Chapter II

LITERATURE REVIEW

2.1 Layout Problem

The problems of an industrial process arrangement have the significant effects on the overall production system. Production engineers always concern how to correct these kinds of problems throughout the development of the factory system. Some approaches taken in solving the plant layout problem are as follow:

2.1.1 Traditional Schematic Technique

The use of this technique is stated in the books of Mallick and Gaudrau (1951), Muther (1955), Apple (1963), Reed (1961), Immer (1950) and Moore (1962).

The approach of this technique was typically of minimizing the distance material traveled between work centers. In this technique, the flow diagram and the process charts are developed with the help of two-dimensional templates and three dimensional scale models. These were evaluated with a view to minimize the material handling costs.

The development and evaluation of the layouts were depended primarily on the judgment, intuition, and experience of the analyst.

2.1.2 Graphical and Systematic Technique

1. Travel Charting

   The use of travel charting was first introduced by Cameron (1952) and then is followed by Smith (1955) and Llewellyn. Travel charting enables the layout analyst to arrange and analyze a large quantity of the material handling data in a concise and rapid way. The procedure involves the following steps:

   - Collection of data pertaining to the volume and sequence of handling
   - Calculation of distance volume matrix from an initial layout
   - Analysis of the matrix determining both the criteria move and the ideal
   - Change the department and evaluate the improvement
   - Analysis should be continued until no further improvement can be done

2. Sequence Analysis

   It is based on the analysis of sequence of the operation of the products. This technique was developed by Buffa (1955). The steps followed in this type of analysis are as follows:

- Collected data concerning the sequence of the operation, production requirements and unit load all parts. Areas required for each department or section was estimated.
- Develop a sequential summary giving the work center each part will go next.
- Compile a summary of loads, time period between all work centers.
- Develop improved layout by trial and error such that flow product is unidirectional so far as possible.

This method represents a slight improvement over the traditional approach and is inferior to travel charting.

3. Systematic Layout Planning

It was developed by Myther (1962). This is a method of schematically analyzing the relative relationship between work centers. The steps involved in these methods are as follows:

- Relative activities to each other by a method of closeness desired rating that results in a relationship chart.
- Establish required area and configuration of each activity.
- Graphically relate activities and arrange space to form a basic pattern.
- Evaluate alternative layouts against objectives and constrains as desired management.

2.1.3 Mathematical Programming Models

Some of the popular algorithms are briefly discussed in the following section:

1. CORELAP (Lee & Moore, 1967)

Computerized Relationship Layout Planning (CORELAP) constructs a layout for a facility by calculating the total closeness rating (TCR) for the department. TCR is the sum of the numerical values assigned to the closeness relationships between a department and all other departments (A=6, E=5, I=4, O=3, U=2 and X=1). Then departments are selected basing on the highest-rated relationship to departments already selected, with tie broken first by largest TCR and then largest size. CORELAP evaluates the layout by calculating the layout score as follows:

Layout Score = $\int_{\text{All dept}}$ numerical closeness rating * length of shortest path

2. ALDEP (Seehof and Evans, 1967)

Automated Layout Designed Program (ALDEP) has the same basic data input requirements and the objectives as CORELAP but the procedure are different. CORELAP selects the first department and breaks tie with the total closeness rating, while ALDEP selects the first department and break ties randomly. The philosophical difference the two algorithms is that CORELAP tries to give the best layout, whereas ALDEP produces many layouts, rates each of them and leaves the evaluation of them to the facility designers.

3. CRAFT (Armour and Buffa, 1963)

Computerized Relative Allocation of Facilities Technique (CRAFT) tries to develop a layout with the minimum transportation cost. Transportation cost is defined as a product of flows, distances and unit travel costs. Transportation cost for the initial layout is calculated first, and then CRAFT will consider the interchanges of departments that have the equal area or a common border in an effort to reduce the transportation cost.

4. COFAD (Tomkins and Reed, 1967)

COFAD is modified from CRAFT so it allows using the move costs for a variety of material handling equipment alternatives. To include such move costs, the material handling methods and cost must be determined for each alternative layout.

5. COALA (Porth, G.M. and Vernadat, F., 1991)

The authors have developed a new manufacturing layout algorithm and software, called COALA. They suggest a new three-stage approach for manufacturing plant layout. The first stage called manufacturing cell design, consisting in grouping physical facilities within the cells. Finally, the cell location stage is concerned with placing the cells on the shop-floor surface.

In addition to the software or algorithms above, investigators have tried to model the facilities layout problem as:

- Linear Assignment Problem (LAP): LAP is capable of taking several interactions among the facilities as well as the relocation costs but it has the restrictions that there should not be any interaction among the free moving facilities.
- Traveling Salesman Problem (TSP): It can take into consideration the relocation costs but it has the limitation that there should be only one input and one output to and from a facility respectively.
- Quadratic Assignment Problem (QAP): QAP can take into account both the relocation costs as well as the multi-interactions among the facilities. This model is suitable for the plant layout problem of M/S Century Textile Company Ltd. QAP belongs to nonpolynominalbounded group and combinatorial in nature, they do not tend themselves easily to analytical solution. Moreover, complete enumeration of the possible assignment of the facilities to locations with the exception of very small problem can't be considered computationally feasible. QAP with $n > 15$ (n is the no. Of facilities) are usually not solved in exact way. So, heuristic methods are the only possible solution techniques.

2.2 Chosen Techniques in Research

2.2.1 Technique of Muther and Apple

The traditional schematic technique of Muther and Apple is chosen in this case. They suggested two methods for the layout development: for the existing and current layout. In this research, the technique for the existing layout is discussed only. The reason of redesign for the existing layout is the layout should be adapted by following the environment in order to sustain or improve the productivity in the change of environment. Moreover, the lifetime of the suitable layout depends on the type of industry. The process of the existing layout development consists of 4 steps as follows:

1. Study the current condition of the factory

To improve the existing layout efficiency, the objective and scope of development must be clear. Thus, the commitment from the management should be provided. The examples of information provided from the management are the type of product produced in future, the number of type of product, and so on. Additionally, there are 3 groups of data should be collected.

- the existing layout: we should check whether the layout in plan is correct with the actual or not. If it's not correct, the data should be updated.
- the flow of material and WIP: Operation Process Chart (OPC) is introduced to check the appropriate process with the situation. After the current process is verified, Flow Process Chart (FPC) will be used. This chart will help understand the production time, waiting time, the condition of transportation and so on. These can identify that the condition of flow, the point of bottleneck or the correctness of layout.
- Other data about the current layout: the examples of data in this group is the data about resource in factory such as machine, station area, production capacity, man power and so on. This information will be useful for improvement.

2. Analyze the Problem

In this step, the information collected in last section will be used to analyze. The result of analysis may be:

- the continuation of material flow
- the point of bottleneck
- the number of moving round
- the formation of flow
- the correctness of process
- the productivity
- and so on.

All of results are categorized to conclude which problem should be the first or second priority. More details in this section will be discussed in section 2.2.2.

3. Propose the correction method

As a result of analysis, many correction methods may be provided such as the change of the production process, the equipment change, or the change of the transportation method.

4. Theory Estimation

According to the theory, the aim of improvement is to maximize the productivity and minimize the cost. That means the new layout should provide the short throughput time, low labor cost, the short moving distance and so on. Therefore, we should provide the variety of improved layouts to have more choices for any purposes.

2.2.2 Flow and Relationship Analysis

Because there is the problem in the moving distance, this method is introduced. There are 3 parts in this method: flow analysis, relationship analysis and the integration of both methods.

2.2.2.1 Flow Analysis

1. Overview of Flow Analysis

Flow analysis is the important factor with layout development. Before using this method, we should confidence that our production process is correct. Then, the data required for this analysis is the transportation process, the moving frequency, the distance between stations and the number of WIP and material. Additionally, some tools are useful for analysis. These tools are OPC, FPC, Multi-Product Process Chart (MPC), From-To Chart, or Flow Diagram. In this research, MPC is chosen because it's appropriate with the number of product type and the size of orders.

2. Multi-Product Process Chart

This chart shows the process of each product in details and the density of transportation between stations. Thus, we can use the density to be guideline for building the new layout. The concept of this method is both stations should be closed in which both activities have high density.

3. Total Distance Calculation

Although the result from MPC can be the criteria for layout generation, it's not enough for estimation. Thus, the total moving distance in production should be used. This method is a part of MPC application. It is calculated by multiplying distance between stations with load or the moving rounds.

2.2.2.2 Relationship Analysis

There are 4 steps of this analysis. The example of Relationship chart is shown in Figure 2-1.

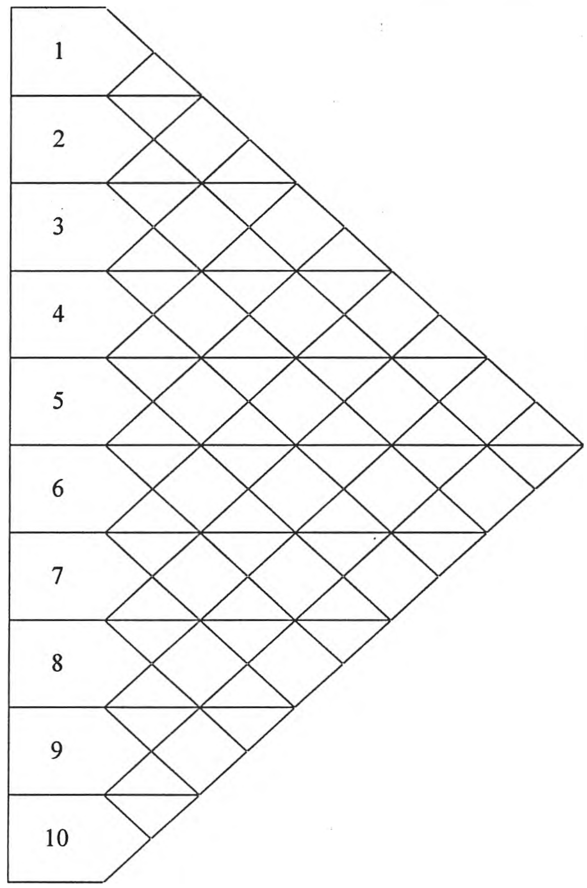

Figure 2-1: Relationship Chart

1. Specify Activity

First step is to specify the necessary activities and fill in the table. In practical, it should not have over 40 activities in table. If there are over 40 activities, we should mix the activities looked like the same with together.

2. Study the factors affecting the relationship

To evaluate the level of relationship effectively, the factors should be studied. Some examples are the permanent of equipment, the change in the future, the width of aisle and so on.

3. Categorize the level of Relationship

The level of relationship used for analysis can be categorized into 6 levels.

- A: Highest
- E: Higher
- I: High
- O: Normal
- U: Low
- X: Lower

These levels are filled in the chart for each relationship.

4. Reason for the level of Relationship

Due to no mathematical method for the relationship estimation, the reason should be given. This can be proof of the level for each relationship.

2.2.2.3 Integration of Analysis

If we use either flow or relationship analysis, we may get the layout which is not good enough. Thus, the integration of analysis can still sustain the benefits from both methods.

1. Level of Relationship between both Analysis

Because flow analysis may be more useful than relationship analysis in some layouts, the level of relationship between both analyses should be provided. Figured 2-2 presented by Muther can be used to select the level of relationship.

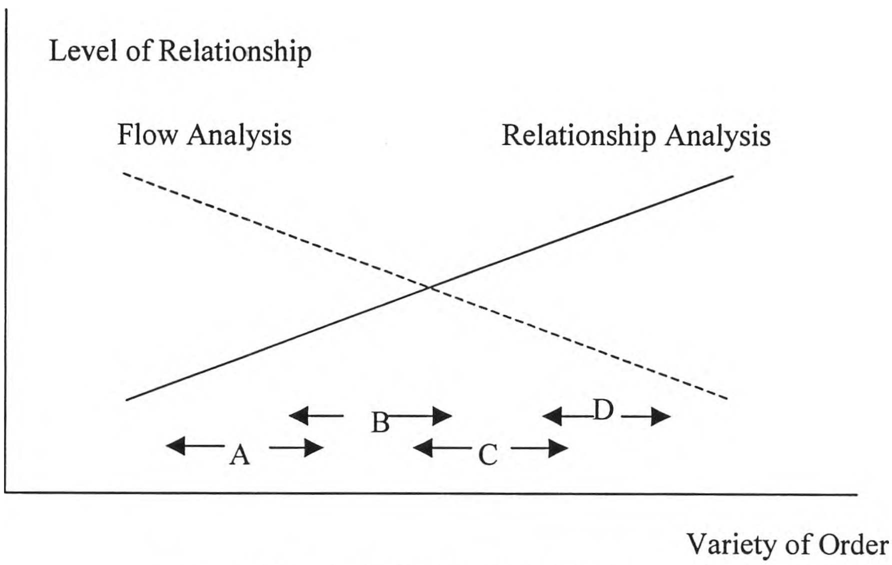

Figure 2-2: Graph for the level decision

According to figure 2-2,
A is used for the high production factory such as the car industry.
B is used for the factory producing by orders such as the plastic industry
C is used for the service company would like to use more paper
D is sued for the normal office.

2. Analysis Integration

The level chosen in last step is used in this step to calculate new the priority level of activities.

2.3 Simulation Tool

2.3.1 Overview of Simulation

Simulation means the techniques for using computers to imitate, or simulate, the operations of various kinds of real-world facilities or processes.

Discrete event simulation concerns the modeling of a system as it has involved overtime by a representation in which the state variables change instantaneously at separate points in time. These points are times when the events occur. Event here is defined as an instantaneous occurrence that may change the state of the system.

As a technique, simulation is one of most widely used in operations research and management science. Application areas for simulation are numerous and diverse. Below is a list of some particular kinds of problems for which simulation has been found to be a useful and powerful tool:

- Designing and analyzing manufacturing systems
- Evaluating hardware and software requirements for a computer system
- Determining ordering policies for an inventory system
- Designing and operating transportation facilities such as freeways, airports, subways or ports
- Evaluating designs for service organizations such as hospitals, post offices, or fast food restaurants
- Analyzing financial or economic systems
- And so on.

The advantages of simulation are to permit us to investigate:

- Planned real system
- Existing system without interruption of its operation and organization before making decision
- Checking the systems that are changed in some factors
- System behavior over long period of real time in short simulation time
- Staff training

Simulation modeling involves creating a model using computer software. A satisfactory model can be obtained by three possibilities:

1. Write a program in general purpose computer language such as FORTRAN, Pascal, C^{++}, or etc.
2. Acquire and use an already written generic model whose parameters can be altered and adjusted by the user.
3. Acquire simulation software and build the model in mode and accompanied language provided by the package. ProModel software is software like this.

The last has the following advantages:

- Powerful software tailored to the purpose of simulation
- Permitting user to focus on system logic, not on programming
- Making available much experience and programming effort of specialists
- Models to be developed more quickly than in general purpose computer language and more particular than in already written models.

ProModel is used in this thesis for building the model of study because it is available and of many advantages as mentioned.

2.3.2 ProModel Software

1. Overview of ProModel

ProModel is a state-of-the-art manufacturing simulator. It is a computer-based simulation/animation-modeling tool designed for engineers and managers alike to evaluate competing alternatives prior to making important business decisions.

ProModel combines the ease of a data-driven-simulator with the flexibility of a general simulation language. It can be used by the variety of jobs such as Industrial Engineers, Manufacturing Engineers, Operations Research Personnel, Production Schedulers, Educators, Management, Plant Layout Personnel, Consultants and so on.

Typically, the ProModel is applied for Flexible Manufacturing Systems (FMS), Automated Material Handling Systems, Warehousing and Distribution Systems, Job Shops, Group Technology Cells, Just-in-Time Manufacturing and Continuous-Flow Manufacturing. Some examples of ProModel Users are as follows:

- Aerospace: BOEING, HUGHES, VICKERS
- Automotive: GENERAL MOTORS, FORD
- Appliance: GE, WHIRLPOOL, HIEL QUAKER
- Chemicals: DUPONT, AMOCO
- Computers & Peripherals: HP, IBM, UNISYS, XEROX
- Consulting: EATON-KENWAY, RUST INT'L
- Consumer Products: BRISTOL MEYERS, RUBBERMAID
- Energy: ALLIED SIGNAL, WESTINGHOUSE
- Leisure: EASTMAN KODAK, WILSON
- Healthcare Products: BAXTER, BRISTOL MYERS
- Metals: KAISER ALUMINUM, LOGAN, WARREN

- Service: WILLIAM BEAUMONT
- U.S. Government: U.S. ARMY, U.S. NAVY

2. ProModel Usage

Much of the ease in using ProModel comes from the simple and straightforward way in which the models are defined in the Model Editor of the program. A model is defined the same way in which a manufacturing engineer would naturally describe a production system by using the same familiar terminology. At the same time, on line, context-sensitive help screens provide useful hints for data input.

Most users prefer to define a model using ProModel's Automatic Model Build mode, which guides you step-by-step through each of the definition modules. Each of these steps is performed using easy-to-complete menus that are automatically invoked based on information supplied in a previously completed menu. This unique feature of ProModel insures data integrity and saves valuable engineering time.

Models may first be defined graphically as well. To define a model graphically, we can begin by placing locations on our layout screen. A location may be a machine, a workstation, a queue, a department, a position on a conveyor or a transporter path, etc. We may choose a location symbol from ProModel's library of icons or may create our own icon using the pixel-based graphics editor. After laying out our locations, we define the flow of parts through the system in the Routing module of ProModel. Then, we can use the complete mode to guide through the rest of the model building process and check for any definitions that may have been overlooked.

After our model has been completed, we can save it and then run a simulation. At this time, if there are any errors or inconsistencies in model input that could not be detected while the model was being defined, ProModel provides error messages that help point out which elements may have caused the error. If model input is free of errors, ProModel begins executing the simulation. Moreover, all model data is written to an ASCII file, which can be quickly edited or saved for documentation purposes. Thus, this also allows experienced simulation users to bypass the menus and develop models using a text editor.

3. ProModel Elements

In this section, the necessary elements in this thesis are discussed only.

- Routing

The routing defines the part flow logic including location and operation sequences, operation times, part input-output relationships such as assembly or disassembly, routing conditions, move times, etc. Parts can be routed conditionally (built-in or user-defined), probabilistically, or deterministically. Operation times and move times can be defined using built-in statistical distributions, user-defined distributions or functions, user variables, attributes or subroutines.

- Part Scheduling

Part Scheduling refers to the mechanism for introducing parts to the production system. Raw materials, purchased parts, sub assemblies, or WIP can be scheduled into the system using Part Scheduling. Scheduling can be done randomly, deterministically, or cyclically. The necessary data for scheduling parts includes: part name, location where the parts enter the system, batch size, arrival frequency, number of arrivals, and the starting time for the first arrival. Scheduling data can be imported into ProModel from an external manufacturing database.

- Resources

Resources refer to items that are used for producing parts. These include: routing locations (i.e. machines, storage areas, queues, etc.) where parts are sent for the execution of some operation and general resources (i.e. operators, tools, fixtures, etc.), which may be used during an operation or part movement. Resources may be assigned priorities and downtimes. Resources must be assigned capacities. The capacity of a resource is the maximum number of parts that can independently use the resource at any given time. For a storage or queuing location, it is the maximum number of parts that can simultaneously occupy that location. For a machining location or a general resource, it is the number of resources available to perform identical operations.

- Parts

Parts refer to items that are processed in a production system. These include raw materials, piece parts, assemblies, loads, WIP, finished products, etc. Each unique part type is defined with alphanumeric characters (part names or part numbers) and has its own defined routing. Parts can be put into temporary or permanent batches, and they can be assembled and disassembled. Parts may be assigned attributes that can be used for complex routing logic or for customized reporting.

- Model Features

The general simulation features are what give ProModel its power and flexibility necessary for modeling complex manufacturing and material handling systems. A brief summary of these features are presented below:

Part attributes (999 per part type)

Integer and Real User Variables (999)
System Variables
Discrete and Continuous User-defined distributions (999)
User-defined functions (100)
User-defined Subroutines (No practical limit)
Expressions (Arithmetic, Relational, Logical)
Built-in Statistical Probability Distributions (Exponential, Normal, Uniform, Triangular, Beta, Gamma, Erlang, Weibull, Lognormal)

Figure 2-3 on the next page represents the model built in ProModel software.

```
ProModel model: BASE
*Test model

ROUTING
                                         Output  Next      Condi-     Move
Part  Location Operation (min)            part   location   tion Qty  time (min)
----  -------- ---------------            ----   --------   ---- ---  ----------
LOAD  STORAGE  0                          LOAD   INPUTQ     0    1    .2
LOAD  INPUTQ   .05                        PLATE  GRINDING   0    10   .05
PLATE GRINDING .8                         PLATE  OUTPUTQ    0    1    .05
PLATE OUTPUTQ  .05                        PLATE  INSPECT    0    1    .3
PLATE INSPECT  USE INSP .5                PLATE  EXIT       800  1    0
                                          BAD    REJECT     200  0    .05
BAD   REJECT   ACCUM 10                   BAD    INPUTQ,1   0    1    .4
BAD   INPUTQ   .05                        BAD    GRINDING   0    10   .05
BAD   GRINDING .4                         PLATE  OUTPUTQ    0    1    .05

PART SCHEDULING
                              Qty per  No. of    Start     Arrival
 Part     Location            arrival  arrivals  (min)     frequency (min)
 -----    --------            -------  --------  -----     ---------------
 LOAD     STORAGE             30       1         0         0

CAPACITIES
Resource Qty   Resource Qty   Resource Qty   Resource Qty   Resource Qty
-------- ----  -------- ----  -------- ----  -------- ----  -------- ----
GRINDING 2     INPUTQ   3     INSP     1     INSPECT  &3    OUTPUTQ  3
REJECT   20    STORAGE  30

SIMULATION PARAMETERS                        GRAPHIC OPTIONS
Run    Startup Rept Resource                 Graph Max Max Scr Fig Icon
(hrs)  (hrs)   code to track     Seed        mode  row col clr clr file
-----  ------- ---- --------     ----        ----- --- --- --- --- ----
2      0       D    0            0           4     100 200 D   W   PM.LIB

STATIC SYMBOLS
ID       Sym Clr Row Col  ID       Sym Clr Row Col  ID       Sym Clr Row Col
-------- --- --- --- ---  -------- --- --- --- ---  -------- --- --- --- ---
GRINDING 6R  C     7  18  INPUTQ   ZU  C    12  18  INSP     8   C    23  21
INSPECT  WB  C    20  21  OUTPUTQ  ZD  C    10  21  REJECT   WB  C    20  17
STORAGE  WB  C    15   8

DYNAMIC SYMBOLS
ID       Sym Clr  ID       Sym Clr  ID       Sym Clr
-------- --- ---  -------- --- ---  -------- --- ---
BAD       ,   R   LOAD      .   6   PLATE     .   8

FIGURES AND LABELS
Type Clr Row Col Figure
---- --- --- --- ------
HORZ 6    13   4 STORAGE
HORZ 6     4  13 GRINDING
HORZ 6    20  24 INSPECT
HORZ 6    20   9 REJECT

END
```

Figure 2-3: The example of Model built in ProModel