# CHAPTER 2

# THEORETICAL CONSIDERATION AND LITERATURE SURVEYS

## 2.1 Theoretical consideration

Plant layout design is the analysis and management of allocating the production resource in order to maximize the efficiency of the process and also utilize the workforce. Plant layout design consists of the layout design and the material handling systems design. Equipment, machinery and support structure within the plant area are considered in the plant layout design. According to Tompkins et al (1996) said that the plant layout design determines how an activity's tangible fixed assets satisfy the activity's objective. The main objectives of the plant layout design are to enable manufacture of the product in required volume with the low cost of production and the others can be the effective utilization of workforce, space. In order to achieve these objectives, the following ideas should be made in designing plant layout.

### 2.1.1 Type of plant layout

In designing the plant layout, according to Tompkins (1996) in Facilities Planning there are 3 different types of layout.

1. Product layout

   This type of layout is suitable for the mass production, the location of the department and machine will be located according to the sequence of the production.

2. Process layout

Process layout is the type of layout that put the machine and equipment with the same operation together.

3. Fixed position layout

This type of layout is the layout that fixes the product at the same position and moves the equipment, machine, labour, and material to the product in order to built or make.

**2.1.2 The basic ideas of designing plant layout**

1. Idea of involving all the activities

Good plant layout must combine material machine and human all together. The relationship of all threes thing creates the activity within the workplace.

2. Idea of the material handling and material flow

Good plant layout must provide the least of transferring material between each process and suitable handling system in order to reduce the material handling cost. By trying to allocate the department or machine in the sequence of work, this can reduce the distance of transferring material. The route of the material flow should also be as simple as possible and avoiding the complexity, the confusion of the route.

3. Idea of utilizing the space

Good plant layout must be utilized the available space as much as possible. The allocation is not considered only on the ground but also in the upper space or even the underground.

4. Idea of providing well-being and moral of the worker

Safety work place and the compatibility of working to the worker must be considered in designing plant layout also. This will directly effect to the performance of the worker, the worker can perform the full ability when the workplace is well designed to be suitable for each activity. Bad plant design can cause the accident to the worker and cause the lost of the property.

5. Idea of the flexibility of the plant

Good plant design must be flexible enough in order to change or reallocate economically and comfortably. It is very important nowadays since the new product need updating more often. However, this also depends on the characteristic of each industrial, with the large size of product or machine the less flexibility it possibly is.

**2.1.3 Theory of collecting data that is used in improving plant layout**

**2.1.3.1 Flow of materials**

In analysing the flow of the material, the purpose of making the best flow is to sequence the order of each activity into the right sequence. The effective flow must be in the simple straight line as much as possible, the process of back and forth should be avoided as much as possible. Analysing the flow of material is the heart of doing plant layout because the flow of material is the main factor of the production, especially when the material is big, heavy or when the material handling cost is high.

Method of analysing the flow of material

- Flow process chart

Flow process chart is the mapping record of the process by using the symbol to indicate the activity and time of the worker in performing each task. The symbols are divided into 5 actions, which are operation, transportation, inspection, delay, and storage.

Table 2.1: Symbols used in flow process chart

| Symbol | Meaning |
|---|---|
| ○ | Operation |
| ⇨ | Transportation |
| □ | Inspection |
| D | Delay |
| ▽ | Storage |

Table 2.2: Process chart

| Symbol | Description | Operation time | Department | Total time | Distance | Total distance |
|---|---|---|---|---|---|---|
| ○ ⇨ □ D ▽ | | | | | | |
| ○ ⇨ □ D ▽ | | | | | | |
| ○ ⇨ □ D ▽ | | | | | | |
| | | | Total | | | |

Flow process chart shows the clearly understanding of the material flow within the production. The chart is started from the beginning of the receiving the raw material up until the end of the finished product. By looking at the chart, the activities are easily to be analysed then the improvement can be done afterward.

- Flow diagram

Flow diagram shows the flow of the activities in the plant layout by using the symbol of five actions in process chart to show how material flow in the plant layout.

### 2.1.3.2 Time of each activity

The method of collecting time of each activity will be collected from studying, recording, and interviewing. The worker will be interviewed in order to ensure that the data is an average time and conform to the real situation. In this research the stopwatch will not be used because the unit of time is in hour or day so it does not need to be precise.

### 2.1.3.3 Distance of each activity

For the methodology of collecting distance data of each activity, it will be measured from the blueprint. After the material flow is analysed then the distance of material flow between each activity can be identified.

### 2.1.3.4 Factory area data

Both factory areas, existing plant and new available area, will be used to identify the location of the department and flow of material. All of these data is very useful to identify the proper position and the possibility of the department located within the area.

## 2.2 Example of plant layout improvement

1. Yiangkamolsing (1998) wrote a thesis about an application of genetic algorithms in plant layout design. The author classified the facility layout into 2 classes, quantitative data and qualitative data. The author used genetic algorithms to search for a good facility layout and to improve the searching speed.
2. Amarase (2001) wrote a thesis about the warehouse design for plastic resins trading company. The author wrote about the designing a new warehouse for Polymer Marking and Trading Co, LTD, the plastic resins trading company to cover 1000 tons per months sales expectation. The theories of warehouse design, characteristics of each plastic resin type, and the existing warehouse are studied. Then the material handling equipment and material-handling employees are designed. And, the result, the warehouse can cover the expected sales amount.
3. Tantrakool (2000) wrote a thesis about studying the problems in a motorcycle parts manufacturing factory in Thailand. The purpose of the study is to improve the productivity in the same factory. From the results of the study, the problems of low productivity are from factory planning and layout, production processes, and storage areas. After that the problems were defined and analysed. The location was relocated, and then the productivity was increased afterward.
4. Charojrochkul (1999) wrote a thesis about improving material handling routing in a warehouse in an automotive parts industry and improving transportation operation within the company. The problems are analyzed and improved. The results are the new warehouse design, the reduction of material handling, and the reduction of transportation route.

5. Kamonpatana (2001) wrote a thesis about improving plant layout of a plastic utensil processing ling. Before improvement, the company had meandering route of material flow, high number of work in process and finished goods that results in excessive use of workforce, time, and transportation. After improvement, by using plant layout design, the unnecessary activities were eliminated that results in the reduction of transportation, time, and cost.
6. Tompkins (1996) wrote a book that concern with the facilities planning including development of material handling and layout, function of manufacturing operations, and quantitative and quantitative facilities planning.
7. Phillips (1997) wrote a book that concern with the analysis of all the requirement of manufacturing plant layout, material handling, relationship of the activities, and alternative layout configuration.
8. Heragu (1997) wrote a book that concern with the approach to the facility layout problem, the book emphasizes on the mathematical models and algorithms that used to model and solve facility problems.
9. Lee (1997) wrote a book that concern with facility and workplace design. The book emphasizes on practicing the industrial engineer to the facility planning. The facility design, workstation design, and space planning are explained in this book.
10. Cedarleaf (1996) wrote a book that concern with the analysis of process flow, planning a new plant including, designing, new layout, preparing, drawing.
11. Francis (1974) wrote a book that concern with facility layout by using analytical approach. The book covers the problem of layout and location planning with a different type of location type and using analytical model to solve.

12. Gerald R. Aase, John R. Olson, and Marc J. Schniederjans (2002) have studied the impact on labour productivity in working in U-shaped assembly line layouts. The decision to move straight-line assembly systems to U-shaped assembly lines systems constitutes a major layout design change and investment for assembly operations. U-shaped assembly systems offer several benefits over traditional straight-line layouts in the aspect of lean manufacturing and just-in-time philosophies, also including an improvement in labour productivity. The purpose of this research is to empirically confirm that U-shaped assembly lines improve labour productivity. Results indicate that labour productivity will improve significantly under certain conditions when switching from a straight-line layout to a U-shaped layout but not in all cases. The research also reveals some limitations of such a layout change when factors such as the number of tasks and cycle times are varied.
13. Hwang (2004) has studied, analysed, and adapted heuristic transporters routing model for manufacturing facility design. Given fixed facility layout and predetermined material flow paths, this study determines the minimum number of transporters required to transfer material within a given manufacturing facility with minimal handling effort. The manufacturing facility design problem is particularly complex and involves the sub-problems such as design of the material network and the transporters routing problem, which provides the fleet size and the routing of each transporters over the flow network. The problem is formulated as an integer program. The heuristic and integrated vehicle routing models are used to solve the problem. Also the heuristic solution program and several tests is applied along with an industrial example to indicate the effectiveness of this method.

14. Yang, Brett, and Tu (2003) has studied the layout design for flexible manufacturing systems considering single-loop directional flow patterns. In the study, in order to achieve high productivity in a flexible manufacturing system (FMS), an efficient layout arrangement and material flow path design are important things to concern due to the large percentage of product cost that is related to material handling. The layout problem has departments with fixed shapes and pick-up/drop-off points. It is an open-field type layout with single-loop directed flow path. A two-step heuristic is proposed to solve the problem. It first solves a traditional block layout with directed-loop flow path to minimize material handling costs by using a combined space-filling curve and simulated annealing algorithm. The second step of the proposed methodology uses the resulting flow sequence and relative positioning information from the first step as input to solve the detailed FMS layout, which includes the spatial coordinates and orientation of each FMS cell. This detailed FMS layout problem is formulated and solved as a mixed integer program. Empirical illustrations show promising results for the proposed methodology in solving real-world type problems.
15. Balakrishnan, Chen, Conway, and Lau (2002) have studied a hybrid genetic algorithm for the dynamic plant layout problem. The dynamic plant layout problem (DPLP) deals with the layout of multi-period layout plans. Although an optimal solution method based on dynamic programming is available, it is not practical for large DPLPs. It has recently been shown that heuristics based on genetic algorithms can solve large DPLPs. In this research, the use of genetic algorithms are extended and improved by creating a hybrid genetic algorithm. A computational study is carried out to compare the proposed algorithm with the existing genetic algorithms

and a recent simulated annealing algorithm. The study shows that the proposed algorithm is effective. Thus it may be useful in solving the larger problems.

16. Pelinescu, and Wang (2002) have studied about the multi-objective optimal fixture layout design. The study concerned about a major issue in fixture layout design to determine and evaluate the acceptable fixture designs based on multiple quality criteria and to select an optimal fixture with appropriate trade-offs among multiple performance requirements. The performance objectives considered are related to the fundamental requirements of kinematics localization and total fixturing (form-closure). Three performance objectives are defined as the work piece localization accuracy and the norm and dispersion of the locator contact forces. The study focuses on multi-criteria optimal design with a hierarchical approach. An efficient interchange algorithm is extended and used for different practical cases, leading to proper trade-off strategies for performing fixture synthesis. Examples are given to illustrate empirical observations with respect to the proposed approach and its effectiveness.

17. Bai, Chen, Bin and Hu (2004) have introduced the concept of the PLF (Product layout Feature), including descriptions of GDEs (Geometric Datum Elements) and engineering symbols, as well as the method of how to define them, and provided a solution to the problems of PLF modeling. As a result of the solution, collaborative design activities among multi-teams from different disciplines can be consistently carried out on PLF models in the PDM environment. It resolves the tough problem of consistently maintaining a product scheme to prevent defects arising from inconsistent general design data or incorrect versions of the layout scheme existing within the schemes of downstream design. By using the principles of the given

method and utilizing previous research projects, a prototype system is developed to support collaborative design based on the PLF model in complicated product design.

18. Mir, and Imam (2001) have studied a hybrid optimisation for the layout design of unequal-area facilities. Simulated annealing is used to optimise a randomly generated initial placement on an "extended plane" considering the unequal-area facilities enclosed in magnified envelope blocks. An analytical method is then applied to obtain the optimum placement of each envelope block in the direction of steepest descent. Stepwise reduction of the sizes of the envelope blocks allows controlled convergence in a multi-phase optimisation process. The presented test problems include two large size benchmark problems of 50 and 100 facilities of unequal areas. The results indicate that although the computational cost is relatively quite high, the technique is a significant improvement over previously published techniques for unequal-area facilities and can yield solutions of the same quality as obtained by PLANOPT, a general-purpose layout optimisation program based on pseudo-exhaustive search.
19. Korves, and Loftus (2000) have studied Designing an immersive virtual reality interface for layout planning This study discusses the reasons why manufacturing layout planning is considered to be an appropriate new area of virtual reality (VR) utilisation; develops a framework for a VR-based layout planning tool and reports on a study comparing the use of immersive VR to a monitor-based system for detecting layout design flaws. The evaluation of the proposed framework has been conducted in a study, which did not have provision for an interactive alteration of the layout. The aim of the study was to compare an immersive system and a monitor-based VR system for workplace analysis. Participants were asked to

investigate a workplace environment, which included three serious layout design flaws (tool arrangement, visibility, and tool location) and give their assessment about potential improvements.

20. Lin, and Sharp (1999) have studied about quantitative and qualitative indices for the plant layout evaluation problem. The authors found that in the past two decades, the researchers used to develop simulation models or mathematical programming models to estimate the performance measures of a production system which may or may not include the considerations of layout design, rather than develop indices specifically for evaluating a layout alternative. These models usually ask for very detailed information. Most of them involve oversimplifying assumptions and request overwhelming computational efforts such that they cannot be manipulated with ease in practice. The limitations and deficiencies of previous indices and performance measures include: parameters hard to obtain; inappropriate detailed data requirement; much effort to obtain little accuracy improvements; data available after operations start; no generic approach and no clear validation provided. To overcome these deficiencies, the generic approaches for developing quantitative and qualitative indices are provided and new indices for the flow criterion group and environment criterion group are presented. The parameters of each index are easier to obtain and do not require much effort on data collection. The validations of each quantitative index with examples are also provided. The generic approaches also allow the users to revise the indices according to the specific case considered.

21. Schmidt-Traub, Köster, Holtkötter ,and Nipper (1998) have studied about conceptual plant layout. The study of layout is involved the spatial arrangement of equipment within the steel structure or building of a plant and considers the inter-

connections through pipes and ducts as well as walks and vehicle transportation. An optimal layout has to ensure operability, adequate safety and an economic design. Therefore, it is influenced by a whole range of factors such as process needs, maintenance, operational requirements, safety considerations and the available site. The resulting parameters differ significantly and compete with one another. Moreover, the conventional sequential workflow of layout and detail engineering does not allow improvements of the layout at a late state of the project. Today commercial CAD-systems are used as design tools for plant layout and detail engineering, but they do not support planning and optimisation of the layout. These decisions still need to be made by experienced senior engineers and designers.

22. Ziai, and Sule (1989) have studied about computerized materials handling and facility layout design. We are proposing a systematic approach to the design of materials handling (MH) system that includes an algorithm to select the most suitable equipment. Initially, a conveyor system is proposed while determining its association cost. To seek improvements of the system in terms of cost and equipment utilization, the possibility of supplementing or replacing the conveyor with one or more forklift trucks (trucks) will be investigated. The final MH system configuration will consist of conveyors and trucks so that total system optimization will be achieved. The literature on MH design is very limited and often this problem is not directly coupled with the layout problem. The model proposed uses the results of a tentatively designed layout and two important characteristics of the materials, namely size and weight. Facility in this paper refers to a manufacturing plant with low to medium production volume in a process-oriented environment. Facility layout and materials handling are two highly interdependent problems. The location

of departments, the corresponding distances and production rates dictate the cost of MH. On the other hand, MH costs between departments, influence the departmental arrangements. An iterative process is developed between the layout design and MH selection problems.