Line name		160 differential carrier assembly line							
processes		1	2	3	4	5	6	7	8
workers									
A		○	○	○	○	○	○	○	○
B		◐	◑	○	○	○	◑	◑	◑
C			◑	◑	◑	◑			
D		○	○	○	○	○	○	○	○
E		◑	○	○	○	○	○	◑	◑
F		●	●	◐	○	○	○	○	○
G		○	○	○	○	○	○	○	○
H		○	○	○	○	○	○	○	○
Line chief		◑	○	○	○	○	○	○	○

Figure 4.9 Job training plan sheet. (Source: Monden, Yasuhiro [42:109].)

Stage three is *Job Rotation several times a day*. As workers become more familiar with all the jobs in the shop, *Shojinka* becomes a reality. Workers can tolerate several job changes in the course of a day.

* *Continuous revision of the standard operating routines*. The layout and the standard operating routine of a shop must be known to every member of the team allowing the move from process to process to become simple and easy. People get better at a job by learning and practicing it. A basic rule for continuous improvement is to make sure that the standard operating routine is revised on a constant basis. As time goes by working systems change and improve, machinery is replaced and layouts are changed. In order to maintain flexibility it is essential that the load on each employee be changed by revising the standard operating routines. Figure 4.10 shows the layout of a shop, the processes involved and the standard operating routines.

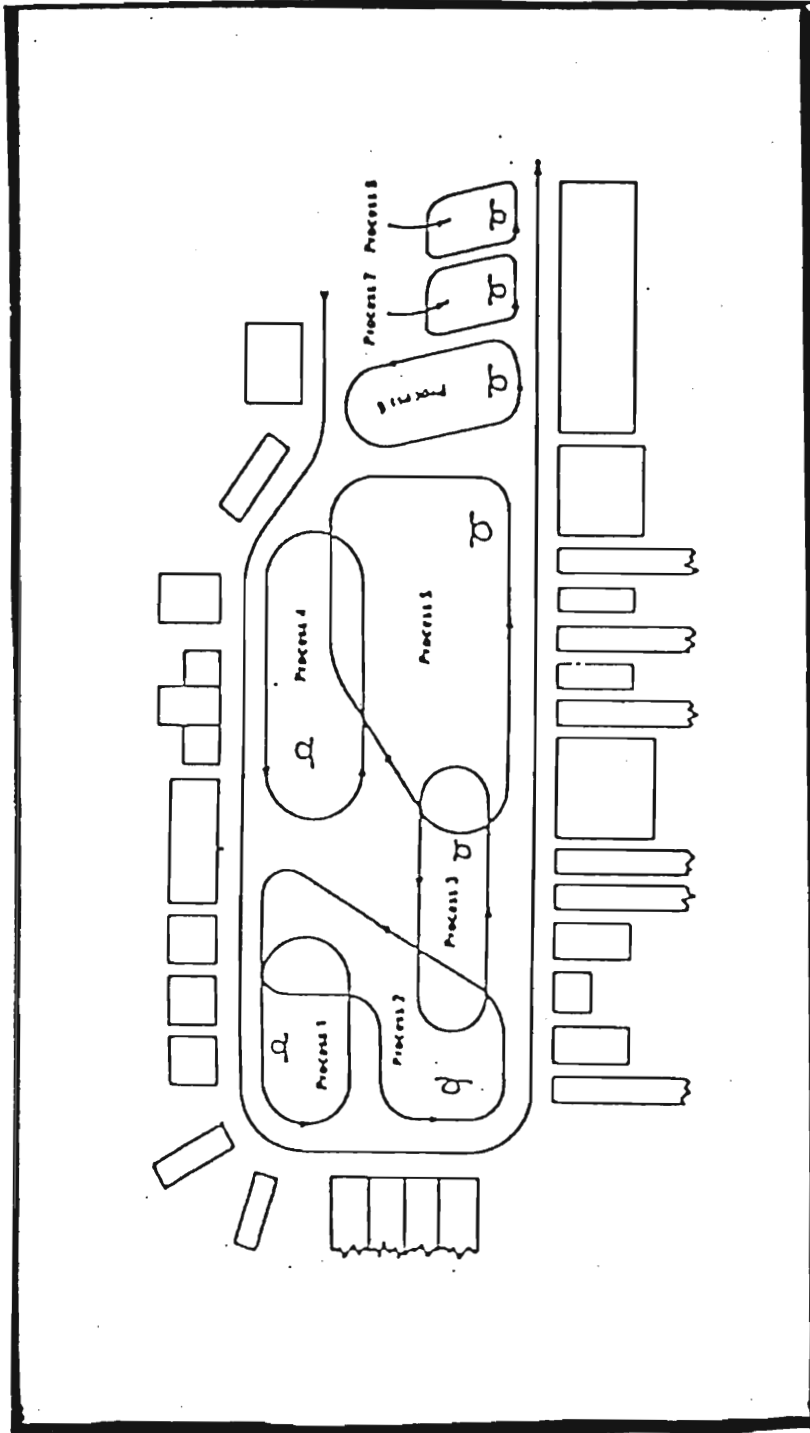


Figure 4.10 Layout and standard operating routines.
(Source: Monden, Yasuhiro [42:110].)

4.3.4 SMOOTHING OF PRODUCTION

Production smoothing is a technique that allows the sub-assemblies and preceding machine parts to be produced at a constant rate or at a fixed quantity per hour. This technique is needed as subsequent processes go to the preceding processes to withdraw the necessary amount of parts as required. If a subsequent process withdraws parts in variable quantities per time period the preceding process would require to gear itself to satisfy the peak in the variance of demand by means of manpower equipment and inventory. When such variances are introduced into the production process, productivity is reduced at all production points. It is therefore necessary to make special efforts to minimise variance. One way of minimising variances is to reduce the lot size produced by the last production station to the minimum possible (ideally one unit). Thus the last production station will withdraw small lots from the preceding station and the effects of change in demand for the final product will be minimal and controllable.

The advantage of smoothed production is the ability to adapt to production changes caused by variation in customer demand. Adaptability is achieved by gradually changing the lot size and the frequency of withdrawing parts from the preceding production points. Figure

4.11 details the prerequisites for production smoothing and the steps that must be followed in order to ensure success in production smoothing.

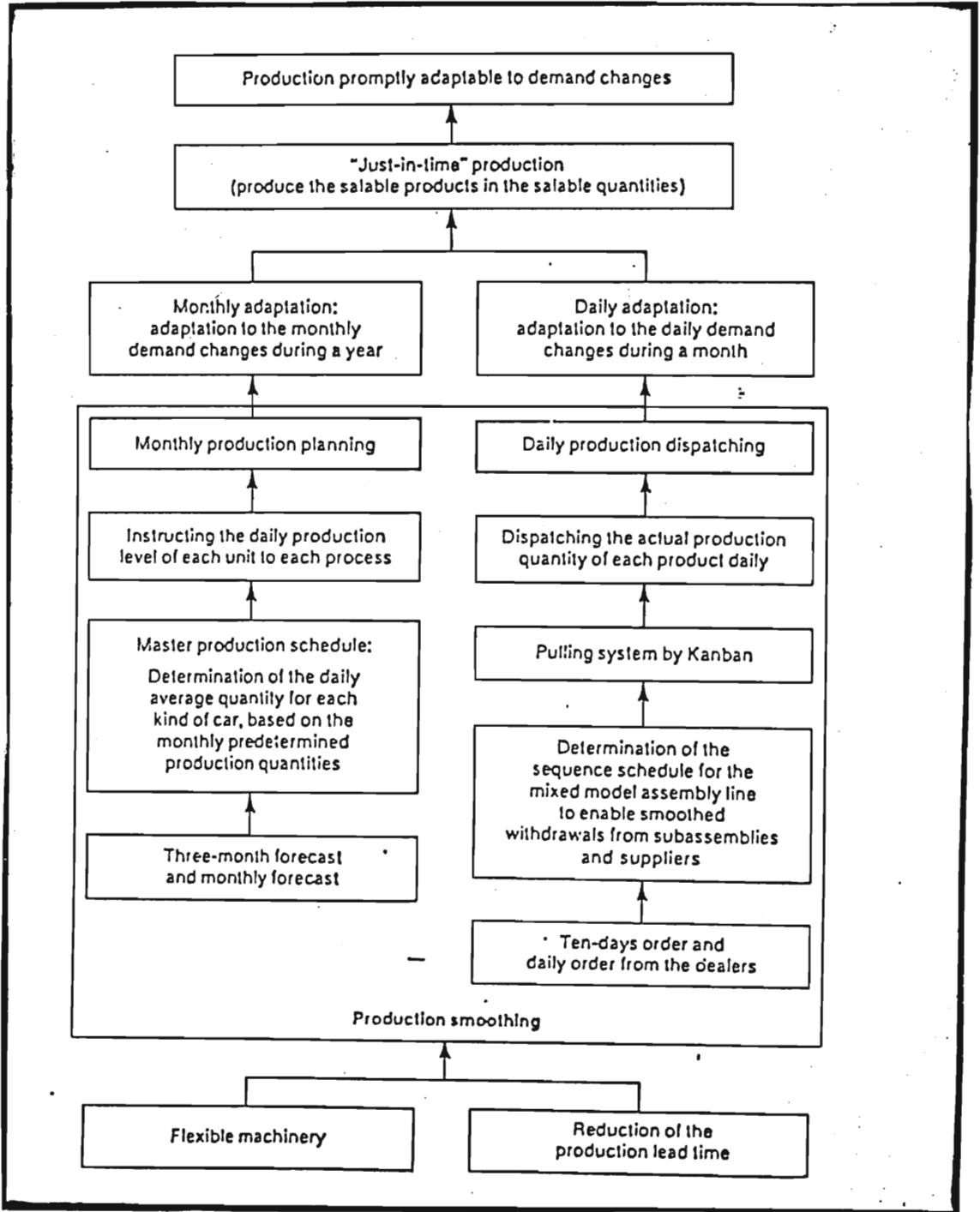


Figure 4.11 Framework of Toyota's Production Smoothing.
(Source: Monden, Yasuhiro[42:56].)

Figure 4.11 shows that before starting with the process of production smoothing two main features should exist.

Flexible machinery - This involves the implementation of flexible layouts such as "U" form (paragraph 4.3.2.), and the usage of machines that can be easily switched from one kind of work to another or from the manufacturing of one product to another.

Reduced lead times - This process which was discussed in paragraph 4.3.3., implies that the set-up times and lead time of every process should be reduced to the minimum.

When both features exist and are implemented the production smoothing process can begin.

4.3.5 STANDARDISATION OF OPERATION

Standardisation of Operation implies the prior determination for every operation of the labour hours required to produce a unit at each machine including the order in which the operations should be performed by each worker. Figure 4.12 shows the variety of elements involved in standardisation of operation.

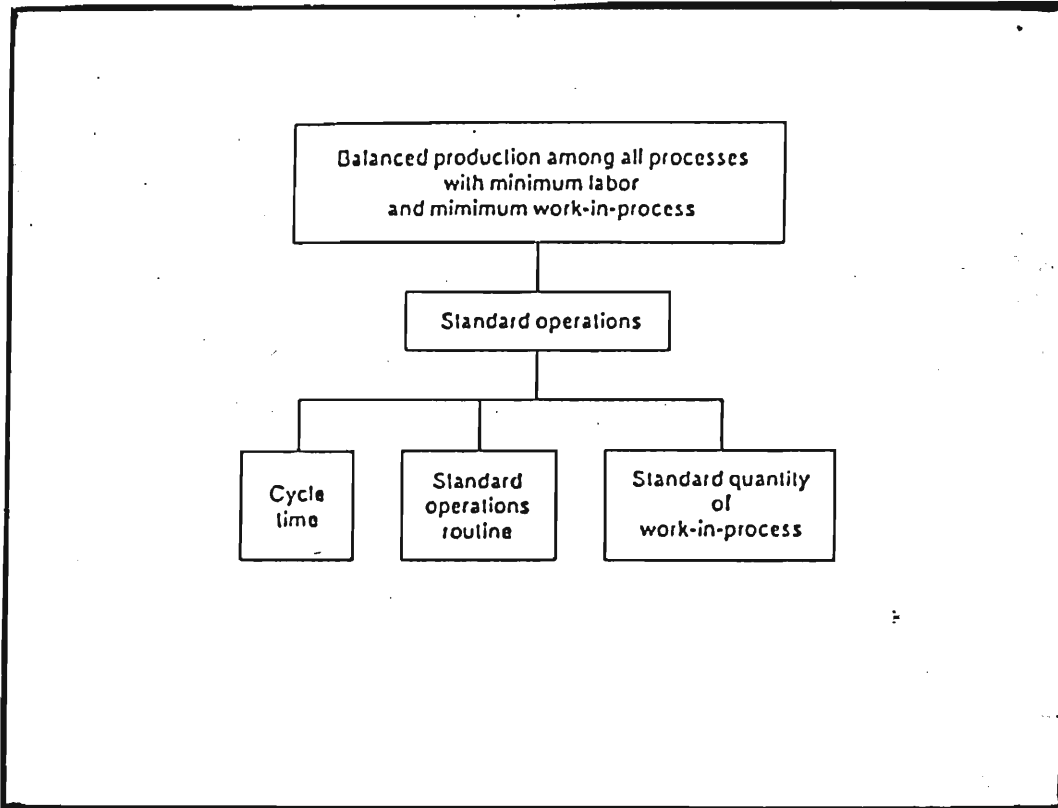


Figure 4.12 Elements of standard operations
(Source: Monden, Yasuhiro [42:86].)

The process of standardisation of operation should follow a five step procedure.

Step one is "*Determine cycle time*". Cycle time is the time in which one unit of production must be produced. It requires the calculation of the effective time in which each unit should be produced in order to achieve the amount of production required.

$$\text{Cycle Time} = \frac{\text{effective daily operating time}}{\text{required daily production (quantity)}}$$

The second step is to "*Determine completion time per*

The second step is to "*Determine completion time per unit*". Completion time per unit means the time required for a single unit to be processed. If the cycle time of a machine is two seconds and the machine is producing two units every cycle, the completion time per unit will be one second.

The third step is "*Part production capacity calculation*". The capacity of a multi-functional operator in a shop in terms of output units should be calculated. This step determines the number of units a shop can produce. This is done by listing the machines in the shop in operating order. In line with each machine on the list, the precalculated net production and tooling times for each part is listed. Based on these figures the shop capacity and the number of parts that can be produced in a shop, can be calculated. Figure 4.13 is an example of a part production capacity sheet used at Toyota in Japan.

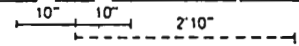
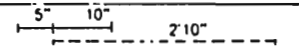
Part production capacity sheet			Item no		Item name		Necessary quantity per day		Worker's name			
Order of processes	Description of operations	Machine no	Basic time						Tool's exchange		Production capacity (960 min) units	References manual operation machine processing
			Manual operation time		Machine processing time		Completion time per unit		Exchange units	Exchange time		
			min	sec	min	sec	min	sec				
1	center drill	CD-300		07	1	20	1	27	80	1'00"	655	
2	chamfer	KA-350		09	1	35	1	44	20	30"	549	
3	ream	KB-400		09	1	25	1	34	50	30"	606	
4	ream	KC-450		10	1	18	1	28	40	30"	643	
2-1	mill	MS-100	(20)	(2	10)	(2	20)		1,000	7'00"	820	
2-2	mill	MS-101	(15)	(2	10)	(2	15)		1,000	7'00"		
	(two stands of machines)		18									[manual operation] $\frac{20 \cdot 15}{2} = 17.5$ - 18"
3	bore	BA-235	(08)		(50)		(58)		500	5'00"	1,947	
	(two units processing at a time)		04				29					[manual operation] $\frac{8}{2} = 4$ "
4	gauge (1/5)		(18)									
	(one unit inspection in every five units)		09									[manual operation] $\frac{18}{2} = 9$ "
total												

Figure 4.13 Part production capacity sheet.
(Source: Monden, Yasuhiro [42:88].)

Step four is "Determine standard operating routine". In this step the number and sequence of the different operations that each operator must be assigned to are determined. The allocation of the various operations among the operators in the shop must be such that every operator can finish his assigned operations within the specified cycle time. Figure 4.14 illustrates a standard operating routine sheet.

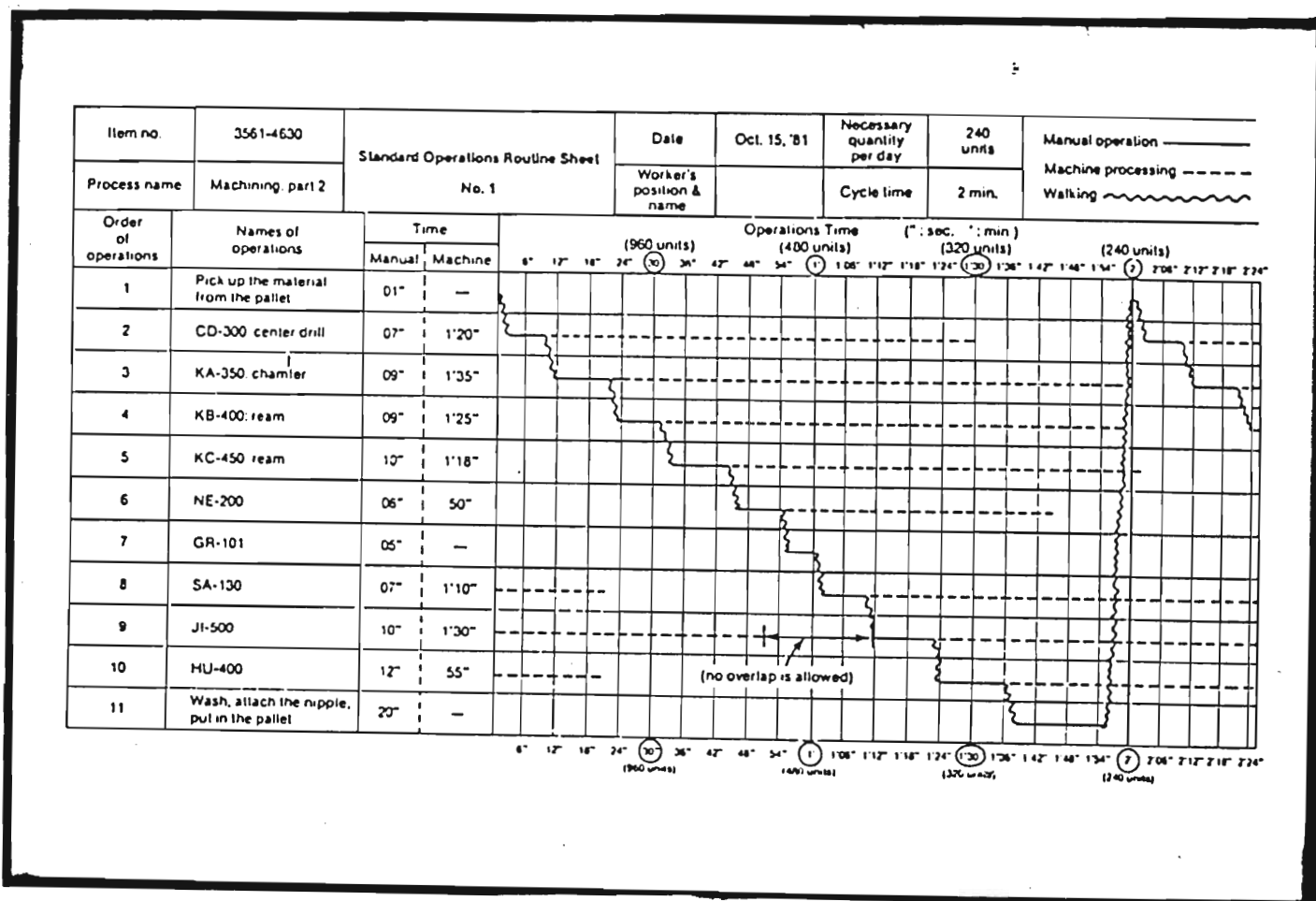


Figure 4.14 Standard operating routine sheet.

(Source: Monden, Yasuhiro [42:90].)

The last step is "Determine standard quantities of work in process" which means the necessary minimum quantities of work in process within a production line. These quantities consist of work attached to each machine in the process line and quantities laid out and stored in between machines. The minimum amount of work is the amount sufficient to enable the goals of the line to be achieved, taking into consideration the rhythmic operation of machines, the current layout of machines and the process flow. It will vary continuously according to the determined time per unit, part out-put and specific technical demands for the operation.

All the calculated data applied in the five steps should be collated on a "Standard Operating Sheet", which will contain the following information:

- * Operations routine;
- * Standard Quantity of Work in Process;
- * Cycle time;
- * Actual operation time;
- * Positions to check the product quality - check points in the process where the quality of the product will be observed;
- * Positions with a safety factor for workers-working points where there is concern for the safety of the worker and to which special attention must be given.

Figure 4.15 represents a schematic "Standard Operating Sheet".

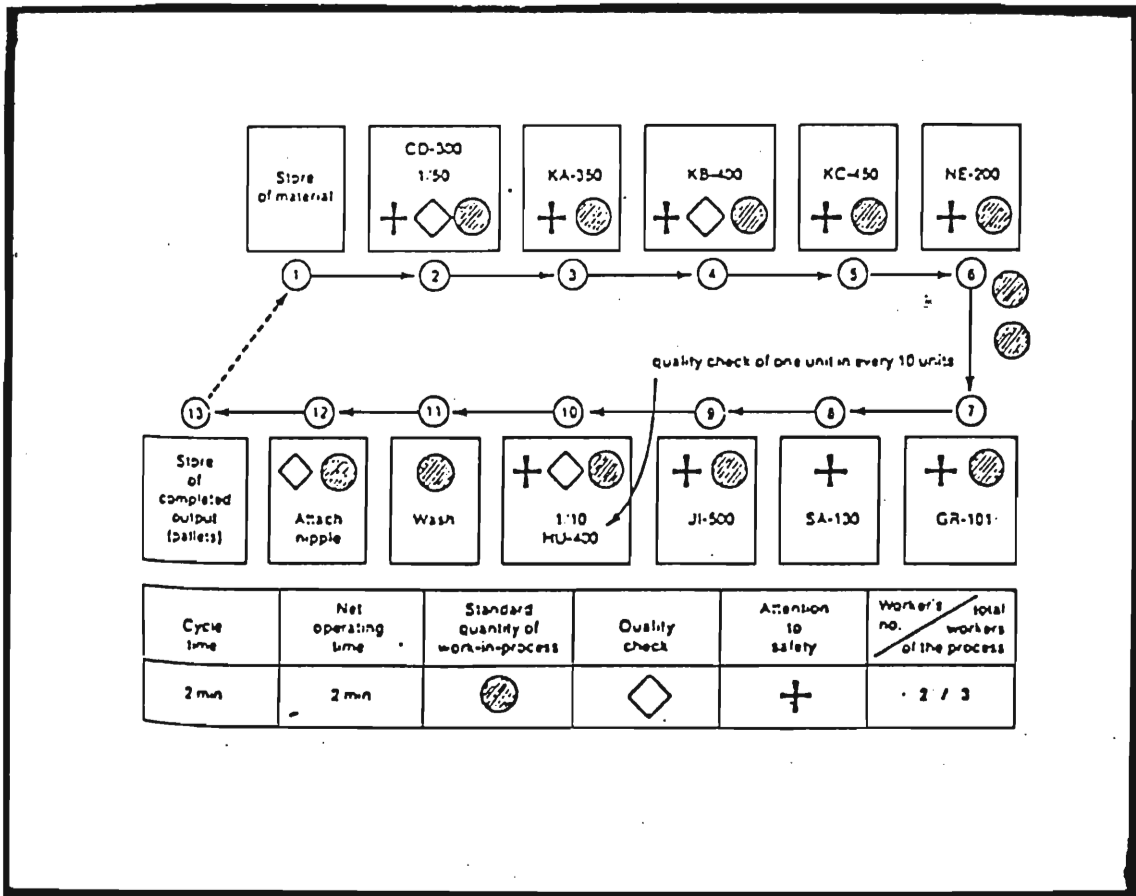


Figure 4.15 Standard operating sheet.
(Source: Monden, Yasuhiro [42:97].)

The standard operating sheet is displayed in the factory for all operators to observe how each centre contributes to the procedures of the plant as a whole. The benefit of having such a sheet published in this way is that every operator in the plant will become familiar with the standards required of him, his team and the total plant. Additional benefits are :

- * A guideline for each operator to maintain the current "standard operating routine."
- * Better and easier supervision as the performance of each operator can be checked quickly and easily.
- * Management can evaluate supervisor's ability as they have access to a constantly revised standard operating sheet. This will indicate how dedicated a supervisor is to improved operation and how innovatively he adapts production to varying demands.

4.3.6 QUALITY CIRCLES

The process which enables most of the goals of Just-In-Time to be realised (quality control, quality assurance, cost reduction, respect for humans) is the process of activity improvement. Each operator has an opportunity to make suggestions for improvements via small quality circles. Suggestions are open and can be related to any of the goals. In general, these suggestions can be split into two main categories:

- * *Suggestions for the elimination of manual motion waste.* Elimination can be done by changing the pattern or sequence of movements such as 'Pure Waste' which indicates double transfer, waiting time, intermediate product stores or 'Non-value added operation'. Non-value added operation includes walking to pick up parts, shifting tools from place to place and unloading suppliers products in intermediate locations.

- * *Suggestions for remedial operation.* These suggestions include operations that will add value to raw material or sub-assemblies. The value added can be through the installation of new machinery to avoid expensive manpower or by reduced costs resulting from better use of materials.

Figure 4.16 illustrates the process of improvement of activities through quality circles as well as the connection of improved activity with "Kanban" and Shojinka and how the combination between them results in high productivity and respect for humans.

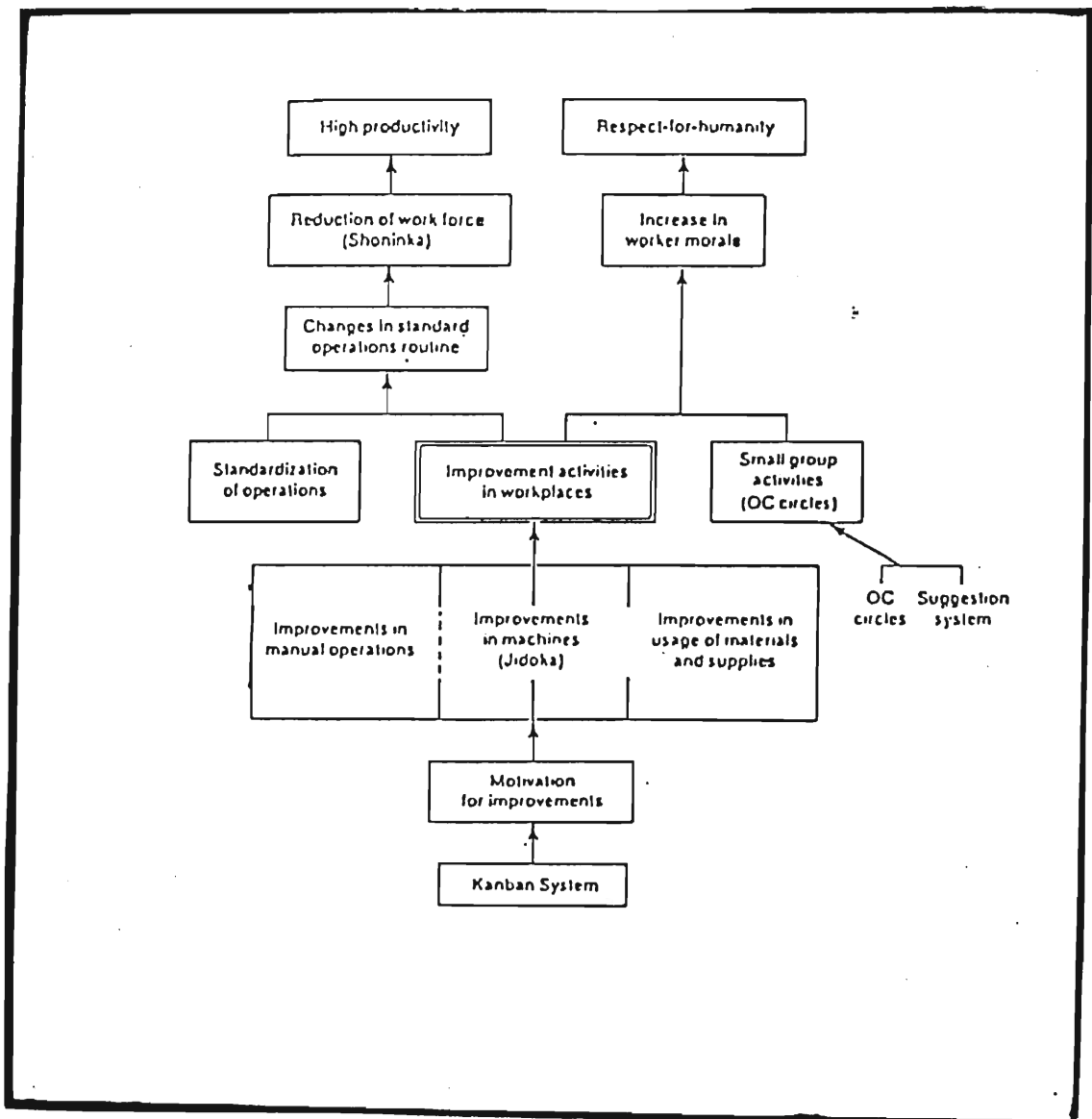


Figure 4.16 Framework of improvement activities. (Source: Monden, Yasuhiro [42:118].)

4.4 TOTAL QUALITY CONTROL

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Total quality control is defined by the Japanese as the total dedication of all workers of the company, from development through design, manufacturing, sales and customer service, to the provision of a product that will satisfy the customers' needs at the lowest possible cost. At the same time workers should sustain an habit of quality improvement towards perfection. Total Quality Control also implies that workers and foremen (not the Quality Control department) carry the primary responsibility for quality, while everyone else in the organisation is expected to contribute.

In order to achieve that goal, the Japanese Total Quality Control System requires that three elementary levels of responsibility for quality exist in an organisation;

- * *Autonomous defect control,*
- * *Statistical sampling methods and facilitators,*
- * *Company-wide Quality Control.*

4.4.1 AUTONOMOUS DEFECT CONTROL

The idea behind Autonomous Defect Control is based on the term 'Make it right the first time'. It means prevention of defects so that routine inspection can be eliminated. The purpose of this idea was to introduce self inspection of units. In order to achieve 'make it right the first time' quality checks should be performed at elementary stages of assembly and not at the end when the product or process is completed and too late to be corrected. Feigenbaum[56:48] points out;

"Quality-proof rests not with inspection, but with the maker of the part, the worker, mechanic, assembly foreman, vendor, customer service officer, as the case may be".

It can be concluded from the above that each operator or each process executor should be responsible for his own quality control so that he becomes immediately aware of problems and charged with responsibility to correct them ("Autonomous Control"). The effect of autonomous defect control and its connection with other principles of Just-In -Time like "supply only the good units and in the right quantity", "an operator can handle more than one machine in a cycle time" and "improvement activity" are well illustrated in figure 4.17.

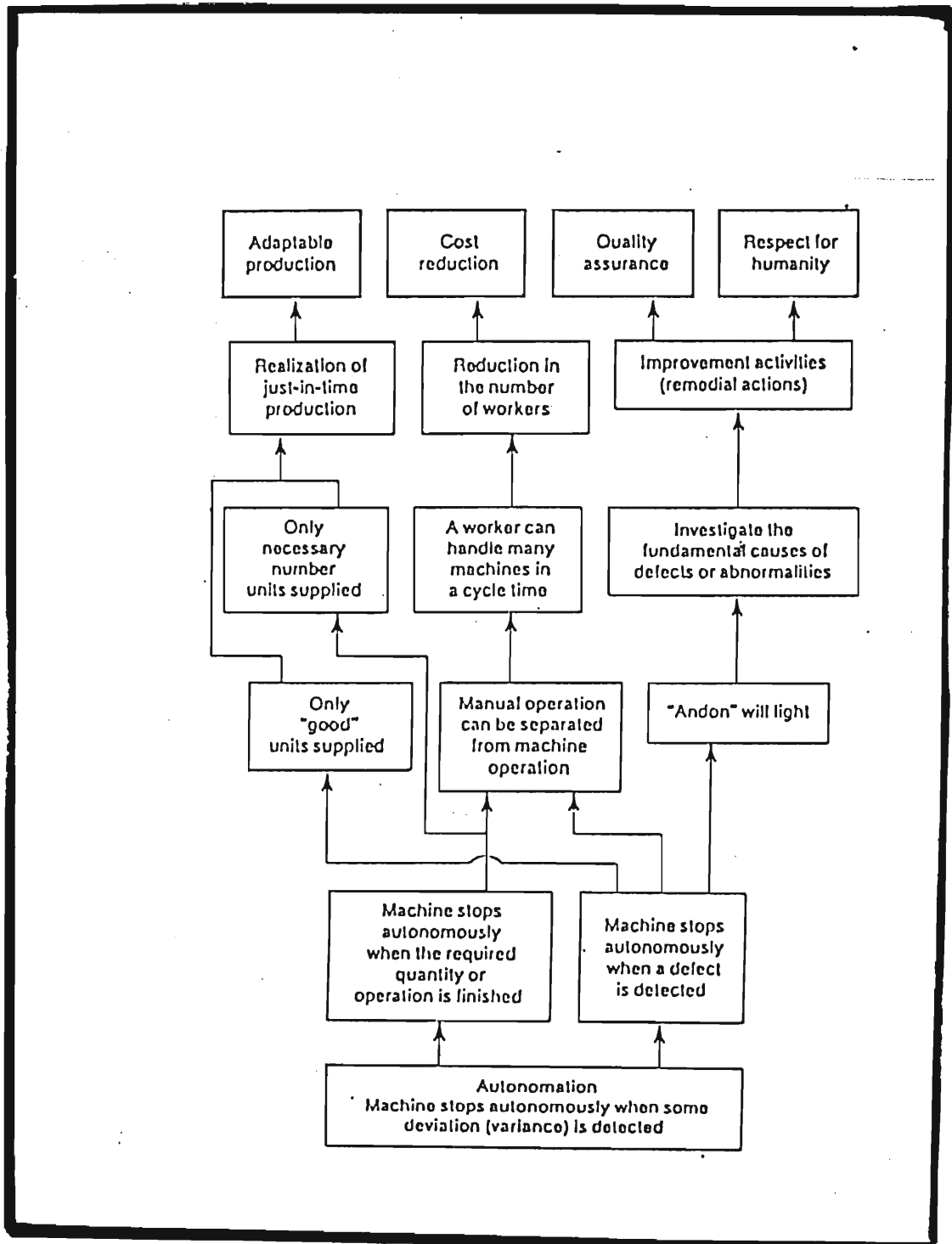


Figure 4.17 How automation attains its purpose. (Source: Monden, Yasuhiro [42:142].)

Some of the main principles of Autonomous Defect Control are:

- * *Machine Stop - Line Stop.* As the first priority in the Japanese manufacturing concept is 'quality', the authority and responsibility for the stopping of a machine, and consequently all the line, when an abnormality occurs, rests on each worker. Stoppage of a line can also occur if all the operations in the line cannot be performed according to the standard operating routine. The work centre foreman in charge of the department where the abnormality occurred must be notified immediately. Depending on the cause to the abnormality, whether it be a preceding machine or line or the malfunctioning of a machine, the right people must be notified in order that corrections can be made quickly by the people in charge of the source of the abnormality.

- * *Correcting One's Own Errors.* This principle implies that the operator or group that produced an abnormal part will rework the part again to correct the error. This principle should not be regarded as a punitive action. It returns the ownership of the problem to the source allowing for investigation of the fundamental causes of

the defects or abnormalities. Once the causes are identified, the necessary measures to eliminate the source of the problem can be taken. Although the implementation of such a principle will affect the total output of the line, it could increase motivation and encourage personal contribution to minimise future defects.

4.4.2 Statistical Sampling.

Japanese companies placed great emphasis on the use of statistical quality control and frequency distribution on quality level. Through the years, as the lot sizes became smaller, the importance of these tools diminished and the Japanese converted their philosophy to "100% inspection". As a result statistical quality data is used nowadays in reports and annual overviews and not as a technique to improve quality.

4.4.3 COMPANY-WIDE QUALITY EXCELLENCE.

Company-Wide quality excellence is described as the total commitment of the whole company, from the board of directors down to the worker on the shop floor, to quality excellence through effective cost management. Quality excellence is defined as the assurance that the quality of the product at all stages, from product design to after sales service, promotes customer satisfaction, product reliability and low cost.

Figure 4.18 shows that responsibility for product quality lies with all departments from the head of the department to all of the workers of the department and through all the disciplines of the business. At the product planning stage the sales department manager is involved in forecasting market share and assigning the proper quality targets. At the product design stage, the design manager and engineering managers are involved in designing prototypes to meet quality, performance, safety and reliability standards. Proper inspection methods and process control plans are prepared at the preparation for manufacturing stage. Purchasing managers are involved in ensuring that all the materials and parts purchased conform to specification with the help of inspection departments who sample check received goods. All manufacturing department managers together with production control take part in matching product quality to standards and

FUNCTIONAL STEPS	PERSON IN CHARGE	PRIMARY OPERATIONS FOR Q.A
<p>PRODUCT PLANNING</p>	<ul style="list-style-type: none"> - Sales Department Manager - Product Planning Department Head 	<p>Forecasts of demands and market share. Obtain the quality to satisfy marketing needs</p> <ul style="list-style-type: none"> - set and assign proper quality target and cost target - prevent recurrence of important quality problems.
<p>PRODUCT DESIGN</p>	<ul style="list-style-type: none"> - Design Department Manager - Body-Design Department Manager - Engineering Department Managers - Product Design Department Manager 	<p>Design of prototype vehicles</p> <ul style="list-style-type: none"> - meet quality target - test and examine car for: Performance Safety Low Pollution Economy Reliability, <p>Initial design to confirm necessary conditions for Q.A.</p>
<p>MANUFACTURING PREPARATION</p>	<ul style="list-style-type: none"> - Engineering Department Managers - Q.A Department Manager - Inspection Department Managers - Manufacturing Department Manager 	<p>Preparation of overall lines to satisfy design quality, Preparation of proper inspection methods, Evaluation of initial prototypes, Develop and evaluate a plan of initial and daily process control, Preparation of line capacities.</p>
<p>PURCHASING</p>	<ul style="list-style-type: none"> - Purchasing Department Managers - Q.A Department Manager - Inspection Department Manager 	<p>Confirmation of qualitative and quantitative capabilities of each supplier, Inspect initial parts supplied for product quality, Support in strengthening Q.A system of each supplier.</p>
<p>MANUFACTURING</p>	<ul style="list-style-type: none"> - Manufacturing Department Managers - Production Control Department Manager 	<p>Match product quality to established standards, Establish properly controlled lines, Maintain necessary line capacities and machine capacities.</p>
<p>INSPECTION</p>	<ul style="list-style-type: none"> - Inspection Department Manager - Q.A Department Manager 	<p>Inspect initial product for quality, Decision whether to deliver product for sale.</p>
<p>SALES AND SERVICE</p>	<ul style="list-style-type: none"> - Sales Department Manager - Export Department Manager - Q.A Department Manager 	<p>Prevention of quality decline in packaging, storage and delivery, Education and public relations for proper care and maintenance, Inspection of new cars, Feedback and analysis of quality information.</p>

Figure 4.18 Product Quality Responsibilities.

(Source: Monden, Yasuhiro [42:157].)

establishing control lines. When the production process is completed, inspection departments inspect the quality of the initial products and take decisions about delivery. Sales and export managers then take control of the product preventing quality decline in packaging, storage and delivery. They use the public relations function and the media to educate the customer in the proper care or maintenance of the product.

The integration between Just-In-Time production and Total Quality Control is very important, as it creates a "synergy affect". Some of the results of this synergistic affect are manifested in fewer rework labour hours, less material waste and higher quality of finished goods. This integration is shown in figure 4.19.

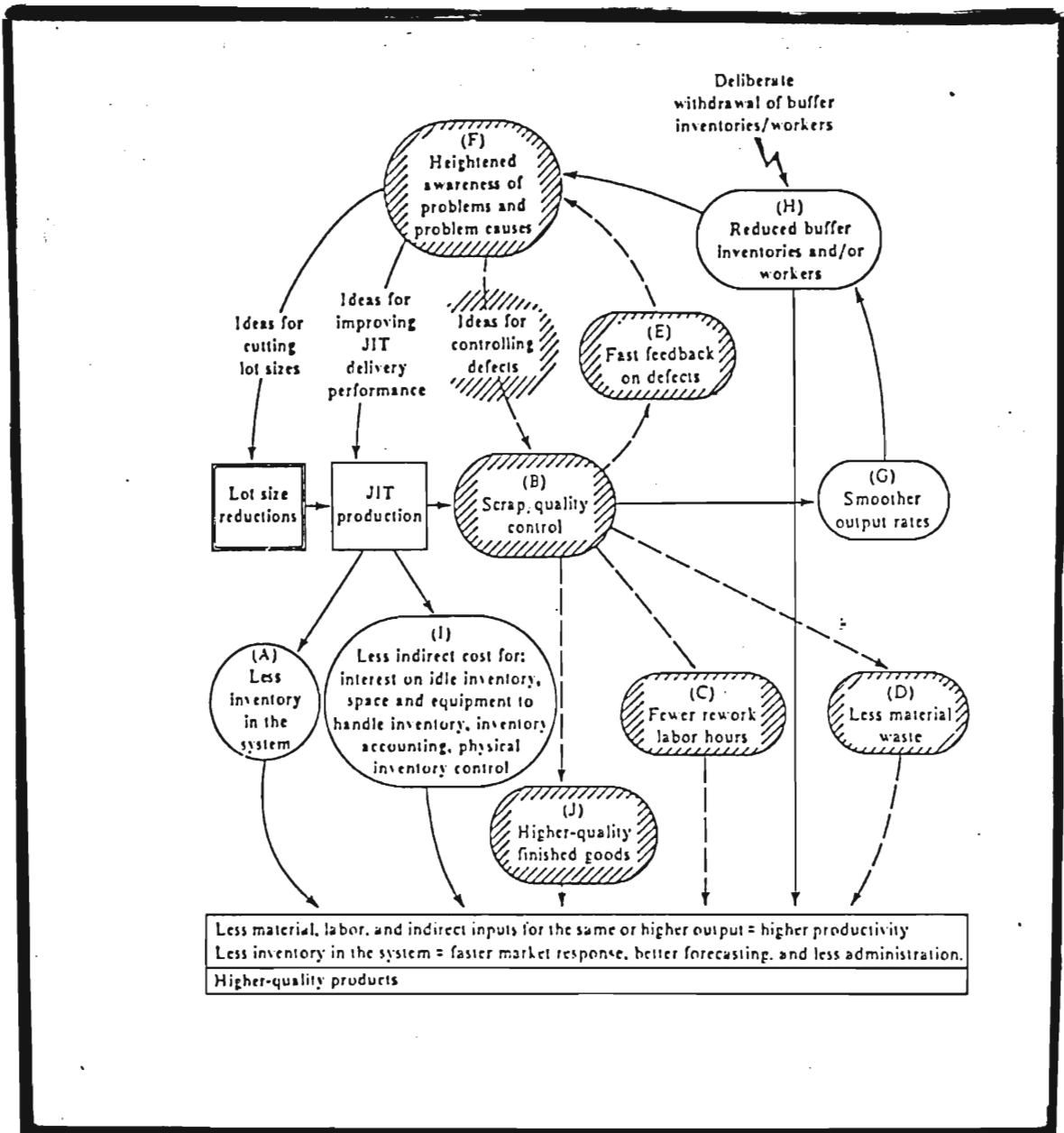


Figure 4.19 Total Quality Control combined with Just-In-Time production.
(Source: Schonberger [56:36].)

4.5 SUMMARY

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After discussing the principles of the Just-In-Time Manufacturing System in detail, the objectives of the system can be summarised as follow:

- * The primary objective of the system is *COST REDUCTION*.
- * The following secondary objectives should be aimed for in order to achieve Cost Reduction:
 - *QUANTITY FLOW CONTROL*. The successful use of a set of techniques enabling the system to adapt to demand fluctuation, called Just-In-Time Production.
 - *TOTAL QUALITY CONTROL*. The use of a set of techniques ensuring the supply of the correct units from each process to subsequent processes.
 - *RESPECT FOR HUMANS*. The successful motivation of all the workforce, from top management down to the shop floor worker, to effectively utilise and respect human resources.

These objectives influence one another and therefore cannot exist or be achieved in isolation. Figure 4.20 shows the four main elements of the Just-In-Time Manufacturing System, - cost, production, quality and humanity, how they influence one another and together contribute to the achievement of the main objectives.

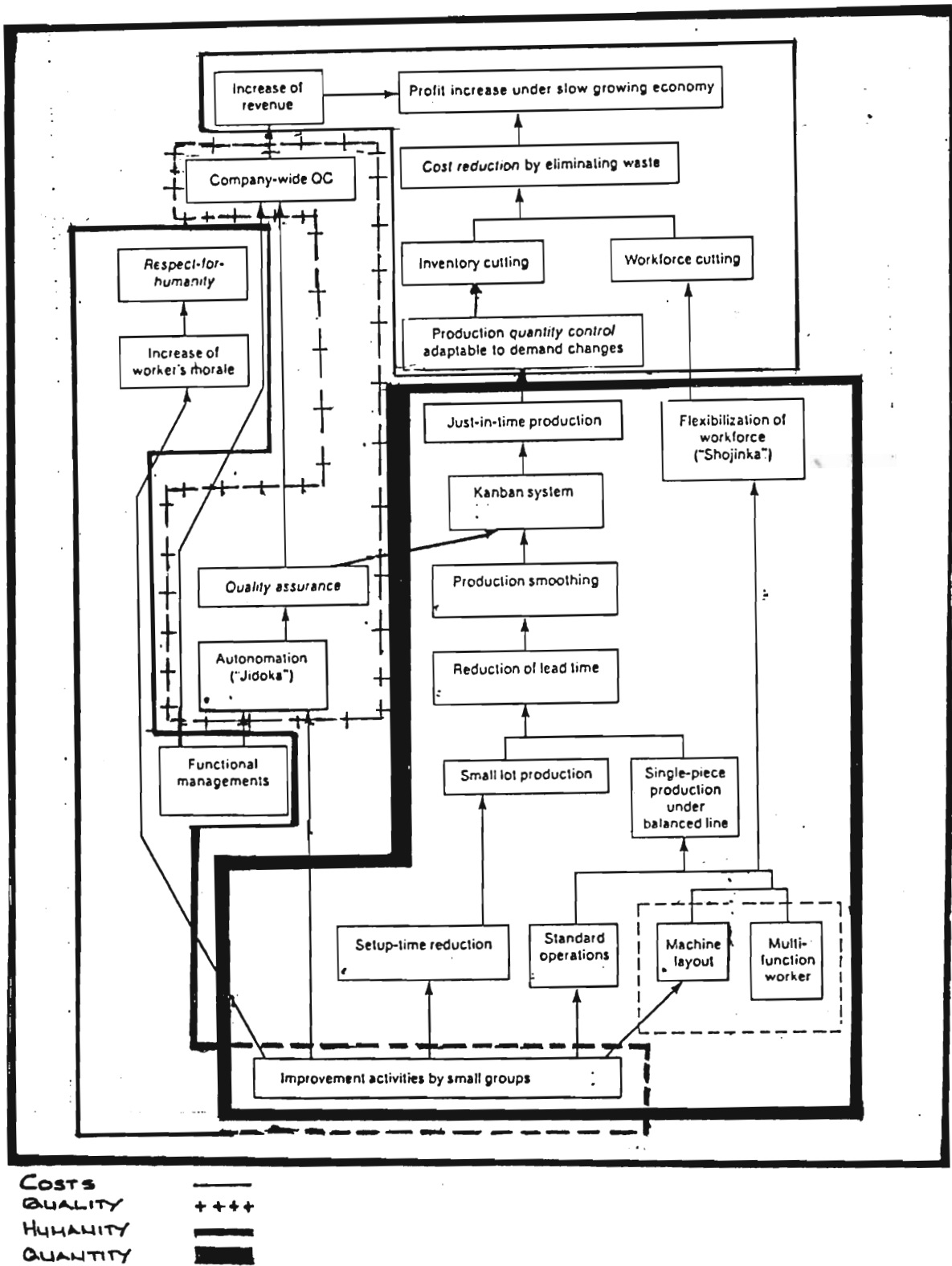


Figure 4.20 How costs, quantity, quality and respect for humanity are improved by Toyota, Japan.
 (Source: Monden, Yasuhiro [42:3].)

Figure 4.20 illustrates that the continuous search for improved activities by small groups in the organisation is the core of Just-In-Time system. Striving for continuous improvement involves directing the production element through changes in machine layouts, reduction in setup times and the improvement of standard operations. Improved activities drive the quality through Automation, where workers are allowed to stop lines in case of malfunctioning and, by the use of quality circles, find solutions to correct the problem. The fact that improved activities are done by small groups of workers, including shopfloor and management, boosts the pride and morale of the workers which is a part of the respect for humans.

These three elements : production, quality and respect for humans if implemented as per Figure 4.20 automatically drive towards cost reduction and increased profit which are the main objective of the fourth element, cost, and of the Just-In-Time system.

CHAPTER 5. COMPARISON BETWEEN MANUFACTURING RESOURCE PLANNING (MRP II) AND JUST-IN-TIME (J.I.T.)

5.1. INTRODUCTION

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The aim of this chapter is to compare the techniques and philosophies of the two systems, Manufacturing Resource Planning and Just-In-Time. Comparisons will be based on identifying and analyzing differences, similarities and commonalities. During the comparison, "Blind Spots" which are elements in production and inventory management that are not covered in one system or the other, and other elements which are potentially complementary, will be identified and highlighted. Although the goals and aims of Manufacturing Resource Planning and Just-In-Time are very similar, in that they aid manufacturing companies in improving customer service, inventory turnover and productivity, the tools used and the philosophical approaches differ.

Manufacturing Resource Planning uses the "push" system, where every work centre works to its full capacity and keeps pushing inventory to the next work station. Just-In-Time uses the pull system, where the previous work centre will not produce unless the next work centre pulls the stocks.

Inventory and queues can be assets in Manufacturing

Resource Planning, but wastage in Just-In-Time.

In order to validate the first hypothesis presented in paragraph 1.5, it is necessary to establish that: No part or element in either of the two systems precludes the use of tools or philosophies of the other. Should this be true, it will be feasible to attempt to validate the second hypothesis through the development of a new model based on both systems.

5.2 COMPARISON OF CONCEPTS BETWEEN MANUFACTURING RESOURCE P L A N N I N G A N D J U S T - I N - T I M E . =====

In order to present the differences between the two systems it is imperative to distinguish between the philosophical differences and the different tools used by each of the systems.

The philosophical differences can be compared based on key factors such as inventory, humanity and quality, techniques for the control of education or methods and communication lines.

In order to assess and understand the philosophical differences, terms of reference must be established so that the differences can be assessed on an equal basis. The most efficient way to compare philosophies is through key factors which are components of the philosophy of each system. The key factors which will

be used in the comparison are:

- * *INVENTORY* - Amount of inventory that is used in the factory, how it is managed and how it is looked at;
- * *QUALITY* - The importance and emphasis that is given to the quality of the product in each systems;
- * *SET-UP TIMES* - The priority that is given to set-up time reduction in planning and in problem solving;
- * *LOT SIZES AND LEAD TIMES* - The different approach to lead time and lot size in the two systems;
- * *WORKER* - The approach to workers as a resource used by management or a part of the decision making body. Workers as a vital ingredient or just a resource that must be measured;
- * *QUEUES* - The different approach to queues as a necessity or a fact of manufacturing, are queues to be eliminated or reduced to a minimum;
- * *WASTE* - Waste a part of the production process or can a "Zero defect" environment be expected;

The differences in approach of each of the two systems to the above key factors, form the basis of the comparison appearing in table 5.1

FACTOR	Just-In-Time	Manufacturing Resource Planning
INVENTORY	A liability. Every effort must be made to do away with it, inventory does not add value to the finished product.	An asset. It protects against forecast errors, machine problems, late deliveries. It can help more than it costs.
HUMANITY/ WORKERS	Team management. Management by consensus. The vital ingredient of "Ownership" is achieved. The workers are an important part in the decision making of the company.	Management by edict. New systems are installed in spite of the workers. Establish measurements to determine whether or not workers achieve targets. The workers are looked on as groups and not as individuals. Workers do not gain ownership.
QUALITY	Zero defect - no scrap. If quality is not on target production is in jeopardy. Correcting one's errors, autonomous defect control.	Tolerate some scrap. Develop formulas for predicting scrap. Quality control department to detect faults. Errors are left as scrap or reworked by special teams.
LOT SIZES	Try to reduce lot size to the minimum possible (desirable-1). Only the immediate need of manufacturing and purchasing.	Develop formulas to revise the optimum lot size based on a balance between cost of set-up and cost of inventory.
SET-UPS	Try to reduce set-up time to minimum to reduce drastically the impact on production or the availability of an extra machine. Fast change-over allows for small lot size to be produced with a frequent production of a wide variety of parts.	A portion of the effort goes into achieving quick set-ups but not as the priority. The usual goal is maximum of output.
QUEUES	Queues are waste and must be eliminated. When queues occur a full investigation must be made to identify and correct the cause. If queues are short, it intensifies the need to identify and fix the problem quickly.	Queues are a fact of life. Queues are a necessary investment to ensure the line is not stopped in the event of a problem in the feeding operation. Provides management with a tool to compare operator skills with machine capacities.
LEAD TIMES	Keep to minimum as it reduces the need for expediting.	A part of the system. All people involved (foremen, purchasing, despatch) would like to have more lead times.

TABLE 5.1. COMPARISON BETWEEN THE KEY FACTORS IN JUST IN TIME AND MANUFACTURING RESOURCE PLANNING
(Source: MODERN MATERIAL HANDLING/WALT GODDARD NOVEMBER 1982)

Table 5.1 can be summarised as follow:

Under Just-In-Time system inventory is a liability which does not add any value to the finished product and every effort must be made to reduce it to the minimum.

Under Manufacturing Resource Planning, inventories are an in asset protecting against forecast errors.

The Human Resource (people) are managed in Just-In-Time by consensus. While in Manufacturing Resource Planning people are managed by edict. In Just-In-Time the workers are a part of decision taking body, while in manufacturing resource Planning they are only supposed to achieve targets imposed by management.

Lead Time reduces the flexibility of the shopfloor and must be kept to minimum in the Just-In-Time system. In Manufacturing Resource Planning it is a part of the system and each discipline such as the production foreman or despatch manager would like to have more.

Both Just-In-time and Manufacturing Resource planning would like to have minimum reject levels but Just-In-Time puts a great emphasis to reduce rejects to the ideal "Zero defect" and manufacturing Resource Planning tolerate a preformulated reject rate.

5.3. COMPARISON OF TECHNIQUES BETWEEN MANUFACTURING
RESOURCE PLANNING AND JUST-IN-TIME

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Both systems were developed to assist management to plan and control purchasing, production and distribution in order to achieve the goals of the business. Both systems emphasise the integration and co-ordination of manufacturing. Various interfacing activities stress the importance of a levelled master schedule and regard shop floor control as a key feature. Both systems see vendor management as an important tool to achieve success.

Every manufacturing environment has certain functions that must be performed in order to achieve goals. To be in a position to evaluate situations on the shop floor and to plan production, some tools must be used. These tools provide a mechanism for controlling the situation so that the right action can be taken to achieve targets with the minimum cost.

Manufacturing Resource Planning and Just-In-Time approach the main functions and activities which are the backbone of any production system very similarly, and only differ in the tools they use to obtain and assess the results. Table 5.2 illustrates the

different tools used in each system to control key functions.

THE FUNCTION	CATEGORY CONTROLLED	Just-In-Time	Manufacturing Resource Planning
MATERIAL REQUIRED	<i>Components - manufactured and purchased</i>	<i>"Kanban" card</i>	<i>Material-Requirement Planning (MRPI)</i>
CAPACITY REQUIREMENT	<i>Output of key work centres and machines</i>	<i>Visual</i>	<i>Capacity Requirement (CRP)</i>
PRODUCTS TO BE PRODUCED	<i>Make to stock or make to order</i>	<i>Master Production Schedule</i>	<i>Master Production Schedule</i>
RATE OF OUTPUT	<i>Families of products</i>	<i>Levelling production</i>	<i>Production plan</i>
EXECUTIVE MATERIAL PLANS (PURCHASING)	<i>Bring the right items</i>	<i>"Kanban" cards that are unofficial orders</i>	<i>Purchasing reports</i>
EXECUTIVE MANUFACTURING PLANS	<i>Work in the right priorities</i>	<i>"Kanban" cards</i>	<i>Despatching report</i>
EXECUTIVE CAPACITY PLANS	<i>Produce enough output to satisfy plans</i>	<i>Visual</i>	<i>Input/Output controls</i>
FEEDBACK	<i>Problems on shop-floor</i>	<i>"Andon" signs, lights</i>	<i>Anticipated delay reports</i>

TABLE 5.2 TOOLS IN JUST-IN-TIME AND MANUFACTURING RESOURCE PLANNING TO CONTROL KEY FUNCTIONS
 [Modern Material Handling/Walt Goddard /November 1982]

Table 5.2 can be summarised as follows:

Under the Just-In-Time system the tools are manual such as Kanban cards, lights, visual checks and oral orders. When using Manufacturing Resource Planning the most important tool is the computer.

Both systems, Just-In-Time and Manufacturing Resource Planning, emphasise the importance of levelling master schedules. They differ in how they level. Manufacturing Resource Planning levels on capacity whilst Just-In-Time levels in terms of material. A master schedule which is levelled by material requirement will always cater in terms of capacity requirement, but the reverse is not always true. A Master Schedule which is levelled by material requirement, takes into consideration the capacity of the production units to calculate the total material required. A capacity levelled Master Schedule only makes sure that the production units capacity is levelled.

In Manufacturing Resource Planning the execution is a logical extension of a planning process through work orders, input/output controls and despatch. Data must be collected after every operation so that progress can be monitored and the output measured. Moreover, its substantial processing capability, the computer, is needed to backtrack orders on the shop floor and update manufacturing priorities.

In the Just-In-Time concept, material flow patterns are clearly structured and defined. The flows are one way with almost no backtracking. Capacity is determined by the rates of flow along the variable flow paths. Work orders are not issued to every work centre daily, but instead signals and Kanban cards are used to control the rate of flow. Very little data is collected and a small amount of information is needed for execution of operations.

5.4. "BLIND SPOTS" VS COMPLEMENTARY ASPECTS

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No evidence is found in either of the systems that the use of one precludes the use of the other. It is only when implementing the systems that their shortcomings become obvious (Blind Spots). The purpose of the following discussion is to establish whether the 'blind spots' occurring in each of the systems can be covered by the other system. To establish if in some situations the systems with small modifications and adjustments can be seen to complement each other and create a synergistic affect. In order not to over-emphasise the "Blind spot" concept, but rather to use it as a tool to prove or disprove the complementary nature or "synergy affect", the idea will be presented in a very general way.

Some of the shortcomings of Manufacturing Resource Planning are lack of sensitivity to the shop floor and the manufacturing process as well as quality and workforce issues. The system facilitates the monitoring of results and the rescheduling of production, but it does not consider the redesign of product structures, manufacturing standardisation, or changes in factory floor process and layout. A major "blind spot" of Manufacturing Resource Planning is its reactive view. Master schedules are issued on a weekly or at most on a daily basis, which might prolong the reaction time.

The main "blind spot" of Just-In-Time is its administration facility. Although administration is regarded as "waste" in a big organisation or in some operational areas, Just-In-Time lacks information and procedures for activities which are essential to the efficient running of a manufacturing business. Some missing procedures and information are the order entry function, the purchase of material, material plans and the recording of committed purchases.

If the main concepts and philosophies of systems are bound together with the "Blind spots", many complementary characteristics can be found. table 5.3 illustrates the complementary aspects of the two systems.

ASPECTS/ CHARACTER	Manufacturing Resource	
	Planning	Just-In-Time
MASTER SCHEDULE	Provides processing capability information Emphasises short lead time importance	Level capacity requirement and material requirements Provides ways to make short lead time through focus on material flow
Vendor Management	Blanket order Provides means for determining the requirement for materials Provides information processing and formal communication with vendor	Provides mechanism for levelling material usage Provides a means for reflecting actual usage
Teamwork	Functional level	Worker supervisory level. Integration of operation, inspection, maintenance. Emphasises the role of workers in the process and improvements
Lot Sizes	Calculations based on stocks and lead times	Standard container for transport
Shop floor Control	Input/Output reports reactive Choose the best for the right environment	Kanban, Andon proactive
Quality & Workforce	Quality, workforce, shop floor taken as "given", not dealt with	Strive for better quality, improvements through constantly trained workforce and improved environment
Others	Excellent and satisfying planning systems with high capabilities	Execution tools Recognition of excellent planning

Table 5.3 Characteristic aspects of Manufacturing Resource Planning

5.5 SUMMARY

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After comparing and analyzing Manufacturing Resource Planning and Just-In-Time in detail, the following points represent a summary of the last three chapters:

- * Just-In-Time represents a development of manufacturing strategy which has impacted on manufacturing companies worldwide through its effectiveness in some large Japanese operations, the simplicity of its logic, its involvement in basic analogy and smart problem solving, all proven in repetitive operations.

- * Manufacturing Resource Planning is involved in directing "smart" people towards planning and scheduling job shops rather than overall problem solving. It still represents the most thorough planning and scheduling strategy tool, necessary for the implementation of a manufacturing strategy.

- * The strategy of an effective manufacturing company should consist of the following points:
 - *what market to serve*
 - *how to serve the market (service level)*

- *what must be produced*
- *what products to be provided*
- *how to justify financial investments.*

CHAPTER 6. THE "MODEL"

6.1 INTRODUCTION

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An exploration of both systems, including checking and analysing their similarities, conflicts and "blind spots" was presented in chapters 3, 4 and 5. As nothing was found during the exploration that contradicts the two hypotheses presented in chapter 1 then,

- * *It is possible to overcome conflicts between Manufacturing Resource Planning and Just-In-Time as there is nothing in either system that precludes using the other.*

- * *The merger of Manufacturing Resource Planning and Just-In-Time will create a "synergy affect" overcoming "all blind spots" occurring in both systems.*

The next step is the development of a modular "model" that will use fundamental principles based on the two systems. Some slight changes and adaptations should be made in order to retain the best of both systems. The purpose of developing a new "model" is to address the concept of "*Total Inventory Planning and Flow Control*" or in other words, "Just Enough Inventory to keep up

the flow of a production environment". The idea behind "enough" inventory and "flow" is to move away from attempting to control inventory levels through work orders, towards a situation where the flow of inventory is controlled. One possibility is to balance the priorities which control the utilisation of capacities and materials using Just-In-Time philosophy and the computerised techniques of Manufacturing Resource Planning.

6.2 THE BASIC IDEA AND PHILOSOPHIES.

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6.2.1 INTRODUCTION

The "Ideal" manufacturing operation would operate under the following conditions :

Zero inventory - zero lead time; products made exactly when they are needed and no waste. Since the "ideal" is not achievable in the foreseeable future any move towards closing the gap between actual and the "ideal" will be considered an improvement.

In order to promote continuous activities towards the closure of the gap towards "the ideal", several philosophies and strategies should be adopted.

Komza[35:100] Summarises the philosophies and strategies which are further developed in this chapter.

6.2.2 THE IDEA

The idea will enlarge on the development of a system which uses schedules in place of orders. The plan shifts from the "Lot Mentality" of an order to the "Rate Mentality" of a schedule; from "Inventory Control" to "Flow Control". With the "Zero Inventory" crusade, such a movement should reduce inventory to a minimum. Batch production has no future. Planning should be geared to convert from batch production to flow production. In other words, there should be no waste batches to complete orders, but plans for the flow of production to adhere to schedules. No control of inventory levels, but rather control of inventory flow. The system should have an administration and tracking facility to accommodate daily recording of production at key control points of process. Inventory should be administered in a network computerised system similar to that of the Manufacturing Resource Planning System where schedule exception messages should be generated. Parts should be clearly identified through a simple Bill Of Material to allow for capacity plan. Tool and techniques like "Kanban" and "U" shape layout should be used to allow efficient balancing of supply and demand. Most important is the adoption of these guidelines through all the diverse functions of the organisations.

6.2.3 THE PHILOSOPHY.

The philosophy that should be used is: "Concentrate on the process to expose and eliminate the 'Rocks in the River'". In other words, use the techniques of problem solving to address communication flow and physical material flow. The philosophy is illustrated in Figure 6.1 (a & b).

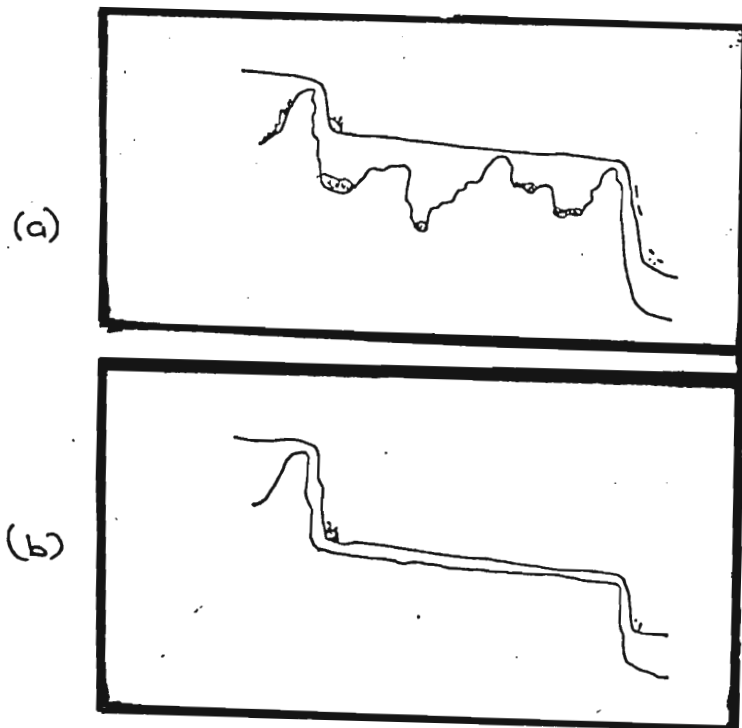


Figure 6.1 (a & b) The philosophy of "Total Inventory Planning And Flow Control". (Source: Stork [60:30].)

Figure 6.1(a) portrays a manufacturing environment like a river with many rocks and obstructions which reduce and slow down the flow of the river. As an analogy this represents a manufacturing process that takes a long time to complete, with many stops, obstacles and problems. Such an environment will require a large number of complex manufacturing controls to cope with the slow moving flow. Figure 6.1(b) represents a more effective production environment. Work is done through a "clean river" which is possible through problem solving on the factory shop floor. If work is done through a "clean river" environment, the process flows and subsequently is easier to manage and control.

6.3 STRATEGIES TO BACK UP THE PHILOSOPHY.

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6.3.1 ORGANISATION STRATEGIES.

6.3.1.1 INTRODUCTION.

Organisation strategies involve a wide range of actions and changes which affect the entire workforce from top management down to shop floor workers. The strategies involve examination of the culture of the organisation and its structure.

6.3.1.2 CULTURE.

To ensure that any system will succeed, it is fundamental to gain the full approval and support of top management, from the chairman or chief executive through to the board of directors, down to line management and support function management. This support and approval of top management is realised by:

- *Meeting with all levels of Personnel* - daily or weekly, the meeting to consist of top management, line management and workers to create a constant interaction with the workforce. Worker involvement groups should receive the most attention, whether they are called Quality Circles, Green Areas, meeting places or something else. Participation is voluntary, but encouraged by management.

- A formal suggestion system must be introduced to manage all suggestions coming from the shop floor, attending to them, evaluating them responding to individual suggestions and rewarding the right people for beneficial suggestions. The whole process must be handled with a positive approach to encourage as many suggestions as possible. As suggestions are made, implemented and taken notice of, the workforce will be motivated to look for more improvement resulting in valuable suggestions. Through involvement with the suggestion process, workers will benefit as part of the "decision taking body".

- Incentive programmes must be developed for the originator of good suggestions, whether they be implemented or not. Incentive programmes must be used to achieve improvements in production, quality and a versatile multi-skilled workforce. Rewards can be remunerative as well as in the form of recognition by publicising the suggestion of the originator and the contribution it has made to the success of the business.

- A good form of recognition involves creating job security within the workforce through internal opportunity. It must be perceived by the

workforce that internal opportunities are available, that every worker has the opportunity to advance through the ranks and to fulfil his personal expectations with the help of the company through training and encouragement.

6.3.1.3 ORGANISATIONAL STRUCTURE.

The structure of the organisation must create a conducive environment and a positive attitude. The structure must convey to all levels of the organisation that the process is managed and not episodic. In an effective structure all specialised support functions such as: Quality Assurance; engineering; Information System; and Administration should structure their activities to enhance production quality, deliveries on time and cost performance.

The organisation should be structured in such a way that it will encourage every employee through-out the organisation to come up with suggestions of "How to obtain better achievements", and should allow communications meeting to take place in a participative atmosphere.

6.3.2 TRAINING AND EDUCATION STRATEGY.

Every member of the workforce must be educated so to become a better businessman. Knowledge which assists the worker in a better understanding of his workplace and of the nature of the business industries.

Know the Competition - Foreign and Domestic. Make every employee aware of the competition, their strengths and weaknesses. Visit, if possible, mills and plants.

Encourage everybody to think innovatively. - Make the workforce think differently. Organise visits to other factories.

Encourage shop floor cross-pollination. Expose on notice boards of the company external and internal publications related to the industry on the kind of work done in the company.

- Newspaper articles related to the industry.
- Technical publication which can impact or enrich the knowledge of the shopfloor workers.

6.3.3 ASSET STRATEGIES.

The optimum utilisation of assets should be measured to monitor the total effectiveness of the organisation. Key measures should be:

QUALITY - Reject rate, rework percentage, improvement path, number of customer complaints.

DELIVERY- Delivery of goods on time, cost effectiveness of delivery.

PERFORMANCE TO SCHEDULE - Constant comparison between planned schedules and actual performance. As long as performance matches scheduling, the organisation can be regarded as effective.

CYCLE TIME - The period of time it takes for one unit of a product to be produced.

TURNS OF INVENTORY PER PERIOD - The period of time it takes for an inventory base unit to be despatched, or how many times inventory turns in a given period of time (week, month, quarterly, yearly).

SCRAP - Waste, unusable raw materials, unusable stocks, redundant stock.

DOWN TIME - The time that machinery and other equipment is not utilised due to breakdown, set-up time. This factor has a large impact on return on sets.

6.3.4 THE PRODUCT STRATEGY.

The product strategy involves two main key factors. The first key factor is keeping the product structure simple and direct by eliminating multiple levels of assembly. That is, reducing the levels in the Bill Of Material to a minimum. The second key factor involves the production and material management personnel in the product design. Design teams should ensure that newly developed products will be simple to manufacture. Products with characteristics that will distort scheduling or will be problematic in production scheduling should be avoided. Therefore, involvement of material management personnel during the product design period is essential to prevent many disturbances during the production process.

6.3.5 PROCESS STRATEGY.

The process strategy consists of two major factors. The first key factor is the constant improvement of manufacturing cycle times, using problem solving, quality circles and innovation. The second key factor is balancing manufacturing resources so that material will flow. The balancing of all resources, machinery, raw materials, human resources, tools and storage

space, reduces to the minimum bottlenecks which will allow material at all stages, raw, sub-assemblies, finished goods, to flow.

6.3.6 PLANNING STRATEGY.

In order to achieve a meaningful, effective and workable plan, certain guidelines should be taken into consideration when preparing the plan.

The first guideline is to plan/schedule in terms of day or hours. Scheduling in short terms, to promote easy monitoring will provide prompt feedback from the shop floor, so that when plans are not met, the next schedule can be altered in good time.

The second guideline is to try and establish, as far as possible, frozen time fences. Production should be planned in time brackets to be maintained without change for as long as possible.

The third guideline is to keep production flexible and use different techniques to schedule different items. The scheduling of all items according to the same system can create problems. Different item types such as unique items and common items should be scheduled using different methods to promote uninterrupted production.

6.3.7 SOFTWARE STRATEGY.

As planning expands and becomes more detailed, the use of a computer is essential to cope with higher levels of complexity in the execution of the planning process. Some basic rules are useful to keep the software as simple and flexible as possible.

The first rule is to use a simple and portable computer for the compilation of inventory tracing, rough cut capacity planning and short business simulations.

Rule number two is to simplify to the utmost the Material Requirement Planning process. This is done by keeping the Bill of Material simple and direct, keeping reports to the minimum required level and avoiding the accommodation of policy codes like safety stocks and scrap factors into the system. The use of a simple portable computer enables lead and cycle times to be continuously updated, vital characteristics of an efficient plan and schedule.

6.3.8 EXECUTION STRATEGY.

All strategies (Culture, Planning, Product, Assets) are important for a successful organisation, but without an execution strategy to back-up all the other strategies, the end result will be doubtful. Some basic shop floor tools and systems should be used such

as the "pull" system to uncover bottlenecks. The use of systems like Kanban or Andon are also very effective and easily understood. Transport of stocks from one place to the other should be carried out in standard containers (tot bins) to enable the use of standard material handling equipment and storage systems. Production should concentrate on major issues and daily production schedules should be communicated to and within departments.

6.4 THE MODULES.

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6.4.1. INTRODUCTION

The model of "Total Inventory Planning and Flow Control" can be designed in two stages.

The first stage is "The Schematic" stage which indicates the major elements of the model.

The second stage consists of a detailed diagram of the modules, their connection and interrelation.

6.4.2 THE SCHEMATIC MODULES.

The schematic modules as illustrated in figure 6.2 consists of five major elements which are fundamental to the proposed system.

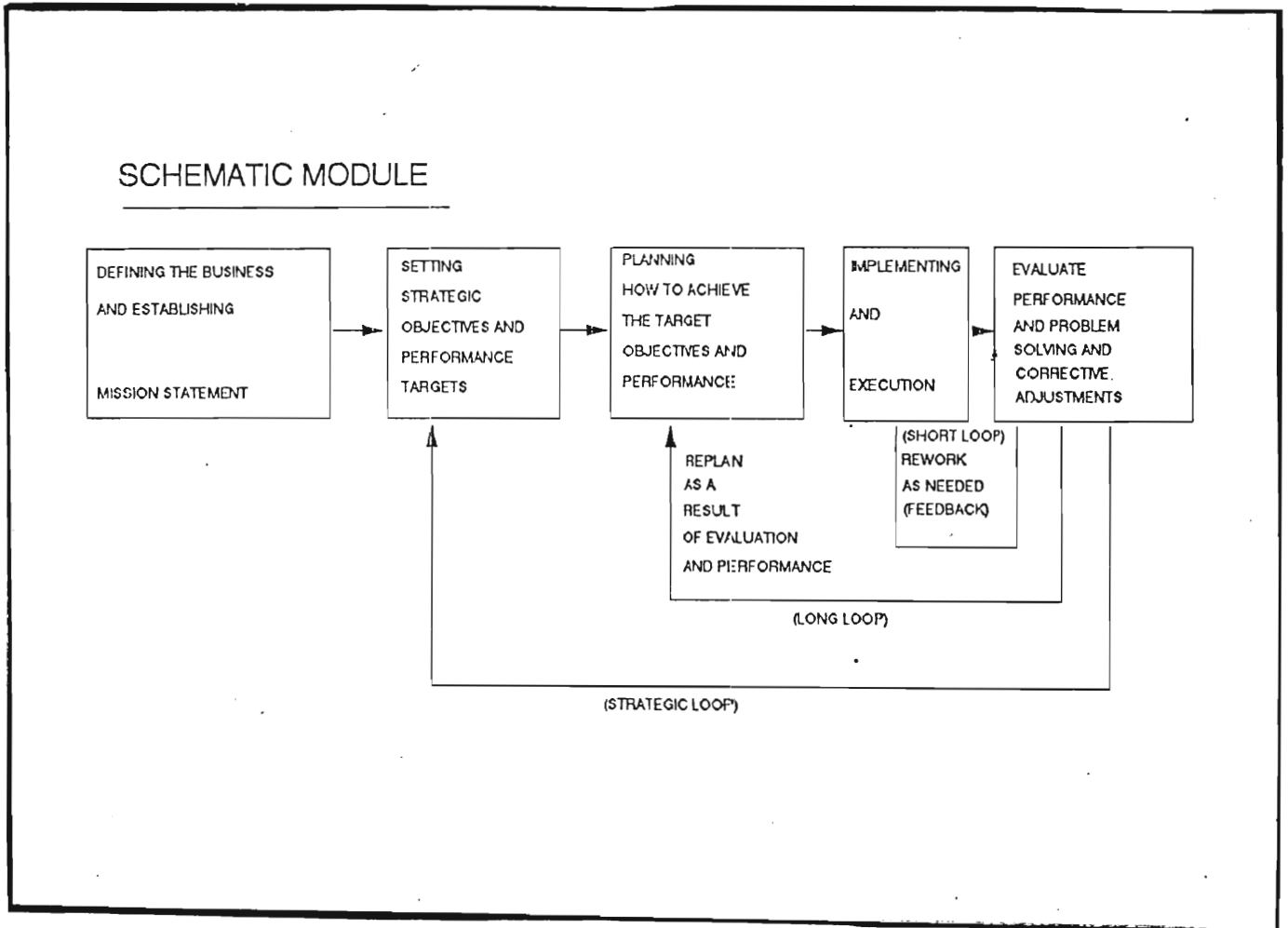


FIGURE 6.2 THE SCHEMATIC MODULES OF "TOTAL INVENTORY PLANNING AND FLOW CONTROL.

(Source: Thompson & Strickland [1:15]).

The five main elements of the schematic model are:

- *Defining the business;*
- *Setting strategic objectives for the business;*
- *Planning how to achieve the objectives and targets as set in the previous element;*
- *Implementation and execution of the plans;*
- *Evaluation of execution.*

Although it seems as though one element follows the other, much feedback and corrective action takes place between each of the elements. The direction of the information flow and its influence on elements, is dictated by the reactions of the environment.

6.4.2.1 DEFINING THE BUSINESS.

This element consists of direction setting from senior management. It broadly charts the future direction of the organisation based on present knowledge. It should answer the question, "What is our business and what is it to be?". In other words, what kind of organisation is it at present, in what direction is the organisation going, in what markets should it be in and which needs of the buyer can it best serve.

6.4.2.2 SETTING STRATEGIC OBJECTIVES.

The act of establishing formal objectives and specific performance targets provides an organisation with focused vision to guard against drift, aimless

activity and confusion.

6.4.2.3 PLANNING THE ACHIEVEMENT OF TARGET OBJECTIVES.

This element consists of two stages. Firstly, "Strategic Planning". At this stage management should try to find solutions to questions such as:

- How are the target results to be accomplished?
- What are the means of achieving the objectives?
- What resources are to be utilized to take full advantage of opportunities and to minimise the chance of under achieving?

The second stage is involved with actual "Production Planning" of the work. A system like Manufacturing Resource Planning is ideal to schedule rough-cut, resource and material balancing, order and despatch administration and inventory control.

6.4.2.4 IMPLEMENTATION AND EXECUTION.

This element is simply called "Make It Happen" and also consists of two stages. The one involves implementation of strategies and the second, execution of the production plans.

The strategic stage involves the implementation of the basic organisational strategies like culture, structure, training and education, reward and incentive systems. This is the time to create the right atmosphere and environment so that production

execution plans can be achieved.

The production execution stage involves the implementation of Just-In-Time shop floor philosophies such as cycle time, quality, improvement of flow, low inventory, waste reduction, keeping the production process flexible, "pull" and Kanban.

The intention of this element is to bring the business close to achieving its' goals, but more importantly to establish a situation of continuous improvement. By keeping the target flexible, improvement can become a way of life.

6.4.2.5 EVALUATING PERFORMANCE AND MAKING CORRECTIVE ADJUSTMENTS.

"A never ending story". Circumstances which arise every now and then make corrective action desirable. This element is about evaluating and monitoring whether implementation and execution went according to plan, better or worse, and consequently making the necessary adjustments.

There are three loops of feedback and evaluation in the corrective adjustments section of the element. The first loop, feeds back to the execution element and is the "REWORK LOOP". When results achieved prove to be as planned, only minor internal conditions need to be changed according to experience, trial and error.

The second loop feeds the how to achieve element and is the "REPLAN LOOP". Here a large amount of minor improvements or major changes in product structure or process route are planned. When such events occur a full replan of the production process should take place without changing the objective and targeted performance.

The third loop is the "STRATEGIC LOOP". Due to major changes and improvements, changes in the market or environment a call will be made for a strategic review which can drive different implementation approaches, and the testing of new ideas. Usually a review like this will change some of the strategies and will lead to a big improvement in goal setting and performance targets.

6.4.3 SOURCES OF SCHEMATIC ELEMENTS.

Now that the purpose of the main elements has been clearly defined, the source of each element should be established, bearing in mind the ideas and philosophies of the new model (paragraphs 6.2 and 6.3). As the model is based on Manufacturing Resource Planning and Just-In-Time, some of the techniques, methods, sub-systems and philosophies of these two systems will be adopted to establish the fundamentals of each element.

The first element, *"Defining The Business"*, is a strategic step where guidelines about markets, manufacturing resources and goals for the future of the business are defined. This element is a basic requirement of both systems. In Manufacturing Resource Planning it is a module named the "Business Plan" (paragraph 3.2.1) and in Just-In-Time it is a prerequisite, as it is aimed at "Customer satisfaction at the lowest cost". In the new model, this element will adopt a "For The Customer" motto extracted from Just-In-Time.

The second element, *"Setting Strategic Objectives"*, where formal objectives and specific performance targets are established, is a part of the "business Plan" in Manufacturing Resource Planning. Objectives and targets are set for a defined period of time and all the systems are geared towards them. In the Just-In-Time system objectives and targets are set for a momentary period as the system encourages and stimulates continuous improvement in every aspect of the business. This element in the new model will consist of a mixed approach. Future strategic objectives and targets will still be established, not for a predefined period of time, but rather as a guideline for the continuous search for improved proficiency.

The *"How To Achieve Target Objectives"* element involves two stages, "Strategic Planning" and "Production Planning". "Strategic Planning" deals with the question "What means of resource and technique should be used or acquired to achieve the target objectives? This stage is missing in Manufacturing Resource Planning as it bases plans on a rigid given situation. On the contrary, the Just-In-Time approach makes provision for constant innovations to the "Strategic Plan" through Quality Circles and the "Open to Suggestions" philosophy. Just-In-Time is the desirable concept bearing in mind the main idea and philosophy of the new model. The "Production Planning" stage provides formal techniques for Master Schedule, Rough Cut Capacity, Material Requirements and Capacity Requirement Planning. Apart from Capacity Requirement Planning which is a part of the Shojinka technique (paragraph 4.3.4) in the Just-In-Time system, all the other parts are missing. The computerised Manufacturing Resource Planning modules which compile Rough Cut Capacity and Material Requirements based on Master Schedule and a Bill Of Materials will be used in the new model, together with Capacity Planning which is based on "Part Production Capacity", a section of Shojinka.

The next element, *"Implementation and Execution"*, consists of two stages. "Implementation", a time when

all the basic organisational strategies (paragraph 6.3.1) are implemented, and "Execution" will be largely based on the Just-In-Time system which places great emphasis on the execution of the plans as explained in Just-In-Time Production (paragraph 4.3). Some sub-sections of "Shop Floor Control"(paragraph 3.2.8) such as Input/Output Control and Despatch Plans representing the administration of the process, will be adopted from Manufacturing Resource Planning .

The last element is "*Evaluate Performance*" This element consists mainly of problem solving and corrective adjustments which should be based on computer reports, comparing results and plans, anticipated delay reports, work-in-process evaluation against budget, experience from the shop floor, outcomes from quality circles and management meetings with workers, evaluating workers' suggestions and evaluating changes in the market place. In order to cover all of the above, this element will have to utilize sections of "Shop Floor Control"(pararaph 3.2.8) as well as sections from "Quality Circle"(paragraph 4.3.6).

To summarise, Figure 6.3 indicates the sources of the schematic elements of the model.

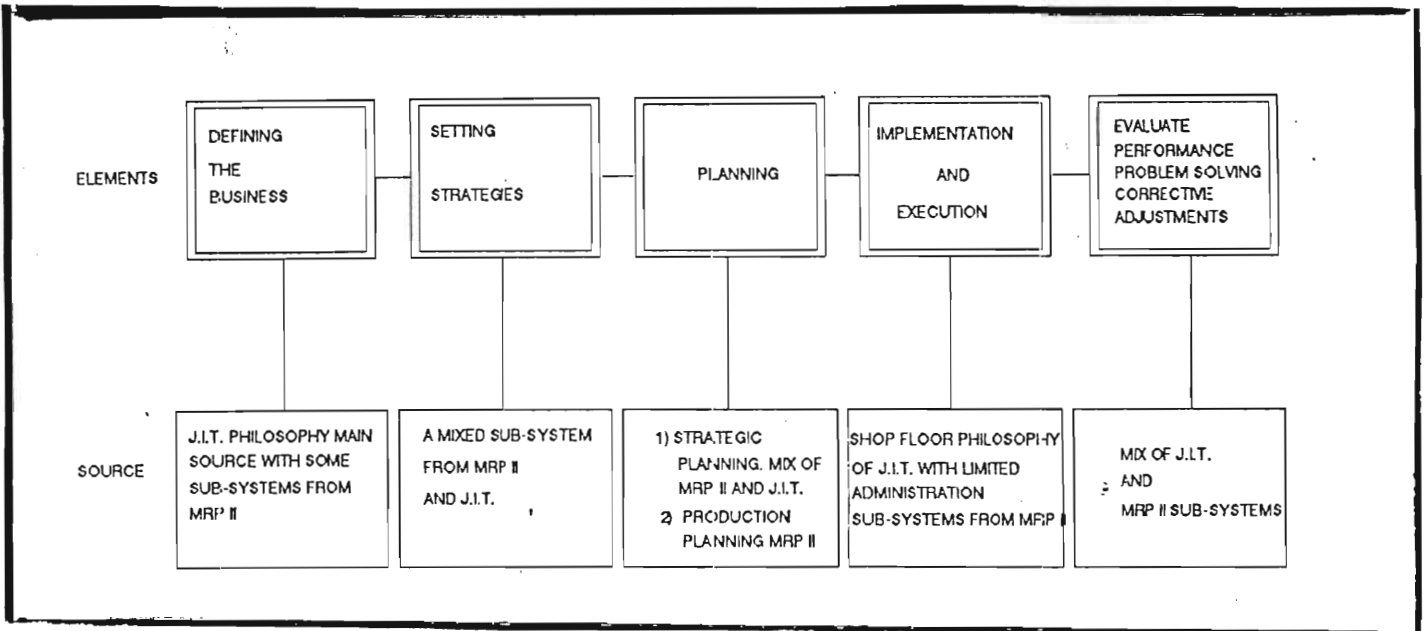


FIGURE 6.3 SCHEMATIC ELEMENTS OF "TOTAL INVENTORY PLANNING AND FLOW CONTROL" AND THEIR SOURCES.

6.4.4 DETAILED MODULES OF THE MODEL.

The purpose of this dissertation has been to develop a new model. In the first instance the various elements involved in the schematic model were explored. With the purpose of each element firmly established and clarified, stage two set about defining the source of the module involved in that element. As the proposed model is a mix of Manufacturing Resource Planning and Just-In-Time, so are the modules that build up the elements of the model.

In order to achieve the "synergy affect" by combining modules from the two systems, the modules adopted from these systems should be slightly modified in some cases in the pursuit of a perfect match between the systems. While structuring and building up the proposed model, the main philosophy and strategies (paragrapg 6.2, 6.3) have constantly been kept in mind. Figure 6.4 represents a detailed structure of the modules in the "Total Inventory Planning and Flow Control" model. The figure also shows the flow and interrelations between the various modules and the feedback of information between the elements.

Defining the Business. Setting Strategic Objectives. Planning. Implementation and Execution. Evaluating Performance and Feedback to cause corrective adjustment.

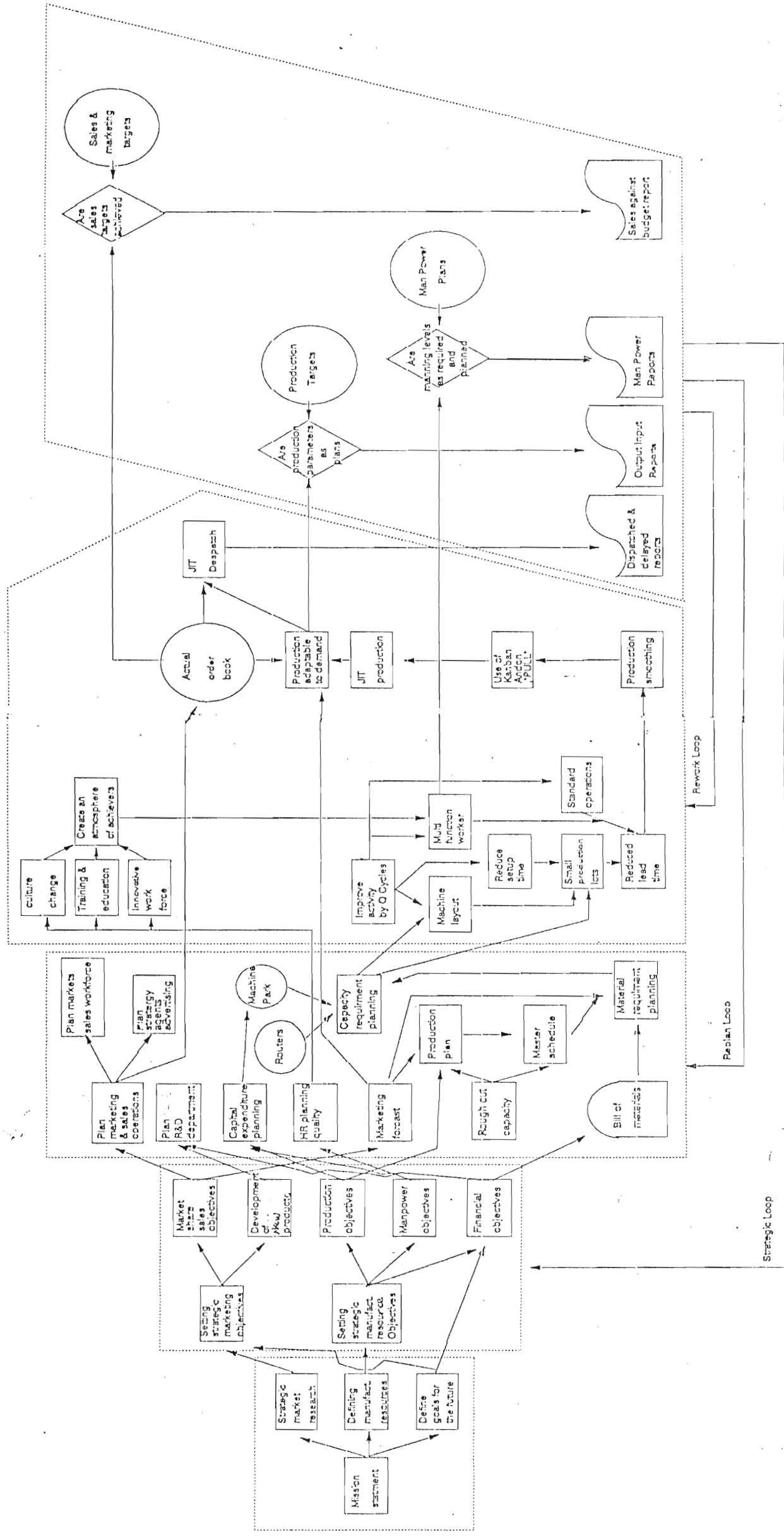


Figure 6.4 DETAILED STRUCTURE OF THE MODEL "TOTAL INVENTORY PLANNING AND FLOW CONTROL"

A brief discussion of the modules making up the "new" model follows:

Defining The Business element. - This element is built up from four main modules: Mission Statement (or Direction Statement), Strategic Market Research, Defining Manufacturing Resources and Defining Broad Goals. The Mission Statement or Direction Statement module is usually issued by the chairman or the chief executive officer. It is a short statement or declaration of how the person who drives the business views it at present and its planned development in the future. It should specify the main values of the business, the goals of the business and future vision. Figure 6.5 is an example of a Direction Statement borrowed from a South African oil refinery.

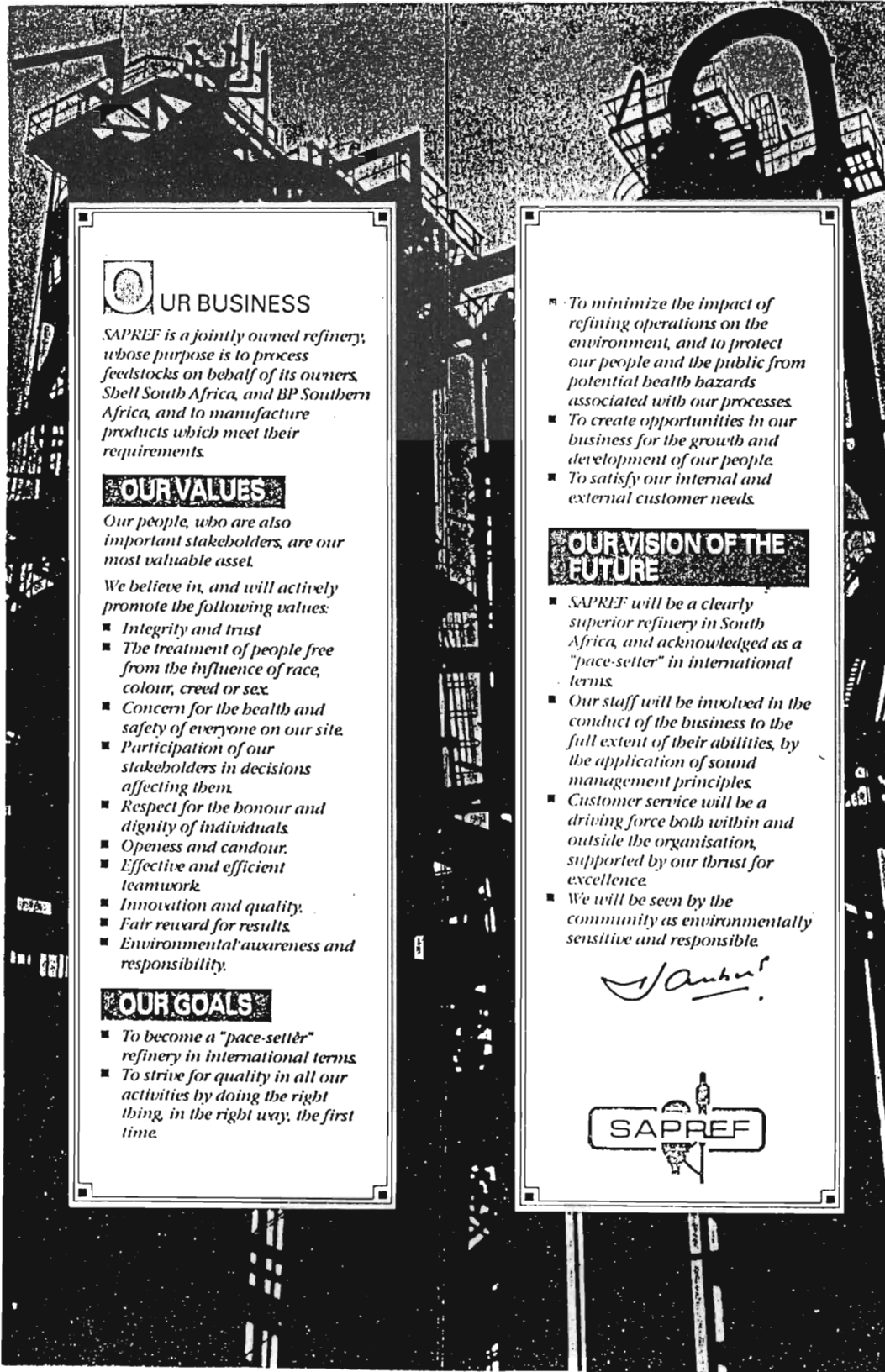


Figure 6.5 Direction Statement.

(Source: SAPREF direction statement, 1990)

The Strategic Market Research module is directed by senior management for market research based on the mission statement to determine what segment or niche of the market the business wants to focus on and the accessibility of that segment or niche.

Defining Manufacturing Resources is the stage where senior management defines the manufacturing resources involved in making the business viable.

Defining Broad Goals for the future is the process of defining goals that are non-marketing or manufacturing related such as community and environmental goals, safety issues and financial principles.

The *Setting of Strategic Objectives* element is made up from seven modules. The first two modules Setting Strategic Marketing Objectives and Setting strategic Manufacturing Resources Objectives are directly driven from Defining The Business element, while the other five modules Marketing Share - Sales Objectives, Development Objectives, Production Objectives, Manpower Objectives and Financial Objectives - are driven from the first two modules of this element.

The Setting of Strategic Marketing Objectives module is the phase where market and sales objectives for the medium and long term are established, taking into consideration the development of new products. This module is further broken down into two specific modules.

Market Share Sales Objective is self explanatory. In this module the market share the business wants to capture is set, as well as sales objectives for the various products.

Development Objectives is the module where objectives are set for the research and development of new products, complementary products and replacement products. The feasibility of developing such products within the scope of the segment or niche as defined by the Strategic Market Research module, must be checked. The module of Setting Strategic Manufacturing Resource Objectives is the setting of general objectives for manufacturing such as overall efficiencies, man hours per unit and ratios, for example manufacturing cost to sales and manufacturing overheads to sales and to direct labour. This module is diversified into three further specific modules.

The Production Objectives module sets defined targets for production in money terms such as, items to the value of R2m should be produced per time unit. It should also set specific efficiency targets for departments or product lines, production hours and machine utilisation.

The Manpower Objectives module sets targets for manning levels in the various departments - overtime limits, training levels and objectives, recruitment objectives, turnover targets - that will be used as guidelines in the pursuit of improvement.

The Financial Objectives module sets financial objectives for the business such as stock levels, debtors and creditors days, working capital, borrowing, turnover, the value of fixed assets, ratios such as return on net assets and profit to sales. This module should also outline financial objectives and responsibility to the environment and the community.

The Planning element is built up of two sets of modules. The first batch of modules consists of strategic planning which deals with Human Resource Planning, Policies, Research and Development Planning. The second part is the actual planning of the manufacturing process.

The strategic planning consists of four modules which are Human Resource Planning, Capital Expenditure Planning, Research and Development Planning and Marketing and Sales Planning.

Human Resource Planning is the stage where the guidelines set at the Manpower Objectives module are used to plan the culture of the organisation in order to achieve a "quality" workforce ideal for the implementation of the manufacturing plans.

Capital Expenditure Planning is an evaluation of the machinery and equipment available in the plant against new machinery and equipment available in the market. This evaluation should be followed with an action plan to replace or add new equipment to the business in

order to make it more efficient and to facilitate the achievement of the objectives.

The Research and Development Planning module deals with the planning of research and the development of new products by developing totally new products or changing existing ones. In addition to projecting timing, the required budgets and the acquisition of "know-how" should be planned.

The Marketing and Sales Operations Planning module deals with the actual achievement of the set objectives. The planning of sales either through sales personnel or agents, direct sales or third party distributors, systems of reward such as commissions or flat rate salaries as well as the use of advertising and the media, payment terms and discount policies are formulated at this stage.

The second part of this element, Planning Manufacturing is a set of six modules adopted "as is" from the Manufacturing Resource Planning. These modules are Marketing Forecast, Production Plan, Rough Cut Capacity, Master Schedule, Material Requirement Planning and Capacity Requirement Planning explained in detail in chapter 3.

Two main difference exist between the modules as they appear in Manufacturing Resource Planning and in the new model. The first is that the schedules in the new model are done on a daily or twelve hourly basis, complying with the planning strategy (paragraph

6.3.6). Scheduling on a more frequent basis will allow for changes to the database of set-up time, cycle time and lot sizes for the continuous improvement of the production process, systems and methods. Another significant difference is that in the new model the aim of the schedule is not to plan orders or independent demand by lots, but to schedule the flow or to plan the rate of production. This is the main idea or concept of the new model as presented in (paragraph 6.2.1).

The Implementation and Execution element consists of two parts. The first part is implementation. This part is built up of five modules, each of them dealing with the implementation of one of the main strategies of the model namely Organisation Strategies, Asset Strategies, Production Strategies, Process Strategies and Software Strategies. The second part is Execution which uses as a guideline the Execution Strategy (paragraph 6.3.8) and adopts Just-In-Time principles (paragraph 4.3). These principles consist of the use of Kanban, Production Smoothing, Reduction in Set-up Time and Lead Time, Shojinka, Improved Activity and Quality Circles.

The Evaluation of Performance and Corrective Adjustments element realises the main philosophy of the model (paragraph 6.2.2) which aims to expose and

eliminate "The Rocks in the River". These are the problems that do not allow "The River to flow" or for better achievements to be reached. This is a never ending story or process as there is never a limit to improvements and changes. It stimulates the workforce to be more innovative and to strive for continuous improvement. Represented in this element is evaluation of achievement against the plan through reports such as Input/Output reports, Manning Levels Reports, sales against forecast or budget reports. Once targets and goals are achieved, the search for better systems and methods to improve performance should not stop, but must continue as an entrenched way of life. These evaluations and the search for ongoing improvement are the basis of a feedback system represented in the model by the three loops Rework Loop, Replan Loop and Strategic Loop. These create a situation providing for corrective adjustments targeted at the respective element of the model depending on the reason and the kind of change or adjustment required (paragraph 6.4.4.5).

Chapter 7 - CONCLUSION AND RECOMMENDATION

7.1 Conclusion
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A new modular model was developed based on two main production systems used in industry, Manufacturing Resource Planning and Just-In-Time.

Although it seems at first sight, that the two systems are totally different a closer investigation has shown many similarities and mutual goals.

The new model is driven by the philosophy of "concentrate on the process to expose and eliminate the Rocks in the River" which implies problem solving to address communication flow and physical flow.

The philosophy is backed by a set of strategies which involves each discipline within the organisation. From the Marketing through Design, Planning, Production, Purchasing, Sales and after sales services.

The strategies are related to the various resources of the organisation such as:

People or the Human Resources, which places emphasis on the culture of the company, the training and education of the people and the structure of the

organisation.

Assets - Ways and tools to measure the effective usage of the physical assets, such as production machinery, workshop machinery and computers (hardware & software).

The above philosophy and strategies formed the fundamental base, in which were added modified tools and methods used in MRP and JIT.

The model has five elements each consisting of sets of modules. The modules are designed in a generalistic way, mainly specifying the principle idea of the module, available tools and methods to implement the module and its connection to the other module of the model. Each of the modules can be dealt with separately according to the specific requirement of the organisation, resulting in a flexible model that can be adopted and implemented in various environments and industries.

7.2 RECOMMENDATIONS

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In order to optimise the chances of succeeding in the implementation of the model in any organisation, it is recommended that the following points be considered;

- The company as a whole must be committed to the system.

- The implementation process must follow the elements in the right order as they appear in the model chart.

- All the disciplines of the organisation must take part in the education and training process toward a change in culture.

- The implementation of such a system is a "Never Ending Story" involving a continuous search for better and more efficient ways of doing things whether in Marketing, Designing, Planning, Producing or Servicing. The only way to evaluate the progress and the success of the implementation is by monitoring the organisation and finding continuous improvement compared to

the previous monitored period.

- In the implementation process the relevance of each module to the specific organisation should be considered. Modules with no impact on the organisation can be disregarded and bigger emphasis put on other relevant modules. For example in a service orientated or retail organisation the modules related to production can be disregarded and more emphasis must be given to marketing and customer service modules.

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