# Chapter 2
# Theoretical Study and Literature Surveys

## 1. Introduction

Product and service choices, process selection and decisions upon selecting location and layout of the factory appropriately for the manufacturing environment are the most basic decisions for managers because those decisions have long-term consequences for the industrial organizations.

Processes are the essential of operation management which convert inputs into outputs. It affects the entire organization and its capability to achieve the mission and business objectives of the firm's supply chain. So process selection choices influence a lot in strategic decisions.

Process environment selection and the arrangement of work place are closely related. Changing an environment directly forces the factory layout to changes consequently. This chapter will consider about associate theories and knowledge studies that have been surveyed continuously in existing textbooks, reports, and thesis researches, in years that the studies have been liberated. The details are involved in the sample air conditioner factory redesign. The topics will cover in types of process environment, types of facilities layout, time compression operations, procedures and work measurements respectively.

## 2. Process Selecting Consideration

The principle of selecting a process represents how the way to producing goods and services is designed and organized. It has major implications for layout and facilities, equipment, and design of the work systems. Processes decision occurs when new products or services are being planned or the firm planned to rearrange for improvements of the manufacturing factory.



The process selection approaches is determined by the firm's process strategy by considering three important aspects which are:

1. Make or buy decisions – The extent to which organization will produce goods or provide services in-house as opposed to relying on outside organizations to produce or provide them.
2. Capital intensity – The mix of equipment and labor that will be used by the organization.
3. Process flexibility – The degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume processed, and changes in technology.

# 3. Manufacturing Analysis

The initial step of implementing a process redesign is that firstly, we must performed an analysis on the internal and external analysis of the manufacturing company. The methods, concepts, tools, and techniques can be applied into the manufacturing factory to investigate production characteristic and operation performance.

## 3.1 Make or Buy decisions

Basic approach to manufacturing analysis is to consider whether the company will come up with an idea of "make or buy". Manufacturing company continues to focus their resources on core business processes and technology where they feel their central value to their customers reside. The very first step in process planning is to consider whether to make or buy some or all of a product or some or all of a service from available providers. Manufacturers might decide to purchase certain parts rather than make them. Sometimes all parts are purchased with the manufacturer simply performing assembly operations. Many organization contract cleaning services and some contract for repair services. When a decision is made to buy or contract, it will eliminate or reduce the need for process selection and the complexity of reallocation.

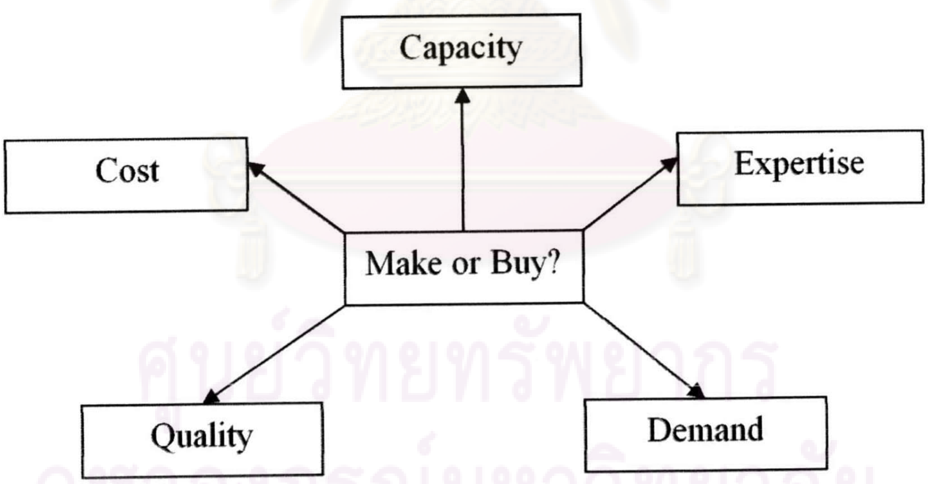


Figure 2-1; Factors to consider making or buying

When an operation decides to purchase products or services from a supplier it means making the decision not to create those products or services itself. This may not always be a straight forward decision. If an organization has available equipment, skillful workforces, enough expertise and time, it is sensible to produce an item or perform a service in-house. In some cases the operation may be able to produce parts or services in-house at a lower cost or at a higher quality than can suppliers. Yet in other cases suppliers may be able to specialize in the production of certain parts or services and produce them more cheaply or at higher quality than can the firm itself. It is part of the responsibility of the purchasing and manufacturing function to coordinate to investigate whether the operation is better served buying in products or services, or choosing to create them itself.

Often the major criteria used to decide whether to make or buy is the financial aspect. Both fixed cost and unit cost must be calculated. If a company can make a part or service in-house more cheaply than it can buy it, it is likely to do so, unless there are other following reasons concern with quality and specializations problems. The financial analysis involvement is not always straightforward. The decision often needs to be based on the marginal cost of producing something in-house. The marginal cost is the extra cost which is incurred by the operation in creating the product or service. For example, if an operation already has the equipment and staff in place to make a particular product and there is spare capacity within the part of the operation which could make that product, then the extra, or marginal, cost of making the products in-house will be the variable costs associated with their manufacture.

In other cases, an operation might decide to perform part of work itself and let others handle the rest in order to maintain flexibility and prevent against loss in relationship with subcontractor. Moreover, this provides a bargaining power in negotiations with contractors. An increasingly popular rationale for buying in is that they are not core to the operation's main activity. Many companies are increasingly out-sourcing such services as transportation, cleaning, computing, catering and maintenance or even sub-assemblies for final assembly. Pushing these services and production out to specialists allows an operation to concentrate on what directly wins it business in the market place.

When demand for a product is high and constant, the firm should so the work itself. But if demands are fluctuate or receiving a small order each time, it usually better handled by specialists who are able to combine orders from multiple sources, which results in higher volume and tends to offset individual buyer fluctuations.

### 3.2 PEST Analysis

One technique for analyzing the external environment is called PEST analysis. This sub-divides the external factors into 4 groups; political, economic, social and technological. A successful PEST analysis does not produce a huge list of all the external factors that can be thought of but selects those which will produce an opportunity or threat for the company or business unit. There are number of key environmental drivers of change that is forces likely to affect the structure of an industry which are significant and crucially need an urgent redesign.

The following table gives an indication of some of the more important factors that normally considered in global aspect. It is vital to have some understanding of these opportunities and threats in order to identify where to target improvement actions and to help prioritize these actions to get the best return.

Table 2-1; Factors involved in PEST analysis

| | |
|---|---|
| Politic | • Monopolies legislation<br>• Environment protection law<br>• Health and safety legislation<br>• Employment law<br>• Wage and price control<br>• Taxation policy |
| Economic | • Business cycles<br>• Economic growth and GDP trends<br>• Domestic disposal income<br>• Interest rates<br>• Inflations<br>• Exchange rate<br>• Energy availability and cost |
| Social | • Population demographics<br>• Trends in life style, leisure, health<br>• Social mobility<br>• Consumerism<br>• Income distribution<br>• Pollution |
| Technology | • Industry focus on technological research and R&D innovation<br>• New development and knowledge<br>• New criteria of work and management<br>• Speed of technology transfer<br>• Information technology and communication<br>• Transport infrastructure |

PEST analysis of environmental influences these analysis purposes:

1. What environmental factors are affecting the organization?
2. Which of these are the most important at the present time? Or several years in the future.

There may be advantages of global operations. This is especially the case in industries in which large volume or standardized production is required for optimum economies of scale, as in some components to the electronics industry.

Other advantages might be achieved by central sourcing efficiencies from lowest-cost suppliers across the world.

### 3.3 Product & Process Classification

Product classification is a model that helps the company to fundamentally clarify the position of their goods into the appropriate quadrant of the marketplace. This tool was created some years ago as a result of studying the Japanese. The idea is to really understand the markets then develop services and products that are in harmony with the needs of that market. Then develop factories, systems, processes, cultures, organizations, structures and so on that are in harmony with providing those products and services.

The model consists of four different ways in adjusting goods to the right market which are separated into super value goods, consumer durable, fashion, and commodities goods shown in figure 2.

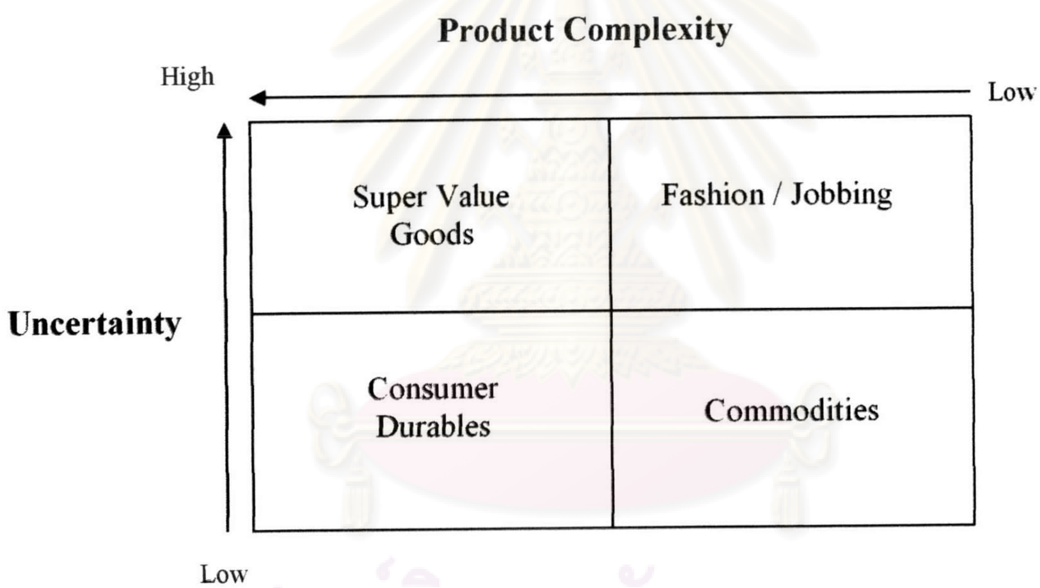


Figure 2-2; Product classification model

Competitive Design Management: University of Warwick, UK, 2002 (chap.2, p.6)

There are four grids in the model separate each type of product with axes of relative complexity and relative uncertainty. Each single grid does not refer that you should do better by settling in one than another. It depends on particular business and making decision where you aiming to be (finding your goal), then try to understand customer's perception and critical competence respectively. This tool will possibly give a lot of clear path of performance planning. It is another tool for internal analysis of the manufacturing company to perform process redesign.

The super value goods are simplified by complex and advance technology products such as aerospace, ship and construction which have lots of parts, components, suppliers, work centers and technologies. That is the reason for their complexity. They are generally uncertain because the products are sold to very specific customers in particular demand and usage. The factory layout for super value goods are mostly fixed-position which the goods remain stationary while the workers, materials and equipments are moved to the site as needed.

Consumer durable are typically technological goods which have been produce in high volume which Japanese industry has been most successful in the surveys. The technology itself may not be as complicate or require much facility as super value goods. And they are not fashion-base like fashionable goods. This group of product has high complexity and low uncertainty so it located in the bottom-left grid of the model. The examples for this type of products are white goods, simple automotives, and the refrigerators.

Fashion goods are not certain as well as jobbing or craftwork. It characteristic of the product changes rapidly and unpredictably. On the other hand, they can be very simple products such as boutique, clothes, shoes, jewelry and chocolate.

Commodities are made in very large quantities for a large number of customers. The product detail is simple and straightforward with low technology.

The model can be applied to manufacturing processes to create critical competence in further business competition in each product type by the next two models.

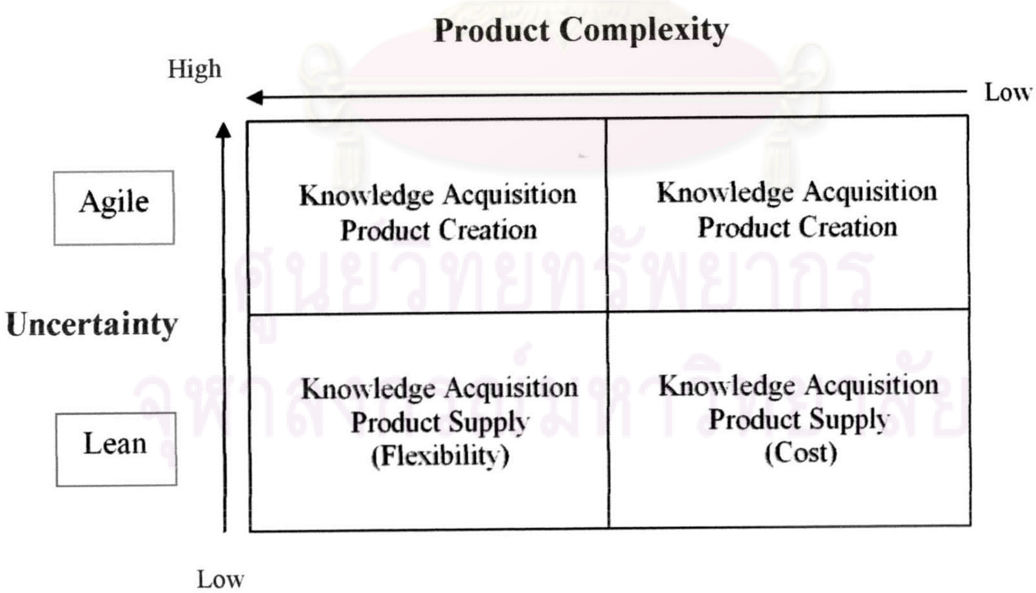


Figure 2-3a; Critical business model

Competitive Design Management: University of Warwick, UK, 2002 (chap.2, p.8)

The model shows that knowledge acquisition is the most important business process throughout and that product creation is the most important in the top two, and product supply is the most important in the bottom two.

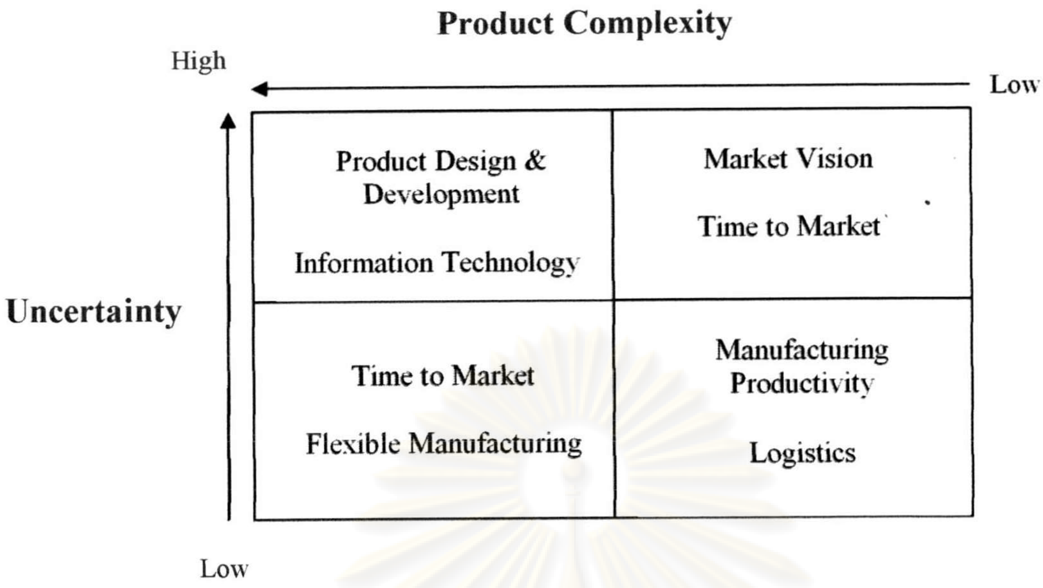


Figure 2-3b; Critical competence model

Competitive Design Management: University of Warwick, UK, 2002 (chap.2, p.8)

The principle of critical competence model begins to focus on design implementations where super value goods are aiming at product design but durable and commodity goods are more suitable with processes redesign for shorter lead-time and flexible manufacturing.

### 3.4 Product Type/Quantity (PQ) Analysis

Product type and quantity (PQ) analysis is applied from Pareto analysis technique. Pareto is named after the 19th century Italian economist Vilfredo Pareto who determined that wealth is not evenly distributed. Some of the people have most of the money while many others are not. The concept is for focusing on the most important problem areas. The idea is to classify cases according to degree of importance, and focus on resolving the most important, leaving the less important.



PQ analysis is used to display the product mix as Pareto chart. The analysis makes lines on the chart to test the situation against several situations called PQ ratios. A high volume of a few product types manufacturing appears as a 20:80 PQ ratio, where 20 percent of product types (horizontal axis) account for 80 percent of total quantity (vertical axis). This is considered a low-variety production.

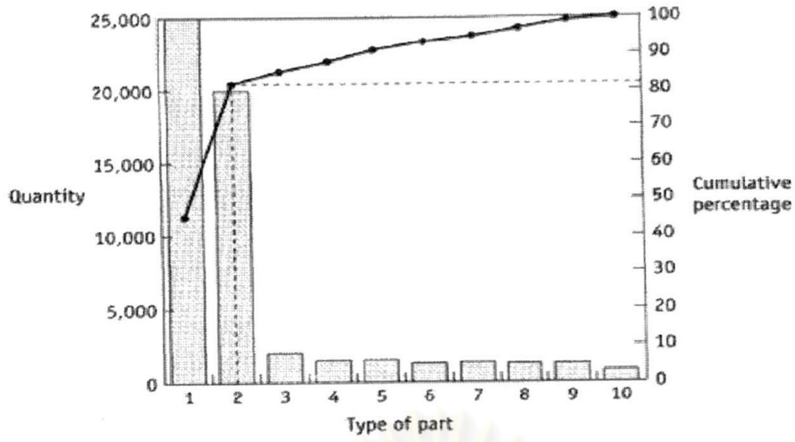


Figure 2-4a; PQ analysis chart showing a 20:80 PQ ratio
Cellular Manufacturing: Productivity Press, Portland, Oregon, 1999 (p.24)

A 40:60 PQ ratio, on the other hand, indicates high variety types with relatively low volume of each type, where 40 percent or more production types account for about 60 percent of total quantity.

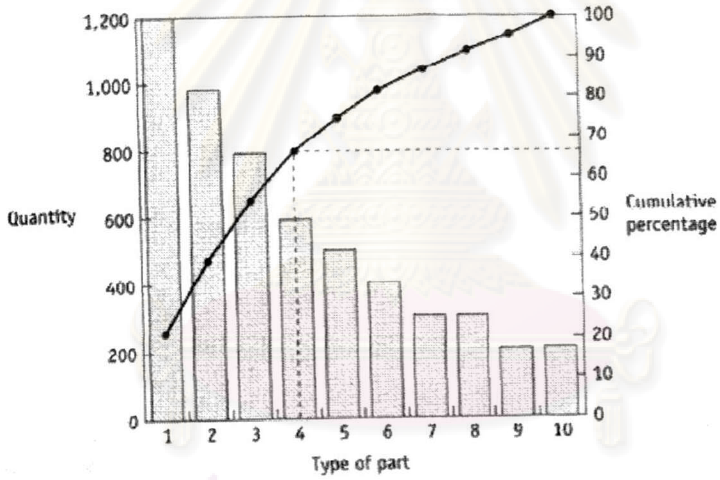


Figure 2-4b; PQ analysis chart showing a 40:60 PQ ratio
Cellular Manufacturing: Productivity Press, Portland, Oregon, 1999 (p.25)



### 3.5 Fishbone Diagram

There are number of tools that an organization can use for problem solving and process improvement which one of them is called a 'fishbone diagram' or a 'cause and effect diagram'. Fishbone diagram offers a structure approach to the search of possible causes of a problem. It can be considered as internal analysis.

It was first developed in 1943 by Kaoru Ishikawa at the University of Tokyo. They are also known as Ishikawa diagrams after their founder and Fishbone diagrams due to their appearance. The name 'Fishbone' resembles its structure shape. This tool helps to organize problem-solving efforts by identifying categories of factors that might be causing problems. Usually this tool is used after brainstorming sessions.

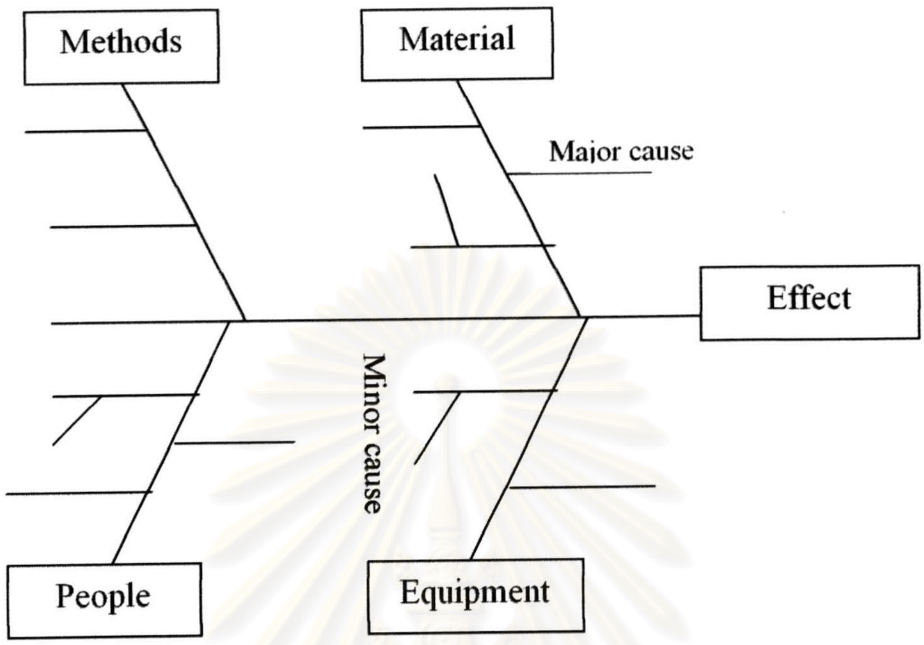


Figure 2-5; Construction of a fishbone diagram

In figure 2-5 represent a fishbone diagram. Each of the factors listed in the diagram is a potential source of effect. The effect is located on the right side and the causes on the left side. The causal relationships are denoted by the arrows between the major causes and the effect and between minor causes and the major cause to which they contribute. If the cause is still not obvious at this point, additional investigation into the root cause maybe necessary, involving a more in-depth analysis. More information maybe acquired by asking questions about factors that appear to be the most likely sources of problem.

## 4. Types of Production

There are many types of production in the history which characterize in different production volume, workers and labors, process, and environment. In this chapter will initially explain all types of production in the manufacturing industries that change overtime.

### 4.1 Craft Production

Craft production is the earliest form of production that originated in Europe at the end of nineteen's century. It uses highly skilled workers and simple but flexible tools to make what exactly the customer asks for. They make one item at a time with each job. Never had any two products made identically even based on the same procedures. The good thing about craftsmanship is that it gives full attention to their customers, and the customer gets what exactly they want.

However there are obvious drawbacks of craft production. Production cost was too high and that meant only the rich could afford. Production volume was very low. Craft techniques inherently produced variations due to no consistency and low reliability.

### 4.2 Mass production

The mass production started at the beginning of twenties century by Henry Ford who began the concepts, uses narrowly skilled professionals to design products which will be made by unskilled or semi-skilled workers. Machines in mass productions are usually dedicated or single-purpose expensive machines which produce standardized products in a very high volume.

Mass production uses interchangeable parts, simple fitting with each other, moving or continuous assembly line. Taken together it produces low cost products in large volume with consistent quality and reliability. As a result, the consumer gets the low price at the expense of product variety. As Henry Ford, the president of Ford's Car quotes that *"customers can have any colored car they want so long as they are black"*.

### 4.3 Vertical Integration

Further development from Henry Ford who still tried to bring everything in-house so he need Ford car's part with closer tolerances and on tighter delivery schedules than anyone had previously done.

Vertical integration is normally operated in the organizations with powerful financial aspect. It requires intellectual and ability in management for expanding growth for integrating both backward suppliers and forward distributors into consideration which increase opportunity of gaining market share to benefit the whole chain. This integration will help the firm to reduce costs, inventories and increase efficiency in work scheduling and operations. However, vertical integration is not appropriate for small or medium sized manufacturing organizations which are not strong in financial investment and resources to updating advance technology continuously.

### 4.4 Lean Production

The complete vertical integration in fact is neither beneficial nor possible. The suppliers and buyers relationship returned not long after the peak of vertical integration.

Since 1970s high volume production to reduce unit cost is no longer effective in a long run of business competition. To date, the world is embracing the new technology development and ever increasing customer demand and market expectation for low price, quality, service and choice. World class manufacturers are geared up in facing this global challenge through lean production led by Japanese leading manufactures typically the Toyota manufacturing systems. A host of tools and techniques of lean production have been adopted by the Western firms. Most important of all is the wide acceptance of the lean philosophy which has its focus on improving efficiency through reducing or elimination waste and focus in reducing lead-time.

## 5. Manufacturing Environments

It is important to be familiar with the range of possible operations environments. On the one hand effectiveness of the organization is closely aligned with the appropriate choice of process. Creating an environment which will provide a distinct advantage in the market place is known to be one of the key objectives for manufacturing strategy. On the other hand it is also important to understand the characteristics of the environment to be able to control it and choose the right control methods, therefore, redesigning further processes correctly.

### 5.1 Types of Process

Operations environments can initially be divided into those producing a physical product and those providing a service. These process types are found in a wide range of manufacturing and service setting. The concept is to have process match product or service requirements. Failure and misunderstanding in correct process type can result inefficiencies, generate higher costs and lead-time than necessary and lose position in market.

This section starts by defining features of the four basic process types which are job shop, batch, repetitive, continuous flow, and cell.

#### 5.1.1 Job Shop

Job shop manufacture is when very small lots or even single products are made in response to separate customer orders. It generally operates on a relatively small scale when a low volume of high-variety goods or services will be needed. In practice jobbing shops can produce small batches of product, but each batch is a one off.

Processing in a job shop is intermittent. It shifts from one small job to the next, each with somewhat different processing requirements. High flexibility of equipment and skilled workers are important characteristics of a job shop. There is a high degree of interpretation of the customer's requirement and the supplier also requires a high degree of operator skill to cope with the one off specialist jobs. Because each job is different, investment in jigs and fixtures, automation and dedicated equipment can not normally be justified. The piece price is often much higher than the same product in volume production. Manufacturing examples of a job shop is a craft product, prototype, tool, and die shop that is able to produce one-of-a-kind tools. A service example is a veterinarian's office, which is able to process a variety of animals and a variety of injuries and diseases.

The job shop provides an infinite product range, limited only by the range of skills of its operators, and the equipment it has available. In strategic terms it must compete in areas rather than price such as differentiation.

### 5.1.2 Batch

A batch manufacturing process is used when a moderate volume of goods or services is desired, and it can handle a moderate variety in products or services. The product is processed in lots, each item of production passing through the same sequence of operations. The equipment need not be as flexible as in a job shop, but processing is still intermittent. The skill level of workers does not need to be as high as in a job shop because there is less variety in the jobs being processed.

The implication with batch manufacture is that the repetitive demand of similar products allows batches to be collected together and manufactured in the same run, but that the variety of products offered means that between each run the processes must be reset to make a slightly different batch the next time. For example a company offering a very wide range of product options, with low volumes for each option may choose to manufacture in batches if the manufacturing process time is low, or set-up times are very high.

On the other hand a company selling large volumes of similar products may choose to manufacture in batches rather than a line or flow process if the manufacturing content is low. The procedure followed in batch manufacture is to divide the manufacturing task into a series of operations which together make up the complete product. A series of operation is usually grouped together and carried out on batch of products. When all of this series has been carried out on batch it is passed on to the next department. Sometimes components or products are passed on prior to completion of the whole batch.

These are sometimes referred to as transfer batches. If short manufacturing lead times are important for example, passing on small transfer batches to the next series of operations is beneficial.

Examples of batch manufacture are stamping die and sheet metal punching which require new setting up when making new parts. Other examples might be manual assembly of components where a batch of the same component is processed before the operator changes jigs or fixtures to process the next batch. In practice batch manufacturing environments are found across a very wide cross section of manufacturing. From the survey, trends in the 1990's towards lean manufacture imply a general move towards reducing the batch sizes.

Volume flexibility can be achieved in batch manufacture by reducing the normal 'economic batch quantity' (Batch size) to a minimum. This can be achieved by reducing set-up times using Single Minute Exchange of Dies (SMED) principals. Jig and fixture design is often a source of reducing the set-up time for assembly tasks. If the operator can change very quickly from one component to the next, then batch sizes can be reduced. Components can be produced in the quantities and variety demanded by the market.

### 5.1.3 Repetitive

Repetitive process is required when producing higher volumes of more standardized goods or services. The consistent output means only slight flexibility of equipment is needed. Skill of workers is generally low. Examples of this type of system include production lines and assembly line. In fact, this type of process is sometimes referred to as assembly.

Familiar products made by these systems include automobiles and white goods such as television sets, pencils, and computers or fast-food like Mc. Donald's, KFC, and Dunkin Donuts. An example of a service system is an automatic carwash. Other examples of service include cafeteria lines and ticket collectors at sports events and concerts.



A literature survey at Harley-Davison York assembly plant in Pennsylvania by Heizer and Render in 1999 also refer that the plant use repetitive process to repeat the production to each workstation then transfer parts to assemble the finish goods.

### 5.1.4 Continuous Flow

When a very high volume of highly standardized output is desired, a continuous system is used. A flow or continuous process is considered as highly repetitive process which could theoretically run 24 hours per day, 7 days per week, and 52 weeks per year. It normally manufactures the same product or products with no change.

These systems have almost no variety in output and, hence, no need for equipment flexibility. As in assembly systems, workers are generally low skilled. It is normally true that if wider product ranges are to be processed on the line, then the investment to provide the flexibility is correspondingly higher. Line rates and line balancing are also important considerations when mixed model production takes place on the line. The willingness comes to design-in labor saving automation and other dedicated facilities to reduce the cost of manufacture as major improvement target.

Examples of products made in continuous systems include petroleum products, steel, sugar, flour, and salt or the production of Coca-Cola. Continuous services include air monitoring, supplying electricity to homes and businesses, and the Internet.

Table 2-2; Comparison between each types of process

| **Types / Detail** | **Job Shop** | **Batch** | **Repetitive** | **Continuous Flow** |
|---|---|---|---|---|
| **Characteristic** | Customized goods or services | Moderate customization of goods or services | Standardized goods or services | Highest standardization of goods or services |
| **Volume** | Low | Low and moderate | High | Very high |
| **Variety** | Very high customization | Moderate customization | Low customization | Very low customization |
| **Advantages** | Able to handle a wide variety of work | Better Flexibility in higher volume | • Low unit cost<br>• High volume efficient | • Very efficient<br>• Very high volume |
| **Disadvantages** | • Slow<br>• High unit cost<br>• Complex planning and scheduling | • Moderate cost per unit<br>• Moderate scheduling complexity | • Low flexibility<br>• High cost of downtime | • Very rigid<br>• Lack of variety<br>• Expensive to change<br>• Very high cost of downtime |

The practice in many operations environments surveyed since 1990's is to split operations into small manageable sections, often known as cells, which are managed and controlled de-centrally. So there are three characteristics which can be used to describe an operations environment:

1. Repetitiveness and volume of operation:
2. Product or process orientation.
3. Grouped and controlled centrally or de-centrally and non-cell or cells

Operations environments in practical consist of complex different types of processes, often being formed with a combination of elements from the range given above. For example, a company manufacturing parts for the automotive industry might have a jobbing shop for producing prototypes and repairing tools. It might also have a number of product based component cells for manufacturing the main components in batches, and assembly lines for final assembly.

### 5.1.5 Cells

Cellular manufacturing environments can take a variety of forms. They are often characterized by de-centralize control, team working, multi disciplined operators and managers, and product rather than process oriented machine groupings. The sort of market conditions for which cells would be an appropriate choice would be fairly high volume to justify dedicating machines to products, but with high variety to cope more easily with changing conditions, fast product introductions, changing quality and agility requirements.

Physically cell manufacture often means splitting what might have been process based layouts into groups of machines and processes dedicated to one product or a family of products. Hence the implication is that volumes are a bit higher than batch and variety is lesser than both jobbing and batch.

The other side of the concept is that often cells are managed and controlled de-centrally. From a Harvard Business Review, May – June 1974 by Wickham Skinner. He discussed about the concept concentrate on the idea of choosing certain products and technologies and focusing on developing core competence in these areas. Other peripheral products and technologies would be subcontracted or outsourced to suppliers.

Skinner argues that a company can only perform well in a small number of core competencies. He also says that once these have been defined, from a manufacturing point of view separate business units or factories within the factory can be set up. This corresponds to cell concept where a separate section of production is formed. The section is managed locally on a day to day basis, allowing the section to develop and improve it's competence without interference of central authorization.

In this respect the management side of the cell concept is applicable for many manufacturing environments. There are variations in the way the concept works in practice. For example, a factory which produces a range of quite dissimilar products, but whose main raw material across the range is common, must have a central function controlling the purchasing and scheduling of that material. Conversely where each cell uses very different raw materials there is the opportunity for de-centralized raw material call off from suppliers.

Furthermore, the equipment and operating performance in cell usually laid out in a curved shape to bring the end point of the process close to the beginning point to minimize the distance the operator has to travel to the begin the next cycle.

## 5.2 Order Environments

Manufacturing companies operate in many different order environments depending on the certainty of demand of customers, ordering volume, and how long they are acceptable of waiting. Theories divided types of order into two aspects which are:

### 5.2.1 Make to Stock

Make to stock is usually applied to bulk materials such as steel, glass or chemicals, or to a limited range of discrete parts. It is appropriate when the manufacturing lead-time is longer than the delivery lead-time required by customers. It is inherent in this case that the product specification should be stable over a period of time so that the costs of obsolescence can be tolerated.

Therefore, inventories cost are the main factors for consideration. The cost of holding inventory, especially of finished goods, has to be accepted as part of the expense of remaining competitive on delivery. There should be preventive stocks to handle occurring failures in able to make it on time, in case of transporting failure, and failure to predict demand increases. This can be to overcome seasonal demand so finished goods stock must always meet the peaks. According to the demand for the product must be stable, and reasonably predictable by historical record. Generally, customers order the goods in a very high volume in similar routines.

It is often possible to hold stocks of part-finished goods especially at some stage immediately prior to an expensive or lengthy operation, so that the total lead-time can be shortened without the high cost of maintaining inventories of fully-finished products. This is often referred to as assemble to stock environment.

### 5.2.2 Make to Order

When customers order in lists of products and services to make the company produce their good and services to suit each order requirement in low to moderate volumes, it is consider as make to order environment.

This environment is mainly confined to discrete part industry. It is particularly relevant in high value product markets or those where design changes occur frequently. Obviously, jobbing production such as pattern-making is virtually always to order.

Between these two environments are a huge range of possibilities and the impact of customization and range of options. The strategy of whether a company makes to order or makes to stock is greatly affected by the P and D ration (P/D).

The P time is the production lead-time and D time is the delivery time the customer is prepared to wait for the product. If the customer is not prepared to wait any time, that is means P/D is higher than 1. Then the manufacturer must operate in a make to stock mode.

If delivery speed is becoming increasingly important in competitive advantage, then again this must be reflected in the manufacturing environment. Manufacturing process time, setup time, and the strategic use to buffer stocks are all keys of reducing the manufacturing lead-time. All companies want the P time to be much lesser than the D time so that they can make to order and avoid storing inventory which create amount of costs. In figure below represent practical example of P/D time of the Aerospace industry.

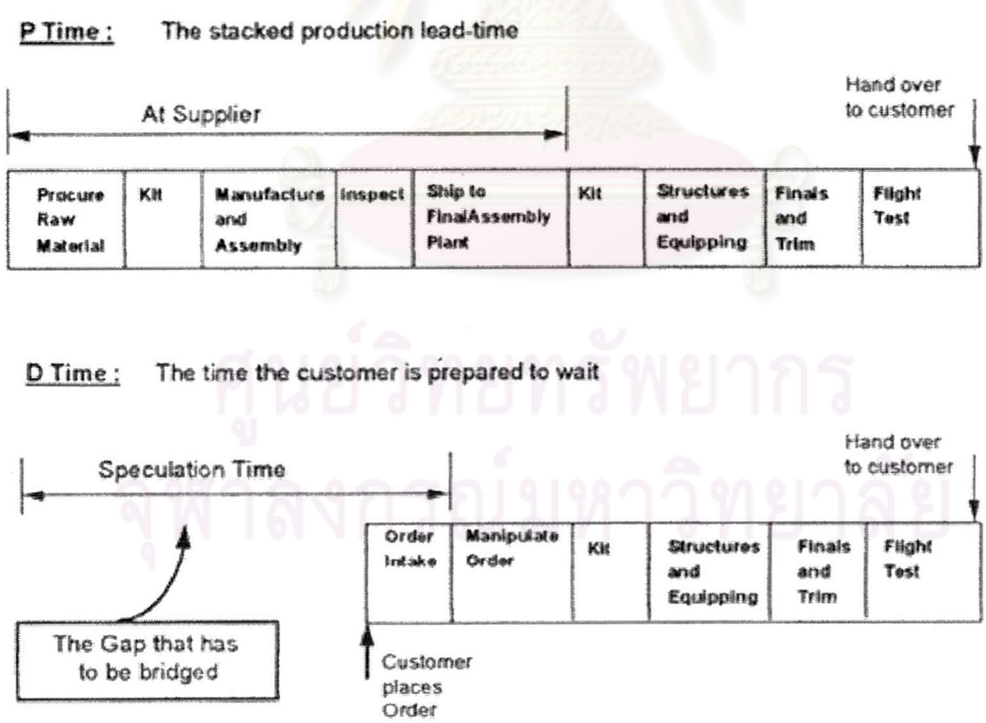


Figure 2-6; P time and D time in Aerospace industry
Logistics and Operations Management: University of Warwick, UK, 2003 (chap.1, p.7)

# 6. Facility Layout

Layout refers to the configuration and determination in replacing of departments, work centers within the department, workstations, machines, equipment, and stock holding position, particularly emphasis on movement of work through the system. The objective is to ensure a smooth flow of work in a factory.

As in aspect of system design, layout selection is important for four basic reasons which are:

- They require substantial investments of money and effort.
- They involve long-term commitments, which make mistakes difficult to overcome.
- They have a significant impact on the cost and efficiency of operations. This section describes the main types of layout designs and the models used to evaluate design alternatives.
- They are great solutions for implementing three different areas of design which include product design, process design, or logistics.

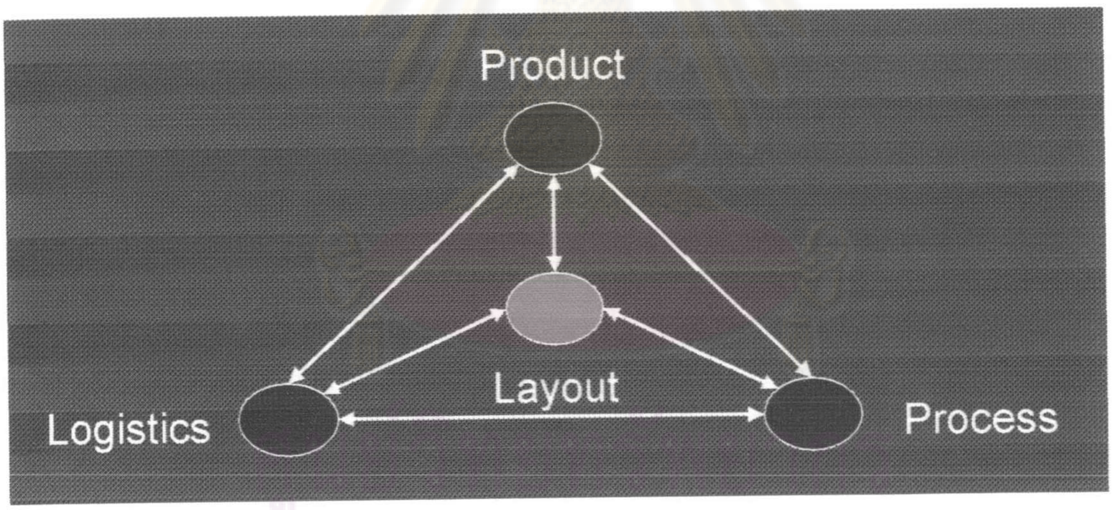


Figure 2-7; Layout for design solution
`www.opm.wb.utwente.nl/staff/ronald/ps3.ppt`

The need for layout planning arises both in the process of designing new facilities and in redesigning existing facilities. The most common reasons for redesign of layouts are to increase efficiency in operations and create optimize both labors and spaces. Change for better layout will result overall cost reduction in material handling, reducing cycle and delivery time .And also eliminate bottlenecks, improving safety and better environment such as lesser accidents, hazards, or mental problems. It offers capability in designing current products and services or an introduction of new ones and even for the factory adaptation which require changing methods of work into different manufacturing environment or production volume as well.

There will be three basic types of layout in consideration to apply in the sample case company which are process layout, product layout, and cellular layout.

### 6.1 Process Layout

Process layouts are design to process items or services that involve a variety of processing requirements. The characteristic of the layout is to separate work into single functional department or work center separate each group of job from each other from which similar types of activities are performed and grouped together. The variety of jobs that are processed requires frequent adjustment to equipment which will cause intermittent workflow. Example of a process layout expressed in figure 6 is the machine shop usually used in jobbing or batch environment that need distinctive department for milling, drilling, painting, or grinding, which serve customers with different needs.

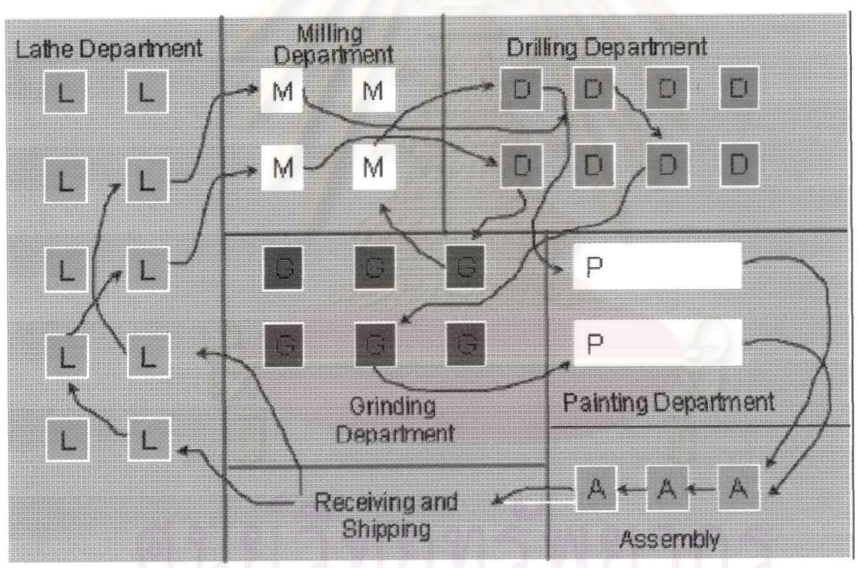


Figure 2-8a; Example of a machine shop layout
(Layout Planning: M. Tersine, p.14)

Work in process that require those operations are frequently moved in lots or batches to the departments in a sequence that varies from job to job. The movement between departments is to use trolley or vehicles like trucks and forklift to transfer goods. The usage of general equipments creates flexibility necessary to handle a wide range of processing requirements. Workers who operate the equipment are usually skilled or semiskilled.

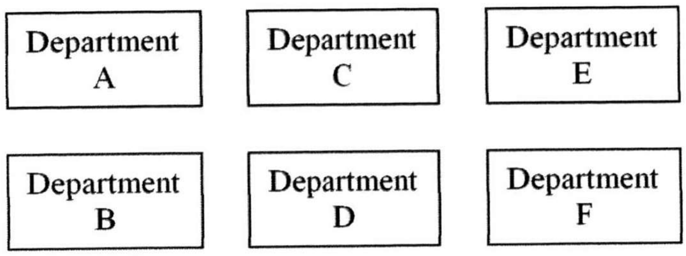


Figure 2-8b; Departmental arrangement typical of a process layout

Process layouts are quite common in service environments. Examples include hospitals, colleges and universities, banks, auto repair shops, airlines, and public libraries. For instance, hospitals have departments or other units that specifically handle surgery, maternity, pediatrics, psychiatric, emergency, and geriatric care. And universities have separate schools or departments that concentrate on one area of study such as business, engineering, and science.

Because equipment in a process layout is arranged by type rather than by processing sequence, the system is much less vulnerable to shutdown caused by mechanical failure or absenteeism.

Maintenance costs tend to be lower because the equipment is less specialized than that of product layouts, and the grouping of machinery permits repair personnel to become skilled in handling that type of equipment. Machine similarity reduces the necessary investment in spare parts. On the negative side, routing and scheduling must be done on a continual basis to accommodate the variety of processing demands typically imposed on these systems. Material handling is inefficient, and unit handling costs are generally much higher than in product layouts. Work in process inventories can be substantial due to batch processing.

### 6.1.1 Advantages and Disadvantages

The advantages of the process layout are:

- The main advantage is flexibility and can handle a variety of processing requirements.
- General purpose equipment is often less costly than the specialized equipment used in product layouts and is easier and less costly to maintain.
- It is possible to use individual incentive systems.

The advantages of the process layout are:

- The main disadvantage is inefficiency because jobs do not flow through system in orderly manner and equipment utilization rate are low due to its complexity.
- Backtracking is common and queues tend to develop.
- Movement from department to department can take a long time and routing and scheduling is complicated.
- Storage space is large around work centers to accommodate large amounts of work in progress inventory especially batch manufacturing with moderate volume.
- Cost per unit is higher than product layout with higher degree of customer's satisfaction.

## 6.2 Product Layout

Product layout is also known as assembly line which arranges activities in a line according to sequence of operations needed to produce the product. It tries to achieve a smooth and rapid flow of large volumes of production through a system. This is made possible by highly standardized goods or services that allow highly standardized, continual processing. The work is divided into a series of constant tasks requiring specialization in both labor and equipment which is suitable for repetitive and flow environment.

The large volume handle by these systems usually advantages by economic of scale and economical to invest money in equipment job design because only one or a few similar items are involve. It is feasible to arrange an entire layout to correspond to the technological processing requirements of the product or service. For example of manufacturing operation required the sequence of cutting, sanding, and painting. The appropriate pieces of equipment would be arranged in that same sequence, in the same pattern, and each item follow the same sequence of operation so it often utilized fixed-path material transferring equipment such as conveyers to transport items between work stations depending on the type of activity involved. Major concern in product layout is balancing assembly line so that no one workstation becomes a bottleneck.

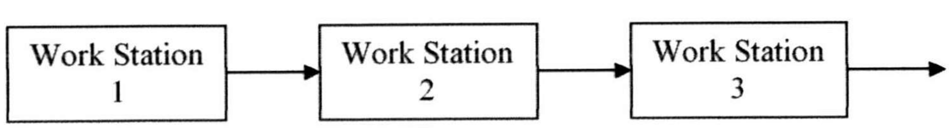


Figure 2-9a; Operation sequence of a work station in product layout

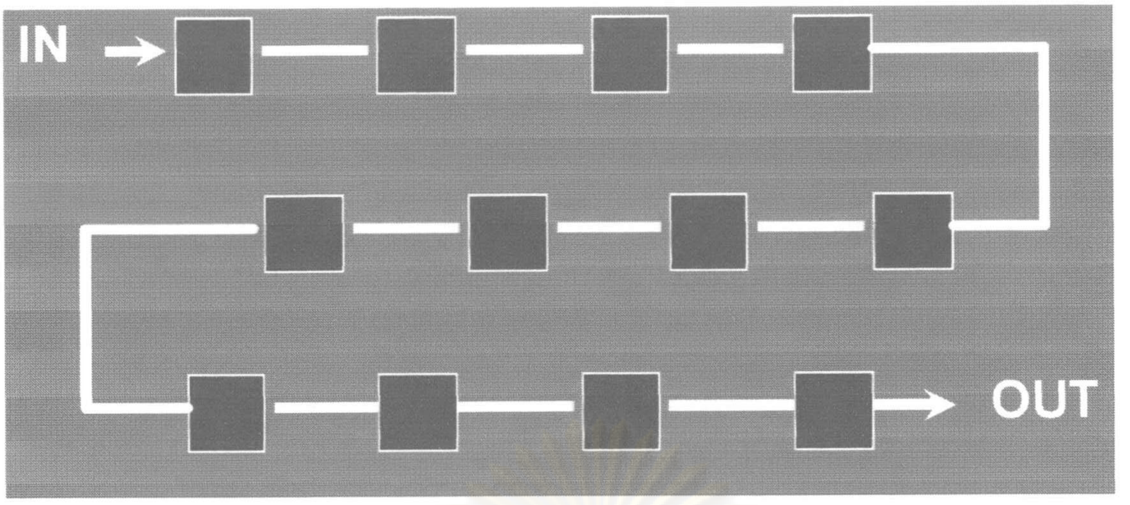


Figure 2-9b; Assembly line sequence in product layout
(Layout Planning: M. Tersine, p.16)

Without high standardization, many of the benefits of repetitive processing are lost. When lines are used, certain compromises may be made. For example, an automatic car wash provides equal treatment to all cars-the same amount of soap, water, and scrubbing-even though cars may differ considerably in cleaning needs, As a result, very dirty cars may not come out completely clean, and relatively clean cars go through the same system with considerable waste of soap, water, and energy.

Product layouts achieve a high degree of labor and equipment utilization, which tends to offset their high equipment costs. Because items move quickly from operation to operation, the amount of work in process is often minimal. However, operations are so closely tied to each other that the entire system is highly vulnerable to being shut down because of mechanical failure or absentees.

Preventive maintenance anticipates in replacement of critical parts before the failure actually happens. This will inspect for high failure rate that reduces the probability of breakdowns during the operations. Although, no amount of preventive activity can completely eliminate failures, so management must take measures to provide quick repair. These include maintaining an inventory of spare parts and having repair personnel available to quickly restore equipment to normal, operation. These procedures are fairly expensive because of the specialized nature of the equipment.

### 6.2.1 Advantages and Disadvantages

The advantages of the process layout are:

- The main advantage is due to its general efficiency in high output rate.
- Low unit cost and material handling cost due to high volume and because unit follow the same sequence of operation.
- It provides a high utilization and standardization of labor and equipment which reduce training cost and time.
- The activities are fairly routine and do not need much attention once the system is activated.

The disadvantages of the process layout are:

- The main disadvantage is inflexibility responds to change when significant new design is implemented which requires purchase of new equipment and new assembly line.
- High fixed cost associate to its complication may limit design changes as expected.
- Repetitive jobs create morale problems and boredom to the workers and provide unskillful workers that show little interest in quality of output and maintaining equipment.
- There is a high rate system shutdown caused by equipment breakdown or absentees.

## 6.3 Cellular Layout

Another type of manufacturing layout is moving away from process layouts in an effort to capture together both benefits of product layouts and process layout. Eventually, a system that is flexible and yet efficient with low unit production costs is designed to be known as cellular manufacturing.

Cellular layout is a hybrid layout which combines characteristics of product and process layouts. It groups dissimilar machines into work centers called cells that process families of parts with similar shapes or processing requirements. Cellular layout is appropriate for repetitive environment or manufacturing which require quite a high amount of volume but slightly less flexibility and variety than batch environment. The cells may have no continuous movement such as conveyor of parts or sub-assembly between machines, most manufacturers use trolley to move work in process parts but sometimes may have a flow line connect by automatic transfer.

Large machines which cannot be split among cells will not be removed but will be located near other cells which use them. Layout of machines within cells resembles small assembly line, which means:

- Line balancing procedures can be used.
- Workers skilled at operating all machines in cell, often at same time.
- Layout between cells is a process layout

**6.3.1 Types of Cell**

In 1998, a studied by Mr. Kantachart Krungsumlucksme decided to break down manufacturing cells into three types which are component manufacturing cell, process cell, and assembly cell.

1. Component manufacturing cell are defined by co-locating and managing as a single unit all the equipment needs to manufacturer a family of geometrically related components, or process related components. There are responsible for the output of a finished family of the components and all the processes required machining, drilling, milling, pressing, etc. those are located in cell. Component cells have a series of customers in the assembly business to satisfy.

2. Process cells are defined by the process they carry out such as heat treat, surface treat, etc. They are built around a core process which they provide as a service to other areas of manufacturing, selling, and this service to the other team leaders in the business whose bring their work to it. The team leader in the process cell will form working relationships with the people in the cells, start to understand the working patterns of the cells, and understand what they have to do to provide each cell with the service it needs.

3. Assembly cells characteristics are that it was organized around a family of assembled products rather than a family of components. They are planned around the hierarchy of component subassembly and final assembly. The complexity of the product determines whether you need both a subassembly and a final assembly. Sub assembly cells draw parts from one or more of the component cells from the external suppliers who provide bought-out component. Excellent cell design and engineer act as enables for teaming and team-based manufacture which provide significant, durable benefits in productivity, lead-time and quality.

**6.3.2 Group Technology**

Cellular manufacturing must have groups of identified items with similar processing characteristics. This strategy for product and process design is known as group technology and involves identifying items with similarities in either design characteristics or manufacturing process characteristics, and grouping them into part families. Design characteristic are about ergonomics that include size, shape, and function while processing characteristics involve type and sequence of operations required.

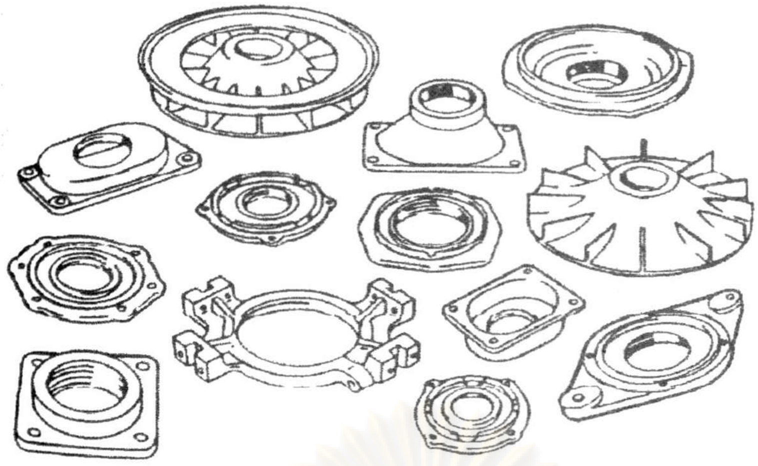

Figure 2-10; Group of parts with similar manufacturing process
Operation Management: William J. Stevenson, McGraw-Hill, 2002 (p.239)

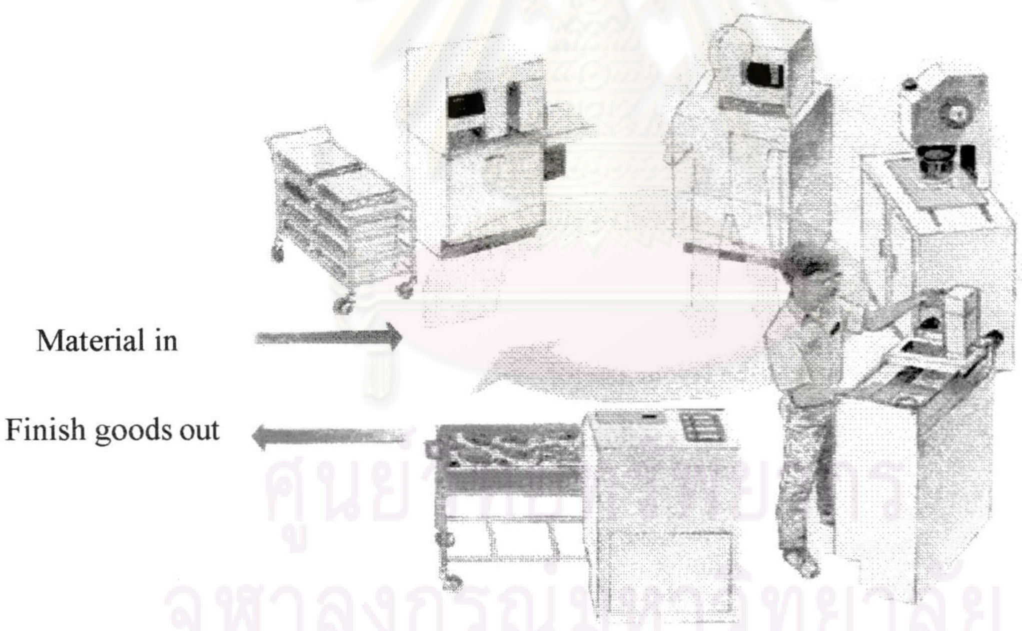


Figure 2-11; Group technology provide single worker with multiple machines
(Layout Planning: M. Tersine, p.19)

The below figure will describe how cellular layout different from process layout in a machine job shop which consist of many manufacturing procedures such as lathing, milling, drilling, grinding, and assembling.

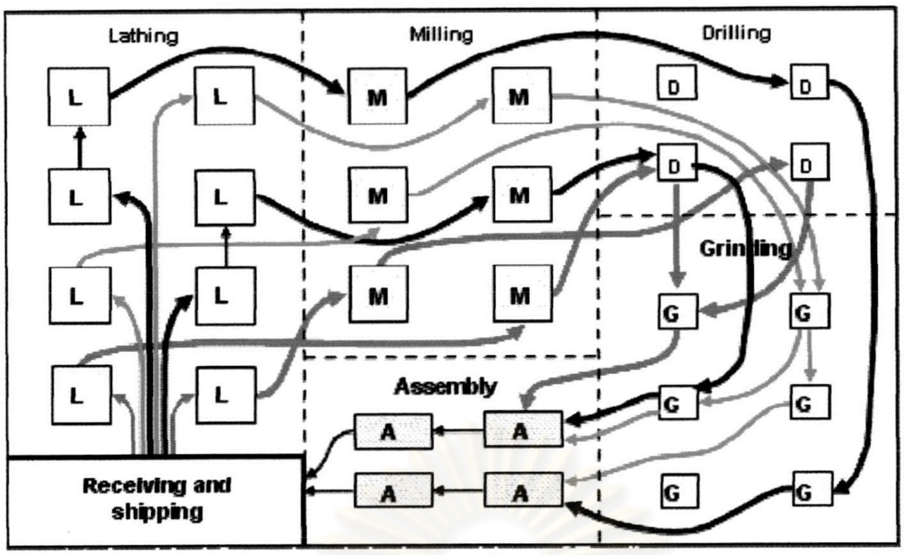


Figure 2-12a; Process layout of a job shop without group technology cells
(Layout Planning: M. Tersine, p.24)

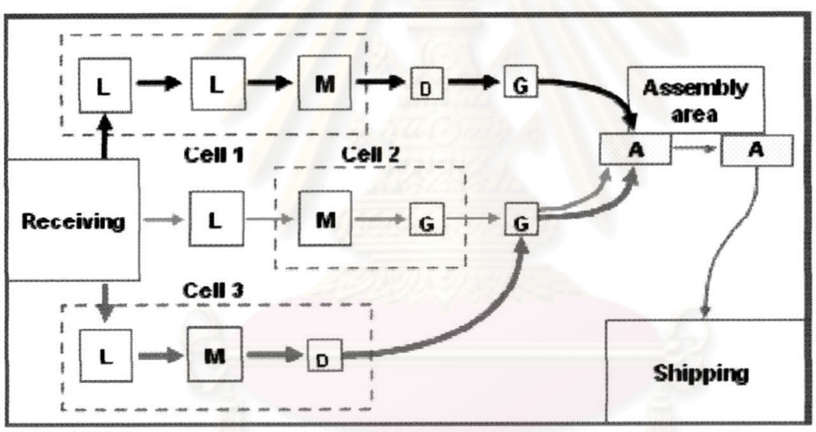


Figure 2-12b; Process layout of a job shop without group technology cells
(Layout Planning: M. Tersine, p.28)

The pictures represent comparison between both layouts shown that in cellular layout machines are arranged to handle all of the operations necessary for a group or family of similar parts. Thus, all parts follow the same route although minor variations like skipping an operation are possible. In contrary, the process layout involves multiple paths for parts and there is only little effort or need to identify part families which will easily cause bottle necks, idle time and delays.

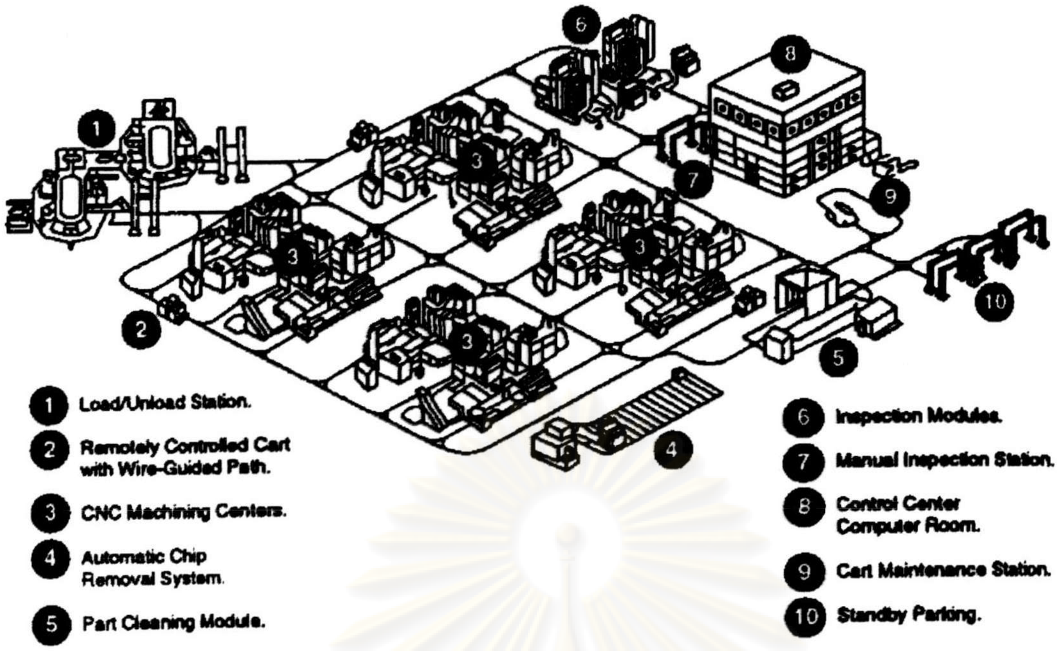


Figure 2-13; Example of cellular layout with group technology cells

### 6.3.2. One-Piece Flow

Cell also enables one-piece flow of production line like referring in figure 2-12b. One-piece flow is the state that exists when products move through a manufacturing process one unit at a time, at a rate determined by the needs of the customer. The opposite of one-piece flow is large-lot production. Although many companies produce goods in large lots or batches that approach to production build delays into the process. No items can move on to the next process until all the items in the lot have been processed.

### 6.3.3 U-Shape Production Line

Generally, straight production line may seem simple and easy to control but it is not truly efficient and cause intangible problems like human aspect. A long straight line of production might interferer with travel of workers and vehicles. So a U-shape line was developed with number of advantages that is worthy considerable. One important advantage is that it increases communication and stimulate team working among workers along the line because workers are kept inside U-shape area. A U-shape line requires only half the length of the straight line. Flexibility occurs because workers can handle on both sides of the line.

U-shape for cells is popular for manufacturing cells because it facilitates rotation of workers among several machines and can reduce morale problems and also numbers of workers in traditional system.

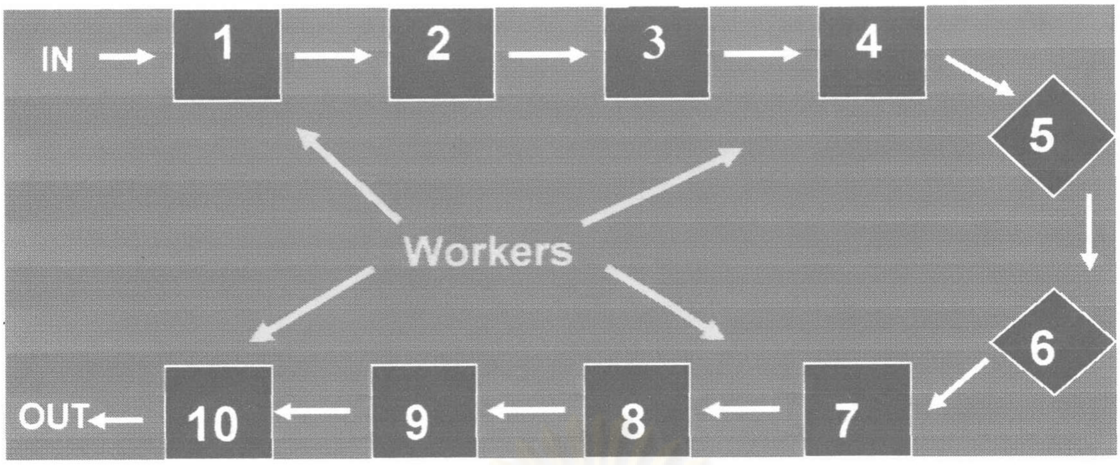


Figure 2-14; U-shape production line
(Layout Planning: M. Tersine, p.17)

### 6.3.4 Advantages and Disadvantages

The advantages of the cellular layout are:

- The main advantage is to reduce material handling cost and transmit time during manufacturing operational stage. It will shorten the production lead-time to serves customers need.
- The layout provides capability to reduce work in process inventory, making in small lots, which is easier for manage and control along with other pull-system such as Kanban system.
- Saves spaces in the factory that can be used for other value-adding purposes.
- There is a way of reducing work in the process and bottle neck due to the smooth and rapid flow of work piece and processes.
- It provides better use of human resources according to U-shape line (less man with multiple machines or jobs) and team working approach in decentralization.

The disadvantages of the cellular layout are:

- The main disadvantage is its high investment in purchasing new machines and equipment because it requires multiple small-size machines rather than a single powerful one needed in each cell.
- Expanding trained workers is needed due to cellular layout utilized man to do different jobs.
- Complications might cause inadequate part families and difficulties in aligning machines within cells. So the layout is appropriate only with medium-size factory.
- Poorly balanced cells usually occur with loose planning and especially when there is new product development.

Pass literature in Thailand shown that in 1989 Mr. Jirasak Charoesook research aimed to compare the operation performance of a shop with group technology layout together with process layout. The shop under the study is a flat sheet metal fabricating under the same production conditions.

In order to determine how the cellular manufacturing system can be beneficial to the factory, the possible changes in production management are studied. By varying the reorder cycle time, number of product per order and production volume per order, the performance of the two layouts are compared in term of manufacturing flow efficiency. The results from the simulation confirmed that the cellular manufacturing with production mix exhibited superior operation performance than the process layout job shop.

In 1998, Mr. Kantachart Krungsumlucksme studied the way to develop a cellular manufacturing and incentive plan for manufacturing cutting die as a case study. The case is the operation of cutting die department in a machinery made to order manufacturing in Thailand. Cutting die is a batch manufacturing, usually ordered in reasonable time and qualities.

The traditional productions have a problem with work in process, long production time, high overtime and employees can do only one task. Cellular manufacturing used group technology and part families' technique to improve productivity and result of the study shown that cellular manufacturing can reduce lead-time to work and make the employees have various skills.

The surveys evidenced that there are some approaches of cellular environment implemented in Thailand for manufacturing of sheet metal and components, but yet there is no further studies of applying cells on assembling company before, which require very few machines, but focus on process sequences and methods instead.

## 7. Implementing Theories

This topic will now describe some efficient methods that might be decided to apply in redesigning a manufacturing factory. All methods and systems will focus on time-based implementations to reduce production lead-time and manage other operating activities. The detail will cover about processes and operations, Kanban methods, and time-based technique.

### 7.1 Processes and Operations

A process is a continuous flow through which raw materials are converted to finished products in series of operations. The focus is the path of the materials as they are transformed into something to sell.

Manufacturing processes have four basic types of steps or phases:

- Transformation: assembly, disassembly, alteration of shape or quality
- Inspection: comparison with a standard
- Transport: change of location
- Storage: a waiting period when nothing else is happening

Materials and parts often go through several steps during a manufacturing process. Notice that only the 'transformation' step adds value to the product.

An operation is any action performed by workers or machines on the raw materials, WIP, or finished goods. So operation improvements will focus on how specific actions are carried out. Improvements include studying the motions required for a specific action, adjusting the height or angle of a work surface for easier use, and so on.

### 7.2 Pull System

The term push and pull are used to describe two different systems for moving work through a production process.

Traditionally, push system is often used in manufacturing or mass production environment. A push system can explain by a work is pushed to the next station as it completed in that station. In case of the final operation, it is pushed on to finished goods inventory to stock them. Contrary, pull system defines a workstation that only depend output from a preceding station only as it needed by avoiding storing huge pile of work in process of materials and parts.

In a pull system, control of moving the work rests with the following operation. Each work station pulls the output from the preceding station in the amount it needed. Output of the final operation is pulled by customer demand or the master schedule. Thus, work moves on in response to demand from the next stage of the process, whereas in a push system, work moves on as it completed, without regarding to the next station readiness for the work and consequently might pile up at workstations that fall behind schedule or unplanned production system. This is the important cause of bottle neck.

#### 7.2.1 Kanban Method

In 1978 Toyota's chief production executive, Taiichi Oho has written a book about Toyota production system. The book explains about Just-in-Time and Kanban system.

Kanban method was originally developed at Toyota in the 1950s as a way of managing material flow on the assembly line (Perelman, 1994: 85). It was another type of pull system. Over the past three decades the Kanban process, which Bernstein (1984: 48) identifies as a highly efficient and effective factory production and inventory control system, has developed into an optimum manufacturing environment leading to global competitiveness. It also encourages industrial re-engineering such as a "module" and "cellular production" system, and, Japanese human resources management, where team members are responsible for specific work elements and employees are encouraged to effectively participate in continuously improving Kanban processes within the Kaizen concept (Stainer, 1995: 11).

In order to ensure that the objectives are met, the control mechanism relies upon a pull type to call for the production or delivery of parts as replacements for the parts already in use. The level of inventory within the system is thus controlled by the form of the pull instruction.

A lean manufacturing system is one that meets high throughput or service demands with very little inventory. Despite its significant success, Kanban control is not a perfect mechanism to control a lean system. Kanban control uses the levels of buffer inventories in the system to regulate production. When a buffer reaches its preset maximum level, the upstream machine is told to stop producing that part type.

This is often implemented by circulating cards, the Kanbans, between a machine and the downstream buffer. The machine must have a card before it can start an operation. It can then picks raw materials out of its upstream (or input) buffer, perform the operation, attach the card to the finished part, and put it in the downstream (or output) buffer. Work center is under instruction to make parts to pass on to the next stage of production only when there is a Kanban available.

The number of cards circulating determines the buffer size, since once all cards are attached to parts in the buffer, no more parts can be made. When the machine picks up raw materials to perform an operation, it also detaches the card that was attached to the material. The card is then circulated back upstream to signal the next upstream machine to do another operation. This way, a demand for a unit of finished goods percolates up the processing stage.

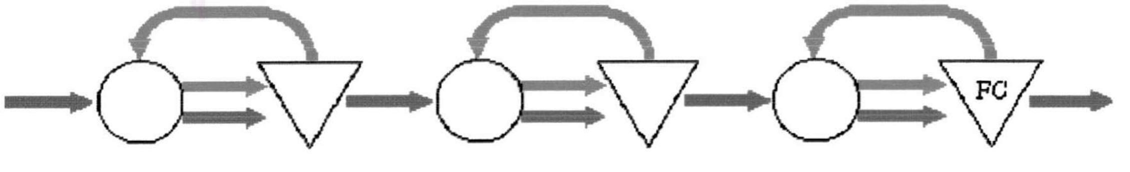


Figure 2-15; Overview of a Kanban system
Source: http://web.mit.edu/manuf-sys/www/amb.summary.html

Figure 2-15 represent a Kanban control. The blue line describes the movement of parts or materials while the red line is the circulation of Kanban along the processes. Machines are shown as circles and buffers (WIP) as triangles. The last buffer is the finished goods (FG) inventory. Kanban control ensures that parts are not made except in response to a demand. For example, a supermarket will restock the shelves only when the goods have been sold.

In a Kanban system the number of cards will set an upper limit to the amount of inventory between any two successive stages of production. Therefore, the number of Kanbans directly controls the level of work in process inventory in the system. So it is necessary to decide about number of Kanbans required by any particular production unit.
The theoretical number of Kanbans needed can be calculated with the following formula:

$$n = \frac{D * L (1+s)}{c}$$

where
n = Number of Kanbans
D = Demand per unit time
L = Lead time
s = Safety stock
c = Capacity of container

This formula begs the question of how much safety stock is required and how many item should each container hold.

## 7.3 Time-Based Methods

### 7.3.1 Takt Time

Takt time and cycle time are almost in common. Takt time is used in time-based method as a basis for doing time observation sheet or value added sheet in cellular manufacturing while cycle time is a consideration of continuous line production known as assembly line.

The team determines the takt time for the process. Takt time is the rate at which each product needs to be completed to meet customer requirements. It is calculated by dividing the daily work time by the daily required quantity.

$$\text{Takt time} = \frac{\text{Daily work time}}{\text{Daily required quantity}}$$

Takt time is expressed in minutes or seconds per unit, becoming the pulse of the factory. By coordinating process cycle times with takt time, the company can avoid excess product inventory.

### 7.3.2 Cycle Time

There are various aspects of assembly line from fairly short, with just a few operations to lines that have a large number of operations. Some lines are quite intermittent such as batch manufacturing while some are truly repetitive and continuous in an environment such as flow line. Repetitive or cell assembly line are located in the middle range with the mixture of both environments.

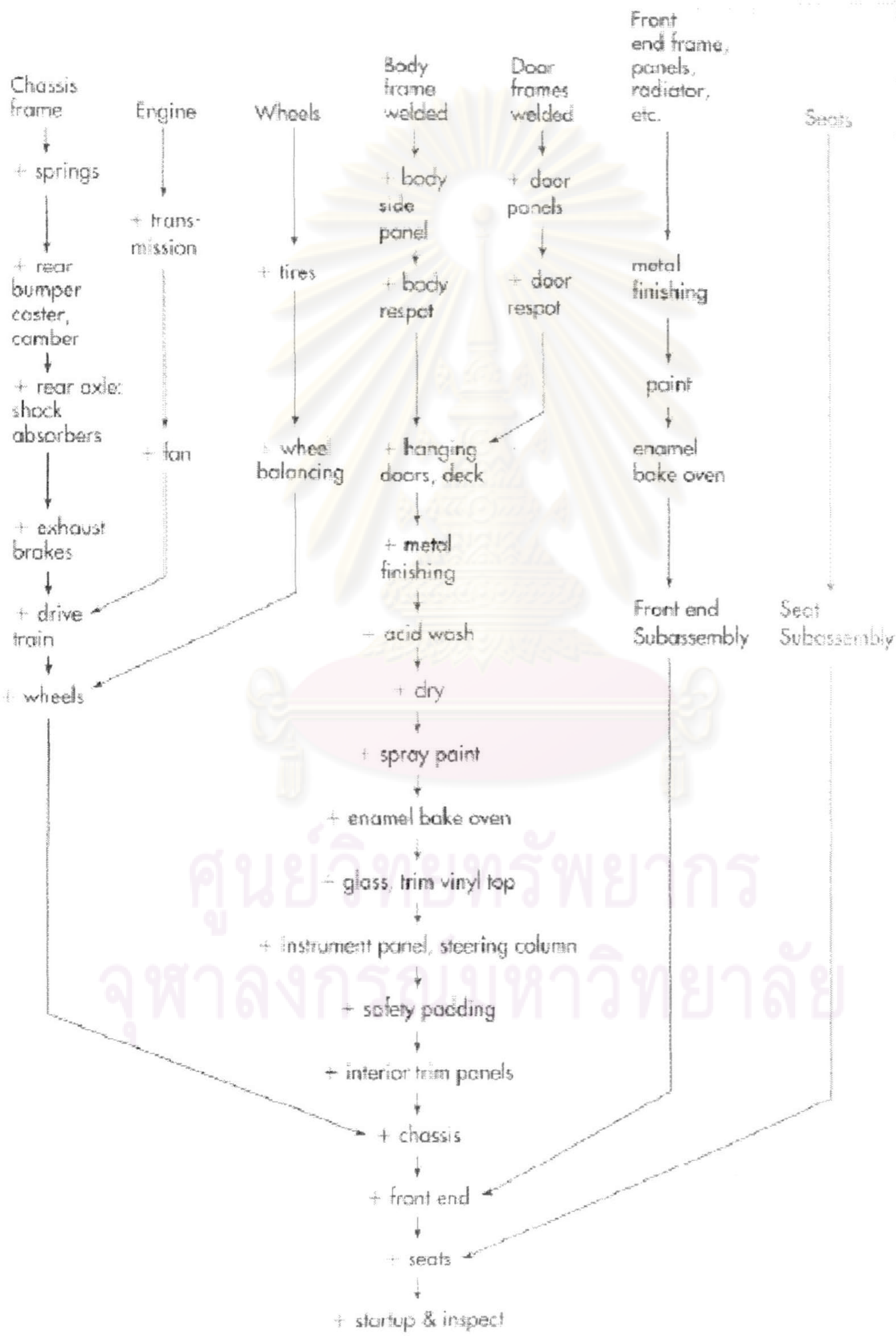


Figure 2-16; An illustration of assembling step in automobile assembly line

Line balancing method is about the techniques of deciding to assign tasks to workstations. The objective of line balancing is to obtain task groupings that represent approximately equal time requirements. This minimizes the idle time along the line and results in a high utilization of labor and equipment.

Idle time occurs if task times are not equal among workstations. Some stations are capable of producing at higher rates than others. These fast stations will experience periodic waits for the output from slower stations or else be forced into idleness to avoid buildups of work and stocks between stations. Unbalanced lines are undesirable in terms of inefficient utilization of labor and equipment and because they may create morale problems like stress and pressure at the slower stations for workers who must always rush their work.

Lines that are perfectly balanced will have a smooth flow of work as activities along the line are synchronized to achieve maximum utilization of labor and equipment.

### 7.3.3 Throughput Time

The cycle time is the elapsed time between starting and completing a job. Another related term is throughput time. Throughput time includes the time that the unit spends actually being worked on together with the time spent waiting in a queue.

As a simple example, consider a paced assembly line that has six stations and runs with a cycle time of 30 seconds. If the stations are located one right after another and every 30 seconds parts move from one station to the next, then the throughput time is three minutes. (Operation Management: Chase, Aquilano, Jacobs, McGraw-Hill, 2002, p.101)

### 7.3.4 Workstation Design

How does a manager decide how many stations to use? It depends on what the cycle time will be. Cycle time is the maximum time allowed at each workstation to perform assigned tasks before the work moves on. The cycle time also establishes the output rate of the line. For instance, if the cycle time is two minutes, units will come off the end of the line at the rate of one every two minutes.

The maximum cycle time would apply if all tasks were performed at a single workstation. The minimum and maximum cycle times are important because they establish the potential range of output for the line, which can be computed using the following formula:

$$\text{Output capacity} = \frac{OT}{CT}$$

where OT = Operating time per day
CT = Cycle time

As general rule, the cycle time is determined by the desired output. So the output level must have been selected then the cycle time will be calculated. If the cycle time does not fall between the maximum and minimum ranges, the desired output rate must be revised. We can apply another formula to find the cycle time which are:

$$CT = \frac{OT}{D}$$

where D = Desired output rate

The number of workstations that will be needed is a function of both the desired output rate and our ability to combine elemental tasks into workstations. We can determine the theoretical minimum number of stations necessary to provide a specified rate of output as follows:

$$N_{min} = \frac{\sum t}{CT}$$

where $N_{min}$ = Theoretical minimum number of stations
$\sum t$ = Sum of task times

These evaluations can be made to build a precedence diagram and task arrangement solution which clarifies all assigned tasks in table. Figure 2-17 illustrates a simple precedence diagram. It visually portrays the tasks that are to be performed along with the sequential requirements, that is, in order in which tasks must be performed.

| Task | Predecessor | Task | Predecessor |
|---|---|---|---|
| A | None | E | D |
| B | A | F | E |
| C | None | G | B |
| D | A, C | H | E, G |

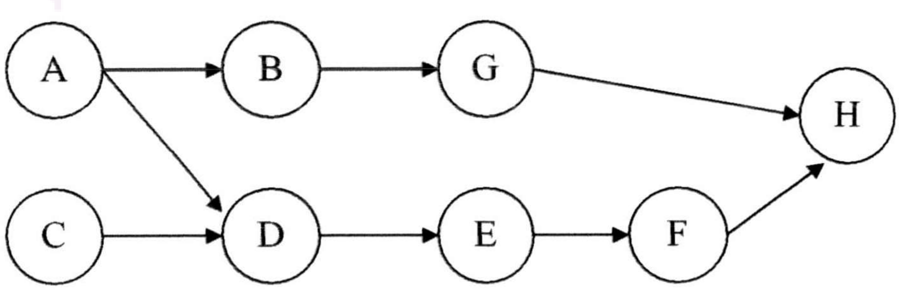


Figure 2-17; A simple precedence diagram

## 7.4 Measuring Process (cellular) Layout Effectiveness

The majority of layout problems involve single rather than multiple locations and they present unique combinations of factors that do not lend themselves to a standardized approach. These layouts require customized designs and should permit flexibility in design.

The design process layouts require the following information:

- A list of departments or work centers to be arranged, their approximate dimensions, and the dimension of the building that will house the department
- A projection of work flows between the various work centers
- The distance between the locations and the frequency of loads between locations
- A list of any special consideration (for example, operations that must be close to each other or operations that must be separated)

Operation Management: William J. Stevenson, McGraw-Hill, 2002 (p.252-253)

From the received information, we can derive the effectiveness of the current or a newly design layout by creating a table like below and calculated the total effectiveness by multiplying total number of loads with total distance ranges from all department relationship.

Table 2-3; Example of layout effectiveness measurement table

| Department | Loads per day | Distance (m) | Loads x Distances |
|---|---|---|---|
| 1 – 2 | 20 | 3 | 60 |
| 1 – 4 | 20 | 2 | 40 |
| 1 – 6 | 80 | 2 | 160 |
| 2 – 3 | 10 | 2 | 20 |
| 2 – 5 | 75 | 2 | 150 |
| 3 – 4 | 15 | 1 | 15 |
| 3 – 6 | 90 | 3 | 270 |
| 4 – 5 | 70 | 1 | 70 |
| **Total** | | | **785** |

### 7.5 Sequence and Quantity Planning

Mixed-model sequencing begins with daily production requirements of each product or model. For instance, suppose a department produces three models, A, B, and C, with these daily requirements:

Table 2-4; Example of model require per daily

| Model | Daily quantity |
|---|---|
| A | 10 |
| B | 15 |
| C | 5 |

There are three issues that need to be resolved. One is which sequence to use (C-B-A, A-C-B, etc.), another is how many times (cycles) the sequence should be repeated daily, and third is how many units of each model to produce in each cycle.

Firstly, the number of cycles per day depends on the daily production quantities. Find a smallest integer that can evenly divide into each type's daily quantity will indicate the number of cycles. This will be the fewest number of cycles that will contain one unit of the model with the lowest quantity requirements. For model A, B, and C shown in the preceding table, there should be five cycles (5 can be evenly divided into each quantity).

If dividing by the smallest daily does not yields an integer value for each model, a manager may choose for using the smallest production quantity to select a number of cycles to make up the difference

We determine the number of units of each model in each cycle by dividing each model's daily production quantity by the number of cycles. Using five cycles per day would yield the following:

Table 2-5; Methods of finding production units per cycle

| Model | Daily quantity | Units per cycle |
|---|---|---|
| A | 10 | 10/5 = 2 |
| B | 15 | 15/5 = 3 |
| C | 5 | 5/5 = 1 |