# CHAPTER II

# THEORETICAL CONSIDERATION AND LITERATURE REVIEWS

## 2.1 Theoretical Consideration

This section will explain the basic concept of the theories, tools and techniques that will be used throughout this project.

### 2.1.1 Plant-Layout Definition

Many academics, such as Muther, 1973; Weiss, 1993; Apple 1973 and 1977; and Reed, 1961, have defined the term plant-layout. Although their definitions maybe slightly different in details, they all have the same basic undertone. From these established definitions, it can be summarised that

*"Plant-layout: A study and analysis of the factors that affect manufacturing, specifically the physical attributes and constraints of the manufacturing area, but not limited to. The purpose of the study is to maximise the efficiency and effectiveness of the manufacturing process in order to reduce the manufacturing cost and lead time, to improve the product quality, and to stimulate the employees. "*

The author will use the above definition as the basic understanding for this research.

The job of designing a plant-layout is not only restricted to the design of a new factory as many people may understand. Plant layout design also includes the continuous rearrangement and improvement of machines and work stations as the business grows and changes. Furthermore, other indirect functions that support the manufacturing process such as material handling system, scheduling system, quality control system and material reordering system may be included as part of the plant layout design process.

To further clarify the definition of plant layout design, the term 'plant' shall also be explained in details. In general, the term 'plant' or 'factory' are used interchangeably. When the general public think of a factory, they can only picture the workers and the machines that are used. However, in the case of a plant-layout design project, the term 'plant' represent a place that bring together all the factors that are required to make a product. These factors are – man power, raw material, machineries, supporting systems, power and management. Therefore, a good plant-layout design should take all of the above factors into account and make sure that they can all function together effectively.

### 2.1.2 Different Types of Plant-Layout

In different factories, the arrangement of the facilities and workstations will varies according to the requirements and constraints of each factory. No factory will have the exact same layout even if they are owned by the same company and making the same product. Despite the definite differences, plant layouts can be classified into three basic layout types, (Russell and Taylor III, 2003):

1. Product layout
2. Process layout
3. Fixed-position layout

Each type of layout is suitable for different situation depending on the nature of the product. Brief definitions of the different layout types and its suitable conditions shall be given below

**Process Layout**

Process layout is also known as '*functional layout*'. The basic idea is to group similar machines that perform similar task together into departments or work stations. E.g. for a job shop, this will mean the grouping together of drilling machines, lathes, milling machine, polishing machines and so on. See figure 2.1 below for an example of a process layout.

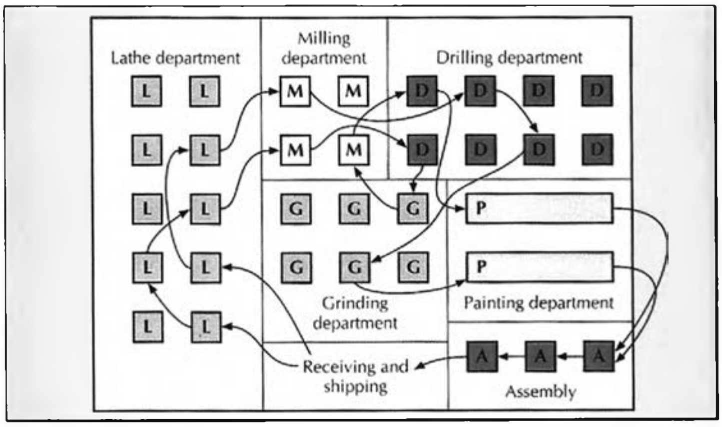


Figure 2.1 – example of a process layout, (Russell and Taylor III, 2003)

Process layout is suitable for a factory that has:

- a wide product range
- large number of low volume batch orders
- frequent changes in the production line and one-off orders
- variations in manufacturing sequence of each product
- machines that are non-specialised

**Product Layout**

A factory with a product layout will arrange their facilities according to the sequence of operations that need to be performed to manufacture a product. It is essentially an assembly line type of arrangement. See figure 2.2 below for an example of a product layout. The red boxes in the picture could represent any type of machineries that are required in the manufacturing sequence.

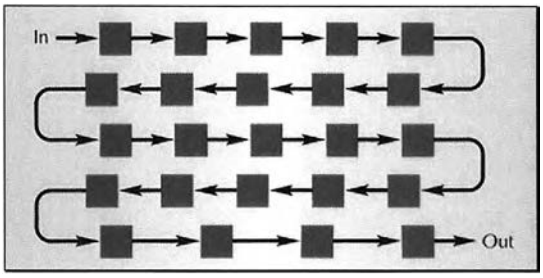


Figure 2.2 – example of a product layout, (Russell and Taylor III, 2003)

Product layout is suitable for a factory that has:

- low variety of products
- products with standard manufacturing sequence
- products with high production volume
- products with relatively constant market demands (or made to stock)
- specialised machineries

**Fixed-Position Layout**

Unlike the first two types of layouts where the product will move along some kind of manufacturing route, a fixed-position layout will keep the product stationary and the machineries and workers will move around the product instead. One of the most well-known example of a fixed-position layout is the manufacturing of an aeroplane, see figure 2.3 below. The aeroplane will spend most of its time in a fixed place and the workers and machines will move around it to complete the plane.

Figure 2.3 – Example of a fixed-position layout, (Russell and Taylor III, 2003)

Fixed-position layout is suitable for a manufacturer that has:

- products that are too large and heavy to move i.e. ships, houses and aircrafts.
- specialised and highly skilled workers
- multipurpose machineries
- products that have flexible manufacturing sequence

### 2.1.3 Group Technology

**History of Group Technology** – Group Technology (GT) originated from Germany during the period of WW2 and subsequently applied throughout Western Europe. In the 1970's Japan has adopted larger scale GT applications and has since then, been the basis for establishing many of the Japanese's current factories.

**Basic concept of Group Technology** – GT is simply a concept that developed from the idea that by grouping similar problems together can result in a single solution; saving both times and effort, (Levulis, 1976). In the manufacturing world, the grouping of similar problems translates to the grouping of similar products or components to reduce the manufacturing time and effort. The main idea of GT is to find a commonality in a group of parts and to exploit that commonality. The grouping criteria can be based on many things such as the required manufacturing process, manufacturing sequences, physical shape of the parts, raw material types, sourcing locations etc. The grouping method will varies depending on the specific circumstance of each problem. One of the most common grouping methods is the grouping of parts that have similar form that require similar manufacturing process or sequences. This grouping method leads to the concept of **"cell formation"**. In a cell, parts of similar form or process can be efficiently manufactured by a group of machines that are in close proximity because it reduces the distance that the parts have to travel and the setup time. With cell formation technique, the traditional functional departments (e.g. lathe, milling and drilling) are replaced by machining cells that has the required machine tools complete the parts in the cell.

Cell formation is now a major aspect of the group technology concept. Group technology can provide great benefits for a job shop that has many batch orders. Cell formation will create a 'factory-within-a-factory'. This will provide the structure to help simplify the shop floor control by isolating operations into specific area; thus, control is increased, and parts rather than operation can be controlled. Other generic benefits of the GT concept are given in figure 1.3 in section 1.8.

### 2.1.4 Process Flowchart

Process flowchart is a tool that helps graphically analyse the manufacturing process quantitatively (time and distance). It provides a systematic examination of all the aspects of a manufacturing process to improve its functions and identify the non-productive activities. Process flowcharts identify five different processes within the overall manufacturing process – operation, transport, inspection, delay and storage.

Each of these process are represented by different symbols, see table 2.1 below for details.

Table 2.1 – Symbols used in process flowcharts

| Symbol | Meaning |
|---|---|
| ○ | Operation |
| ⇨ | Transport |
| □ | Inspect |
| D | Delay |
| ▽ | Storage |

Process flowcharts need three types of information – description of process, time and distance. An example of a process flowchart is given in table 2.2 below.

Table 2.2 – A blank process flowchart

| Title of process | | | | |
|---|---|---|---|---|
| Step | | Description of process | Operation time | Distance |
| 1 | ○ ⇨ □ D ▽ | | | |
| 2 | ○ ⇨ □ D ▽ | | | |
| 3 | ○ ⇨ □ D ▽ | | | |
| | | **Total** | | |

Process flowcharts will help identify the non-productive activities (transport, inspect, delay and storage) so that appropriate action can be taken to eliminate or reduce these activities.

### 2.1.5 Production Flow Analysis (PFA)

Production flow analysis is another tool that can be used to help with cell formation. A production flow analysis is a matrix that shows which product uses what machines. The PFA helps identify families of parts with similar processing requirements. Figure 2.4 below shows an example of a PFA

| | Machines | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parts | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| A | x | x | | x | | | | x | | x | | |
| B | | | | | x | | x | | | | x | x |
| C | | | x | | | x | | | x | | | |
| D | x | x | | x | | | | x | | x | | |
| E | | | | | x | x | | | | | | x |
| F | x | | | x | | | | x | | | | |
| G | | | x | | | x | | | x | | | x |
| H | | | | | | | x | | | | x | x |

Figure 2.4 – an example of a PFA (Russell and Taylor III, 2003)

From the information in the PFA in figure 2.4, the parts can be grouped together to form product cells according to its process or machine requirements. This can be done by moving the parts that are using the same machine together to form a cell. Figure 2.5 below illustrate this concept.

| | Machines | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parts | 1 | 2 | 4 | 8 | 10 | 3 | 6 | 9 | 5 | 7 | 11 | 12 |
| A | x | x | x | x | x | | | | | | | |
| D | x | x | x | x | x | | | | | | | |
| F | x | | x | x | | | | | | | | |
| C | | | | | | x | x | x | | | | |
| G | | | | | | x | x | x | | | | x |
| B | | | | | | | | | x | x | x | x |
| H | | | | | | | | | | x | x | x |
| E | | | | | | | x | | x | | | x |

Cell 1: Parts A, D, F
Machines 1, 2, 4, 8, 10

Cell 2: Parts C, G
Machines 3, 6, 9

Cell 3: Parts B, H, E
Machines 5, 7, 11, 12

Figure 2.5 – Rearranged PFA showing cells of parts. (Russell and Taylor III, 2003)

### 2.1.6 Travelling Chart

Travelling chart is a diagram showing the transfer frequencies between different departments or machines. A travelling chart is much like a distance table often found in a map that shows the distances between different cities. Table 2.3 below shows an example of a travelling chart. The chart is read by looking at the intersecting box between the two interested entities. For example, the transfer frequency between point B and D is 15.

Table 2.3 – Example of a travelling chart

| | A | B | C | D | E |
|---|---|---|---|---|---|
| A | | | | | |
| B | | | | 15 | |
| C | | | | | |
| D | | | | | |
| E | | | | | |

The travelling chart is an important tool to help with the new layout design process. It will determine the machine placement priority. The entities that have the highest transfer frequency can be given the highest attention so that they can be placed close together and so on. This is will make the design more effective. It is imperative that a travelling chart is used for the layout design process where there are multiple products present. The product volume information alone is insufficient as some product may travel between the same places more than once.

## 2.2 Literature Reviews

Productivity has always been one of the main focuses in any business. There are many methods that an organisation can follow in order to increase productivity. Regardless of the method that the company has chosen to improve its productivity with, efficiency and effectiveness of the processes are the two factors that ultimately determine productivity. Every theories that have been created utilises this fact as the underlying principle – how to do things faster and better. Gunasekaran, et al (1994) have given the following list as the key concepts in which most organisations are utilizing as the means to increase their productivity:

- Strategic planning
- R & D
- Marketing
- Product/Process development and maintenance
- Tooling and Production programming
- Production management
- In-process material movement
- Production operations
- Incoming material control
- Outgoing material control
- Production quality control
- Human resources
- Information systems
- Facilities management

Because facility layout is essentially the backbone of the company, many of the method in the above list are, in one way or the other, associated with facility layout. Facility layout affects the productivity of an organisation enormously. Where and how work is being performed is crucial to the outcomes. The main idea to be observed is that no single theory can act as a silver bullet to increase productivity, overall balance must be achieved. Facility layout is merely a part of the mechanism of the master plan to improve productivity.

From Russell and Taylor III (2003), the concepts that are generally used to produce facilities layout design for manufacturing organisations are:

- Process layouts
- Product layouts
- Fixed position layouts
- Cellular layouts
- Flexible Manufacturing systems (FMS)
- Mixed-model assembly line

Each concept is suited for different types of manufacturing organisation depending on their product variety and volume of production. The first three concepts are considered as "basic concepts" and the latter three as "hybrid concepts". The basic concepts use extreme measures to achieve its goal (high throughout rate or high flexibility) with no compensation for adjustment. Hybrid concepts combine the best of both worlds to gives a more flexible production while maintaining a reasonable throughput rate. In the old days most manufacturing organisations seem to focus on extreme strategy. Currently, the new trend is to move toward a hybrid layout concept; as so with this project.

Vakharia (1986) investigates the methodology of cell formation and established a framework for evaluation. This is one of the rare papers that deal with the comparison of different type of cell formation methods. A brief overview of a number of cell formation techniques such as descriptive methods, block diagonal matrix methods, similarity coefficient methods and mathematical model methods are covered in the paper which gives a good start for further reading.

Billo (1998) also deals with design methodology for configuration of manufacturing cells. This paper focuses on the development of a general and more robust methodology for cell design in contrast to the more traditional methods such as array-based model, cluster analysis methods etc. Billo provides an in-depth detail accompanied with a 10 steps method for general cell formation.

Yang, Peters and Tu (2004) studied layout design for flexible manufacturing systems. They focused on single-loop directional flow patterns to maximise productivity in a flexible manufacturing system using a two step heuristic. Although FMS may not be suitable for this project, some of the basic FMS formation techniques such as space-filling curve (SFC) may prove to be useful.

Massoud (1999) gives a thorough example and a case study for layout design in cellular manufacturing. Massoud's case study also provides a practical link for the theory.

Mak, Wong and Chan (1998) present the use of genetic algorithm as a general methodology for facility layout design. This heavily mathematical based method inspects the machine's layout and material flow within a typical job shop which provides a direct example for the project.

Logendran and Talkinton (1997) provide an interesting study of an analysis of cellular and functional manufacturing systems in the presence of machine breakdown. This spark a very realistic alert of the need for robustness in the layout design which is often overlooked in a theoretical research.

Lohasomboon (1989) studied a similar productivity problem for a small aluminium ware factory in Thailand. The research uses the knowledge of industrial engineering and management to improve the productivity. Lohasomboon suggested that problems such as poor operation management, ineffective plant layout and production process, poor working environment, inadequate storage space and poor production planning and control are the factors that lead to low productivity. The plant's operations were improved by redesigning the management organisational structure to better balance and equally distribute work loads amongst the managements. Furthermore, the plant layout was redesigned using systematic layout planning and group technology approach. New belt conveyor system was applied to improve the material handling. The working environment was also improved by installing local exhaust ventilation system to eliminate undesirable working conditions caused by toxic exhaust fumes generated by the machines. All of these small improvements lead to the grand objective of productivity improvement.