FACILITIES LAYOUT PLANNING OF A PLASTIC PRODUCT MANUFACTURER

by

Ms. Nattayaporn Chiewchalermsri

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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Project Title	Facilities Layout Planning of a Plastic Product Manufacturer
Name	Ms. Nattayaporn Chiewchalermsri
Project Advisor	Dr. Chamnong Jungthirapanich
Academic Year	November 2002

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

Approval Committee:

(Dr. Chamnong Jungthirapanich)
Dean and Advisor

(Prof.Dr. Srisakdi Charmonman)
Chairman

(Assoc.Prof. Somchai Thayarnyong)
MUA Representative

November 2002

ABSTRACT

This project is a study about rearranging working area for delivering the highest benefit of Plastic Product Company. This study also analyzes and evaluates the current space utilization in each process. We have collected information about raw material and finished product, working steps of production process, raw materials flow, production system and technology that company used to produce finished product and maintenance process of machines. The source of information was collected by interviewing company staffs, which are responsible for each particular area, and by observation at each production area.

The information will bring to make area relationship analysis of each area by using tools of SLP pattern and space requirement sheet in order to represent suitable and enough space requirements for production process with effectiveness and space utilization. The results of analysis will be illustrated in form of diagrams. This diagram also uses Closeness rating to represent each activity, suitable space requirement and uses number of straight lines representing activity relationships of each activity. From the analysis results, we will rearrange the space of production area in various alternatives in order to reach the highest effectiveness. We will use factors to select the best alternative of area utilization. The best alternative will bring to compare pros and cons with existing layout for last analysis.

From this study, we will have additional comments about increasing layout effectiveness in another perspectives. This will be beyond the minor layout modification adjustment within the building. This also will help top management of Plastic Product Company to benefit of business future.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations, without them, this project would not have been possible.

I wish to express sincere gratitude to my dean and advisor, Dr. Chamnong Jungthirapanich. His patient assistance, guidance, and constant encouragement has led me to project completion. I would like to express appreciation to all Professionals of the MS(CEM) program from whom I gained knowledge. My sincere thanks also goes to the Project Committee members of the Graduate School of Computer Engineering Management of Assumption University.

I would like to thank the management and staffs of Plastic Product Company Limited, for their cooperation and kindness. They gave a lot of valuable information and comments during the preparation of this project.

Special appreciation is due to Mr. Amnaj Phandhufung and my family for their fervent and continuous encouragement. Above all, I am forever grateful to my parents whose willingness to invest in my future has enabled me to achieve my educational goal.

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I. INTRODUCTION

1.1 General Background

For industry, production section is the heart of business. High volumes of production with low production cost reflect the efficiency of company process. All entrepreneurs expect to get high production volume. In real business situation, many entrepreneurs face many problems in production process. Their actual production figure is lower than planned. Most of them solve problems for increasing their production volumes by increasing number of machines, labors, and facilities. Those may cause high production costs.

One of the major problems is from ineffective production layout that causes inconvenience in flow of material from one machine to the other. These production layout problems can have significant effects on the overall effectiveness of the production system.

Designed Layout Planning is the study to help entrepreneurs to find out the effective production layout to increase the company productivity. Re-arranging of machines and facilities to make more space utilization systematically within the limited area.

The crisis of Thai economy affects all types of businesses. Most plastic product manufacturers try to survive from this situation by controlling manufacturing cost at stable customer demand. The study of layout planning will provide the benefit in saving losses that occurred within the production area.

1.2 Statement of Problem

In the current production layout of Plastic Product Company, there are some issues in operation process such as high manufacturing cost, spending much time in changing and setting molds (leading to be more machine downtime and shutdown), raw materials fell down during operation process. Above problems are caused by the following:

(1) Ineffective machinery Layout: Current machine layout located far from Raw material storage and this generated to high production handling costs.

(2) Lack of good spare parts (molds): Non-proper molds storage, molds usually place on the floor near plastic injection machines or around the production area. It caused the operation problem in using molds and narrowing production aisle way.

(3) Inflexibility of production process: Because of aisle and long distance among processing unit, the material movement start from Raw material to Finished product storage was taken long time. So it was not flexible for some process.

Therefore, company intends to revise the layout of production area by applying factory layout planning to get effective and efficient factory layout that can reduce defect rate and cost in production area.

1.3 Objectives of the Study

Production area is the core area of manufacturing. Standard and flexible production machines layout is most important for efficiency and effectiveness of production function. Therefore, the objectives for study plastic production area layout is:

(1) To reduce and control transportation cost: In production area, the movement of material from raw material until finished products can be major causes of increases or decreases in production cost. Then, good production layout can deduce cost that occurred in material handling and transporting between production processes.

(2) To maximize limited space utilization of production area: In the existing production area, the efficient production machines layout can make the limited production area to more effective space utilization.

(3) To optimize operations time. Machine downtime and shutdown are the most critical problems that Plastic Company tries to avoid. This study is to reduce machine downtime and shutdown.

1.4 Scope of the Study

In this project, the scope of the study is to re-layout production machines in the production process by using factory layout planning. Because of economic crisis, planner tries to re-layout for minimum interruptions and minimum cost of adjustments. This layout will make minor adjustments of the existing production layout without changing the over-all layout plan.

1.5 Deliiverables

This product of this study is effective and efficient production area layout. This production area layout will have more space utilization and optimize time.

II. LITERATURE REVIEW

2.1 Nature of Plant Layout

Plant layout is an industrial fundamental which determines the efficiency and the survival of an enterprise (Muther 1955).

Term of Plant Layout (Muther 1955):

Plant Layout is that embraces the physical arrangement of industrial facilities. This arrangement will be made either installed or in plan, includes the spaces needed for material movement, storage, indirect laborers, and all other supporting activities or services, as well as for operating equipment and personnel.

<u>Principle of Plant Layout</u>

There are six principles of Plan Layout Problems are as follows (Muther 1955):

(1) Over-all integration of all factors affecting the layout

The best layout is that integrates the overall working unit which are men, materials, machinery, supporting activities, and any other considerations in a way that results in the best compromise. It must be convenient for the people servicing or supporting the operations. Maintenance persons have to grease machinery; production-control personnel have to keep the various operations running; and inspectors must check the quality of the work-in-process. In addition, there must be protection against fire and fumes, comfortable air conditions, and many other servicing features that facilitates operation (Muther 1955).

(2) Material moving a minimum distance

The best layout is that permits the material to move the minimum distance between operations. The moving of the material can save by reducing the distance of each movement. This means trying to place subsequent operations immediately adjacent to previous ones. Thus, we can eliminate transportation between operations for one operation to other operation (Muther 1955).

(3) Work flowing through the plant

Layout is best that arranges the work area for each operation or process in the same order of sequences that forms, treats, or assembles the materials. The result of minimum distance moved, there would be no backtracking or minimum in cross movement which congestion with other parts or with other pieces of the same part. Material will glide through the plant without interruption (Muther 1955).

(4) All space effectively utilized

In term of Economy is obtained by using effectively all available space-both vertical and horizontal. Good layout must utilize space of the plant by well arrangement of men, material, machines, and supporting activities (Muther 1955).

(5) Satisfaction and safety for workers

Layout is best which makes work satisfying and safe for workers. It can give both reduced operating costs and better employee morale. Safety is a major in most layouts and free from hazards or accidents (Muther 1955).

(6) A flexible rearrangement that can be easily readjusted.

The best layout is that can be adjusted and rearranged at minimum cost and inconvenience. A Plant can be adjusted or a new layout can be made quickly and inexpensively (Muther 1955).

The Advantages of a Good Layout Is to Reduce These Following Cost (Muther 1955)

(1) Reduced Risk to Health and Safety of Employees

(2) Improve Morale and Worker Satisfaction

(3) Increased Output

(4) Fewer Production Delays

(5) Saving in Floor Space (Production, Storage, and Service Areas)

(6) Reduced Material Handling

(7) Greater Utilization of Machinery, Manpower, and/or Services

(8) Reduced Inventory-in-process

(9) Shorter Manufacturing Time

(10) Reduced Clerical Work and Indirect Labor

(11) Easier and Better Supervision

(12) Less Congestion and Confusion

(13) Reduced Hazard to Material or Its Quality

(14) Easier Adjustment to Changing Conditions

(15) Miscellaneous Other Advantages

Nature of Plant-Layout Problems

Plant layout problems can occur in a large number of ways and can have significant effects on the overall effectiveness of the production system (Francis and White 1974).

Plant-layout problems fall into four classes (Muther 1955):

(1) Planning a Complete New Plant

This layout will determine the design of the new buildings and the location of all service entrances and exits. This kind of plant layout problem occurs only when a company goes into production on a new product or expands or moves to a new area. It always involves several specialists in addition to the staff of layout engineers (Muther 1955).

(2) Expanding or Moving to an Existing Plant

The building and services already exist with their limitations on the free hand of the layout planner. The problem is one of adapting the product, facilities, and personnel of an existing organization to a different but existing plant. It may include abandoning old practices and equipment and changing to improve methods (Muther 1955).

(3) Rearranging a Present Layout

This situation is to adept new, efficient methods and equipment. The layout planner have to integrated whole with limited by existing size, shape, dimensions, and service installations of the present building. This problem occurs most often with changes in model or style of products or with modernization of productive equipment (Muther 1955).

(4) Minor Adjustments to Existing Layouts

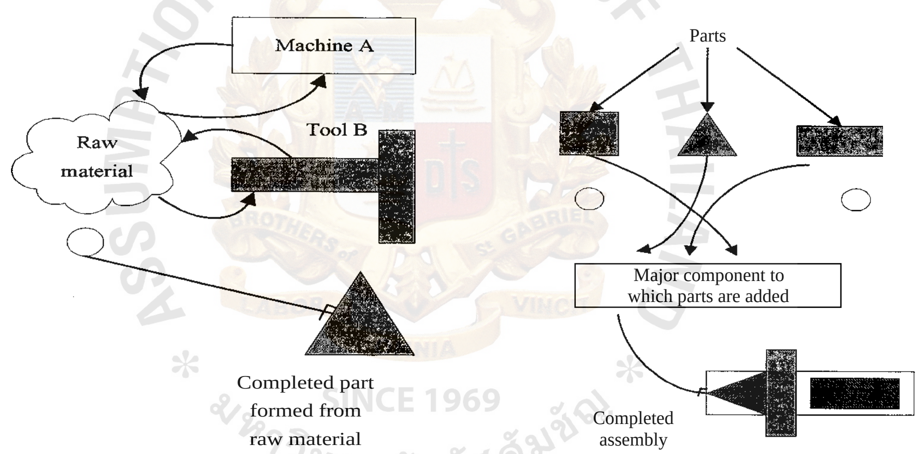
It means adjustments in the arrangement of work areas, personnel, and material placement. These adjustments present the most frequent layout problems. The layout planner must build into an existing arrangement various improvements without changing the over-all layout plan and with a minimum of costly interruptions or adjustments to the existing installation (Muther 1955).

Type of Layout

Production layouts can be divided in to three types as follow (Muther 1955):

(1) Layout by fixed Position or by fixed material Location

This is a layout where the material or major component remains in a fixed place. It does not move. All tools, machinery, men, and other pieces of material are brought to it. The complete job is done or the product is made with the major component staying in the one location. Figure 2.1 illustrates layout by fixed position (Muther 1955).



Layout by fixed position. All operation are performed with the material (in the case of forming or treating) or major component (in the case of assembly) remaining in one fixed location. That is, hold the material at a fixed position.

Examples; Forming and treating — speciality shoe-making, toolmaking any artisan making complete unit. Assembling—hand-embroider work; building a battleship or constructing special machine.

Figure 2.1. Layout by Fixed Position (Muther 1955).

The fixed product layout is used when the product is too large or cumbersome to move through the various processing steps. Examples include the shipbuilding industry, the aircraft industry, and the construction industry. Locating workstations or production centers around the product in the appropriate processing sequence develops the fixed product layout (Francis and White 1974).

Advantages of layout by fixed position (Muther 1955)

(a) Reduces handling of major assembly unit (though increased arts handling to assembly point).

(b) Allows highly skilled operators to complete their work at one point and fixes the responsibility for quality on one worker or one assembly crew.

(c) Allows frequent changes in products or product design and in sequence of operations.

(d) Is adapted to variety to product and intermittent demand.

(e) Are more flexible in that it does not require highly organized or expensive layout engineering, production planning, or a provision against breaks in work continuity.

Limitations of fixed production layout (Francis and White 1974)

Increased movement of personnel and equipment.

Equipment duplication may occur.

Higher skill requirements of personnel.

General supervision required.

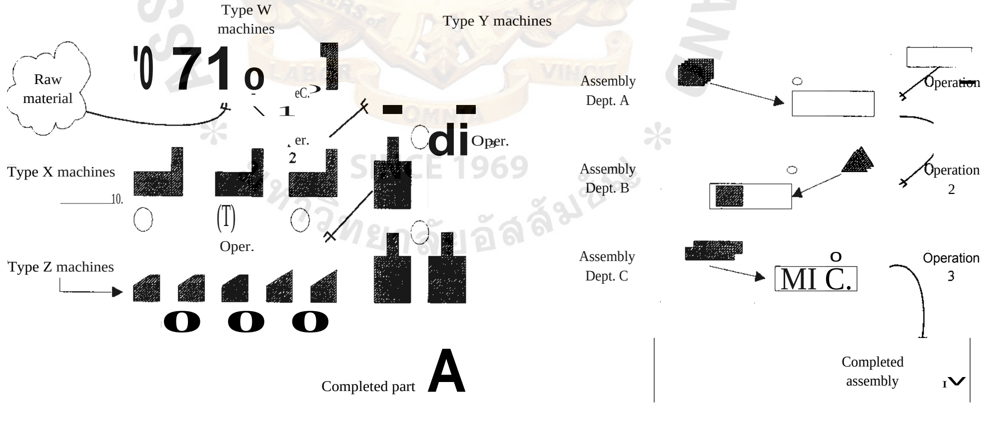
Cumbersome and costly positioning of material and machinery.

Low equipment utilization.

(2) Layout-by-process or Layout-by-function

All operations of the same process or type of process are grouped together. Similar operations and equipment are grouped according to the process or function they perform. Figure 2.2 illustrates layout by process (Muther 1955).

The process layout consists of a collection of processing departments or cells. All machines involved in performing a particular process are grouped together in a process layout. This layout is suitable for low volume and dissimilar output products. The process layout is used when rapid changes occur in the mix and volume of products to be produces (Apple 1977).



Layout by process (function). All operations (processes) of the same type are performed in the same area; like machines or similar assembly operations are grouped together. That is, move the material through process departments or areas.
Examples; Forming and treating — normal machine-shop work: most textile and cloth-making; job printing.
Assembling — sheet-metal assembly by spot welding, riveting, stapling, and soldering.

Figure 2.2. Layout by Process or Function (Muther 1955).

Advantages of Layout-by-process (Muther 1955)

(a) Better machine utilization allows lower machine investments.

(b) It is adapted to a variety of products and to frequent changes in sequence of operations.

(c) It is adapted to intermittent demand (varying production schedules).

(d) There is greater incentive for individual workers to raise the level of their performance.

(e) It is easier to maintain continuity of production in event of:

(1) Machine or equipment breakdown

(2) Shortages of material

(3) Absent workers

Limitations of Layout-by- process (Francis, R.L., and J.A. White, 1974)

(a) Material handling is more expensive when the flow lines are long.

(b) Production planning and control systems are more involved.

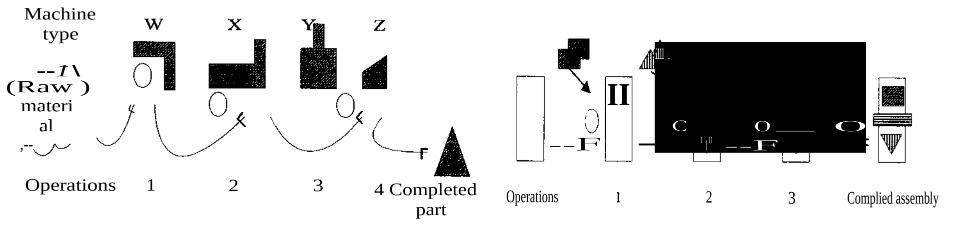
(c) Large amount of in-process inventory

(d) Space and capital are tied up by work in process.

(e) Higher grades of skill are required (Specialize needed)

Line production or Layout-by-product

One product or one type of product is produced in one area. But unlike layout by fixed position, the material moves. This Layout places one operation immediately adjacent to the next. It means that equipment used to make the product, regardless of the process it performs, is arranged according to the sequence of operations. Figure 2.3 illustrates line production layout (Muther 1955).



Layout by product (line production). Machines or assembly work stations arranged in the sequence of operation, successive operations being performed immediately adjacent to each other. That is, move the material from one operation directly to the next.
Examples; Forming and treating — machining a motor block; quick car-washing line.
Assembling—automobile assembly line; assembling a tray of food in a cafeteria.

Figure 2.3. Layout by Product or Line Production (Muther 1955).

Advantages of line production (Muther 1955)

(a) Less handling of parts to the assembly point with reduced congestion around the assembly unit and reduced floor space otherwise allotted to aisles and storages.

(b) Less expensive labor (provided parts do not become disassembled in moving from one station to the next):

(1) Through job specialization

(2) Through ease of training (cost, more quickly to work)

(3) Through wider labor supply (semiskilled and unskilled)

(c) Reduced amounts of material-in-process, allowing reduced time-in-process and lower investment in material.

(1) Of production allows less paper work

(2) Over workers allows easier supervision

(3) Through fewer interdepartmental problems

(d) Easier supervision once the layout is planned and controls are organized.

(e) Reduced movement of specialized assembly equipment.

<u>Limitations of Line Production Layout</u> (Francis and White 1974)

(a) One breakdown machine may lead to complete stoppage the whole line.

(b) Because the product determines layout, a change in product design may require major alterations in the layout.

(c) The slowest machine determines the "pace" of production.

(d) Supervision is general, rather than specialized.

(e) In comparable, high investment is required.

(4) Group Layout

When production volumes for individual products are not sufficient to justify product layouts, group layout is used. The group layout has a high degree of intradepartmental flow. It is a compromise between the product layout and the process layout. The group layout is done by grouping products into logical product families. The groups of processes are referred to as cell. Sometimes this group layout is also referred to as cellular layout (Apple 1977).

<u>Advantages of group layout</u> (Francis and White 1974)

(a) Increased machine utilization.

(b) Team attitude and job enlargement tends to occur.

(c) Compromise between product layout and process layout, with associated advantages.

(d) Supports the use of general-purpose equipment.

(e) Shorter travel distances and smoother flow lines than for process layout.

Limitations of group layout (Francis and White 1974)

(a) General supervisor required.

(b) Higher skill levels required of employees than for product layout.

(c) Compromise between product layout and process layout, with associated limitations

(d) Depends on balanced material flow through the cell; otherwise, buffers and work-in-process storage are required.

(e) Lower machine utilization than the process layout.

2.2 Factors Influencing Plant Layout

There are eight factors are influencing in considerations of Plant layout, which show below (Muther 1955):

2.2.1 The Material Factor

(1) Physical material characteristics

Each product, part, or material has certain characteristics that may affect a layout. The considerations under this factor are size, shape and bulk, weight, condition, and special characteristics (Muther 1955).

Size: A large product may affect the entire method of production, otherwise, some small parts hard to see and get lost if special precautions are not taken. Thus, size is important, for it may influence so many other considerations affecting layout (Muther 1955).

Shape and Bulk: There are many shapes of product, part, or material. Long materials like bars and rods will present quite different problems of storing and handling than kegs or bales of compact material. Odd-shaped materials or products cause difficulty in gaining access to them. Bulky items often cause problems. Bulky products will have a major effect on handling and storage in planning any layout. Solid articles, or those that will nest or stack, always take less space (Muther 1955).

Weight: will affect many other layout factors machinery, floor loads, handling equipment, storage methods, and the like (Muther 1955).

Condition: Fluid or solid, hard or soft, flexible or stiff.

Special Characteristics (Requiring Care or Precautions): These special characteristics are required in some materials that are very delicate, brittle, or fragile. Others may be volatile, flammable, or explosive (Muther 1955).

(2) Quantity and Variety of Products or Materials

The number or different Items: A plant making only one product has an entirely different layout than one which making a large variety. A one-product layout should come very close to the gal of line production. For a large variety of products will call for process departments or layout by fixed position. The term 'variety' applies to various models, styles, types, grades, as well as 'products'. Good layout depends in part on how well it can handle the variety of products or materials to be worked on (Muther 1955).

The quantity or production output of each item required: it will determine the amount of money available for setup costs. When the quantity is high, there is usually money enough to set up a production line. As long as the quantity is small, fixed-position layouts will be used (Muther 1955).

Variation in Output: It is not enough to know the total quantity figures if there are variations in production volume. A good layout must be able to handle the variation in output (Muther 1955).

2.2.2 The Machinery Factor

Information about the machinery including the producing equipment and tools and their utilization is fundamental to a proper arrangement of that machinery (Muther 1955).

Space: Shape and Height

In plant-layout, Long and narrow machines, short and compact ones, or circular or rectangular, each shape affects the machine arrangement in relation to other machinery and to other features and considerations (Muther 1955).

The height of operating equipment including any extensions, superstructures, feed hoppers and etc. machinery height will dictate the minimum height of ceiling, roof, or overhead installation (Muther 1955).

Weight: Some processes require unusually strong floors. A basement or ground floor location is suitable for heavy machinery (Muther 1955).

Process Requirements: Many processes require special provisions. Foundry operations require ventilation for sand, dust, gases, and the removal of heat. Many chemical processes give off fumes. Painting, heat-treating. Plating and similar processes require special protection (Muther 1955).

Machine and man relation: Man and machine utilization are involved in determining the number of machines an operator can handle (Muther 1955).

Methods of getting better machine and man utilization (Muther 1955):

To improve the machine time:

(1) Increase or reduce speed of machine.

(2) Simultaneous operation of two or more machines.

(3) Combine elements to reduce operator's required attention or adjustments during operation.

(4) Design fixtures or add new ones so that operator can pre-position material while machine is running

To improve the man time:

(1) Couple machines; operate machines in multiple.

(2) Reduced load and unload time ('make ready' and 'put away').

(3) Balance times by combining, or eliminating, auxiliary operations like burring, trimming, cooling, and inspecting.

2.2.3 The Man Factor

As one of element of production, man is more flexible than both material and machinery. Man is including supervision and service help as well as direct workers (Muther 1955).

The considerations under the man factor are (Muther 1955):

(1) Safety and Working Conditions

Safety: In every layout, specific safety items should be as follow (Muther 1955):

(a) Floor free of obstructions and not slippery

(b) Workers not located too near moving parts, unguarded equipment, and other hazards.

(c) Workers not located under or above hazards.

(d) Workers not required to use special safety devices or guards

(e) Adequate exits and clear escape ways

(f) First-aid facilities and fire extinguishers nearby

(g) No sharp, moving, or hazardous material or equipment protruding into aisles or work areas.

(h) All safety codes and regulations satisfied

Working Conditions: The layout should be 'comfortable' to the workers. This involves heat, light ventilation, noise, and vibration (Muther 1955).

(2) Manpower Requirements: Types of workers, number required, and operating hours.

Type of Workers Required: Division of work, or specialization of labor, is a basic fundamental of inexpensive manufacture (Muther 1955).

(a) Fixed position-Fixed men: little or no specialization of work and high skill required.

(b) Fixed position-Moving men: Skill usually less, varying with degree of dividing the work and moving the men.

(c) Process Layout-Fixed men: Specialization by type of process (operation)

(d) Line production-Fixed men: Specialization by product and by operation.

The number of worker required: It determines the number of operators for each machine and the number of machines a man can tend. It relies on records of past performance, time data, or experience (Muther 1955).

(3) Man Utilization:

Good work place layout is based on the principles of motion study. To use these principles, The time requirements for various elements or motions and the dimensions of the workplace are required (Muther 1955).

2.2.4 The Movement Factor:

For industrial plants, the way material is moved, handled or transported has a major bearing on plant layout. The most convenient and economical way of doing each productive operation by planning a handling system to get the material, men, or machinery to and away from each operation. It's including inter-and intradepartmental transport and hand handing at various operations, storages, and inspections (Muther 1955).

Movement concept in production (Muther 1955):

"Move material as little as is consistent with other production factors; plan a layout that ensures short moves but moves that are always towards completion of the product; then set up operating controls to keep it moving."

(1) Flow pattern or routing

The fundamental of a flow pattern or routing is that establishing a flow pattern through processes, or a routing, where material moves. It begins with incoming material-out going material (Muther 1955)..

There are various types of flow patterns. Most of them can be classify as either horizontal or vertical. There are at least five basic types of horizontal flow patterns which are straight or I flow, L flow, U flow, circular or 0 flow, and serpentine or S flow (Francis and White 1974).

Incoming material: The means of receiving by highway, truck, plane, mail or express, conveyor, or pipeline. It should have convenient access to the plant (Muther 1955).

Outgoing material: Shipping, or the point of outgoing material or product. Good shipping layout brings the carrier as close to the last operations or finished-product storage as is feasible (Muther 1955).

Service or supply materials: The movements of oil, grease, glue, labels, packing, and the like to the production areas is a part of most industrial operations. Similarly scrap, waste, trim, and cuttings must be taken away (Muther 1955).

Machinery and Tool Movement: Moving machinery is becoming more common in plant layout. The moving of equipment and tools, it is including gauges, dies, fixtures, attachments, and the like, must be planed. The movement to and from tool cribs, die storage, and tool grinding and repair can be vital to an effective layout of machines (Muther 1955).

Man movement: A good layout provides for the movement of production workers, indirect labor, and supervision (Muther 1955).

(2) Reduction of unnecessary and uneconomical handling:

For the reduction of unnecessary and uneconomical handling can make flow pattern can work out effectively (Muther 1955)

(3) Space for movement:

Aisle space is lost space in that it is not productive plant area Aisles should connect the areas that have the greatest traffic, and they should be of proper width to a void waste space or crowding (Muther 1955).

Overhead Movement does not have to be on the ground or floor. Overhead equipment of many kinds can move material up and over the production floor. This saves congestion in aisle ways and utilizes space that is normally wasted (Muther 1955).

Underneath Floor or Workbenches Flow patterns that must cross an aisle or other obstruction can go underneath the floor (Muther 1955).

Outside the Building (along the wall or across the roof) Installing-handling systems that run outside the building have many advantages. This is especially true when the handling system must fit into an existing layout (Muther 1955).

Double-use Space Containers that will nest or stack reduce the space they need when not in use. The same goes for handling equipment. Equipment that will fold up, swing out of the way, or roll aside will give space the other purposes (Muther 1955).

(4) Analysis of Handling Methods:

There are basically two ways to approach the analysis of material handling (Muther 1955):

(a) Through the materials or products being, or planned to be, handled

(b) Through the sequence of operations or routing of a given material

Table 2.1. Handling Objectives Simplified (Muther 1955).

Every transport or handling of material should, wherever possible, move material:

1. Toward Completion	Without backtracking or cross flow
2. On the same device	Without transfers
3. Smoothly and quickly	Without confusion or delays, unnecessary handling, and awkward positioning or placing
4. Over shortest distance	Without long trips
5. Easily	Without rehandling or extra handling motions
6. Safety	Without damage to men or material
7. Conveniently	Without undue physical effort
8. Economically	Without breaking bulk units or making several trips when one could do; combining many small units into a large one
9. To coordinate with production	Without causing production workers extra time and effort by hand handling, bending, and reaching
10. To coordinate with other handling	Without a lot of different handling equipment that cannot be integrated

Table 2.2. A Guide for the Layout of Aisles (Muther 1955).

1. Keep aisles straight	Put in as few corners as possible; above all, avoid blind corners
2. Keep aisles clear	Do not allow protrusions of machinery, equipment, columns, fire extinguishers, or drinking fountains in any through aisles
3. Mark aisle limits	Mark on the floor the limits of aisles. This alone can make order out of a confused layout
4. Locate aisles for minimum distances	Flow charts, flow diagrams, and other movement or proximity analyses will tell where the most traffic is, that is, where aisles should be
5. Make two-sided aisles	Aisles located along a blank wall or against the back of a storage bin serve only one side-or half their potential usefulness
6. Use main aisles	Use main aisles for through traffic; use economically smaller subaisles for distribution, with or without zoning the types or pieces of handling equipment.
7. Keep intersections at 90°	Aisles intersecting at angles cause lost floor space
8. Make aisles of economic length	Aisles too short waste space; if too long, backtracking or cutting through result
9. Make aisles of proper width	Appendix I gives a list of recommended aisle widths
10. Consider one-way traffic possibilities	Practical for limited aisle widths, angular storage, and in many other situations

2.2.5 The Waiting Factor

It's including permanent and temporary storages and delays. There are two basic locations for waiting material (Muther 1955):

(1) In a fixed waiting point outside or beside the path of flow. This should be used when handling costs are low, when material requires special protection, or where waiting material requires much space.

(2) In an enlarged or lengthened path of flow. This should be used when items vary too much to be moved easily on a single handling device, when parts might deteriorate if they remain in a dead bank, and when rate of production is relatively high.

2.2.6 The Service Factor

For layout purposes, plant's services are the activities, facilities, and personnel that serve production. It's including maintenance, inspection, waste, scheduling, and dispatching. The services support and keep in operation the producing men, materials and machinery (Muther 1955).

(1) Services relating to men (Muther 1955):

Access: The movement of men is a problem not unlike the movement of material; therefore the principles of flow and shortest distance apply.

Employee Facilities: The location and arrangement of employee facilities have both moral and economic considerations.

Fire Protection: There are information about the best practice for handling, storing and working with certain materials. The building and layout plan should be inspected and checked by the insurance Company before the layout is installed.

Lighting: It had been proved many times that good lighting is actually less expensive than poor. In this country, good lighting generally represents less than 1 per cent of production costs.

In addition to the levels of illumination recommended above, here is a rule-of-thumb guide to the use of different kinds of lamps.

Heating and Ventilating: The location of heating and ventilating outlets or units can be a major consideration in some layouts. Workers cannot be located too close to steam pipes. The pipes themselves may have to be protected from damage, by careless material handling, for example, if the aisle runs beside them. Unit heaters, on the other hand, give a blast of air that limits placing things in front of them. Exhaust drafts and air blowers can cause the same problem. Paint-booth exhaust was so strong in one plant that it drew in all the grit and lint from adjoining departments, which, of course, stuck to the items being painted.

(2) Services relating to materials (Muther 1955):

Quality: Quality considerations directly influence the layout through the location of inspection areas and equipment and by the accessibility of work areas.

Production Control: Frequently the method of planning, scheduling, or dispatching material can completely limit a layout. At other times, it leads to more handling, greater delays between operations, and down time of complete production lines. Production-planning control probably affects the size of a plant's storage areas and delay points more than anythings else. If affects the waiting time between operations and regulates the amount of space for incoming material and finished products.

(3) Services relating to machinery (Muther 1955):

Maintenance: To make sure their layouts have provided room for maintemnance work, experienced layout men usually develop with their plant engineer a list of features to check. It is usually a list that can probably also be used to check off work that has to be done at the time of layout or equipment installation (Muther 1955).

2.2.7 The Building Factor

Features of the building factor most likely to be involved in a layout problem include (Muther 1955):

(a) Special or general-purpose building

(b) Single or multistory building

(c) Shape of building

(d) Basement or balcony

(e) Windows

(f) Floors

(g) Roofs and ceilings

(h) Walls and columns

(i) Elevators, stairs, and floor holes.

In addition to these, features of the site on which the building stands often affect the layout.

Special or General-purpose Building:

The layout engineer should decide right away whether we want the building custom-made or "bought off the shelf' Special buildings generally cost more and are less negotiable as the product and facilities grow or shrink or change with new conditions. For many industries special buildings are essential if the plant is to operate economically (Muther 1955).

Single or Multistory Construction:

Early factories were generally three or four stories high. Because of limited transportation facilities they had to be built in cities, where land costs were relatively high. This does not mean that every new plant should be one story high, as some industrialists advocate. Plant built around a higher-than-one-story process should certainly have upper floors (Muther 1955).

Shape of Building:

Early buildings were narrow because they needed natural light. They expanded by extending their ended and by adding cross buildings in a rectangular fashion. Today artificial lighting is relatively less expensive. The number and frequency of production changes are greater. Therefore, emphasis today is on plants that are relatively square and not "honeycombed" or obstructed by walls. Such plants are built in rectangular sections, and expansion is by building additional sections onto the sides or end (Muther 1955).

Basement or Balcony:

The plant can hardly avoid having a basement when it is built on land that slopes. And this has very practical advantages. Some plants are built on the side of a hill for the express purpose of having motor-vehicle entries to each floor. This offers the advantage of entry to two or more levels with a minimum of ramp construction (Muther 1955).

Windows:

Old factories had to have small windows because of the cost of construction. The large, steel-sash windows brought the cost down. Windows make buildings more subject to changes in outside temperature. Plants having products or processes especially subject to changes in temperature, light, or humidity find it better to have no window at all (Muther 1955).

Floors:

The levels and strengths of floors are the most important floor influence on layout. Adjoining buildings, and even those far removed that may some day be connected to the main plant, should have floors at the same level. Early factories had dirt or wood floors. Today, various combinations of steel and concrete give the least expensive floor which wears well, strong and easy clean (Muther 1955).

Roofs and Ceilings:

Roofs and ceilings affect layouts chiefly by their height above the floor. Roofs and ceilings are also affected in many cases by the type of construction. The usefulness of overhead space may be limited by what can be attached to the roof or ceiling. Very few plants hang their machinery from the roof or ceiling (Muther 1955).

Walls and Columns:

The column carries the load and no wall is needed, except to keep out the elements. This is a great help to production, for it means large, unobstructed working areas. Inner walls today are only partitions. When certain operations must be segregated, partitions that are generally built up in standard sections can easily be installed or removed. They can be made as high as necessary to shield or protect the area or can be suspended from the ceiling (Muther 1955).

2.2.8 The Change Factor

It's including versatility, flexibility, and expansion. First, identifying what these changes are likely to be. This involves changes in the basic elements of production- men, material, and machinery- and the supporting activities. Finally, we plan our layout with sufficient flexibility to operate within the range of the practical possibilities (Muther 1955).

(1) Flexibility of Layout: Flexibility of layout means easily changing it to some other arrangement.

(a) Mobile or movable machinery and equipment is basically the chief element in layout flexibility. It is achieved by keeping machinery free of all fixed foundations. Cork, felt or steel pads, steel channels, wood beams or skids, wheels with floor locks, and the like are preferred to concrete bases, anchor bolts, and tie-down fittings. Equipment fastened to columns or overhead structure should be attached in such ways that it can be freed easily (Muther 1955).

(b) Self-contained equipment (independent of general plant services) makes for flexibility. This means machinery that has its own motors, hydraulic system, cooling unit, dust collector, supplementary lighting, and the like. Self-contained equipment might include portable conveyor sections with their own drivers or portable storage racks (Muther 1955).

(c) Readily accessible service lines or service distribution systems assist flexibility. Electric outlets can be placed almost as frequently as needed throughout the plant. Compressed air, water, steam and many other services must be available wherever the new layout calls from them (Muther 1955).

(d) Standardized equipment helps many plants obtain flexibility. Standard-size stock racks, assembly benches, conveyor sections, motors, connections, and the like, all lead to savings in both planning a re-layout and executing the change-over. The dimensions, weights, performance characteristics, capacities, and requirements are known or need be determined only once for each item (Muther 1955).

(e) Preplanned or skillful technique of moving are the basis of almost daily moves in some plants. Properly trained millwrights or maintenance men capable of using effective moving equipment can increase the flexibility of plant. Some plants are beginning to plan out three, five, a dozen or so different layouts and have each of them ready to be installed (Muther 1955).

(f) The building construction can aid or hinder flexibility. Large and unobstructed floor areas are most suitable. Large spans, wide column spacing, few walls or partitions, and a minimum of obstructions like stairways, furnace stacks, fixed conveyors and the like-in other words, floor space as free and open as possible. Walls should be mere partitions made in standardized sections for quick erection and removal (Muther 1955).

(2) Layout adaptability and versatility

A good layout should be able to meet emergencies and variations from normal operation without having to be rearranged. When the normal method of moving material is stopped for some reason- machine breakdown, conveyor jam, process equipment cleaning, or overhaul. The way to meet this problem is first of all by solving the technical problems causing the variation and only by juggling the layout. Get the process and operations functioning properly; have adequate machine and equipment maintenance. Versatility in layout is measured by its ability to handle a variety of different products and /or quantities. One way to solve the problem is through better planning, more finished-stock warehouse space, and longer runs, or product-simplification studies. Versatility of any layout depends to a large extent on two additional features (Muther 1955):

(a) The versatility of machinery, tools, and equipment to handle variety and quantity fluctuations.

(b) The ability of supervision to adjust operating conditions: hours of work, reassignment of men to various jobs, changes in speeds of conveyors and equipment, and the like.

(3) Expansion

To consider the future expansion of the layout and facilities is definitely a duty of the layout engineer. It is easy to bother much about expansion. A plant or a layout can grow "like Topsy." Additions may be added that are suited only to a particular use at the time. Expansion involves the over-all development of the company property and the increase in capacity of specific operating departments or areas (Muther 1955).

(4) External changes

It indicates how material is received at the warehouses of a large public utility. It clearly shows a trend that has affected many industries (Muther 1955).

2.3 Systematic Layout Planning

Systematic Layout Planning is an organized way to conduct layout planning It consists of a framework of phases, a pattern of procedures, and a set of conventions for identifying, rating, and visualizing the elements and areas involved in planning a layout (Muther 1961).

Four Phases of Layout Planning (Muther 1961)

Phase I **Location:** determines the location of the area to be laid out.

This is not necessarily a new site problem. More often it is one of determining whether the new layout (or re-layout) will be in the same place it is now, in a present storage area, which can be made free for the purpose, in a newly acquired building or some other potentially available space (Muther 1961).

Phase II General Overall Layout: establishes the general arrangement of the area to be laid out.

The basic flow pattern(s) and the areas allocated are brought together in a way that the general sizes, relationships, and configuration of each major area is roughly established. Phase II is sometimes termed block layout or area allocation or merely rough layout (Muther 1961).

Phase III Detailed Layout Plans: locate each specific piece of machinery and equipment, aisle, and storage area, for each of the activities, departments, or areas which has been roughed out in the general over layout (Muther 1961).

In detail planning, the actual placement of each specific physical feature of the area to be laid out is established. And this includes utilities and services. The detailed layout plan is customarily a sheet or board with replicas of the individual machines or equipment placed or drawn thereon (Muther 1961).

Phase IV Installation: plan the installation, seek the approval of the plan, and make the necessary physical moves.

When the layout has been installed, follow up that the layout was installed as designed is important. If modifications were made during installation, either they should be accepted or arrangements should be made to correct the discrepancies. Periodic checks should be made to see that the layout is performing satisfactorily. (Francis and White 1974)

In the general overall layout (Phase II) and the detailed layout (Phase III) has the essential pattern the same on the three fundamentals. (Muther 1961).

(1) **Relationship:** The relative degree of closeness desired or required among things.

(2) **Space:** The amount, kind, and shape or configuration of the things being laid out

(3) **Adjustment:** The arrangement of things into a realistic best fit.

These three are always the heart of any layout-planning project, regardless of products, processes, or size of project. The pattern of layout planning procedures is based directly on these fundamentals. Figure 2.4 illustrates The Systematic Layout Planning Pattern of Procedures (Muther 1961).

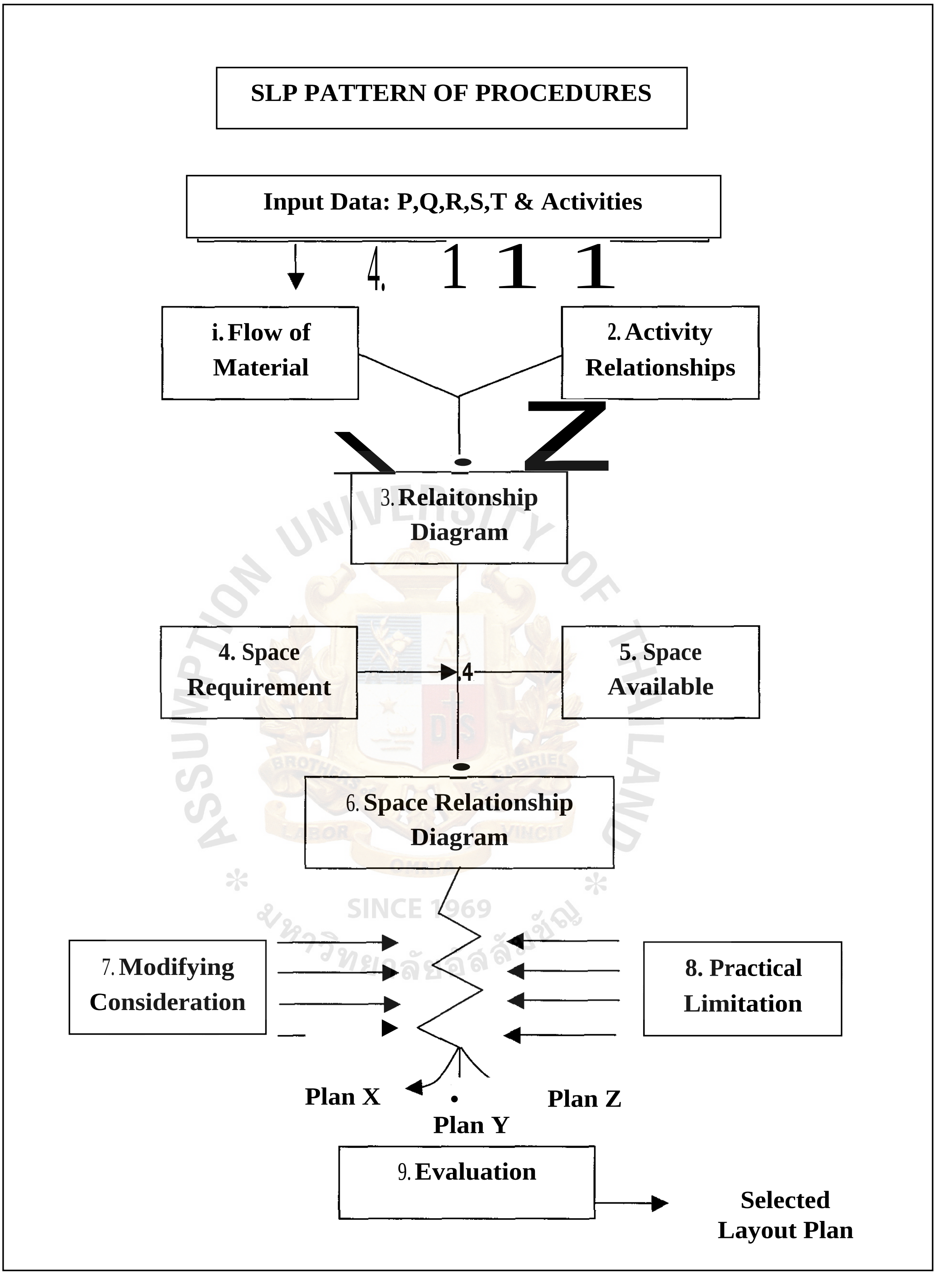


Figure 2.4. The Systematic Layout Planning Pattern of Procedures (Muther 1961).

The SLP procedure is depicted graphically. The appropriate information is gathered. A flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations, when combined with the relationship diagram, lead to the construction of the space relationship diagram. Based on the space relationship diagram, modifying considerations, and practical limitations, a number of alternative layout are designed and evaluated. In comparison with the steps of the design process, the first five steps of SLP involve the analysis of the problem. Steps 6 through 9, including the generation of alternative layouts, constitute the search phase of the design process. The selection phase of the design process coincides with step 10 of SLP (Francis and White 1974).

The SLP Pattern

Input data:

The SLP pattern starts with these following five base elements P,Q,R,S,T that is the basic input data (Muther 1961)

P-product (or material or service) means the goods produced by the company or area, the starting materials (raw materials or purchased parts), the formed or treated parts, the finished goods, and/or service items supplied or processed (Muther 1961).

Q-quantity (or volume) means the amount of goods or services produced, supplied, or used. Quantity may be termed number of pieces, tons, cubic volume, or value of the amount produced or sold (Muther 1961).

R-routing (Process Sequence) means the process, its equipment, its operation, and their sequence. Operation-and-equipment lists, process sheets, flow sheets, and the like may define routing (Muther 1961).

S-Supporting Service means the utilities, auxiliaries, and related activities or functions that must be provided in the area to be laid out, so that it will function effectively. Supporting services include maintenance, machine repair, tool room, toilets and locker rooms, cafeteria, first aid, and frequently ship offices, rail siding, receiving dock, shipping dock, receiving (or 'in area'), and shipping (or 'out area') It is common to include storage areas as a part of the supporting services as well (Muther 1961).

T-Time (or timing) means when, how long, how often, and how soon. Time or timing involves when products will be produced or when the layout being planned will operate (one shift only, during harvest season, Christmas rush). Operation times for the producing operations determine how many of a given piece of machinery are required, which in turn determines the space required, man-power staffing, and operation balancing. Urgency (of delivery or action) is also a part of timing, as are the frequencies of lot or batch 'run' and the response of supporting services (Muther 1961).

The importance of Product (P) and Quantity (Q) are on to any layout. An analysis of then individually and in their 'mix' is a necessary preliminary to any real layout planning. Process routing and equipment, supporting services, and timing information are also basic input data. And in addition, identifying the various activities (or area) included in the layout is a preliminary planning step (Muther 1961).

Flow of Material:

By planning the layout around the sequence and intensity of material moves, we attain of a progressive flow through the area(s) involved (Muther 1961).

In SLP pattern of procedures, Flow-of-Materials Analysis is based on Product (P), Quantity (Q), and Routing (R). The analysis of materials flow involves determining the most effective sequence(s) of moving materials through the necessary steps of the process(es) involved and the intensity or magnitude of these moves. An effective flow means that materials move progressively through the process, always advancing toward completion and with out excessive detours or back-tracking (counter flow) (Muther 1961)

The most popular method of analyzing flow is to use charts and diagrams as follows (Francis and White 1974):

(1) Flow process charts

(2) Multiproduct process charts

(3) Flow diagrams

(4) From-to charts

SLP converts its flow-of-materials intensities into a common rating system. The rating conventions are (Muther 1961):

A	Abnormally high intensity of flow
E	Especially high intensity of flow
I	Important intensity of flow
O	Ordinary intensity of flow
U	Unimportant moves of negligible intensity

The Activity Relationships:

The activity relationships are that the relationships among the service or support activities or functions are frequently of equal or greater importance than relationships based on flow of materials alone (Muther 1961).

In SLP pattern of procedures, Activity Relationship Analysis draws on Product (P), Quantity (Q), and Supporting Service (S) and Time (T) (Muther 1961).

The relationship chart is a cross-section form where the relationship between each activity (or function or area) and all other activities can be recorded. The relationship chart shows which activities have a relationship to others. Also, it rates the importance of the closeness between them and supports the rating with coded back-up reasons.

These measures make the relationship chart one of the most highly practical and effective tools available for layout planning (Muther 1961).

Closeness ratings represent an ordered preference for "closeness". Specifically, an A rating and an X rating are considered to be the most important ranking. Thus, A and X > E > I > 0 > U, where > means "more important of higher ranking than" ((Francis and White 1974).

Flow and/or Activity Relationship Diagram:

The purpose of the activity relationship diagram is to depict spatially the relationships of the activities ((Francis and White 1974).

This diagram is combination of the two investigations of Flow of Material and Activity Relationships. The various activities, departments, or areas are geographically related to each other, without regard to the actual space each requires (Muther 1961).

After the relationship of activities has been charted either by flow-of-material analysis, activity relationship charting, or a combination of the two. The next step is to diagram this information (Muther 1961).

At this stage, the planner is seeking a visual picture of the data gathered up to this point and of the calculations and analysis mad from them. Now the tallied or charted information, which shows the sequence of activities and the relative importance of the closeness of each activity to each other activity, is transferred and translated into a geographic arrangement. This geographic arrangement should in fact now locate the activities according to the degree of closeness charted (Muther 1961).

<u>Conventions for Diagramming</u>

The conventions used in Systematic Layout Planning. They include the following (Muther 1961):

(1) A symbol for the type of activity (see Figure 2.5. Process Chart Symbols & Action.)

(2) A number (or letter) identification for each activity

(3) A number-of-lines code for the intensity of flow or closeness value (see Figure 2.6. Closeness Rating.)

(4) A color code, also for the intensity or closeness value (color use in optional, but recommended for the final diagram.)

(5) A color for each type of activity (optional) (here, but used later when converting to a space relationship diagram)

At this point, the planner is diagramming only the activities, not the space they require. Therefore, it is not attempting to fit certain areas together according to their size, but interested only in visually relating the activities to each other according to the relative closeness established (Muther 1961).

Process Chart Symbol & Action*	**Symbols Extended to Identify Activities & Areas**	**Color Code**
Opertion	Forming or Treating Areas	Green**
Transportation	Assembly, Sub-Assembly, Dis-Assembly	Red**
Storage	Transport-related Activities/ Areas	Orange Yellow*
D Delay	Storage Activities/Areas	Orange Yellow**
Inspection	Set-down or Hold Areas	Orange Yellow**
	Inspect, Test, Check Areas	Blue**
	Service & Support Activities/Areas	Blue**
	Office or Planning Areas, or Building Fetures	Brown** (Grey)- -

* A.S.M.E Standard

* I.M.M.S. Standard

(adopted as basic to SLP procedure)

Figure 2.5. Process Chart Symbols & Action (Muther 1961).

Vowel Letter	No. Value	No. of Lines	Closeness Rating	Color Code
A	4		Absolutely Necessary	Red**
E	3		Epecially Necessary	Orange Yellow**
I	2		Important	Green**
O	1		Ordinary	Blue**
U	0		Unimportant	Uncolored**
X	-1	IN. N	Not Desirable	Brown**
XX	-2,-3,-4,-?	^ \! `/^	Extremely Undesirable	Black

* A.S.M.E Standard

* I.M.M.S. Standard

(adopted as basic to SLP procedure)

Figure 2.6. Closeness Rating (Muther **1961).**

The Space Requirements and The Space Available:

These are developed from analysis of the process machinery and equipment necessary and from the service facilities involved. Area requirements must be balanced against the Space Available (Muther 1961).

To evaluate the space requirements for the layout, the solution is constrained by the amount and configuration of available space. The constraint can be in the form of an existing building, a limitation on the size of the building site, or the availability of capital for new construction. Therefore, it is necessary to consider not only space requirements but also space availability ((Francis and White 1974).

Space Relationship Diagram:

Flow and activity relationships having been determined and diagramed into a geographical arrangement, the space requirements for each activity having been established and balanced against the space available, the planner applies the space to the diagram (Muther 1961).

Fitting space to Diagram, the planner has the flow and/ or the activity relationship alternatives then planner can (Muther 1961):

(1) Combine space with the flow diagram only;

(2) Combine space with activity relationship diagram; or

(3) Combine space with a combined flow and other-than-flow relationship diagram.

The method chosen depends upon the relative importance of materials flow and relationship of supporting services. When using the flow diagram as the basis, convert each activity designated on the diagram from its identifying symbol to its allowed size. Work to some convenient scale to designate the areas. Generally, this is much easier to do on sheet of paper printed with cross-section grid lines (Muther 1961).

Many refinements of space relationship diagrams can be made to show particular information pertinent to the layout planning project at hand: Existing buildings versus new construction; number of employees; need for, or profit potential of, expanding or relocating any activity: fixity or difficulty of relocating: required condition of area; suitability of existing location- all be coded into the diagram by use of colors, symbols, letters, and the like (Muther 1961).

If a specific location for the layout has already been decided, it may be practical to draw the space relationship diagram directly on floor plans of the designated building. This can lead to short cuts in planning. However, it can also lead to jumping to conclusions and missing real opportunities to make major improvements or contributions to the layout. Therefore, to realize the full potential of planning the layout to ideal conditions without the limitations of existing columns, walls, rail sidings, and the like, it is better to work out the space relationship diagram to meet the conditions of the activity relationship diagram (Muther 1961).

On the other hand, if it is known that certain fixed building features, such as walls, columns, or floor loads, definitely cannot be changed in the layout-planning project at hand, it may be unnecessary to go all the way toward the fully ideal space diagram. Then it is better to recognize the physical features and shape of the available space and to place the space diagram in this specific location from the start (Muther 1961).

Modifying Considerations and Practical Limitation:

In modifying considerations, it's usually fall into one of these categories below (Muther **1961):**

(1) Handling methods

(2) Storage facilities

(3) Site conditions or surroundings

(4) Personnel requirements

(5) Building features

(6) Utilities and auxiliaries

(7) Procedures and controls

(8) Shape of detailed activities' layouts

Because of many different modifying considerations and their varying importance from project to project, there are all manners of techniques for analyzing. Each modifying consideration may be investigated in several different ways. A single consideration on some project may actually require several different analyses. Such special analysis-consideration by consideration- is probably best. But where detailed investigation is not justified or convenient, there are two techniques of analysis that are highly practical in analyzing the influence of specific consideration (Muther 1961).

One is the universal problem solving procedure illustrated hardly detailed enough for many complex problem, but it is a simple, basic method of solving problems. The second method is sampling. Its use is limited to existing installations. That is records are spot checked based on existing ways of doing the work. The purpose is to gather information, which can be project into the conditions anticipated to prevail in the new layout being planned. Several types of sampling depending upon the type of information needed (Muther 1961).

Other Modifying Considerations

Arranging storage facilities and areas is the heart of all warehouse layout projects. It is important to a greater or lesser extent in all industrial layouts, service-areas, offices, and retail store layouts as well (Muther 1961).

Practical Limitations:

Considerations, which open for development, design, or decision, we call modifying considerations; those, which impose constraints on our planning, are called practical limitations. The latter include such restrictions as may be built into an existing building, existing handling methods, or a not-to-be-changed production-control-and-dispatching system. Company policy, building codes, labor union contract, and community regulations on waste disposal can all affect the layout. The physical characteristics of the location always exert limitations on the layout. Even a need for straight aisles of adequate width imposes requirements, for main aisles are part of any overall layout plan. Certainly one of the most important limitations is the question of cost savings and available investment money (Muther 1961).

Selection the Layout:

The SLP pattern refers to them as Plans X, Y, Z. Any one of these plans will do the job. Any of them can be made to work satisfactorily. However, each has its own peculiar set of advantages and disadvantages. The problem is to decide which of the alternative plans to selects. Of the number of ways by which this selection can be made, there are three basic methods (Muther 1961):

(1) Balancing advantages against disadvantages

(2) Factor analysis rating

(3) Cost comparison and justification

<u>Balancing Advantages against Disadvantages</u>

Probably the easiest of the three evaluation methods mentioned is that of listing advantages and disadvantages-the pro's and con's system. It is also the least accurate. Therefore, it is used more for preliminary screening of rough alternatives (Muther 1961).

The pro's-and-con's system is merely listing in columns or on adjacent sheets all the advantages of each alternative. Below them are listed the disadvantages. This simple comparison is surprisingly effective and certainly not a time-consuming procedure (Muther 1961).

Weighted Factor Analysis

Every layout plan has intangible costs, which for several practical reasons cannot be measured in terms of dollars and cents. Moreover, a comparative cost analysis of alternatives sometimes doesn't aid in the decision-making, no one plan having a clear cut financial advantage over the other. As a result, perhaps the most effective general method of evaluating layout alternatives is that termed factor analysis (Muther 1961).

The factor analysis method follows the engineering concept of breaking down the problem into its elements and analyzing each one. This makes it more objectives. Essentially, the procedure is as follows (Muther 1961):

(1) List all of the factors, which are considered important or significant to deciding which layout to select.

(2) Weight the relative importance of each of these actors to each other.

(3) Rate the alternative plans against one factor at a time.

(4) Extend the weighted, rated values, and compare the total value of the various plans.

A list of factors, or considerations most commonly involved follows-not in the order of importance (Muther 1961).

(1) Ease of future expansion

(2) Adaptability and versatility

(3) Flexibility of layout

(4) Flow of materials effectiveness

(5) Materials handling effectiveness

(6) Storage effectiveness

(7) Space utilization

(8) Effectiveness of supporting-service integration

(9) Safety and housekeeping

(10) Working conditions and employee satisfaction

(11) Ease of supervision and control

(12) Appearance, promotional value, public or community relations

(13) Quality of product

(14) Maintenance problems

(15) Fit with company organization structure

(16) Equipment utilization

(17) Utilization of natural conditions or surroundings

(18) Ability to meet capacity or requirements

(19) Plant security and pilferage

(20) Compatibility with long-range company plans

Establishing the weight values for each factor. Perhaps the most effective way of setting weight values is to pick out that factor which is considered the most important; give this most important factor a value of 10; and relate the weight of each of the other factors to 10 (Muther 1961).

After rating all factors for all plans, convert the letter rating to a numerical value. Do this by multiplying the weight factor by the numerical value of the letter rating. After the numbers have been extended, the numerical values are totaled for each plan. Ordinarily the result is one of the following (Muther 1961):

(1) One plan clearly stands out head and shoulders above the others and can be accepted as the best logical compromise.

(2) Two plans come out very close. In this case, reevaluation of the two plans, involving more factors, closer scrutiny of the weighting and rating, or inviting more people to share in the weighting and rating process should be undertaken.

(3) The planner will see possible improvements in one or more of the alternatives.

(4) During the rating process, it is discovered that a combination of two or more of the plans can be worked out. A replica of that combination layout must be made. By adding another column to the form (or another sheet), the planner rates the new combination plan on the same basis as the others.

The factor analysis method is one that makes a systematic evaluation out of many otherwise subjective views, and it is, therefore, particularly adaptable where investment costs or savings between plans are not accurately measurable or significant. The procedure is especially suitable, too, for projects where the degree of opinion is high in relation to measurable economic considerations (Muther 1961).

Cost Comparisons

The method of evaluating layouts, which has the most substance, is some form of cost comparison or financial analysis. In most cases, if cost analysis is not the chief basis for decision, it is used to supplement other evaluation methods (Muther 1961).

There are two entirely different reasons for making a cost analysis, although the data used in both cases may be identical. In the first case, the purpose will be to justify a particular project-to find out whether it is economically feasible. In the second case, the problem is to compare alternative proposals with each other, and/or to an existing operation, assuming each to be adequately justified. The layout planner is usually concerned with the second case, though frequently with the justification as well (Muther 1961).

There are basically two approaches to preparing a cost analysis. Either consider the total costs involved or consider only those costs that will be affected by the project under consideration. If alternative proposals for an entirely new layout are being compared, total costs must be used. With a re-layout, it is often simpler, and just as effective, to deal only with the changes in costs reflected in the various proposals under consideration (Muther 1961).

The size of the project also must be considered in deciding what kind of comparison to make. If the project is extensive and complex, it should be evaluated for its effect on the total operation of the company. A relatively small re-layout project, on the other hand, can be evaluated and alternatives compared simply by calculating the change in contribution to profit (Muther 1961).

III. THE EXISTING PLANT LAYOUT UNDER STUDY

3.1 Background of the Company

Plastic Product Company newly enters as a Plastic Product Manufacturer. This company has been established for 3 years. Its location is on Sukhumi/ft road, Bangkok, with factory area of one rai of land. The company is medium size compared with other plastic manufacturing industries. The main objectives are:

(1) To supply plastic products to other production manufacturing groups.

(2) To produce plastic products for wholesalers.

Employees:

There are totally 35 employees in the whole company and 28 employees are in production section. The company operated 6 days per week and the office hours are 8:00 a.m. to 5:00 p.m. for office section and 7:00 a.m. to 11:00 p.m. in production section. Production employees are grouped in 2 shifts. The first shift starts from 7:00 a.m. to 3:00 p.m. and the second shift starts from 3:00 p.m. to 11:00 p.m. Each shift consists of one supervisor and 13 machine operators.

Plastic Product:

Plastic Product Manufacturer produces both general plastic products and made to order plastic products. General plastic products are products, which are usually produced and sold in market like plastic basket. Company will mostly own these molds (model of products) for general plastic products. Made to order plastic products are products produced based on customers' order and supplied to other production manufacturing groups. Most customers will own molds and lend their own molds to company, and then they order the company to produce the products at required volumes. And company will return molds to customer after completion. For the order from the company group, all molds are kept at Plastic Product Company.

There are many and various types of packages and sizes depend on duration of plastic product. Some products, which have attributes in ease to fragility, will be wrapped and packed with thick paper cartons. Some products, which attribute to more duration plastics and large amounts, will be packed in tied in plastic bags.

Raw Material:

The major raw materials for Plastic Company are plastic resins and pigments (colors). Plastic resins are delivered in form of bags packaging with weight 25 kilograms per bag. The dimension in width x height x thickness is 50cm x 75cm x 14cm. Each of them has unique specifications such as duration, easy to fragility and clearness to differentiate output product. The major types of plastic resins are Polypropylene resins, Polystyrene resins (PS), Atomic Absorption Spectroscopy resins (AS), and Acrylonitrlle Butadiene Copolymer resins (ABS). The other is the type of plastic as per customer requirement.

For pigments, company will use them when products need additional colors apart from the original ones. Pigments are delivered in form of resins or powder. Pigment resins are delivered in bags same as plastic resins. But pigment powder is contained in boxes. In producing colored products, plastic resins and pigments must be mixed as prior requirements before sending to plastic injection machine. There are also many different types of pigments. One plastic resin cannot be mixed with any kind of pigment. Therefore, after the selection of plastic type, company must select the pigments too. One advantage is location of manufacturing company is close to material suppliers; therefore it is convenient for material supply and less transportation time.

Machines:

In Plastic Product Manufacturing Company, there are a total of 14 operating machines, which consist of two plastic mixer machines, two ultrasonic plastic welders, eight plastic injection machines, a shrink packaging machine, and one plastic crusher. Plastic Manufacturing Company always contacts with the machine services (machine supplier). Therefore, whenever the machine is out of order, the company can call for machinery maintenance services as soon as possible.

Spare Part (Molds)

In Plastic Product Manufacturer, molds are patterns or models of plastic outputs. Good and neat molds can produce very fine quality plastic products. Molds are different in size, shape and dimensions. Therefore molds can be used with some specification of plastic injection machine. Most machines can change molds with each other, except in small size machines. The small size machine can operate only small mold size.

There are two types of molds, one is company's molds, another is molds that customer owned. Molds that are owned by company will be kept at the company production area. For molds that are customer owned, customers will bring their molds to the company and company will return customer's molds when order is finished.

3.2 Plastic Company Plant Layout

Plant layout of plastic company is divided into plastic production Building, Office, Plastic Crusher, company truck parking, employee's home, restroom, and Garbage area.

Plastic crusher area needs more space to collect waste plastic output. Therefore this area will be separated from the other areas. There is one machine, which is used for crushing unqualified and wasted plastic output.

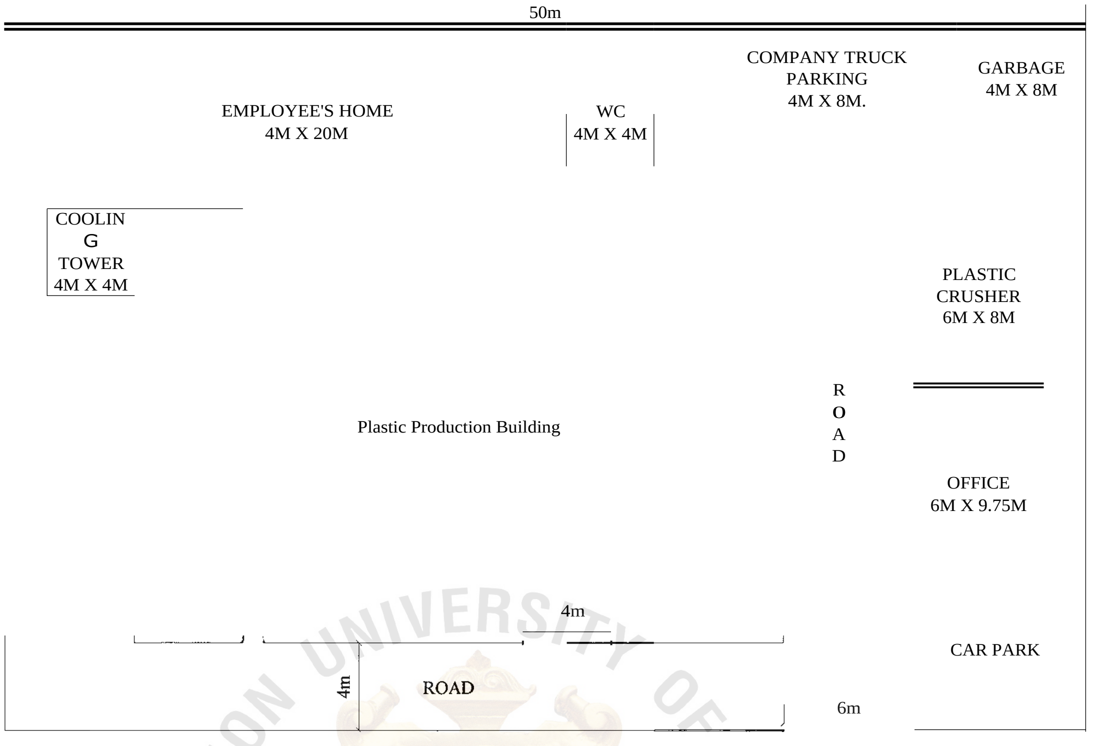


Figure 3.1. Overall Plastic Plant Layout.

The production area is on one floor building size. The dimension of building is Width 20mX Length 30mX Height 4.5m. This one floor operation building consists of raw material storage, plastic mixing area, plastic injection area, ultrasonic area, assembly & packing area, finished goods storage, workshop (mold maintenance and repairing), mold storage, and cooling tower. Figure 3.2 illustrates the Plastic Product Company operation layout.

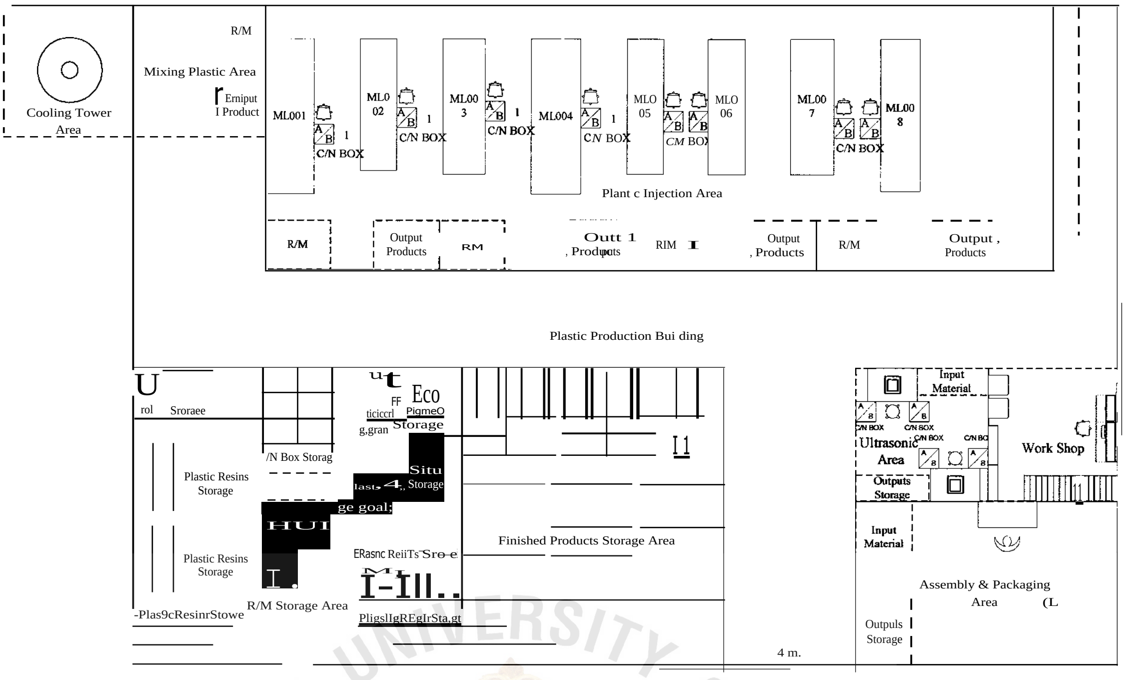


Figure 3.2. Plastic Operation Building.

(1) Raw material storage area: (area: 9m. x 10m.)

This area must keep the floor dry and clean. Its size is 9m.x 1 Om. The company has divided area for space utilization of raw material by keeping plastic resins 80%, pigment 5%, and others 15% (such as silicone spray, carton box, big plastic bag). Each type of plastic resins and pigments must be kept in an orderly separate place and tab name of them for protecting from misunderstanding.

(2) Plastic mixing area: (area: 4m x 4m.)

The plastic mixing area is separated into 3 major sections as follows:

(a) Two plastic mixing machines:

These two mixing machines have the same capacity and size. And these two machines can load raw material 50 kilograms load per time. The dimension in Width x Length x Height of each machine is

100cm.x100cm.x145cm. Figure 3.3 illustrates the picture of plastic mixer machine.

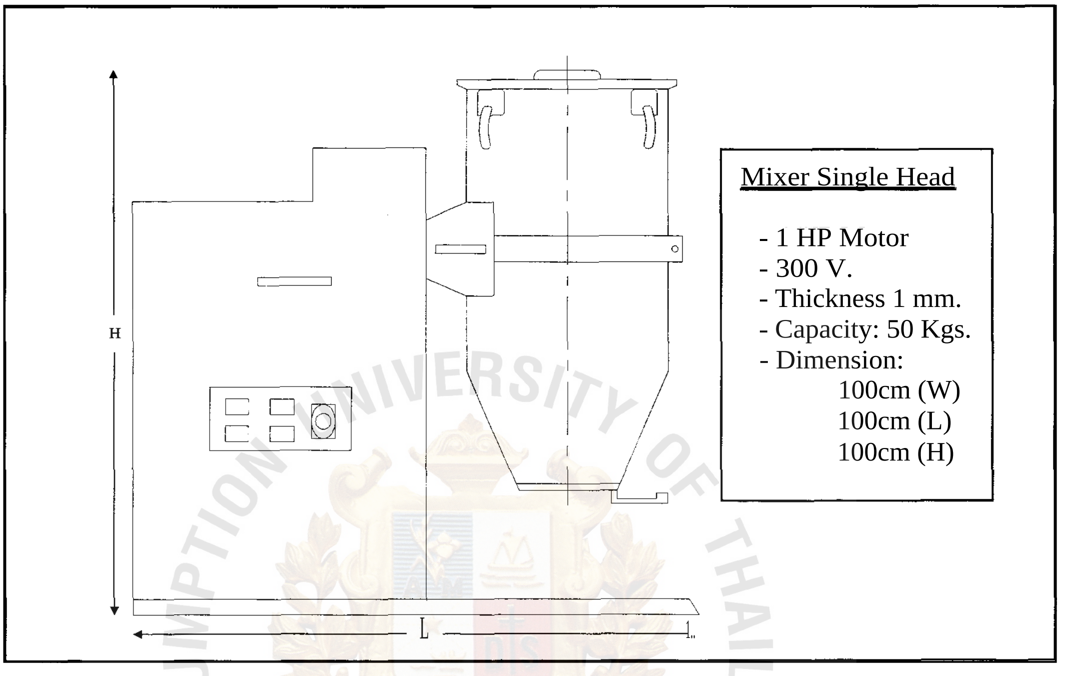


Figure 3.3. Mixing Machine.

(b) Raw material storage area for mixing

This area is used for storing raw material (plastic resins and colors), which wait for supplying to mixing process.

(c) Mixed output storage of plastic resins and colors waited for supplying to further processing:

This area is required for storing the output of plastic mixing machine. These mixed-materials will be kept for supplying to further processing.

(3) Plastic injection area: (area: 24m x 8 m.)

Plastic injection area is the largest area in production building. This area is divided space for:

(a) Plastic injection machines

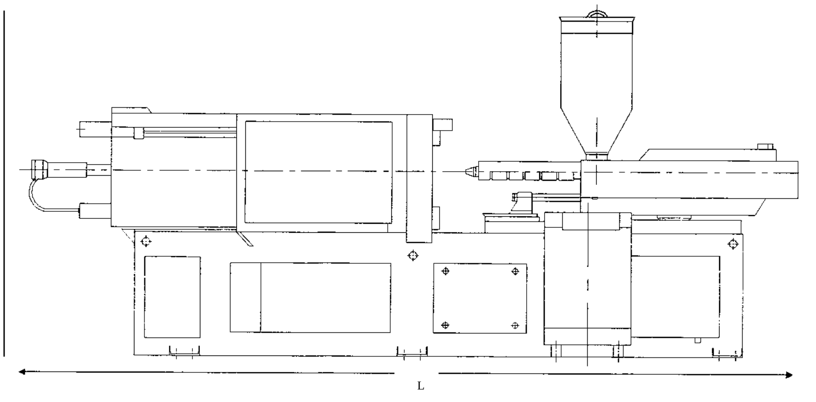
Company has eight plastic injection machines. Each machine is different in size, dimension, and capacity. Though all of them are divided in specification and capacity, they can be categorized by their spare part dimensions (molds dimensions) into two types as follows;

(1) 125mm. — 350 mm.: There are four plastic injection machines in this category.

(2) 150mm. — 300 mm.: There are four plastic injection machines in this category.

(b) Raw Material storage area for injection.

(c) Output plastic product storage area for further production process.



Plastic Injection Machine

Machine No.	Dimension (m.) (L)x(W)x(H)
ML001	4.7 x 1.5 x 2.2
ML002	4.0 x 1.1 x 2.1
ML003	4.1 x 1.3 x 2.1
ML004	4.7 x 1.5 x 2.2
ML005	4.1 x 1.1 x 2.1
ML006	4.1 x 1.1 x 2.1
ML007	4.1 x 1.3 x 2.1
ML008	4.6 x 1.2 x 2.1

Figure 3.4. Plastic Injection Machine.

(4) Ultrasonic plastic welder area: (area: 4m.x4m.)

This area requires space for two ultrasonic plastic welder machines, space for keeping input and output product of raw material. The ultrasonic plastic welder is put on the top of working table.

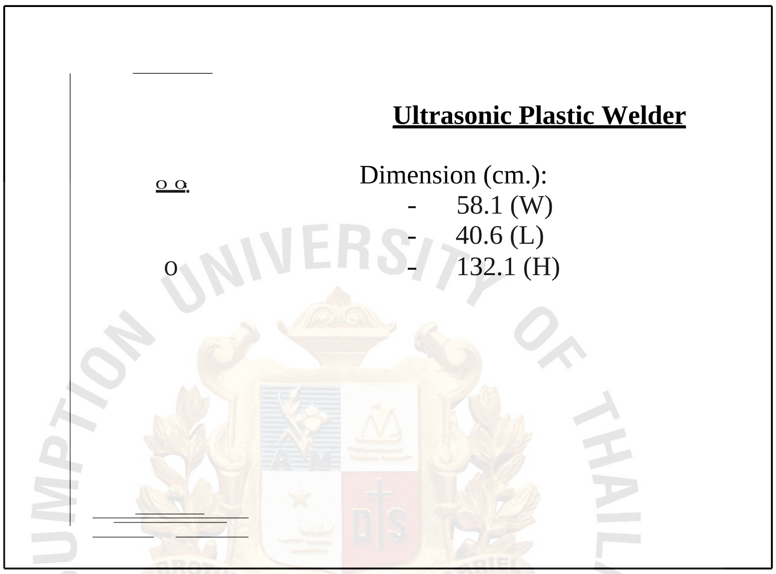
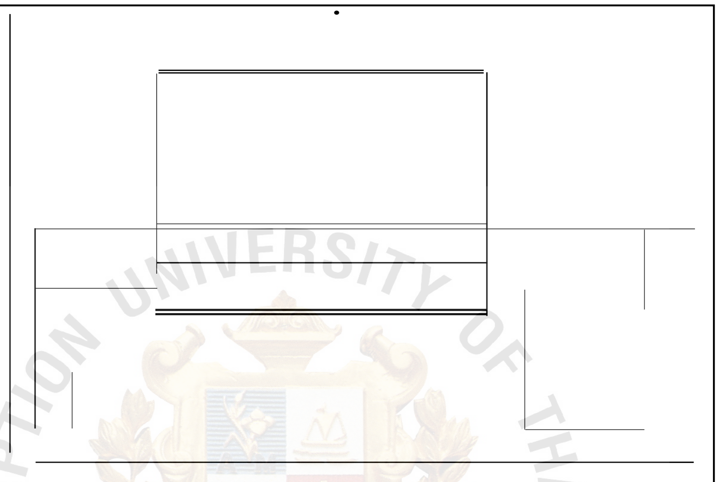


Figure 3.5. Ultrasonic Plastic Welder.

(5) Assembly & packing area: (area: 5m. x 8m.)

This area consists of a shrink-packing machine for wrapping the products and the space for operation. Figure 3.6. Illustrates a shrink-packing machine and its specification.



Shrink — packaging Machine

Dimension:
- 60 cm (W)
- 145 cm (L)
- 155 cm (H)

Packaging Capacity: 1-14 sec./pc.

Tunnel Size:
- 58 cm (W)
- 60 cm (L)
- 65 cm (H)

Figure 3.6. Shrink-packing Machine.

(6) Mold storage area: (area: 2m. x 7m.)

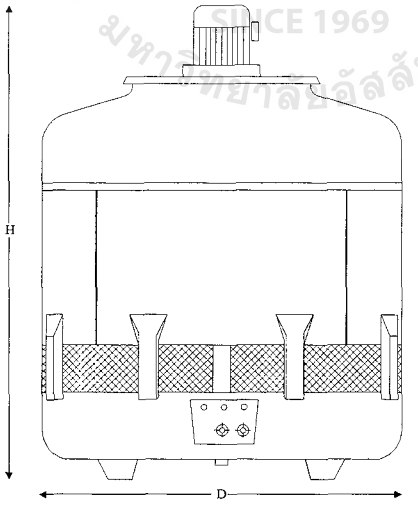
The dimension area of 1.20m.x7m is arranged for mold storage. Molds are placed on the building floor. There are no shelves to store.

(7) Work shop area: (area: 4m. x 4m.)

This area is utilized for maintenance and repairing molds and other equipment. Workshop consists of working table (dimension: 200 cm. x 65 cm x 90 cm.), two steel shelves (dimension: 145cm. x 80 cm. X 150 cm.), two wood shelves (dimension: 120cm. X 30cm x 100 cm) and two closets (dimension: 60 cm x 60 cm x 50 cm) for keeping tooling instruments.

(8) Cooling tower area: (area 4m x 4m)

Cooling tower area is located outside production building. This area required airy space and good water system for cooling tower system. There are two pumps for pumping cooling water along with water pipes to each plastic injection machine.



Cooling Tower

Dimension:
- 186 cm (H)
- 196 cm (D)

Figure 3.7. Cooling Tower

3.3 Production Flow Process

In production flow process, company has classified it into two processes, which are Production flow process and supporting & equipment flow process.

3.3.1 Production Flow Process

Refer to product output; there are made-to-order and general products. Each production orders are produced in large volume and specified the operating function. Figure 3.8 will illustrate production flow process.

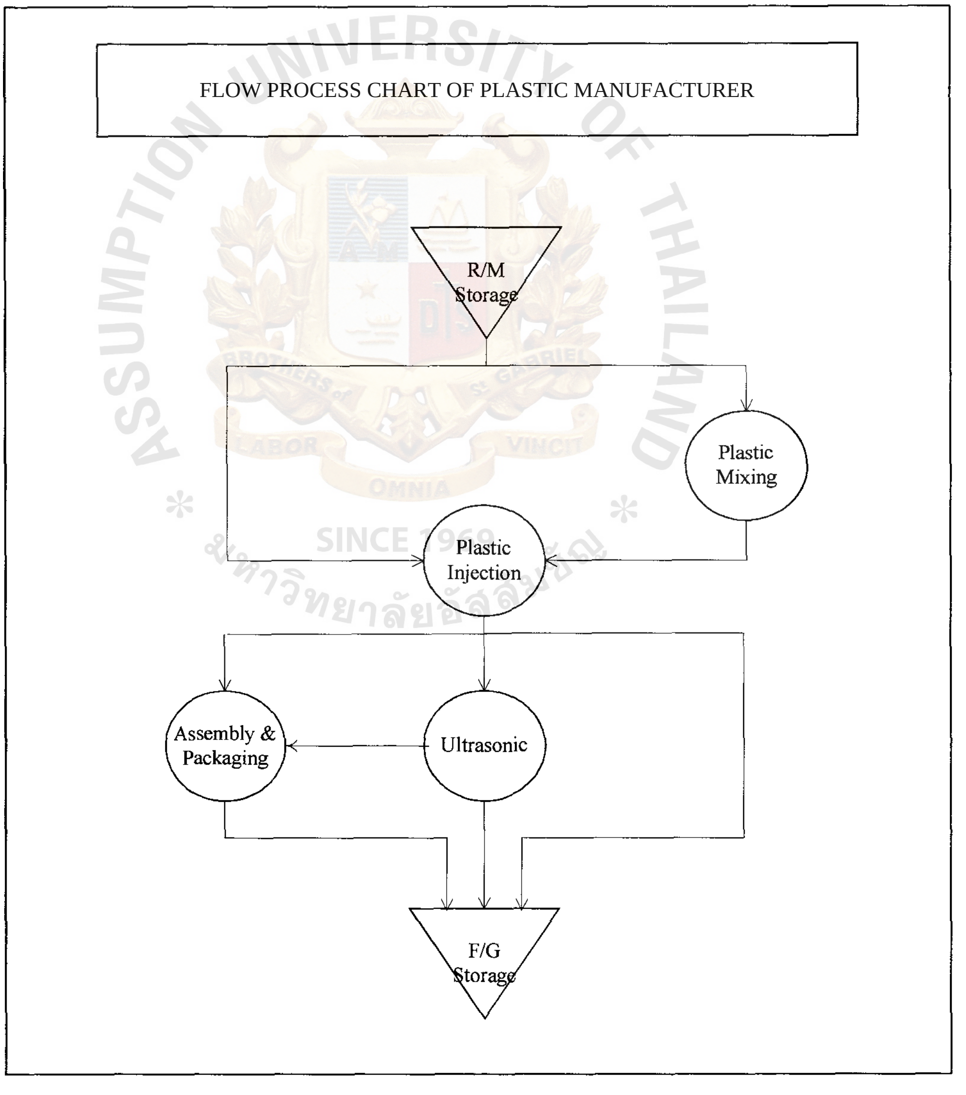


Figure 3.8. Production Flow Process.

The plastic resins can be transferred to plastic injection machine directly when producing mono-color plastic products, which is about 40% of the overall plastic injection process. Another 60% shall pass mixing process before going to the further process. And then 100% Output products from mixing process will go to plastic injection process.

Output products from plastic injection machine, around 20%, needs ultrasonic process, around 50% go directly to shrink-packing machine, and 30% is already packed in tied plastic bags and stored in finished goods storage.

From the ultrasonic process, 80% of output will go to the further process; another will be packed in big tied plastic bags and then stored in finished goods area.

The above production processes can be divided into four processes, which are:

(1) Plastic mixing process: (for mixing color and plastic resins)

This is the first step for color plastic output products. For orders that need plain color for output, they can skip this step. Its process is mixing raw material between plastic resins and desired pigments at standard ratio. There is around 10 minutes for each round. Two mixing machines can load 50 kilograms of plastic resins per time.

The finished color mixing will be sent to plastic injection process. The waste will be sent to the plastic crusher area. The waste hardly occurred except:

(a) Unmatched between pigments and plastic resins

(b) Not reach the specification

(2) Plastic Injection: (for injections plastic resins to be finished outputs)

This step is the heart of plastic operation. This process transforms plastic resins into plastic product.

Plastic injection machine process is as follows:

Figure 3.9. Plastic Injection Machine Process.

The factors that may influence to the qualify of output products are the quality of plastic resins, suitable pigments, water circulation, power supply, mold, and capacity of plastic injection machine.

The speed of injection machines is 20 seconds to 50 seconds per injection time. This injection time is set according to the types of plastic resins and output product shape.

The unqualified output such as uncompleted shape will be selected out and sent to plastic crusher area.

Ultrasonic Plastic Welder: (for joining two pieces of plastic product together)

Ultrasonic plastic welder is welding thermoplastic parts by using high frequency vibrations to the pieces being assembled. The vibration, through surface and intermolecular friction, produce a sharp rise in temperature at the joint. When the temperature is high enough to melt the plastic, there is a flow of material between the parts. When the vibrations stop, the materials solidified under pressure and a uniform weld result. Most plastic welders operate above the range of human hearing at 20 KHz.

Some output product from injection machines can move to packaging function directly such as plastic boxes, which is completely output shape.

(4) Assembly & Packing: (for assembling and packaging plastic product)

For some plastic product, company needs to assemble semi-finished product to finished product before packaging. As box case and cover will be produced from different molds and machines, the company used them to assemble box case and cover together before, and finally transferring finished product to packaging section.

3.3.2. Supporting & Equipment Flow Process

(1) Mold movement:

As mentioned above, mold is the model of product output. Therefore, after completing production order, the operator needs to change mold. As molds' weight is very heavy, mold storage and plastic injection machines are always located near each other. There is facility equipment, which hoists to help the supervisor in changing molds. The hoist is installed over plastic injection machines and molds storage. It can move along with its parallel metal bars.

(2) Cooling water system:

Plastic Injection Machine melts from plastic resins to plastic liquid. Then machine injects plastic liquid into mold for making shape of product. After that mold will cool down to get hard solid finished output. For decreasing temperature of mold, cooling water system will help in adjusting temperature of machine; therefore, company needs to have water pipes from Cooling Tower to each plastic injection machines. Two pumps are required to activate increase water pressure.

IV. DATA COLLECTON AND PRELIMINARY ANALYSIS

4.1 Data Collection

The molds are too heavy in weight to be carried by one or two persons. 'Movable Hoist' is the facility equipment to help the operators in doing activities with molds. This hoist helps the supervisor in ease to change, keep, and move molds. The hoist also helps to put the mold into the injection machines and also for putting out from the injection machine. The hoist bars are installed over plastic injection machines and molds storage from the right to left sight, which is 30 m. in length and 4 m. in width. The movable hoist moves along the short bar, which is installed between the horizontal parallel bars. The height between parallel bars and floor is 4 m. Parallel metal installed away from wall is 1.5 m. Therefore, they can move over all plastic injection machines and to be an important facility to move the molds. It can push up the weight around 2 tons.

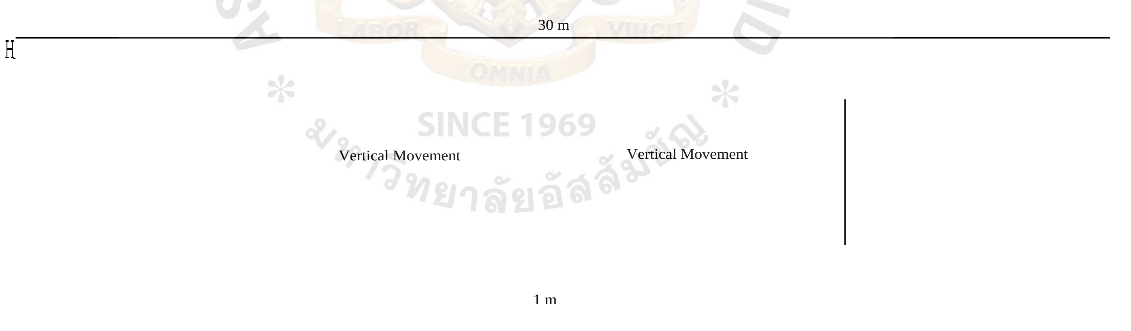


Figure 4.1. The Hoist's Bars.

When one of plastic injection machines needs to change mold, operator will move hoist to the mold storage and then move down to pick up the mold and move to put mold into plastic injection machine. After production order finished, operator moves the hoist help in putting off the mold from plastic injection machine and then moves back to mold storage. Then, place the used mold on the shelf. If there is continuity production the following order, operator moves the hoist to pick up another mold and then move to the plastic injection machine.

Upon observation, there are many types of molds. They can be categorized into two groups, which are:

(1) By the owners of molds

(a) Company owner

(b) Customer owner

All customers owned will be placed in front of shelf for convenience to return to the customers.

(2) By the dimension of molds:

(a) Under 250 mm.

This group of molds can be used with both small and large plastic injection machines.

(b) The height from 250 mm. — 350 mm.

This group of molds can be used with only large plastic injection machines.

Table 4.1. The List of Mold.

Item No.	Mold No.	Dimension (mm) (W)x(L)x(H)	Machine no.
1	M0001	200x300x200	ML001-ML008
2	M0002	200x250x150	ML001-ML008
3	M0003	200x300x150	ML001-ML008
4	M0004	250x300x200	ML001-ML008
5	M0005	250x300x250	ML001-ML008
6	M0006	200x300x150	ML001-ML008
7	M0007	200x300x200	ML001-ML008
8	M0008	200x250x150	ML001-ML008
9	M0009	250x300x250	ML001-ML008
10	M0010	200x250x150	ML001-ML008
11	M0011	300x400x350	ML001,ML004,ML007,ML008
12	M0012	300x350x350	ML001,ML004,ML007,ML008
13	M0013	300x350x300	ML001,ML004,ML007,ML008
14	M0014	300x350x350	ML001,ML004,ML007,ML008
15	M0015	300x400x350	ML001,ML004,ML007,ML008
16	M0016	300x350x350	ML001,ML004,ML007,ML008
17	M0017	200x250x150	ML001-ML008
18	M0018	200x250x150	ML001-ML008
19	M0019	200x300x200	ML001-ML008
20	M0020	300x350x350	ML001,ML004,ML007,ML008
21	M0021	300x350x300	ML001,ML004,ML007,ML008
22	M0022	300x350x350	ML001,ML004,ML007,ML008
23	M0023	300x400x350	ML001,ML004,ML007,ML008
24	M0024	300x350x350	ML001,ML004,ML007,ML008

The above mold list, can show that the existing area was not enough space to support for mold storage. Therefore, there are some molds put on the floor and scattered into other operation areas. The operator often lose time searching the mold.

As plastic products manufacturer has continuity in operation, set-up time is very critical before an operation is started up. Therefore, Plastic Company needs to reduce time for changing and setting mold to higher company productivity and lower down time.

The effective mold storage is needed to apply but it requires large space to store all molds effectively. Therefore, the area must be relocated and reorganized to separate types of molds.

For the other requirement,

(1) Molds storage and plastic injection machine must be absolutely closed for saving movement time.

(2) The closeness of cooling tower and plastic injection machines can save water pipe (length) and power consumption of water pumps.

4.2 Mold Storage

For saving the space of production, the new mold storage will increase rack for keeping molds. There are five levels, which contain eight molds per level. It makes from high quality of metal. Each rack can be drawn forward (for easily picking up by the hoist). Each one is identified the name of mold. The Figure 4.2 illustrates the mold storage.

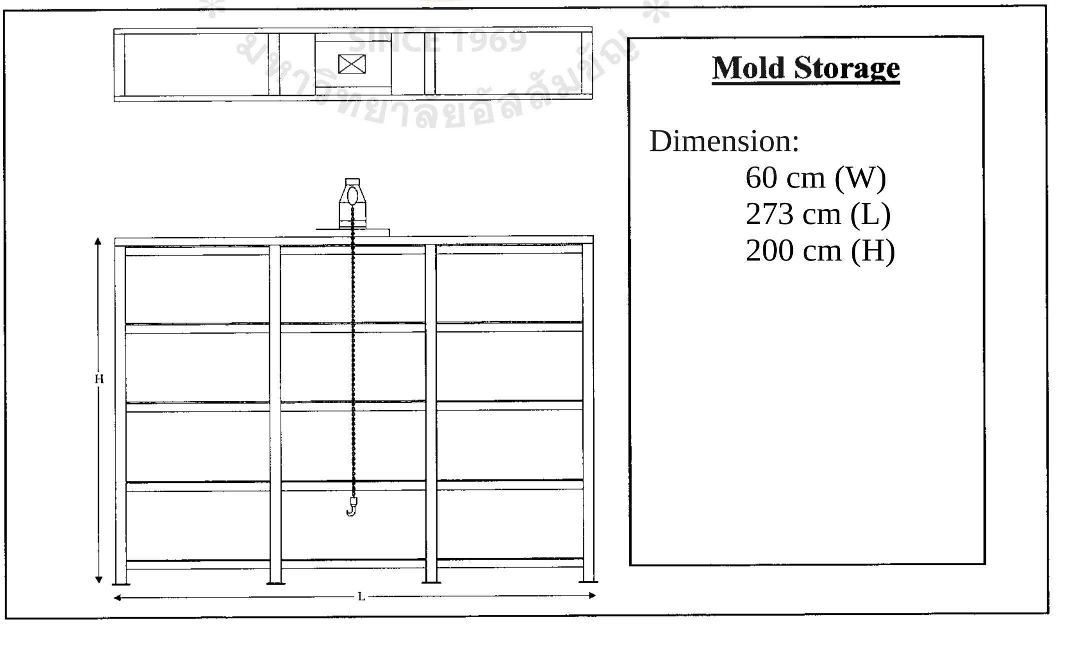


Figure 4.2. Mold Storage.

4.3 Input Data for S.L.P Pattern

Based on study, the next is to input data for S.L.P pattern which are discovered by Richard Muther. There are three forms, which are Flow of Material Form, Other-Than-Flow, and Combined Flow. These forms can effectively generate the relationship for nine areas. The alphabet that fills in each boxes is A, E, I, 0, U, X; It means, A is for Absolutely necessary closeness, E is for Especially important closeness, I is for Important closeness, 0 is for Ordinary closeness OK, U is for Unimportant closeness, and X is for Not desirable closeness.

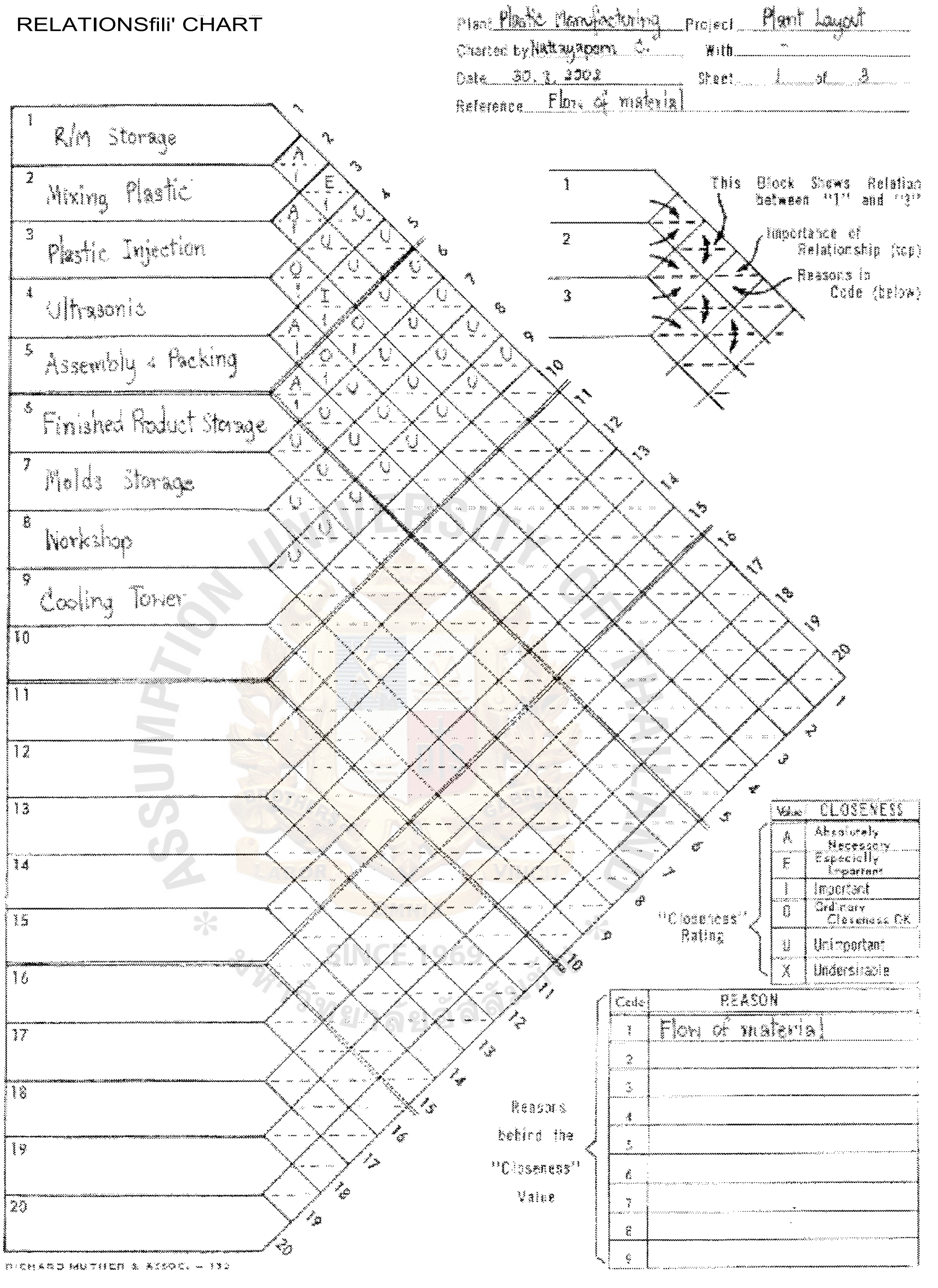


Figure 4.3. Relationship Chart (Material Flow Diagram).

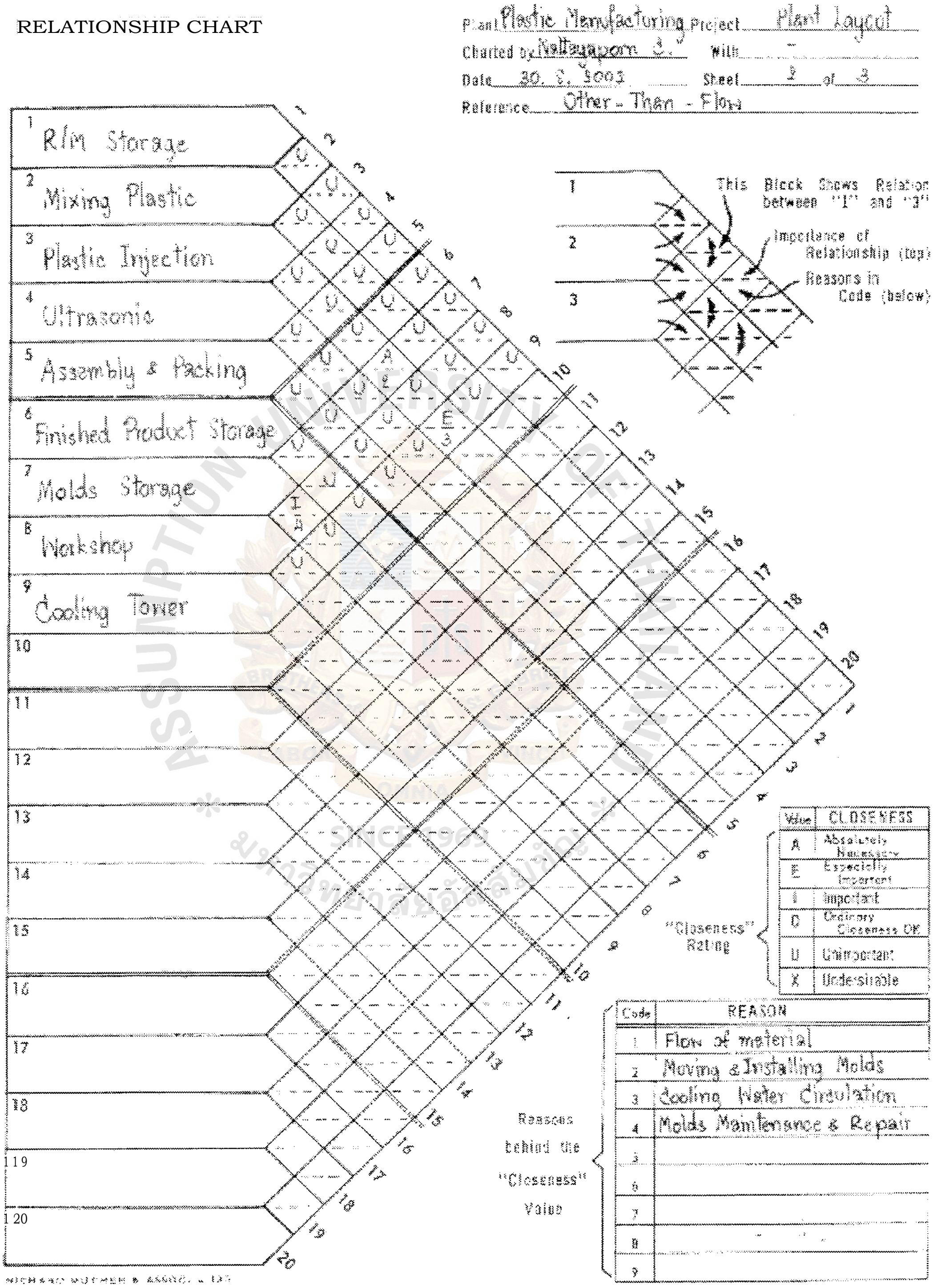


Figure 4.4. Relationship Chart (Other-Than-Flow).

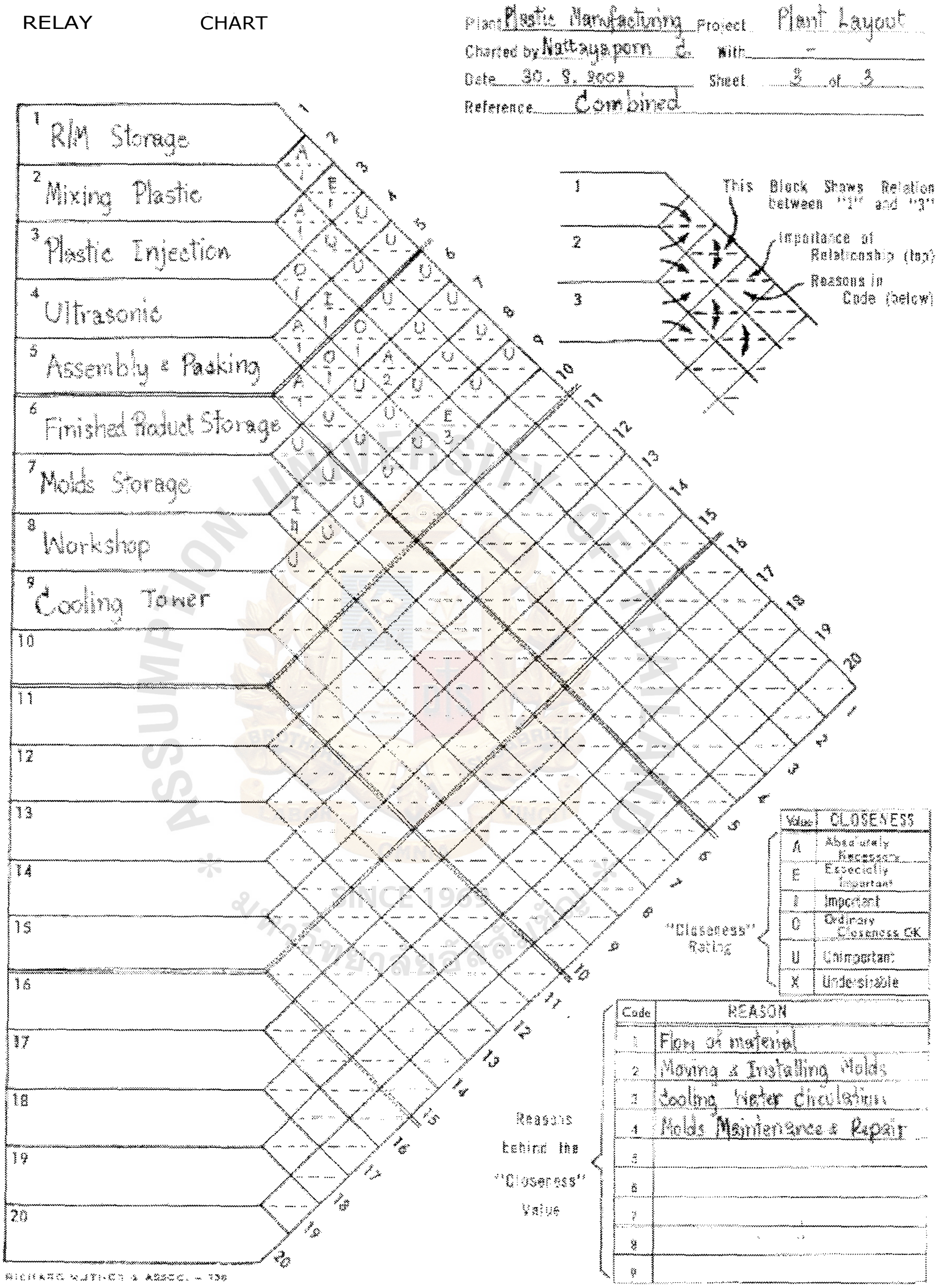


Figure 4.5. Relationship Chart (Combined).

The result of S.L.P pattern, There are four reasons in making consideration on closeness of each area which are flow of materials, molds movement & installation, cooling water circulation, and molds maintenance & repair. Therefore, the value is generated as follows:

Consideration of Flow of Material:

From collecting the data, flow of material is the main reason for six areas, which are raw material storage area, mixing plastic area, plastic injection areas, ultrasonic area, assembly and packaging area, and finished good storage area. In rating closeness relation, it considers the frequency and the percentage of the amount of material flow from and to each areas, as follows:

(a) Raw Material Storage is Absolutely necessary closeness with Mixing Plastic Area because there are around 60% of all plastic resins (main raw material) and all of pigments move from raw material storage to mixing machine.

(b) Raw Material Storage Especially Important closeness with Plastic Injection Area because there are around 40% of all plastic resins (main raw material) move directly from raw material storage to plastic injection area. But it is lower than the movement from raw material storage to mixing plastic area.

(c) Mixing Area is Absolutely necessary closeness with Plastic Injection Area because overall (100%) output from mixing area moves to plastic injection area.

(d) Plastic Injection Area is Ordinary Closeness OK with Ultrasonic Area because there is only 20% of outputs from plastic injection area further process to ultrasonic area, when compare with the outputs move to assembling & packaging area and move directly to finished good storage.

(e) Plastic Injection Area is Ordinary Closeness OK with Finished Product Storage because there is only 30% of outputs from plastic injection area go directly to finished goods storage. It is given the same rating because the amount of the outputs from plastic injection area move to ultrasonic area is nearly the same.

(f) Plastic Injection Area is Important Closeness with Assembly & Packing Area because there is 50% of outputs from plastic injection area move to assembly & Packing area but it is not frequency as the movement from raw material storage to plastic injection area.

(g) Ultrasonic Area is Absolutely necessary closeness with Assembly & Packaging Area because the 80% of outputs from ultrasonic area move to assembly & packaging area, which is more than the output from ultrasonic area move directly to finish goods storage area.

(h) Ultrasonic Area is Ordinary Closeness OK with Finished Product Storage Area because only 20% of outputs directly storage at finished product storage.

(i) Assembly & Packaging Area Absolutely necessary closeness with Finished Product Storage Area because 100% of outputs move to finished product storage.

Mold Movement and Installation:

Plastic Injection Area is Absolutely necessary closeness with Molds Storage because it will be more convenient to install molds in plastic injection machine and move back to storage at molds storage.

Cooling Tower Circulation:

Plastic Injection Area is Especially Important closeness with Cooling Tower because the more closeness can save the pipeline facility and pumping water. Cooling tower needs to locate outside of production building.

Mold Maintenance and Repair:

Molds Storage is Important Closeness with Workshop (Mold maintenance and repair) because the weight of molds, these two areas need to locate nearly. Therefore, molds can move to work shop easily. It is only important to be close to molds storage because the maintenance time is once a week or it may require in emergency cases.

4.4 Closeness Rating

Closeness rating is using number of line and length of line to indicate the value closeness between areas. Four lines is for Absolutely necessary closeness, Three lines is for Especially important closeness, Two lines is for Important closeness, and One line is for Ordinary closeness OK. The shorter lines are indicating more closeness needs between two areas. The following is the closeness rating from the working sheet of S.L.P. pattern:

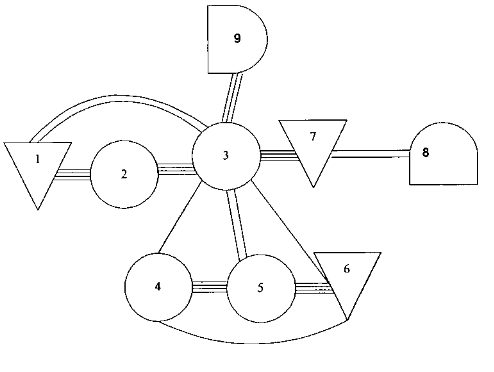


Figure 4.6. Closeness Rating No. 1.

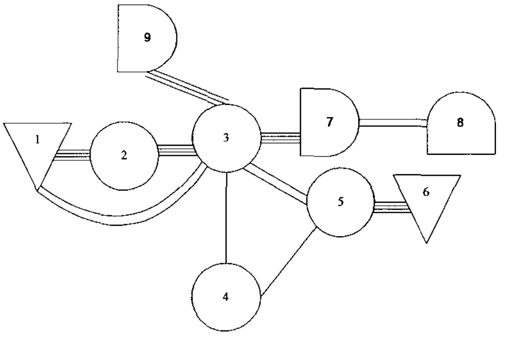


Figure 4.7. Closeness Rating No. 2.

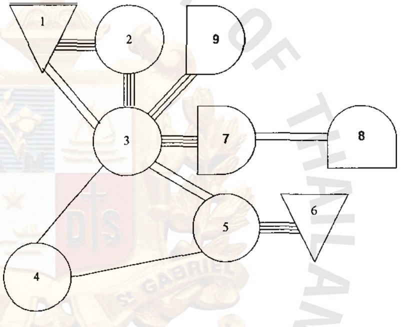


Figure 4.8. Closeness Rating No. 3.

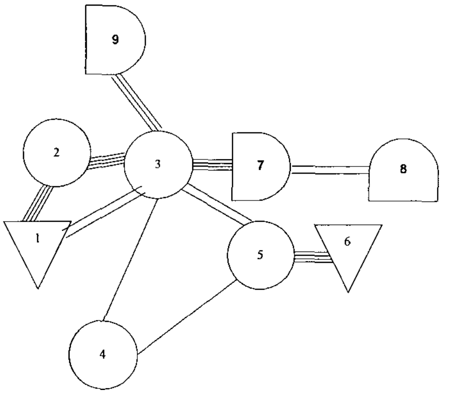


Figure 4.9. Closeness Rating No. 4.

4.5 Space Requirement

For the space requirement, only Cooling Tower area is fixed space. Other areas are rearranged to be more space utilization and effective in processing. The information for working space requirement is from processes observation and operators interview.

Raw Material Storage Area

Raw material storage area is divided into spaces for plastic resins, pigments, sticker, carton boxes, plastic bags, silicon spray, and trolley parking space. The unnecessary width of aisle between each materials consume large space requirement. From the above observation, rearranging space utilization can save the space storage from 90m^3 to 70m^3.

Mixing Plastic Area

In mixing plastic area, there are two mixing machines and space for plastic input and output product. While operation is in process, it is quick movement of raw material input to mixing loading and output product to plastic injection machines; therefore space of input and output can be reduced. The requirement of mixing plastic area decreases from 16m^3 to **1 2m^3**.

Plastic Injection Area

After observation and interviewing plastic injection operators, they require more space between each plastic injection machine for material movement, machine repair and maintenance, and molds installation. The space for plastic input and output product shall be increased for more storage. The existing plastic injection area is 192m^3, the space between each plastic injection machine is 1.40 m., which are too narrow and make trouble for operation. Then the length of plastic injection area shall increase from 24 m. to 27 m. and the width shall increase from 8m. to 8.5m. (Total space increases from 192 m^3 to 229.50 m^3).

Ultrasonic Area

The requirement of operators is to increase aisle in the area to move material in the operation area easily. The space area shall be expanded from $16m^3$ to $20m^3$.

Assembly and Packing Area

From observation, assembly and packing area is located near finished product storage, and then the output product from this process can be moved directly to finished product storage. Therefore, the space for keeping output product can be removed. The space requirement for this area shall be reduced from $40m^3$ to $20m^3$.

Molds Storage Area

The existing space is not sufficient for molds storage. The operators require more space for proper shelves storages. Each shelf requires 4.8 m^3 for shelf standing and molds movement. There are four shelves located; therefore the suitable space shall increase from $8.4m^3$ to $21m^3$.

Work Shop Area

In this area, operator requires the space for placing repair molds. Space 2m.x2m. can keep around 10 break down molds which is enough space for storage. The area of workshop shall increase from $16m^3$ to $20m^3$.

Total operation space in production building is $492.50m^3$. Figure 4.10 is summary of space requirement for each area.

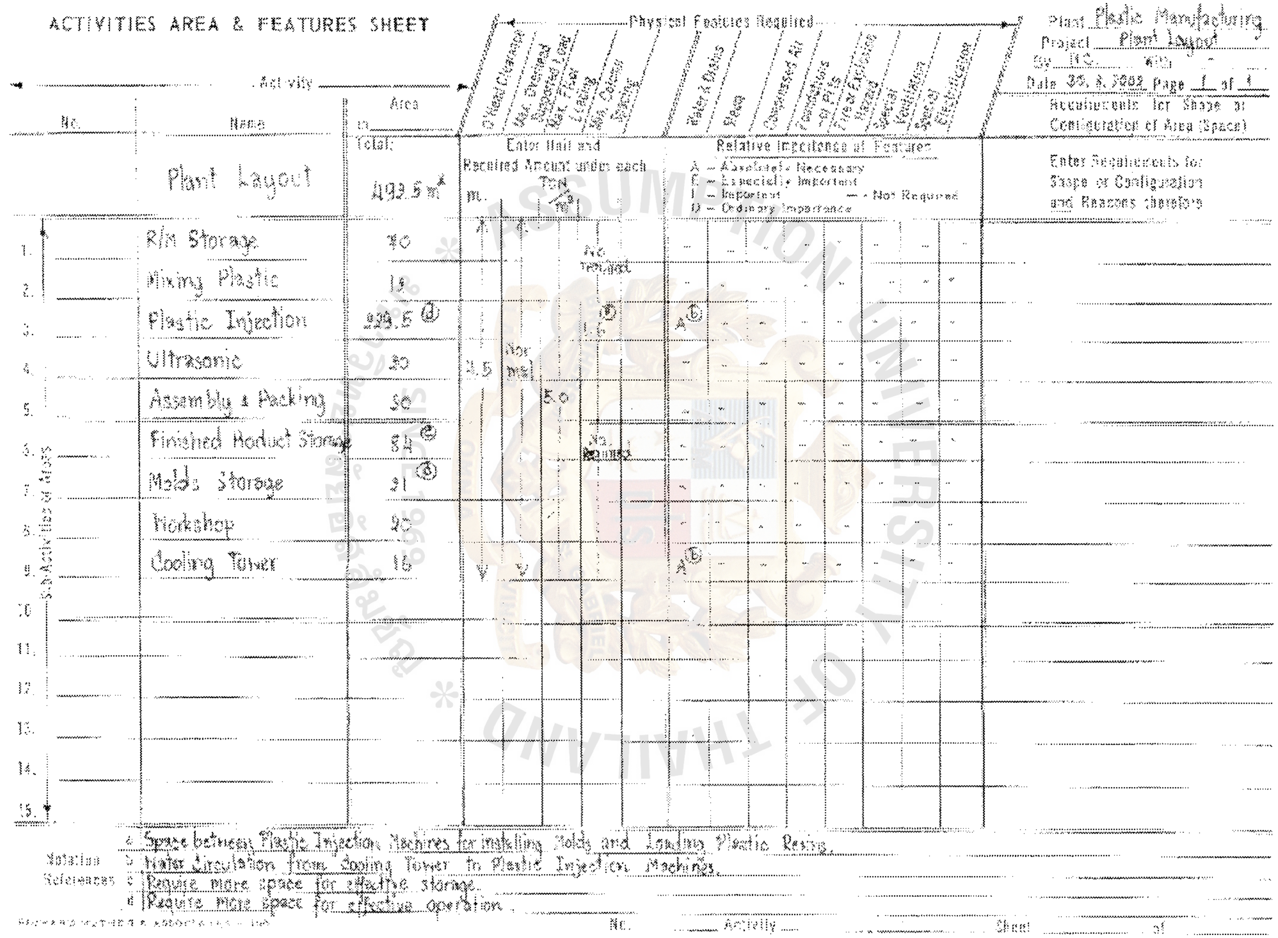


Figure 4.10. Space Requirement Sheet.

Mapping Area between closeness rating and space requirement:

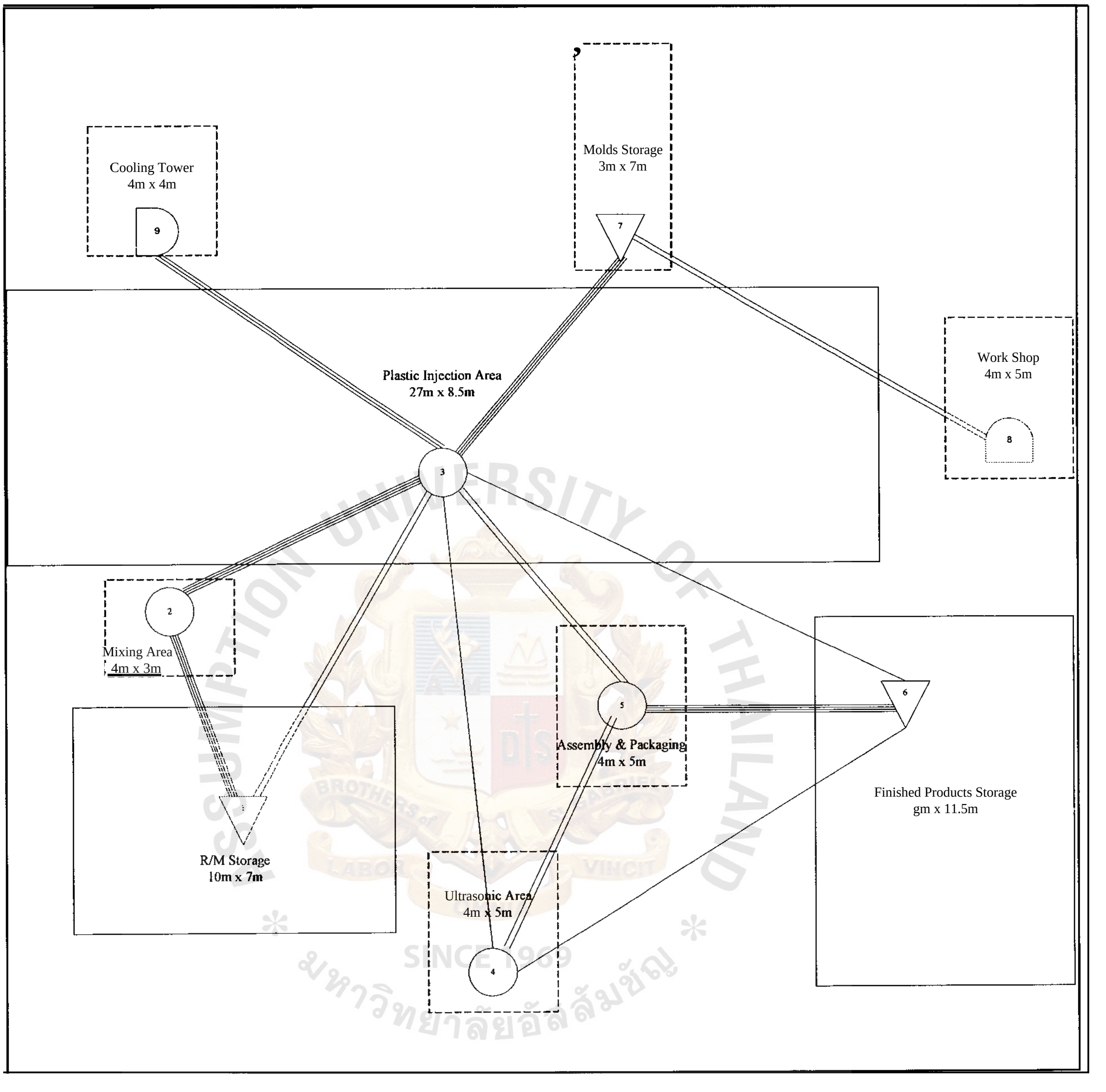


Figure 4.11. Space Relationship Diagram.

The space relationship diagram illustrates the closeness rating and space requirement for each area. The number of lines between each area means the movement of materials or activities.

4.6 Draw Space Relationship Layout

The relation in closeness rating and space requirement sheet is the important details to draw space relation layout. There are four relationship layouts, which are to be alternatives in choosing the effective new layout.

Relationship Layout Alternative 1:

The mixing plastic area moves to be closer to raw material storage. Ultrasonic and assembly packaging area moves to the middle of building close to plastic injection machine. The mold storage area is located at the same area, which is close to workshop area.

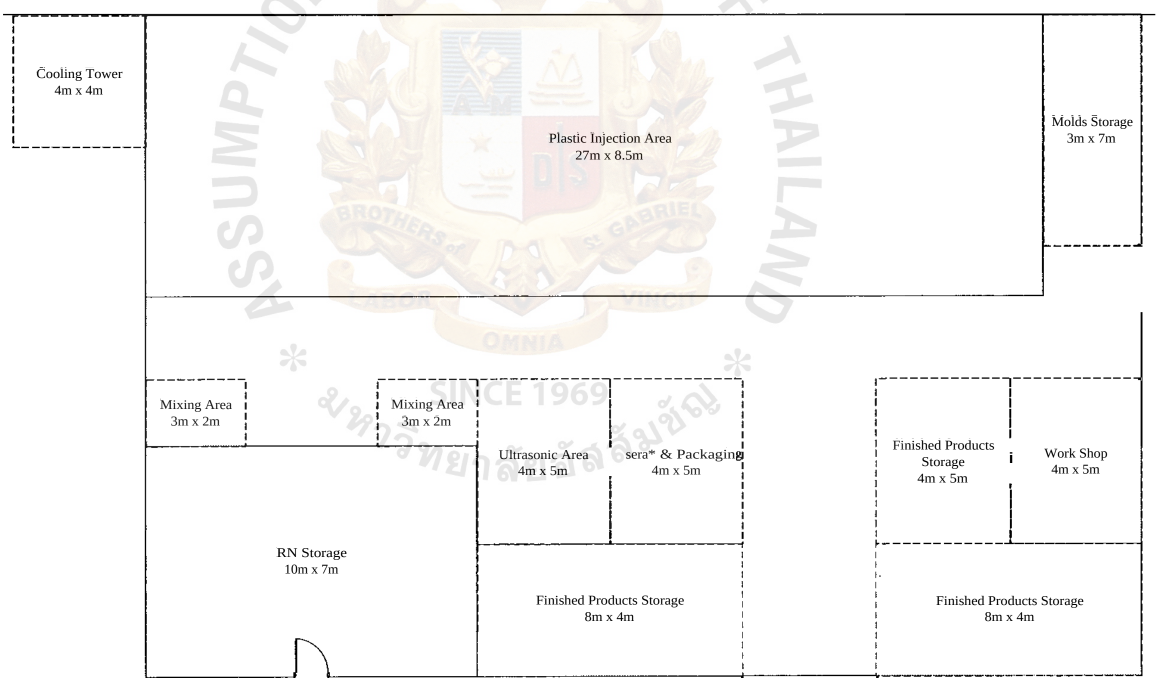


Figure 4.12. Relationship Layout Alternative 1.

Relationship Layout Alternative 2:

The mixing plastic area also moves to be closer to raw material storage. Plastic injection machine area is divided into two parts. Between them is located molds storages at the middle. Workshop moves from right to middle close to mold storages for convenience in maintenance and repair molds. Ultrasonic and assembly packaging area is moved to be closer to plastic injection machine. Finished goods storage is moved to close to the door for easier load.

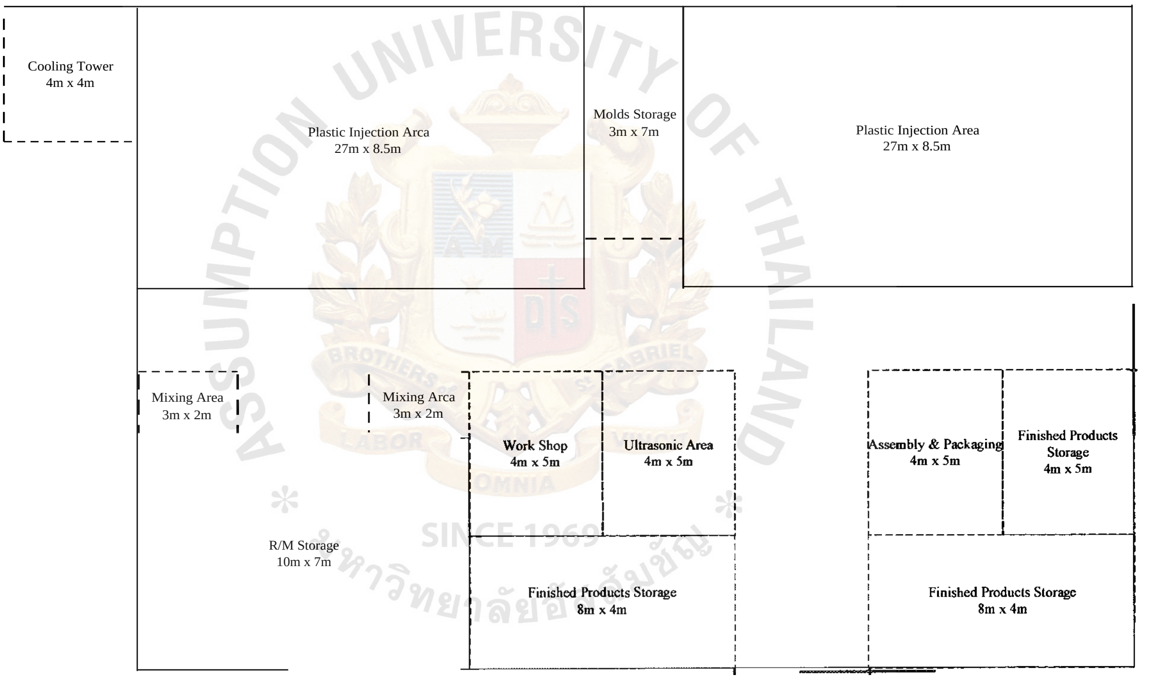


Figure 4.13. Relationship Layout Alternative 2.

Relationship Layout Alternative 3:

Assembly and Packaging area moves to the middle to be closer to the plastic injection machine area. There are two raw material areas for which one stocks plastic resins starting at mixing process, and another stocks plastic resins which are used directly on plastic injection machines.

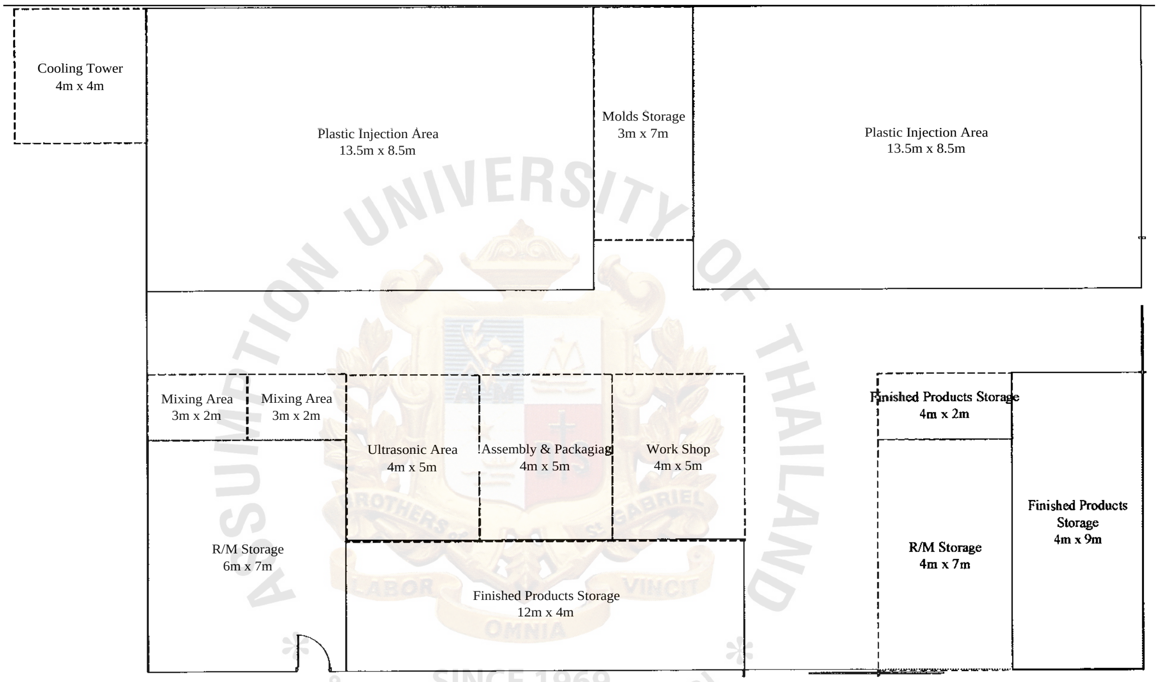


Figure 4.14. Relationship Layout Alternative 3.

Relationship Layout Alternative 4:

Finished Goods Storage moves to the right side of the building to close to doors for easier loading.

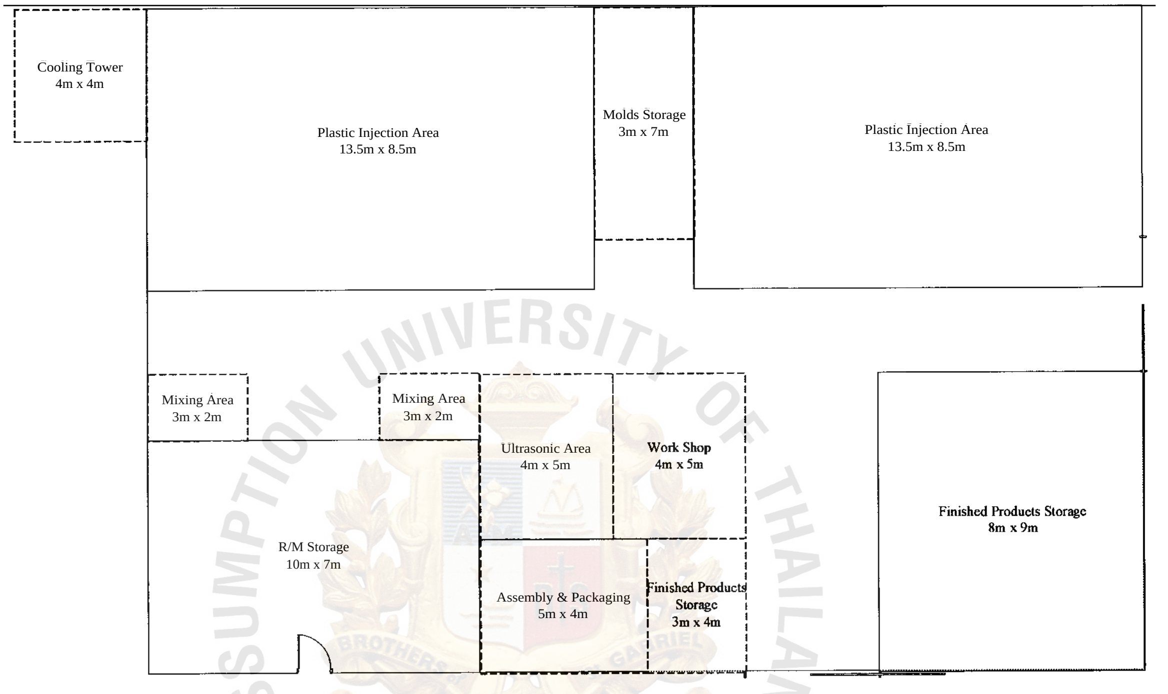


Figure 4.15. Relationship Layout Alternative 4.

4.7 Evaluation Relationship Layout Alternatives

There are six considerations in evaluation process, which are Convenient Material Movement, Effectiveness of Mold Movement and Installation, Effective Space Utilization, Flexibility and Ease of Expansion, Convenience for Receiving R/M and Loading of F/G., and Minimum Money Invest. The weight of consideration is 10, **10,** 5, 2, 8, and 5 respectively. After weighting of consideration, rating factor to existing layout and detailed layout is given by using A, E, I, 0, U to represent a descending order of effectiveness to meet factor objectives. A means almost perfect (=4), E means especially good (=3), I means important results (=2), 0 means ordinary results (=1), and U means unimportant result (=0)

ALTERNATIVES

Plant/Area: Plastic Manufacturing Project: Plant Layout Date: 6. 9. 2002

Description of Alternatives:

A. Relationship Layout Alternative 1

B. Relationship Layout Alternative 2

C. Relationship Layout Alternative 3

D. Relationship Layout Alternative 4

E.

Weight set by: ______ Ratings by: ______ Tally by: ______

	FACTOR/CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E	COMMENTS
1	Convenient Material Movement	10	A / 40	A- / 35	O / 10	O / 10		
2	Effectiveness of Molds Movement and Installation	10	I / 30	A / 40	A / 40	A / 40		
3	Effectiveness of Space Utilization	5	A / 20	E / 15	O / 5	O / 5		
4	Flexibility and Ease of Expansion	2	A / 8	A / 8	O / 2	I / 4		
5	Convenient for Receiving R/M and Loading F/G	8	A- / 26	A / 32	O / 8	A / 32		
6	Minimum Money Invest	5	E / 15	O / 5	O / 5	O / 5		
7								
8								
9								
10								
11								
12								
13								
14								
	TOTALS		131	135	70	96		

NOTES: A = ALMOST P[illegible]T (4), E = ESPECIALLY GOOD (3), I = IMPORTANT RESULTS (2)
O = ORDINARY RESULTS (1), U = UNIMPORTANT RESULT (0)

Figure 4.16. Evaluation Sheet.

Convenient Material Movement:

The weight rate for this factor is 10 score because it is one of the important operation activities. Material movement concerns raw material storage area, mixing Plastic area, plastic injection area, ultrasonic Area, assembly and packing area, and finished products area. Ratings to each alternative are the following:

A rating for relation layout alternative 1 because the proper closeness of each area is the best when compared with the other alternatives.

A- rating for relation layout alternative 2 because the overall area is close but there is much space between ultrasonic area and assembly & packaging area.

O rating for relation layout alternative 3 because raw material storage area is divided into two places at left and right side of building. This will cause the storage problem. And the movement of output product to keep at right side finished product storage is not efficient because it is far away from previous process.

O rating for relation layout alternative 4 because the movement of material from plastic injection area to assembly and packaging area is inefficient because it must pass ultrasonic area and there is aisle problem.

Effectiveness of Mold Movement and Installation:

The weight rate of this factor is 10 score because the effectiveness of mold movement and installation can save time from down time in changing molds. There are three areas, which are plastic injection area, molds storage, and mold maintenance and repair that are related.

A rating for relation layout alternative 2, 3, and 4, these three alternatives are given the same A rating because they are the same plan layout for plastic injection area, mold storage, and mold maintenance and repair. The molds storage locates at the middle of plastic injection area, this can save the molds movement and time.

I rating for relation layout alternative 1 because the movement of molds shall be moved to all the length of building to change or remove molds from the plastic machines, this causes more time movement and consume more electric power.

Effectiveness of Space Utilization:

The weight rate of this factor is 5, though this factor is concerned with the space of all areas, it is not the main factor in evaluating alternatives.

A rating for relation layout alternative **1,** the revised of space area is proper areas for effective space utilization. This alternative is the best effectiveness of space utilization because the arranging between areas is proper for operating activities.

A- rating for relation layout alternative 2, this alternative is also revise space areas to be more utilization but the effective movement of material such as plastic injection area and assembly is not close as relation layout alternative 1.

O rating for relation layout alternative 3 and 4, although they are too revised space areas (the same as relation layout alternative 1 and 2). They are also less effectiveness movement (refer to convenient material movement factor).

Flexibility and Ease of Expansion:

The weight rating of this factor is 2, there is no plan for near future expansion but the prompt expansion also is needed.

A rating for relation layout alternative **1,** this alternative arranges proper areas for expansion. Plastic injection machine can be added in plastic injection area and area of finished product storage can be changed to the other plastic processes.

E rating for relation layout alternative 2, there is not enough space for increasing capacity by adding a plastic injection machine but it can have additional type of process for increasing new product lines.

I rating for relation layout alternative 4 because the layout is also not much proper for expansion but it may not intercept with other processes.

O rating for relation layout alternative 3 because the layout of each area is not much proper for expansion; such as increasing another process, this will intercept material movement with other processes.

Convenient for Receiving Raw Material and Loading of Finished Goods:

This weight rating for this factor is 8 score. This factor is concerning about raw material storage, finished product storage, and receiving and loading docks.

A rating for relation layout alternative 2 and 4 because raw material and finished production storage are located near the doors.

A- rating for relation layout alternative 1, this layout is quite the same as relation layout alternative 2 but some finished product storage area is far from the door.

O rating for relation layout alternative 3 because the separate raw material storage can cause the storage problems in the future.

Minimum money invest:

The weight rating for this factor is 5 score. Though the re-layout of areas can cause operating effectiveness, the money invested is also one of the interesting factors in this economic situation.

E rating for relation layout alternative 1, relation layout alternative 1 uses the smallest money invested for re-location in operating building. Because of minor change, the small process areas move to be close with the plastic injection area (the major areas).

O rating for relation layout alternative 2, 3, and 4 because all of them shall move the plastic injection machines that cause a lot of money investment.

The result shows that relation layout alternative 2 is the highest score 135.5 points. From six considerations, there are also two factors rating A, two factors rating A-, one factor rating E, and only rating 0 for minimum money invest. Therefore, relation layout alternative 2 is chose to further detail layout process.

4.8 Detail Layout

The selected relationship layout alternative 2 shall plan detail layout for each area. Besides cooling tower area that is fixed, there are eight areas which are raw material storage area, mixing plastic area, plastic injection area, ultrasonic area, assembly & packaging area, finished products storage area, molds storage area, and workshop will be arranged as collected information from operators and observation processes.

Raw Material Storage Area:

The dimension of raw material storage is 10m. in length and 7m. in width. This space is divided into plastic resin storage, pigments storage, sticker storage, carton box storage, plastic bag storage, silicone spray storage, and plastic rework from plastic crushing machine. The aisle is not less than 65 cm. for material pick up.

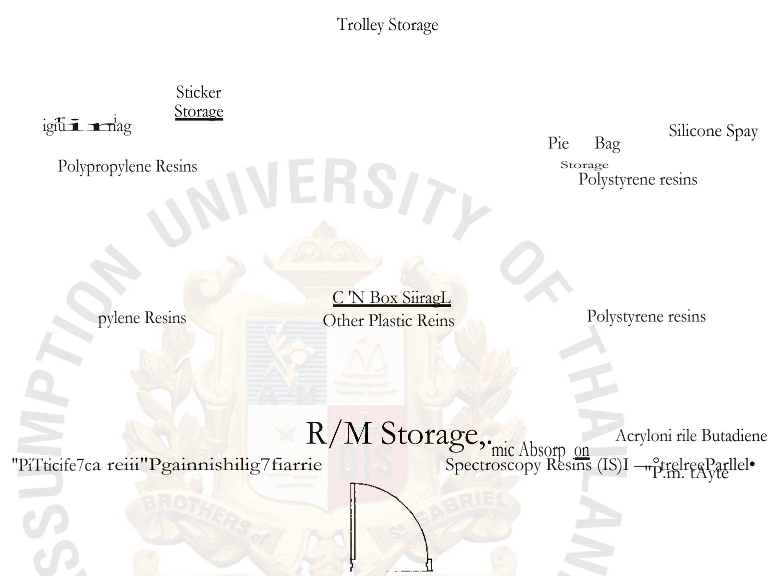


Figure 4.17. Raw Material Storage Area.

Plastic resins have high turn over rate. This area is located near the door for flexibility in receiving material. The major types of plastic resins that is stored in R/M storage area are Polypropylene resins, Polystyrene resins (PS), Atomic Absorption Spectroscopy resins (AS), and Acrylonitrlle Butadiene Styrene resins (ABS), Plastic rework from plastic crushing machine, and others (depending on customer order). The other materials, which are the pigments, sticker, carton box, plastic bag, and silicone spray, are stored at the front of raw material area for easier use. The spaces of each area are fitted with its size and the quantity order.

Polypropylene resins and Polystyrene resins have quite the same high material usage. The ordinary quantity order is 5,000 kilograms (200 bags), while the other is only 1,000 kilograms per order. Therefore, the space set up for each shall be more than others, are around 7.50 m^3.

Mixing Plastic Area:

Mixing plastic area is separated into two locations that are Mixing Area A (2m. x 3m.) and Mixing Area B (2m. x 3m.). The overall space arrangement is the same.

Figure 4.18. Mixing Plastic Area.

The space is divided into three parts that is mixing machine operation area, raw material for mixing process, and output product (storing for further process). Mixing machine-operating area requires more space for flexible in loading material in and out. The space for raw material for mixing process and output product is equal. Each load of mixing machine uses 2 bags of plastic (50 kilograms) at 10 minutes. And then the outputs products move to the plastic injection area. This process has quite high movement of material from raw material input to be output product; therefore the space of only $1m^2$ is enough.

Plastic Injection Area:

Plastic injection area is also separated into two parts that is plastic injection area A (13.5m. x 8.5 m.) and plastic injection area B (13.5m. x 8.5 m.). Each area is composed of four plastic machines, two spaces for raw material inputs, and two spaces for output products.

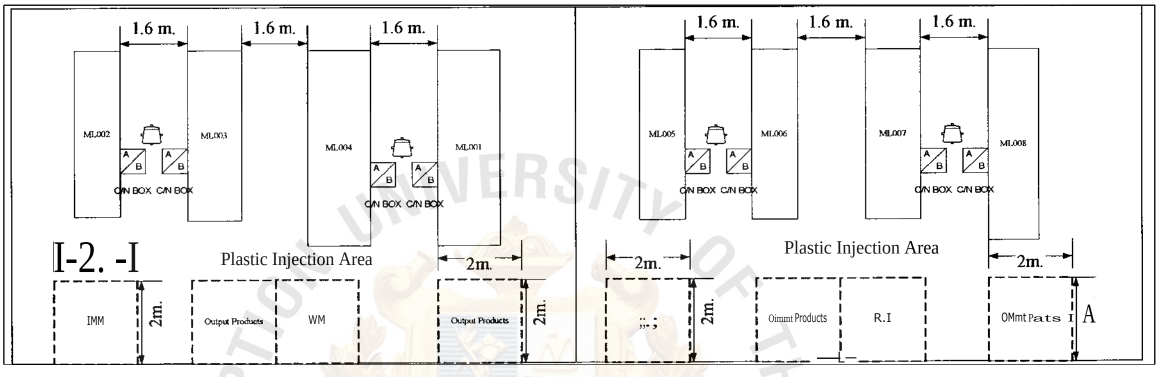


Figure 4.19. Plastic Injection Area.

For plastic injection area, each plastic machine shall keep the space of not less than 1.5m. from others for flexibility in operating process, machine maintenance and molds installation. In this new layout, the space between each plastic machine increased from 1.5m. to 1.6m to be more flexible in moving the output material. The finished output will be put in the carton box size 60cm x 60 cm. and then moved to the output space waiting for moving to the further process. The space of raw material input and output products also increases to more space for placing carton boxes.

Ultrasonic Area:

Ultrasonic area (4m. x 5m.) is set up for two ultrasonic machine operating and space for input material and output products. The aisles way between operator sections is expanded to be lm. for trolley and better working space.

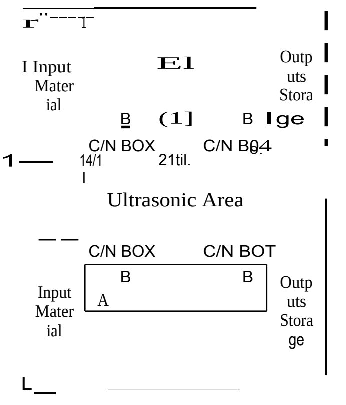


Figure 4.20. Ultrasonic Area.

Ultrasonic machine is placed on the top of desk size lm. X 1.5m. The carton boxes from previous process will be placed in the left, ultrasonic process, and then ordering output products in right carton box.

Assembly & Packing Area:

Assembly & packing area (4m. x 5m.) composes of input material storage (3m. x 1m.), a table size 80cm. x 180 cm. and Shrink-packaging machine.

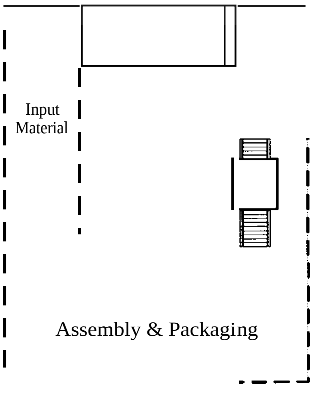


Figure 4.21. Assembly & Packaging Area.

Input Material space is for stocking output product from ultrasonic process and plastic injection machine. There is no output storage space because this process is located near finished products storage. The output product shall move directly to finished products storage.

Finished Products Storage Area:

Finished Products Storage Area is separated to finished products storage A (32 m^2) and finished products storage B (62 m^2).

Figure 4.22. Finished Products Storage Area.

Both the two areas are located near loading doors. Finished products storage A is for storage finished output products from ultrasonic process and plastic injection process. Finish product storage B is for storage finished output products from plastic injection process and assembly & packing process.

Mold Storage Area:

There are totally four mold shelves in this area. Each shelf shall have spacing 1.5m. to flexibly store and move molds.

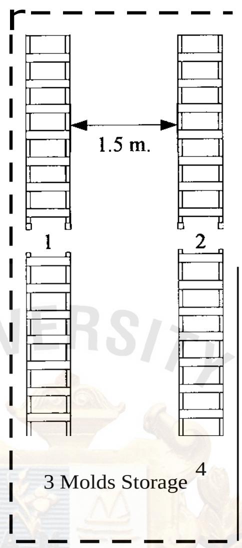


Figure 4.23. Molds Storage Area.

Work Shop:

Work shop area shall have sufficient space for trolley to loading molds to work shop. A table set, two steel shelves, two table shelves, and cabinets are arranged to have more space for flexible moving molds.

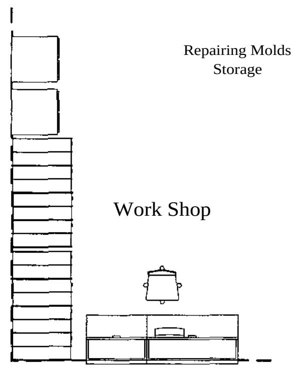


Figure 4.24. Work Shop Area.

Detail Layout Plan of the Selected Relationship Alternative:

From the above detail layout area, each area is mapping in the plan layout. The plastic production building is shown below:

Figure 4.25. Final Plastic Plant Layout.

V. EVALUATION OF THE EXISTING LAYOUT AND THE SELECTED DETAILED LAYOUT

The evaluation between existing layout and selected detailed layout uses five intangible considerations, which are Convenient Material Movement, Effectiveness of Mold Movement and Storage, Effectiveness of Space Utilization, Flexibility and Ease of Expansion and Convenience for Receiving R/M and Loading of F/G. The weight of consideration that concerns about production effectiveness is 10, 10, 5, 2, and 8 respectively. Implementation does not include evaluation process; therefore there are not enough statistic data for using tangible consideration. After weighting of consideration, rating factor to existing layout and detailed layout is given by using A, E, I, 0, U to represent a descending order of effectiveness to meet factor objectives. A means almost perfect (=4), E means especially good (=3), I means important results (=2), 0 means ordinary results (=1), and U means unimportant result (=0)

Figure 5.1 shows the summary of evaluation between existing layout and selected detailed layout.

EVALUAT G ALT T,VES

Plant/Area Plastic Manufacturing Project Plant layout Date 21. 9. 2001

Description of Alternatives: A. Existing layout

B. Selected Detailed layout C.

D. E.

Weight set by Ratings by Tally by

FACTOR/CONSIDERATION	WT.	A	B	C	D	E	COMMENTS
		RATINGS AND WEIGHTED RATINGS					
1 Convenient Material Movement	10	E 30	A 40				
2 Effectiveness of Mold Movement and Storage	10	O 10	A 40				
3 Effectiveness of Space Utilization	5	E 15	A 20				
4 Flexibility and Ease of Expansion	2	A 8	E 6				
5 Convenient for Receiving R/M and loading F/G	8	E 24	A 28				
6							
7							
8							
9							
10							
11							
12							
13							
14							
TOTALS		87	134				

NOTES A = ALMOST PERFECT (4), E = ESPECIALLY GOOD (3), I = IMPORTANT RESULTS (2)
O = ORDINARY RESULTS (1), U = UNIMPORTANT RESULT (0)

RICHARD MUTHER & ASSOCIATES

Figure 5.1. Evaluation Sheet of Existing Layout VS Selected Detailed Layout.

Convenient Material Movement:

The weight rate for this factor is 10 score because it is the core of operation activities. Material movement concerns with 6 areas, which are raw material storage area, mixing Plastic area, plastic injection area, ultrasonic area, assembly and packing area, and finished products area. In rating factor, the convenient material movement between areas is rated by the closeness of each continuing process and the clear path of material flow for the effectiveness of sequenced working operations. The rating is given below:

E rating for existing layout

Reason:

(1) Long distance between continuing area: The mixing area is located at the left side of operation building. The output of mixing area moves long distance to plastic machines, which is located at the right side.

(2) Ineffective operation space: The space between plastic machines is too narrow for material flow.

A rating for selected detailed layout

Reason:

(1) The closeness of continuing process areas is properly arranged: Plastic injection area is the center of plastic operation. This detailed layout is setting the other relating areas is located around plastic injection area for effective material flow.

(2) More convenient for trolley transport: The aisle width of each area is designed for trolley to reach materials.

Effectiveness of Mold Movement and Storage:

The weight rate of this factor is 10 score because the effectiveness of mold movement and storage can reduce molds installation time. The minimum of machine down time also can increase productivity. There are three areas, which are plastic injection area, molds storage, and workshop (mold maintenance and repair), are related. Rating of each layout is considered by molds handling economy on the distance between molds storage and plastic injection machine and the distance between molds storage and workshop, as well as effectiveness of molds storage. The rating is given below:

O rating for existing layout

Reason:

(1) Not enough space for molds storage: Molds are not properly kept and stored. This cause may spend much time for searching the mold.

(2) Long distance between molds installation area and plastic injection machines: The hoist must move from right to left over seven machines to the first plastic machine.

A rating for selected detailed layout

Reason:

(1) Effectiveness of molds storage: Molds shelves are available and sufficient in controlling the effectiveness of molds storage.

(2) Saving time for mold movement from molds shelves and plastic injection machine: This detailed layout locates molds shelves at the middle of plastic injection area. Therefore, it is shorter distance for molds movement.

Effectiveness of Space Utilization:

The weight rate of this factor is 5 score. Space utilization does not directly affect material flow but it only supports for using space the most beneficially and effectively. Every area is concerned with this factor. The rating is given below:

E rating for existing layout

Reason: Too much unused space: There are unused space remaining or large aisle width in raw material storage area, mixing plastic area, and assembly and packing area, while finished product storage requires more space.

A rating for selected detailed layout

Reason: Re-arrange detailed layout can save space to be more effective. Reducing raw material area can save space to locate mixing machines and expanding finished product storage.

Flexibility and Ease of Expansion:

The weight rating of this factor is 2 because there is no plan for near future expansion. Even though, ready for expansion is also needed. This factor is concerned with the flexible layout in expanding manufacturing capacity or additional process. The rating is given below:

A rating for existing layout

Reason: There are remaining spaces for increasing production capacity by increasing a plastic injection machine or additional process for more output product line.

E rating for selected detailed layout

Reason: Not enough space for increasing a plastic injection machine but can additional process for making new product line.

Convenient for Receiving R/M and Loading of F/G:

This weight rating for this factor is 8 score because the convenient for receiving raw material and loading finished products can make effective material movement. This factor concerns with material storage area, finished product storage area and receiving and loading docks. The rating is given below:

E rating for existing layout

Reason:

(1) Narrow raw material storage door: The open door for receiving raw material is only 1 m., therefore, it is an important obstacle in placing material.

(2) Take more time for finished products loading: Finished product area is located at the middle of building, is near only one 4m. slide door. Therefore, it consumes more time for loading than located near both two 4m. slide doors.

A- rating for selected detailed layout

Reason:

(1) Narrow raw material storage door: This is also the same as obstacle of existing layout but it is the building structure which is difficult to change.

(2) Near loading doors: Finished product storage is divided into two areas, that are finished product storage A area, located near middle slide doors and finished product storage B area, located near right slide doors. They are both shorter distances for finished product loading.

From the above evaluation, the totally mark is 140. The selected detailed layout got 134 scores while existing layout got only 87 score. This shows that selected detailed layout can bring more production effectiveness than existing layout because it arranges areas to support both production process and supporting & equipment flow process.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Designed Layout Planning is the study to help entrepreneurs to reach effective production layout especially Thai economic crisis as of now. Plastic product manufactures try to find ways to survive from this crisis. The study of layout planning will provide alternative benefits in saving losses that occurred in production area, in order to generate high profit of company.

The major current problems, which happened on Plastic Product company, are:

(1) Ineffective machinery layout

(2) Lack of good spare parts (mold) and raw materials storage system

(3) Inflexibility of production process

The scope and deliverable of this study is to re-layout production machines in production process by applying factory layout planning concepts. Plant layout embraced the physical arrangement of industrial facilities. This arrangement which will be made either installed or in plan, includes the spaces needed for material movement, storage, indirect laborers, and all other supporting activities of services, as well as for operating equipment and personnel.

Types of Layout:

(1) Layout by fixed position or by fixed material location: This is a layout where material or major component remains in fixed place or is not able to move. This is used when the product is too large to move through the various processing steps.

(2) Layout-by-process or layout-by-function: The process layout consists of a collection of processing departments or cells together. All machines, which

performed a particular process, are grouped together in this layout. This is suitable for low volume output products.

(3) Line production or layout-by-product: One product or one type of product is produced in one area. This layout is unlike fixed position layout because the materials are movable.

(4) Group Layout: The group layout is used when production volumes for individual products are not sufficient to justify product layouts.

Factors Influencing Plant Layout

(1) Material factor contains of size, shape and bulks.

(2) Machinery factor concerns are machine space for shape and height.

(3) Man factor concerns are safety and working conditions.

(4) Movement factor concern is flow pattern or routing.

(5) Waiting factor counts whenever our production includes permanent and temporary storages and delays.

(6) Service factor includes maintenance, inspection, waste, scheduling and dispatching either men, services relating to materials and machineries.

(7) Building factor is special or general-purpose building, single or multistory construction, shape, basement or balcony, window, floors, roofs.

(8) Change factors include versatility, flexibility and expansion.

Four phases of systematic layout planning are (1) Location; determines the location of the area to be laid out, (2) General overall layout; determines the establishing of general arrangement of area. (3) Detailed layout plans determine each specific piece of machinery and equipment, aisle and storage area for each activities. (4) Installation; determines plan for installation or seek the approval of the plan

The SLP procedure can be depicted graphically. In comparison with steps of the design process, the first five steps of SLP involve the analysis of the problem. Step 6 through 9, including generation of alternative layouts, constitute the search phase of design process. The SLP pattern starts with five base elements P (product), Q (quantity), R (routing), S (supporting service), and T (time). The flow of materials analysis is based on Product (P), Quantity (Q), and Routing (R).

Plant layout of plastic company is divided into operation building, office, plastic crusher, company truck parking, and employee's home, restroom and garbage area. Plastic crusher area separated from the other area. There is one machine used for crushing unqualified and waste plastic output. Production area is on one floor building. Within this area, we can separate it into raw material storage, plastic mixing area, plastic injection area, ultrasonic area, assembly & packing area, finished products storage, workshop, mold storage area, and cooling tower. Plastic injection area is the largest area, which is composed of plastic injection machines, raw material storage area, output plastic product storage. Ultrasonic plastic welder area required space for two ultrasonic plastic welder machines for input and output raw material product. Assembly & packing area is area, which consists of a shrink-packing machine for wrapping products. Mold storage area, mold are placed on the floor. Workshop area is utilized for maintenance and repairing molds and other equipment. It consists of working table, two steel shelves, two wood shelves and two closets in keeping tooling instruments. Cooling Tower is located outside production building. It requires air and good water system for cooling system. Company has classified production flow process into 2 processes, which are production process and support & equipment flow process. Production flow process divide into 4 processes; Plastic mixing process, Plastic Injection, Ultrasonic

Plastic Welder, Assembly & Packing. For supporting & equipment flow process can divide into mold movement and cooling water system.

For Data Collection and Preliminary Analysis, molds are too heavy so "Movable Hoist" is helped the operators in doing any activities with molds. The hoist also helps staffs to carry molds to and from injection machines. For mold changing, operator will move hoist to mold storage then move to plastic injection machine and returning back to mold storage via hoist. Mold storage is applied for saving production space. There are five levels, which contain eight molds per level. Each rack can be drawn forward for easily picking up to movable hoist. Raw material storage is absolutely necessary closeness with mixing plastic area and is especially important closeness with plastic injection area. Mixing area is absolutely necessary closeness with plastic injection area. Plastic injection area is ordinary closeness with ultrasonic area. Plastic injection area is ordinary closeness with Finished product storage and is important closeness with assembly & packaging area. Ultrasonic area is absolutely necessary closeness with assembly & packaging area and is ordinary closeness with finished product storage area. Assembly & Packaging area is absolutely necessary closeness with finished product storage area. Raw material storage area is divided spaces for plastic resins, pigments, sticker, carton boxes, plastic bags, and trolley parking space. For mixing plastic area, there are two mixing machine and space for plastic input and output product. For plastic injection area requires more space between each plastic injection machine for material movement, machine repair and maintenance, and molds installation. For ultrasonic area should locate near finished product storage, then the output product can move directly to finished product storage. For work shop area requires the space for placing repair molds.

For overview layout, keeping mixing plastic area close with raw material storage. Plastic injection machine area is divided into two parts by putting molds storage at the middle. Workshop moves to middle closed to mold storage for convenience in maintenance and repair molds. Ultrasonic and assembly packaging area are closed to plastic injection machine. Finished goods storage put close to door for easier loading.

The evaluation among existing and selected detailed layout with 5 intangible considerations (Convenient Material Movement, Effectiveness of Mold Movement and Storage, Effectiveness of Space Utilization, Flexibility and Ease for Expansion and convenient for Receiving R/M and Loading F/G. Convenient material movement for selected layout compared with existing are both convenient for trolley transportation and also closeness with continuing process area. In point of effectiveness of mold movement and storage compared between selected layouts with existing, the selected layout is time saving and effective storage due to available and sufficient of mold storage. For space utilization effectiveness, selected layout can save space compared with existing due to reducing raw material area, which located at mixing machines and finished product storage. For flexibility point, the selected layout is planned to utilize all space more than existing as plant do not have plan for plant expansion in short term basis.

6.2 Recommendations

From the study of production layout, the selected detailed layout nearly reaches all factors' requirement, which are Convenient Material Movement, Effectiveness of Mold Movement and Storage, Effectiveness of Space Utilization, Flexibility and Ease of Expansion, and Convenient for Receiving R/M and Loading F/G. Though this layout is the most space utilization and effectiveness of production when comparing with existing layout and other alternatives, there is also some improvement areas of this selected detailed layout that is hard for future expansion due to full space occupied capacity. The space limitation of this company will become the important problem for capacity expansion in long-term business.

As this research is concerned only with operation building layout because plastic manufacturer already has good overall plant layout. In this project observation, the overall plant layout also has some development points to achieve more effectiveness in both space utilization and layout. For example, this existing layout is designed 3 years ago. At that time most infrastructure like accommodation and transportation was not available of good standard for employees' living. Therefore, the company needs to build employees' home within the plant area. As of now, the infrastructure has improved to standardize. And there are plenty of houses or apartments at reasonable price around the plant. It may be better for company in asking employees to live outside the plant by sponsoring part of rent. Then company can use employees' home area for future operation expansion. This recommendation will enhance company to overcome space limitation for expanding operation.

Another recommendation based on the result of this study, the selected detailed layout can reduce headcount of manpower in operating area from 28 persons to 24 persons. Then company may have alternatives to save headcounts by laying off or moving to another department like maintenance department due to high production volume rate may generate high maintenance rate. Or company may utilize over manpower on having further research to increase or innovate production process to deliver the plastic product differentiation from competitors. This can help company to achieve either good marketing position over competitors or supplying the variety products in line with consumers' requirement.

Besides the study of effective plant layout, another interesting topic is Inventory planning. This recommendation is able to help plastic product manufacturer in both terms of material price acquisition or inventory controlling. For material price acquisition, the plastic product manufacturer can apply effective inventory planning as the most key important factors for efficient operation. For example raw material, price of plastic resins is the key concerns of this plastic industry. As there are many factors that can influence the raw material price fluctuation, this effective planning technique is able to apply in helping the plastic product manufacturer in reaching the competitive price at the material acquisition process. Plastic product manufacturer can apply this key effective inventory planning for preparing contract in advance to prevent risks. The risk of resins price has been influenced by foreign exchange rate or oil price. Based on this influence, sometime the resins price can increase up to 10 baht per kilogram. And based on high price of raw material, effective inventory planning also helps plastic product manufacturer in sourcing the material substitution, which has similar specifications to replace the high cost. Therefore, the effectiveness of inventory planning can help company to save the raw material cost. This will also help plastic product manufacturer in obtaining more opportunities in either having a better product cost structure compared with other plastic product manufacturers and able to deliver the reasonable price with high quality to customer.

For inventory controlling point, raw material of plastic product manufacturer has consumed many tons in one production order. This inventory planning can help plastic product manufacturer in preventing shortage of raw material during production operation. This will help plastic product manufacturer to prevent discontinuity of production running and operation line shutting down. And also effective inventory planning will help plastic product manufacturer in terms of having the appropriate level stock keeping in warehouse.

APPENDIX A

FACTORS OR CONSIDERATION IN SELECTING THE LAYOUT

FACTORS OR CONSIDERATION IN SELECTING THE LAYOUT

When evaluating alternative layouts there are many factors that can affect the selection of the most suitable plan. The factors most frequently identified are listed below. A definition of each is also given. Then key point to consider in making and evaluation are set forth. These factors, definitions, and key points- in making an evaluation are set forth. These factors, definitions, and key points-in a consolidated form or together with others that may be added as appropriate for a particular company or project-can be extremely helpful in keeping a clear understanding and meaning for each factor during the process of evaluation.

1. EASE OF FUTURE EXPANSION *(The simplicity of increasing the space employed.)*

a. Tie-in with long-range potential use of the space,
with the future plans for building or property development,
with the basic overall allocation of space, and
with the overall flow pattern(s).

b. Ability to spread out to adjacent areas beside, above, below,
to encroach on readily moved storage or service areas, or
to add vertical storage equipment, balconies, mezzanines.

c. Freedom from fixed or permanent building features,
from divided or honeycombed areas, and
from space blocked-in by physically long equipment, property lines, natural obstruction or limitations, and the like.

d. Regularity of allocated space amounts in terms of
readily exchangeable amounts and types of areas,
modular units of layout space, multiple unit areas.

e. The amount of disruption or rearrangement of areas of the than the one(s) specifically area expanded.

f. Shrink ability - ease of contracting the layout economically, to cut down the size if necessary.

2. ADAPTABILITY AND VERSATILITY *(The ease of accommodating, in the layouts as planned (without rearrangement), changes (normal or emergency) in, and variety (or number) of items like the following.)*

a. Product, materials, or items
b. Quantity or volume
c. Frequency of delivery
d. Process equipment
e. Operation sequence
f. Working methods and operation time
g. Handing or storing methods
h. Utilities or auxiliaries
i. Other services
j. Type or classification of employees
k. Time-keeping or out system
l. Hours of work
m. Material dispatching procedure
n. Inspection controls
o. Rework procedures
p. Standby equipment
q. Additional space for stock
r. Alternate routes
s. Test runs, pilot lots, experimental engineering.

3. FLEXIBILITY OF LAYOUT *(The ease of physically rearranging the layout to accommodate change.)*

a. Mobility of machinery and equipment
b. Relative size and fixity of \equipment
c. Standardization of equipment, containers, work places
d. Freedom from fixed building features or walls, un-matching floor, other barriers
e. Overly dense saturation of space
f. Independence or self-sufficiency of facilities (not dependent on central coordination or centralized service tie-in)

g. Ready accessibility of service lines, piping power distribution, heating and ventilating, service holes, etc.

h. Access to the area laid out at more than one pint or side

4. FLOW OF MOVEMENT EFFECTIVENESS *(The effectiveness of sequenced working operations or steps-without unnecessary pack-tracking, cross flow, transfers, long hauls-of materials, paper work, ort people.)*

a. Greatest flow intensities with minimum distances

b. Basic regularity or consistency of flow pattern(s)

c. Proximity of related areas to each other where movement of material, people, or major paper work is involved, or where frequent, urgent or significant personal contact takes place

d. Access to, away from, and between major areas (like receiving, shipping , key operating areas)

e. Flow of auxiliary or service materials: supplies, tools, scrap or waste, and other service materials

f. Accessibility for delivery and pick-up, visitors, or employed non-company service personnel

5. MATERIALS HANDLING EFFECTIVENESS *(The ease or simplicity of the handing system, equipment, and containers to move materials in to, through, and out of the areas laid out.)*

a. Ease of tie-in with external handling methods and equipment: rail line, docks, highway, and other access ways

b. Necessity for re-handling, extra handing, delays awkward positioning, undue physical effort, undue dependence on frequency or urgency of moves, undue amount of jury-rig or non-integrated equipment

c. Traffic congestion and interferences other than due to flow pattern

d. Balanced variety of handling systems, equipment and containers

e. High utilization of handling equipment and containers

f. Simplicity of handling devices

g. Equipment integrated for multiple use

h. Dependence on M. H. equipment on maintenance, repair, replacement parts

i. Avoidance of synchronizing two or more people at same time or place

j. Ability to move completely around buildings on company property

k. Take advantage of gravity

l. Combined purposes of handing equipment for storing pacing, sequencing, inspection, work-holding, weighing and the like, as well as moving

6. STORAGE EFFECTIVENESS *(The effectiveness of holding required stocks of materials, parts, products, service items.)*

a. Inclusion of all storage — raw, in-process, finished goods, supplies, tools scrap or waste, trash and equipment or materials not in current use

b. Accessibility of items stored

c. Ease of locating or identifying items stored

d. Ease of stock and inventory control

e. Ability to make stored items available according to urgency of demand

f. Protection of material (fire, moisture, dust, dirt, neat, cold, pilferage, deterioration, spoilage.)

g. Adequacy of storage space (s)

h. Suitably close to points of delivery and use

7. SPACE UTILIZATION *(The degree to which floor area and cubic space is put to use.)*

a. Conservation of floor space, property, or land-or most desirable portions thereof

b. Utilization of overhead space in terms of cubic density

c. Ability to share or exchange space among similar activities, and balancing of areas with seasonally complimentary space requirements

d. Effectiveness of aisle space :
To serve areas adjacent to them,
To lead to areas needing access,
To handle traffic without wasting space or without excessive aisle ways (too few, too many, too wide, too narrow, too cornered or crooked, too angular.)

e. Waste or idle space, caused by split, divided, cornered, scattered or otherwise honeycombed structures, too-close columns, too-frequent partitions or walls.

f. Less desirable or out-of-way space utilized for slow, dead areas; convenient space for fast, active areas

8. EFFECTIVENESS OF SUPPORTING SERVICE INTEGRATION *(The way supporting areas are arranged so as to serve the operating areas.)*

a. Ability of existing (or planned) systems, procedures, and controls to work effectively with the layout, including: production planning, scheduling and control, time-keeping, material or stock issuing, work count, too control, personnel records, receiving and shipping system

b. Ability of the layout to integrate with desired or effective pay plans, performance measure, cost reports, lot size, order quantities

c. Physical closeness of service areas according to each area's need for the service (actual versus desired relationships.)

d. Ability of the utilities, auxiliary service lines, and central distribution or collection systems to serve the layout. (Compressors, steam generators, transformers, chargers, and the like, and their accompanying pipes, ducts, wiring, etc.)

e. Service convenience of baler, salvage equipment, reclaim, incinerators, filter beds, scrap collection, and similar waste control areas or equipment

f. Ability of engineering groups, and technical advisors to support the layout effectively.

9. SAFETY AND HOUSEKEEPING *(The effect of the layout and its features on accidents or damage to employee and facilities, and on the general cleanliness of the areas involved.)*

a. Basic regularity of the aisles and work areas, degree of freedom from equipment protruding into aisles or work areas, congestion, blind corners

b. Degree to which all safety codes and regulations are satisfied

c. Risk of danger to people or equipment

d. Availability of adequate exits and clear escape ways

e. First-aid facilities and fire extinguishers nearby

f. Floors free of obstructions, spillage, and mess, and not overly congested

g. Adequate protection or segregation for dangerous or unsightly operations

h. Workers not located under or above unprotected hazards;
Workers not located too near moving parts, unguarded equipment, and other hazards

i. Workers able to get benefit from special safety devices or guards

j. Effectiveness of ways to clean or clear area of waste, offal, trimmings, trash

k. Ease of keeping areas clean, sanitary, snow-white, under controlled conditions

10. WORKING CONDITIONS AND EMPLOYEE SATISFACTION *(The extent to which the layout contributes to making the area (s) a pleasant place to work and free from inconveniences, awkwardness, or disruptions for employees.)*

a. Effect of layout on attitude, performance of general morale of employees

b. Working conditions suitable to the type of operation

c. Suitability of the layout arrangement and allocated space to the personnel

d. Convenience for employees-access, distances, interruptions, delays, and adequacy and convenience of parking, lockers, rest rooms, food facilities, etc.

e. Freedom from features causing workers too feel afraid, hemmed-in, embarrassed, discourage, discriminated against

f. Noise, distraction, or undue heat, cold, drafts, dirt, glare, or vibrations

g. Utilization of employee know-how and skills

h. Balanced man-power allocations

APPENDIX B

PLASTIC PROCESSING

PLASTIC PROCESSING

Plastic is used predominantly in most products. It can be molded to fit almost any shape and has attributes such as strength, durability, flexibility, and visual appeal. In a large-volume production, use of plastic also become economically viable. Plastic can be recycled, thus reducing waste during production and harm to the environment. Following are some of the processes associated with plastic parts.

Compression Molding

Material that is either in a granulated state or in the form of tablets is placed in a heated mold, where heat softens the material. When the mold is closed and pressure is applied, it cause the softened material to flow and take the shape of the mold. The mold is cooled before the part is ejected; otherwise distortion of the part may result. The process is used mainly for parts made of thermosetting plastics having a uniform wall with thickness of less than 1/8 inch. The process is slow, sometimes taking as much as three minutes per part.

Injection Molding

Injection Molding is much faster than compression molding and is used when thermoplastic can be repeatedly transferred in states from solid to liquid to solid without changing the chemical properties. Granular material is loaded in a heated cylinder and melted. A rotating table with multiple molds is locked in to the injection press and softened material is injected into the mold through a nozzle. As the table rotates, a new mold is attached to the nozzle, allowing the previous mold to cool and the next mold to continue operation without delay. The finished part is then removed from the cooled mold.

Injection molding is used in high-volume manufacturing. Injection molding costs are lower and the process is faster than compression molding, resulting in a low-cost, high-quality product. Articles of difficult shapes and thin walls can successfully be produced. Metal inserts such as bearing, contacts, or screws can be placed in the mold to produce a composite part in one operation.

Toothbrushes, flashlight handles, combs, buttons, lipstick containers, optical frames, and products that do not require heat resistance but require good color and finish are made using injection molding.

Transfer Molding

Transfer molding is also referred to as extrusion, or gate, molding. In this process, the material is heated and compressed in one chamber and forced through a spruce, runner, and orifice into the mold cavity. The mold is costly, but the method is used where a close tolerance is important. The process requires less time for molding thick sections and inserts can be added more conveniently than in other methods. Intricate parts and those having a large variation in section thickness can be produced economically.

Rotary Molding

Thin-wall molds are rotated simultaneously about two axes perpendicular to each other. After charging the appropriate amount of plastic material, the molds are heated while in rotation. The heating causes the particles to melt on the inner surfaces of the molds, resulting in deposition of layers until all the material is fused. The molds are then cooled while in rotation. The hollow molding is removed and the molds are recharged. This method is used for making hollow objects from thermoplastic material.

Products made by rotary molding include fly wheels, gears, fans, sheets, panels, and other parts that require uniformity in sections.

Blow Molding

Blow molding is performed in a series of steps. First, a heated piece of thermoplastic tube (called a parison) is placed on an air nozzle between the halves of the open mold and is extruded. The mold is closed, pinching the open end of the parison. Air is blown to expand the parison to the walls of the mold. The walls are usually cold set the plastic. Finally, the mold is opened and the finished part is ejected.

A major drawback to this method is that the wall thickness can not be maintained uniformly due to variation in stretching characteristics of different parts. Blown surfaces do not have a high gloss because the pressure in the mold is not greater than 100 psi. The process is readily automated and is used to make thin-walled, hollow containers. The process is fast and economical, and since dies and molds do not need runners and gates, they cost less than haft of those required for injection molding.

Thin-wall toys, containers, covers, packing material, and complicated-shaped utensils are some of the parts produced using blow molding.

Extrusion

Many plastics are extruded into long shapes by being forced through dies. This forcing can be performed using a plunger, but a more common practice is to use a screw. The procedure is faster and more economical than traditional molding for a large number of parts. Artificial fiber, tubes, channels, sections, barrels, tool handles, and containers are typical examples of this process.

Thermoforming

Thermoforming consists of heating a thermoplastic sheet until it softens and then forcing it to conform to a mold shape by using air pressure, a vacuum, or mechanical means. Furniture accessories, small boats, auto parts, fenders, ducts, and thin-walled, off-shaped parts are made using this process.

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