FACILITY LAYOUT IMPROVEMENT IN A GARMENT COMPANY

By

PARINPORN JENSATHIT

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
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Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Assumption University
Martin de Tours School of Management
Master of Science in Supply Chain Management

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Facility Layout Improvements in a Garment Company

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Declaration of Authorship Form

I, PARINPORN JENSATHIT

declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

[title of thesis/project] FACILITY LAYOUT IMPROVEMENT IN A GARMENT COMPANY

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ABSTRACT

This research is a study of the improvement in the facilities layout arrangement for a garment company. The poor facilities layout is a root cause that means the company cannot deliver the products to customer on time, and causes it to pay a late penalty. A facilities layout re-arrangement is the best way to solve the root cause of the problem. This study adapted the layout arrangement theories and created the methodologies step by step. The methodologies developed alternative layout plans, before applying a simulation program to generate the results for analysis in order to aid the company in selecting an appropriate facilities layout.

In the facilities layout improvement, the objectives of this study are to reduce the total distance and the transportation time. An appropriate facilities layout starts from consideration of a relationship diagram. The diagram supports the company to consider relationships between different departments in order to know the position of each department in the factory. The advantage of a relationship diagram is to reduce the distance in resource movement. The effectiveness of this diagram should adapt the product layout theories in order to reduce the transportation time effectively. The product layout has many workflows, for example U-shape, L-shape, I-flow, and Serpentine. However, this study applied a simulation program as the measurement for selecting a new facilities layout. Since the program could detect process bottlenecks, rearranging and line balancing can be conducted. Finally, simulation again proved that the selected facilities layout is appropriate to the company.

ACKNOWLEDGEMENTS

The writing of this graduate project has been one the most significant academic challenges I have ever had to face. Without the support, patience and guidance of the following people, this study would not been completed. It is to them that I owe my deepest gratitude.

- Dr.Samarn Chantaravarapan, my lovely advisor, who dedicated his effort in advising the way to conduct a successful project. He made many terrific suggestions which I had never thought of before.
- My beloved parent who is also MD of JST Garment always inspired me to finish the project and its real implementation in the company.
- My friends and colleagues for their guidance in the project format.
- Ekkamol Anuphongsirisakul, without whom this effort would have been worth nothing. Your love and support and compromise.
- ABAC School of management for this tough course.

Ultimately, I wish the study could be beneficial for people who would like to study in related fields.

PARINPORN JENSATHIT
Assumption University
November, 2010

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CHAPTER I

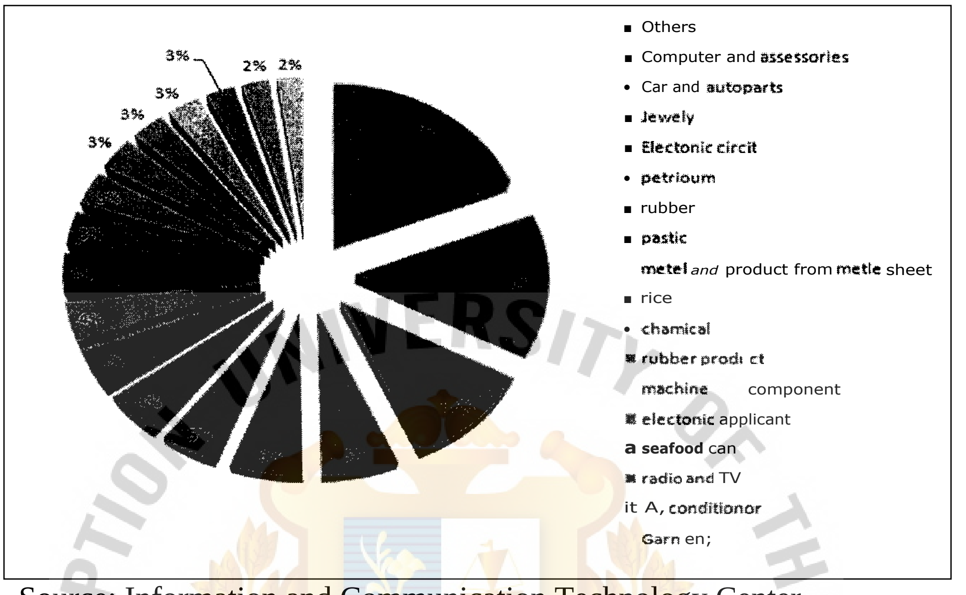
GENERALITIES OF THE STUDY

1.1 Background of the Study

Since ancient time, humans' primary needs are food to eat, shelter for sleep, and clothes for protecting them from temperature. Inevitably, clothes were considered vital for life. Clothing was developed over time, and the Textile and Garment Industry has a long history from as early as 1860, although after World War II, the garment industry started declining In the past, clothing was still hand-made. The first production of garments was for the needs of sailors, slaves, and miners. Ready-to-wear greatly expanded the garment industry in that era, by the production of ready-to-wear men's trousers, pants, and suit. Thereafter, a revolution in clothes became a fashion trend.

Although the financial crisis had a direct impact on the U.S.A., EU and China, which three countries account for 75 percents of global textile output, the situation has changed. Because of the higher production cost in Latin America, Eastern Europe and North Africa, buyers shifted their orders to Asian, and eventually Thailand.
Due to an orders boost in the textile and garment industry during 2006-2009, it has significantly affected Thai economic development, as exporting textiles and garments accounts for up to 2 percent of total export value. The average value of Thailand's garment exports to the world during year 2006 to 2009 is BHT 98,589 millions (www. ops3.moc.go.th).

Figure 1.1: The Average Exporting Percentage of Garment Industry During 2006 to 2009 in Millions Baht.



Source: Information and Communication Technology Center.

However, there are still many negative factors that affect the Textile and Garment Industry such as a fluctuation of the world economic situation in 2009, increasing the production costs from higher wages, and severe in market competitiveness. Also, the agreement on Textiles and Clothing (ATC) and all its restrictions were terminated on January 1, 2005. The expiry of the ten-year transition period of ATC implementation means that trade in textile and clothing products is no longer subject to quotas under a special regime outside the normal WTO/GATT rules which make the world market more intensely competitive. China, India, and Vietnam were both partners and competitors of Thailand in this region (www.wto.org). Not only have quotas been abandoned by WTO/GATT, but China may be blessed with many competitive advantages – a productive workforce, low wage rates and a large labor supply. Also, two enormous advantages that have contributed to China's dominant leap are export subsidies granted by the China currency regime as well as other subsides granted by state control and subsidization of its textile industry, as well as China's export rebate plan (http://cdnet.stpi.org.).

To survive this situation, a company must achieve competitive advantages over competitors. Competitive advantage as defined in Wikipedia (http://en.wikipedia.org) is the position of a company in a competitive landscape that allows the company to earn return on investments higher than the cost of investments. Thereby, either controlling the production cost to be as considerably lower, or having a higher selling price to gain higher profit margin, are solutions. However, the selling price may be difficult to increase due to market price competition, but cost control is an independent issue which the study is focused on. One inevitability in controlling the cost that has to be considered is waste. Theoretically, waste can be classified into seven categories' (www.implement-lean-manufacturing.com) which are;

1. Overproduction - producing more than the demand - by far, the worst form of waste
2. Inventory - too much raw material work-in-process, finished products
3. Transportation - material movement between operations, when not necessary
4. Motion - people or equipment moving more than required
5. Correction - making and fixing faulty parts
6. Over Processing - process steps not required by customer or used to fix a poor design
7. Waiting - people waiting for material or machines to be repaired, etc.

This study will focus on reduction in transportation and motion wastes, which were obviously observed from the three months field study in J.S.T. Company. This company was established in 1992 by Mr. Apichart Jensathit, Managing Director. This company is a Small Business Enterprise (SME) that has seven shareholders with an authorized capital of one million baht. J.S.T. The company is a manufacturer which specializes in cut and sew apparel manufacturing and Original Equipment Manufacture (OEM).

In 2010, the company operates its business with 50 employees and 5 officers, located at Rama II Road. For the product design, nowadays J.S.T. Company mainly focuses on fashion trousers, pants, casual wear, and Denim wear as core products.

Figure 1.2: Examples of Product Models

Source: Author

Normally, the textile and garment industry has a lot of competitors. A company has to gain more competitive advantage to survive in this market, including cost reduction, process time reduction, eliminating waste, and productivity improvements. In year 2010, J.S.T. Company operates in the domestic market, a change from the export market, producing for Tesco Lotus, Big C, and other brands.

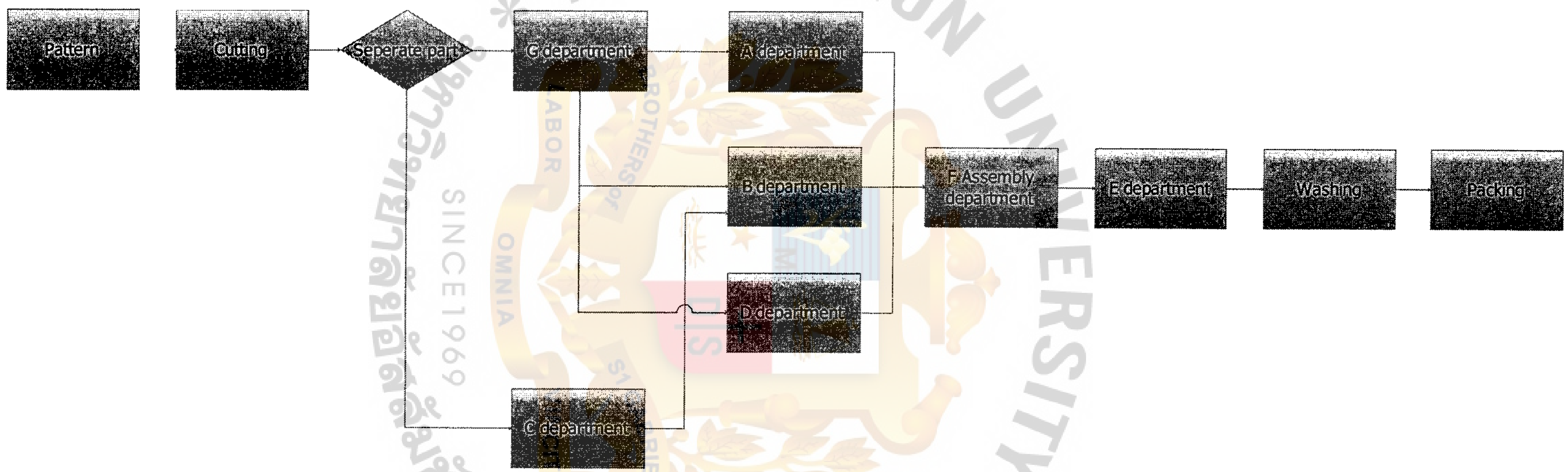
1.2 Statement of the Problem

In 2009, J.S.T. Garment Company found a problem: it could not deliver the products to the customer on time, and had to pay a penalty to the customer, costing approximately 300,000 baht in 2009.This problem became a primary issue for research to find out what should be the optimal solution. In order to monitor what is the root cause of the problem, they observe every process by using a video camera to record and collect the data about process time, waiting time as well as travel time.

This study has selected one product or one production line in collecting data, and this selected product has 42 processes which will be explained in Chapter III. This section explains the manufacturing process, the big picture, for better understanding. in Figure 1.3.

The manufacturing process starts from creating s block pattern for each style and then spread the fabric and put the block pattern on the fabric. The cutting process cuts fabric to be cutting fabric pieces following the block pattern. And then a worker separates parts to distribute to G and C department. G department has two resources for marking the position on the cutting fabric pieces, and then distributes to departments A, B, and D in order to operate. When A, B, C, and D departments finish, F assembly department has duties for combining to be semi-finished goods by using special machines. And then E department receives and operates to produce the finished goods. After that, the company uses an outsource company for washing to the customer requirements. The last process is packing following the description of customer requirements in order to deliver the products to the customer.

Figure 1.3: The Overall Processes in J.S.T. Company



Source: Author

However the observation was not enough to find the answer. Five-why analysis can be used in this case very well, to analyze the problem in order to solve the real problem. The objective of five-why analysis way is to identify the root cause of the problem (5 Whys, in Wikipedia: http://en.wikipedia.org). This case adapts 5 Whys as follows:

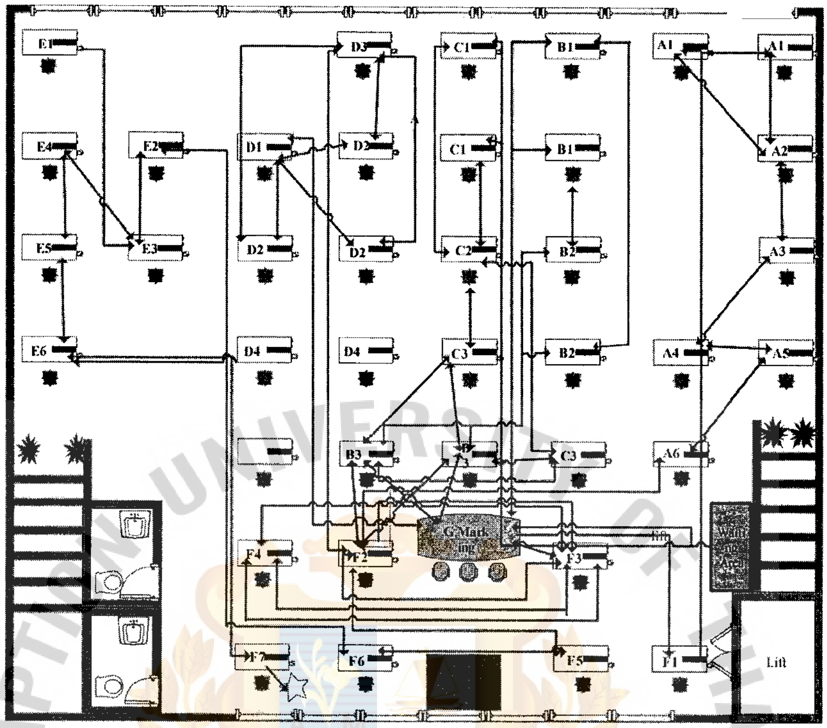
Table 1.1: 5 Whys Analysis

Question	Answer
1. Why cannot the company deliver the goods to customers on time?	The production takes a long time.
2. Why does the company have a long production time?	Some processes have to wait for the material from the preceding process.
3. Why do some processes wait for the material?	The movement of workers from many processes have to move material from one station to another, and around (go forward and backward).
4. Why does a worker have to spend so long in movement?	Inconvenient routing and long distance.
5. Why does the company have inconvenient routing and long distances?	The company has an inconvenient facilities layout.

Source: Author

From the observation of the production process, the problem occurs on the second floor of the plant, where there is the problem of non-optimal facilities layout. There is inappropriate routing and transporting movement of resources, materials, and personnel. The company layout in an as-is model has complex routing of resources, especially around the assembly department. The second floor area has 896 square meters with 41 employees.

Figure 1.4: Drawing of J.S.T. Company Layout on The Second Floor (As-Is Model)



Source: Author

The company layout in an as-is model has complex routing and traffic of resources movement, especially in the assembly department. The movement of personnel and material means that most of the process moves forward and backward. The inappropriate facilities layout leads to unutilized resources. Machines and operators are arranged in wrong positions. The as-is layout has many weaknesses.

1. Weakness comes from an inappropriate department position and machine, that leads to long distance and transportation waste.
2. Weakness is because the company has low space utilization. There is some idle area, some process has no need for storage area but has empty space. On the other hand, some processes need WIP inventories space but no space is available.
3. Bottleneck in some processes comes from unbalance in the production line.

In the current layout, operators spend approximately 1,674 seconds for transportation time. Calculating this in percentage of transportation time, it is about 38 percents of total production time. The transportation time is 38 percents of the total production time. The observation of the current facilities layout significantly shows inappropriate machine position and aisle routing. Starting to solve a small problem is a big problem. In additions, the waiting time is a big problem that affects productivity. Waiting time is about 1,120 seconds or 25 percents of the total production time. This problem comes from imbalance in the production line. Therefore, the solution to this problem is "line balancing". However, the statement of this research tries to find out the problem, and how the company can reduce the total distance to eliminate transportation waste, and have optimal resources utilization in order to increase its productivity. In additions, a what-if analysis will find the solution to reduce the waiting time or eliminate the bottleneck process.

1.3 Research Objectives

According to the statement of problem, the company misses its service level because of late delivery. The reason is the company has an inappropriate layout that leads to the transportation waste problem. Therefore this research has the following objectives:

1. Diminish transportation time that leads to decrease in total production time.
2. Reduce the total distance that resources travel in the overall route.

1.4 Scope of the Research

This research focuses on the facilities layout in a case study of a garment company. The research is about finding the optimal layout in order to decrease transportation waste. Therefore, the topic covers the solution of the manufacturing plant layout. The scope of this research selects one production line, for company product no.047 style, from one customer brand by using P/Q analysis. P/Q analysis is used to display the product mix in order to classify the products in a Pareto chart which will be fully described in Chapter III. The data collection is selected from a single customer or a brand that has the problem of late delivery.

1.5 Limitations of the Research

In data collection time, the study made observations over two months for collecting data. The reason behind this is because during the research period the company has an order for particular pants. Therefore, the study focuses on a selected item which takes approximately two months to completed the order.

1.6 Significance of the Study

The company had to pay a penalty charged in 2009, which is up to 2 percents of total annual sales. Also, nowadays, customers pay more interest on the service level. Thus, a company which can prioritize a full or nearly full service level would get advantages in boosting its opportunities for getting long term orders from customers. This study can support the company to improve its productivity. The above reasons obviously demonstrate why this study is significant.

1.7 Definition of Terms

Simplified Systematic Layout Planning (SLP) procedures are followed when laying out an area. It is suited to smaller projects that do not require the full SLP treatment.

Simulation: is a tool of sophisticated systems-analysis that requires the acknowledgement of a professional analyst about simulation methodology.

Transportation time: is the moving time of resource and material among work centers in the facilities layout.

P/Q Analysis: is used to display the product mix in order to classify the product in a Pareto chart – also known as the 20:80 rule.

CHAPTER II

REVIEW OF RELATED LITERATURE

2.1 Definition and Features of Plant Layout

According to the study of Jakanathan (2010), "Plant layout involves the development of physical relationships among building equipment and production operations which will enable the manufacturing process to be carried on efficiently". The company objectives of rearrangement of plant layout are to ensure that work flows smoothly from one point to another without any delay, avoids accidents, utilizes labor efficiently, provides for quantity and product flexibility, improves productivity, reduces production costs and capital investment, and eliminates bottleneck problems (Edward, 1997). The plant layout type depends on the appraisement of the impact of the layout selection on material handling and the utilizations of resources, equipment, space, and personnel. However there are many ways to determine the arrangement of facilities layout nowadays such as SLP (Simplified Systematic Layout), Apple's plant layout procedure, Reed's plant layout procedure, a heuristic approach, and CAD (Computer Aided Design), simulation.

Plant layouts can be classified as: product or line layout, fixed product, process, and group layouts, as explained in the following:

1) The product layout also referred to as the production-line layout, is used when processes are located following the manufacturing process for the product. This type of layout is used when high-volume production conditions exist. Material flows from one workstation to another workstation. The usefulness of this type is that the product layout can reduce the distances between processing operations (Francis, Mcginnis, & White, 1992).

2) Fixed product layout is used when the product is large and moves through the various processing processes. In other words, the processes are throughout the

product (Francis et al., 1992). The fixed product layout is developed by workstations location or production centers for the product.

3) The process layout is used when a volume of products is produced and customers' order requirements rapidly change (Francis et al, 1992). This type of layout consists of the processing department or work cells. This type is the same as job shop which has the characteristic of product in high variety and low production volumes.

4) A group layout is used when production volumes for a product cannot justify product layouts but groups products to be product families. Group layout is also referred to as cellular layout (Francis et al, 1992). The cell is focused on producing similar component parts or families of parts from different products. Cellular manufacturing is the same as a type of interest pattern in group technology (Edward, 1997). Typically, large business organizations use group technology to produce a wide variety of complicated processes but similar parts.

However each type of layout has advantages and disadvantages. The following shows the advantages and disadvantages of fixed product, product, process, and group layouts:

Fixed Product Layout

Table 2.1: Advantages and Disadvantages of Fixed Product Layout.

Advantages	Disadvantages
1) Minimized movement of material 2) High flexibility Layout 3) Independence of production centers to achieve minimum total time. 4) Job expansion by allowing individuals or teams to execute the job. 5) Continuous operation and required Responsibility in teams.	1) Increased movement of labor and equipment 2) Equipment repetition may occur and low level of equipment utilization. 3) Higher skill for labor requirements. 4) Required in supervisors and management.

Source: Francis et al. (1992, p.59)

Product Layout

Table 2.2: Advantages and Disadvantages of Product Layout.

Advantages	Disadvantages
1) Total production time per unit is minimized. 2) Job simplification. 3) Operation sequence is smooth. 4) Small number in WIP inventories. 5) Minimizing in distances between process operations. 6) Minimizing in material handling.	1) A machine breakdown lead to stop the other line in the next process. 2) Require supervision rather than specialization. 3) Inflexibility in the manufacturing process. 4) Higher skill for labor requirements. 5) Required for major modification in layout. 6) High capital investment.

Source: Francis et al. (1992, p.59)

Process Layout

Table 2.3: Advantages and Disadvantages of Process Layout.

Advantages	Disadvantages
1) Increasing in machine utilization. 2) Flexibility in equipment. 3) Low investment in machine. 4) Specialized supervision. 5) Easy to control and manage. 6) Increasing in individual labor incentives.	1) Higher number in material handling 2) Longer for total production time. 3) High number of WIP inventories. 3) Higher grade skills of specialized departments 5) Needs for production planning and control. 6) High labor incentives cost.

Source: Francis et al. (1992, p.60)

Group Layout

Table 2.4: Advantages and Disadvantages of Group Layout.

Advantages	Disadvantages
1) Increasing in machine utilization 2) Require team attitude and job expansion. 3) Shorter travel distance. 4) Smooth workflow operation. 5) Need for quality improvement. 6) Compromising between product and process layout.	1) Lower level in machinery utilization. 2) Require for higher skill levels of labors. 3) Depend on balancing of material flow. 4) Higher grade skills of specialized departments 5) Needs for production planning and control. 6) Limitation for compromising between product and process layout.

Source: Francis et al. (1992, p.60)

There are many reasons that most companies have to rearrange the facilities layout, such as product design change, new product production, volume of demand change, safety policy, high level of rework, and quality improvement (Francis et al., 1992). Therefore a good layout should have a smooth work flow of materials, equipment, and personnel. The types of flow pattern can be classified as being either horizontal or vertical pattern. There are at least five common types of horizontal flow patterns (Francis et al., 1992); straight-line, L-shape, U-shape, circular, and serpentine flow.

Straight-line flow pattern is referred as I- flow. The characteristic of this pattern is to separate receiving and shipping crews; team work is required. The L-shaped flow pattern is usually used when a straight-line flow cannot be adjusted in a facilities layout. The U-shaped flow pattern is very well-known because of simple flow. The usefulness of this type of pattern is that the starting and ending point is the same way. Besides, U-shape supports increase the communication between operators. Circular flow is appropriate when the position of starting and ending points are very near to each other.

Serpentine flow pattern is appropriate when the production line is so long, the process line looks like zigzagging on the operation floor. The vertical flow pattern is usually used when the production process flow is not in the same building or in a different area. Typically, the cutting process is on the side of the ground floor and the next process is on another side of the building.

2.2 Lean Concept

Many organizations have implemented the lean concept. Lean implementation supports the company by operating cost-reduction principles, producing the highest quality, meeting quality, cost, and delivery requirements, and eliminating all waste in the organization (Tapping, Luyster, & Shuker, 2002).

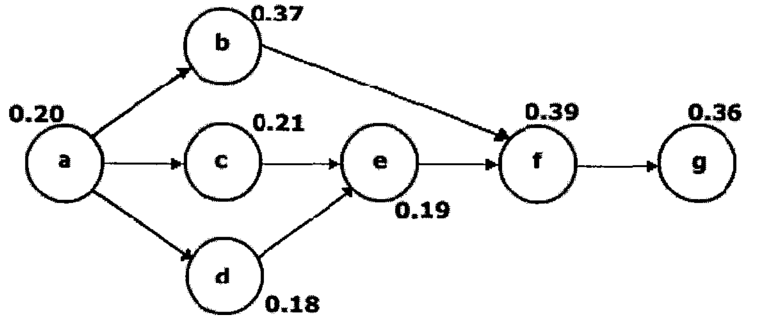
This research adapts the lean concept to support the determining of the facilities layout. The main point of lean implementation in this study is to drive all waste from the production line. Under the current situation of this study, the company is pressured from customers to reduce costs and lead times in order to maintain the highest quality. Customers often set the price, so the eliminating waste is so significant. In this study there are three wastes which are easy to notice in the company facilities layout; transportation waste, excess motion, and waiting. Lean implementation can support the company to eliminate these three wastes in order to follow the cost reduction principle. The root causes of these wastes come from as following:

1) Waste of transportation: The movement of resource and material move more than necessary because of poor layout.
2) Waste of excess motion: The motion includes back-and-forth movement among work centers which is not necessary.
3) Waste of waiting: Idle time occurs during the operations to wait for a missing part, and an unbalanced production line.

In addition, determining a new facilities layout arrangement can support the elimination of these three wastes. There is one concept of lean that can eliminate the waste of waiting, "Line Balancing". Typically, some process has complex operation and spends longer than others which lead to a bottleneck process. Line balancing begins with the analysis of the current operation process. Actually each work station should operate an equal amount of work in time units. In other words, line balancing balances workloads, so that no one work station is doing too little or too much. The balance chart can support this study. There are three steps for creating an operator balance chart, as follows:

1) Determine the total cycle time in the current state. For example, there are 7 operations. The total cycle time from process a to g is equal to 1.9 minutes (see as Figure 2.1).

Figure 2.1: The Analysis of The Total Cycle Time for Each Operation Process.



Source: Author

2) Create a bar chart that can be see as a visual presentation. The bar chart can show where there is imbalance and where is the imbalance process.
3) Determine the number of operators needed by dividing the total cycle time by Takt time:

$$\text{No. of operators needed} = \frac{1.9}{\text{Takt time}}$$

Takt time comes from the customer demand, and is the rate at which a company must produce a product to satisfy customer demand (Tapping et al., 2002).

After that company knows how to balance the assembly line, it has to analyze each unbalance process such as analysis of resource utilization, combining process, and eliminating excess motion.

2.3 Layout Arrangement Procedures

However, determining the plant layout should be done in a step by step procedure before the plant layout is optimal. The first procedure is data collection. This step should be realized early. Usually, data collection is approximately 50 to 60 percent of the work on a plant layout project (Edward, 1997). There is a limit of time when collect the data, depending on each project. Actually, the more time spent will be better, and lead to a more successful plant layout planning choice.

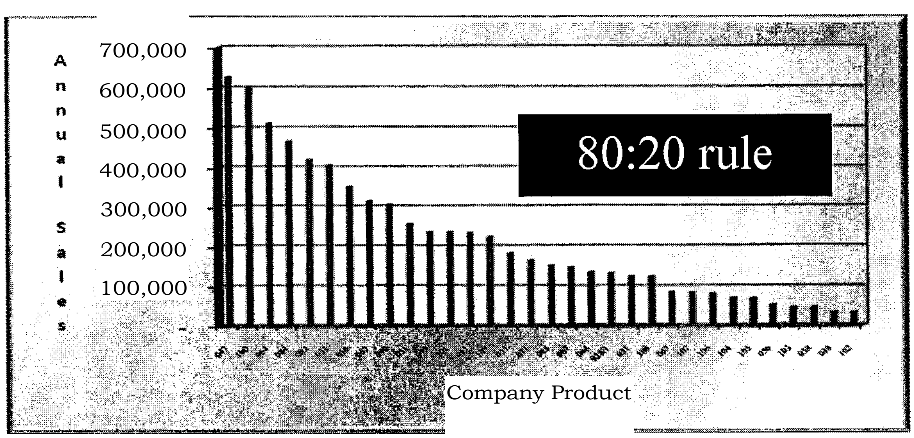
When the fundamental data is collected and before plant layout planning is operated, the next data that should be collected is the manufacturing spectrum. However the company has to find the answer what is the optimal facilities layout for the company. The optimal plant layout depends on the manufacturing spectrum, which has two types:

1. High-volume, low-variety production: The annual quantities for these types of products are very high while the variety produced are relatively low. The production process, equipment, material, and production routing should be fixed and inflexible for changing to customer order requirements (Edward, 1997).
2. Low-volume, high-variety production: This type of layout thinks about the job-shop. Pure job-shop produces several varieties, while the quantity is small in amount. This type of layout should be flexible in process, equipment, and production routing (Edward, 1997).

These two types of manufacturing spectrum offer the most efficient operations for the types of production process. However most companies can use both of these two types to mix together for some department that are high-volume and low- variety, and some department which are low-volume and high-variety production.

Therefore the optimal facilities layout planning will think about product versus quantity. At this point, the P/Q analysis tool can answer very well (Tapping et al., 2002). The product mix, displayed by P/Q analysis is a Pareto chart. This is also known as the 20:80 rule – where 80 percent of the annual quantities of goods manufactured involves only 20 percent of the number of products produced. This research uses PQ analysis for selecting one product line from three product models that has annual sales of more than 80 percent of the total annual sales in order to analyze the rearrangement of facilities layout, because of an assumption of PQ analysis. The assumption is that higher-volume products are the first that should be targeted for improvement (Tapping et al., 2002). Actually, the assumption of P/Q analysis is similar to ABC classification, ABC analysis is often combined with the 20:80 rule (Wisner, Tan, & Leong, 2009). The ABC classification is a useful technique for determining which product should be counted more frequently and managed more closely and which others should not (Wisner et al., 2009). ABC prioritizes product items into three groups; A, B, and C. But this research has no need to divide the products into product classes. Because the fashion product comes and goes, it depends on the customer requirement. The customer order rapidly changes so product styles are changing all the time. Therefore this study has selected the product style that has the most annual sales, the most complex operation, the longest production time, and high repeat orders from customers. Besides, a PQ chart is very significant to start determining the type of production and layout arrangement for layout planner (Edward, 1997). The concept of PQ chart is that normally there is at least one product model or assembly line in a firm. But the company is no need to focus every product line for determining a layout arrangement; the firm should select the product line which has the most annual sales following the 20:80 rule. According to Edward (1997), Figure 2.2 show that "dividing products and production areas into different layouts and material handling systems may be the best and efficient approach". In analysis of PQ chart of several products, sometimes a product is combined in operations to allow some product that has high volume and high productivity (Edward, 1997). The mid-range area of a PQ chart indicates the opportunities for implementing a focused plant layout or work cell. For products falling within the right range of PQ chart, a layout can be a fixed location processing space. Material handling can use traditional handling. Therefore, different product variety or quantity can more efficiently produce with different production methods and different plant layout approaches.

Figure 2.2: Example of PQ Analysis Chart.



Source: Author

The next step in the procedure is material flow analysis. In production routing it is important to study the flow of material. Before material flow analysis is considered, the planner should first review the operation process. Work simplification should be required for plant layout rearrangement. The idea of what, when, where, why, how, and who questions involves the four keys which are Study, Eliminate, Combine, and Simplify. Study means to study and review the operation process carefully. Eliminate means which process is not significant should be eliminated. Combine means which process can be combine or mixed together. Simplify means to keep everything simple. Flow of material analysis is the heart of layout planning where movement of material is important to the operation process, especially for large unit loads which have high costs. Some companies try to increase quantity, size, and weight of the load handled in order to reduce the total number of movements and lower material handling costs (Edward, 1997). However the planner should analyze which system or operation process should use large unit loads and which should use small unit loads. There are many types of containers that most companies use in a plant layout, as shown in Figure 2.3.

Figure 2.3: The Type of Containers; Discrete Unit Loads of Materials May be Small or Large.

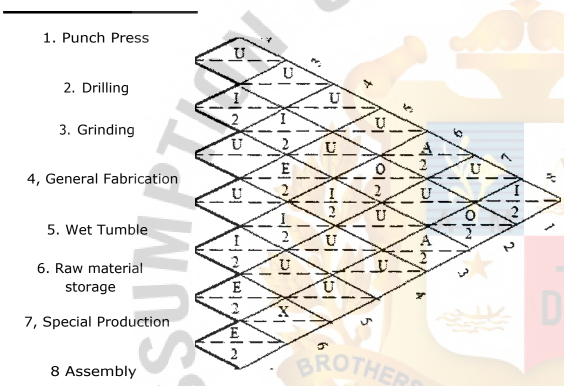
Source: Author

Therefore the material handling should be appropriated for volume of operations, movement, distance routing, size, shape and weight of the product, and improving productivity. To these considerations should be added dimension information that must include safety and to avoid damage also. Material handling efficiency should have no idle time, and minimize cycle times and production rate (Manocher, 2007), continuous material movement, and reduced cost. The company should manage the material into a qualifying group, such as large quantity, biggest material, most dangerous, most expensive cost, and fragile material. This group material management may lead to plans for grouping of layout arrangements. The usefulness of material flow grouping is it is easy to control and move the materials. In addition to material flow analysis, there are many factors to affect the system such as environmental factors, building limitation, or material handling system configuration. However when a company uses the overhead space utilization consideration, the space utilization makes material flow work fully. The overhead space can balance the workload between departments.

Not only is studying the material flow important, but also considering process flow. The next step is activity relationship analysis. The planner should study the relationship among departments for layout rearrangement. According to Muther and Wheeler (1973) who introduced the Simplified Systematic Layout Planning (SLP) method for layout rearrangement, every layout involves: 1. Relationships between different functions or activities, 2. Space of a certain amount and kind for each activity, and 3. Adjustment of these alternatives into a layout plan (Muther & Wheeler, 1973). Flow of material analysis is not enough for the fundamentals of plant layout planning. The activity relationship chart can support the company to analyze the operation process flow and relationships between departments. The main idea of an activity relationship chart diagram starts from the material flow in each department and continuous flow, and then focuses on the two activities that have the highest degree of relationship rating until the lowest. Figure 2.4 is an example of an activity relationship diagram to find the two activities which have the highest score of closeness-relationship rating. This diagram determines the relative closeness between each pair of departments or activities (Muther & Wheeler, 1973).

The main procedures of an activity relationship diagram are to identify each activity and list all activities in every process in a relationship chart, and then determine and record a closeness-relationship rating for each activity related to every other activity. After that, record and write the reason for assigning each closeness rating. The last thing to do is verify the count of relationships. Actually, every company cannot rearrange the layout without making decisions on how close many activities should be to one another. The relationship chart support and helps a company with its problems and clarifies the big picture of the overall production process.

Figure 2.4: Example of Activity Relationship Diagram.



Value	Closeness desirability	No. of ratings
A	Absolutely necessary	2
E	Especially important	3
I	Important	6
O	Ordinary closeness OK	2
U	Unimportant	14
X	Not desirable	1
Total = $\frac{X*(N-1)}{2}$		or 26

Code	Reason
1	Equipment used by some persons
2	Movement of material
3	Movement of personnel
4	Supervision and/or support
5	Require same utilities
6	Noise and dirt

Source: Muther & Wheeler (1973, p.2)

The detailed steps of the relationship chart are:

1. Determining the heading on the form at the right to identify the layout.
2. Identifying each activity and list them on the chart (Not more than 20 activities) (Muther & Wheeler, 1973).
3. Determining and recoding in the upper half of the diamond-shaped block a closeness rating for each activity relative to every other activity.
4. Use the vowel letters (A, E, I, 0, and U) to mean the degree of closeness desired. A means an absolutely necessary function designated by A, that absolutely must be placed close together because this area has the communication of operators. E means especially important. These functions have many benefits from placing functions as close as possible. I means important to be placed close. These functions will not be affected by

transporting distance. The process will run smoother when machine and operator are not too far apart. 0 means ordinary closeness. These functions traditionally are close together and remain near each other for operator morale. U means Unimportant. These functions can go in any place as long as space is available. Another letter is X, use for undesirable closeness, those which should never be together.

5. Give the reason: a reason-code number in the lower half of each block.
6. Explain each reason code used with an appropriate entry in the reason box on the form.
7. Count the number of each vowel letter to check the total by comparson with the computed ideological number of relationships.

The relationship chart provides a usable form by a systematic way of setting up data. Besides, the valid reasons in the chart make the organization valid and prepares for the layout rearrangement.

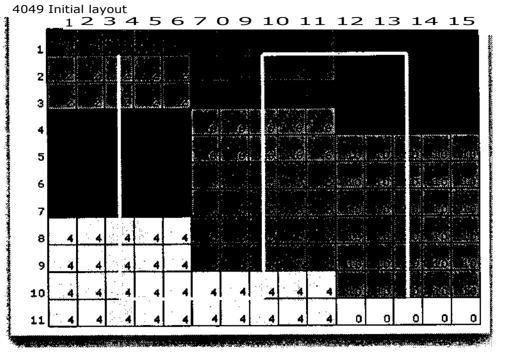
The SLP method has to analyze using a space configuration analysis. The space ratio depends on the current number of employees and machines in the department. The company needs the optimal spaces for resource utilization. The relationship chart shows the relationship among each department or activity, and shows the space relationship diagram also. The SLP method has the configuration of space requirement when layout changes and needs modifying consideration. The data should have the space requirement and space available for a plant layout and include each department. The space configuration requirement is not calculated after the determining space relationship diagram, but the calculation occurs after the analysis of the fundamental organization problem, flow of material analysis, and relationship chart are completed. The planner should know the space requirement, shape of each area, and the budget. Moreover, the planner should consider the number of employees, machines, equipment, and service, to determine the appropriate space requirement.

In addition to establishing the space requirement, the planner must study and know the physical features of each activity in order to develop the space requirements for each activity. The planner needs to check on the utilities of each activity to be more effective.

Other important activity relationships are; rearrange the plant layout properly as it is quite possible that many pieces of material involve a high cost for movement and make work cell areas or department cells expand. Each move may affect other areas of the plant: this is called the "domino effect" (Edward, 1997). Therefore a good layout should be flexible. Lack of flexibility in plant layouts is a problem which a planner cannot avoid. The ranking of material flows can help this problem by the probability of needing the next area expansion, and include capacity analysis for all the activity areas. The bottleneck function is another problem with the highest probability of needing more space (Edward, 1997). Therefore the planner should also consider simplifying the bottleneck analysis by assuming static probabilities with a simulation program.

Another approach for space layout planning is computer-aided approaches (CAD). CAD-based sketches and draws a program which shows areas shapes in real time as the user moves and stretches the shape. Other programs are CRAFT (Computerized Relative Allocation of Facilities), ALDEP (Automated Layout Design Program), and CORELAP (Computerized Relationship Layout Planning). The CRAFT program is an improvement program. A user inputs the existing layout into the program. CRAFT is the only program of these three programs that uses flow of material data for relationships. The drawback of CRAFT is its limitation of the number of activities involved which is up to 40. ALDEP is a construction routine (Edward, 1997) as shown as Figure 2.5. In this program the planner has no need to start with the existing layout. The program randomly selects and places the first activity in the upper left corner of the layout sheet. The other relationships are searched to find the highest relationship score in the first activity. This activity is placed next to the first one and this process continues until all the activities are calculated for. The first activity is randomly selected; many different layouts may be created.

Figure 2.5: Example of ALDEP Program



Source: Edward (1997, p.160)

CORELAP is also a construction program and uses some additional intelligence by calculating the activity which has the most relationship to the others activities. CORELAP starts with a hub activity and places the first area in the center of the layout (Edward, 1997). The activity that has to be close to the first one is then selected and placed next to the first activity. The program searches for more A relationships, and then Es are placed, etc., until all activities are calculated. The CORELAP program takes into the calculations undesirable X relationships, which is different from other programs. However this program has its limitations, which are self-evident. The problems with automated programs include jagged wall constructions, the placement of high transaction areas such as shipping or receiving in the center of a building, and other non-sensible results. Unfortunately, these three programs and methods do not handle realistic cost and distance factors. Based on which work center is placed first on some programs, different layouts will be created with each program considered the optimal by the software.

However, the planner can calculate the space requirements. There is an operational way for establishing space requirement.

1. Identify the activity clearly and use numbers and comments for creating the chart and diagram.
2. Identify the relative machine and equipment which are in the operation and supporting service.

3. Find the work space for space requirement, space available and environment.
4. Find a space which supports the manufacturing activities.
5. Consider balancing between the total space features with the space calculation.
6. Adjust and improve the space to be effective.

After determining space requirements and studying activity relationships, then establishing a relationship diagrams for existing plant is needed.

The next step is drawing space relationship layouts, which convert material flow and relationship diagram into a sheet. This is in reality a layout. This step is to modify and adjust the work arrangement and is shown on the paper sheet in order to consider and select only a few alternatives that seem to be most appropriate. The principles of adjusting or combining space into a diagram are:

1. Using flow diagram.
2. Using relationship diagram.
3. Using both flow diagram and relationship diagram.

The principle selection depends on the level of significance in material flow relationships and activity relationships for service and manufacturing support. After that, change the material flow and relationship diagram into plot of the space and details in the paper sheet, and determine the ratio scale.

What to do in drawing space relationship layout is to establish a work scale which will allow showing the overall plan on one sheet. Draw the outline of the space for each activity and adjust it, and rearrange to combine modifying physical features and other considerations. The last thing is to draw or sketch all solutions (Muther & Wheeler, 1973). However drawing a space relationship layout cannot get the maximum operating effectiveness if the space relationship layout is inappropriate. These diagrams are not significant until converted to blocks of space in the proper area. This step will get specific dimensions and permit the checking of the physical features such as fit on size, entrance way, and minimum surface walls.

The next step is to evaluate alternative arrangements. This step selects the space arrangement plan or a whole layout most appropriate for the company. Making an evaluation objectively can result in the best decision. This evaluation procedure can protect against missing a significant factor. Moreover the evaluation permits the key approvers get involved in the decision making. This step is determining the factors and considerations on the effectiveness of the facility. The way is determining the weight of each of these factors and rating each alternative plan for each factor. Then convert the ratings to number values and select the plan with the highest total. The procedure of this step is as follows (Francis et al., 1992);

1. Determine each alternative plan by vowel letter. Give each letter a brief three to five words description and put on an evaluating alternatives form.
2. Establish and list all factors, objectives, and considerations that the company wants the layout to be successful into a clear form.
3. Assign a weight of 10 for the most important factor. Select the least and assign number as 1, 2, or 3. Weight the importance of each other factor, ranked from the most important till the least important. Then point the weight on the form and record by determining weight value.
4. Rate each alternative for all factors' purpose, using A, E, I, 0, and U to represent a descending order of effectiveness.
5. Convert letters from step 4 to numbers (A-4, E-3, I-2, 0-1, U-0), and multiply by the weight value. Then enter the resulting weight rate values onto the form.
6. Consider the weight rate values for each alternative. Then enter on the form and record correspondingly.
7. Select the best alternative layout, which is the plan with the highest total.

The next step is developing alternative layout configurations. The planner needs to concentrate on the alternatives plans and permit an objectives rating comparison. All the alternatives should permit a review of relationships. Many larger organizations invest in technical resources and establish calculating materials handling costs by resources' own spreadsheet-based computer programs. Some companies use a simulation tool to select the alternatives plan. Simulation is a computer model that mimics the operation of reality or a proposed system, such as the day-to-day operation, the running of a production line in a factory, or resource utilization. The essential manufacturing has provided a model and simulation environment. Danny stated that the simulation study is a systems analysis activity, and a professional analyst should have knowledge of simulation methodology. This knowledge includes model validation, probability distributions theory and selection, design and analysis of simulation experiment, statistics, detailed operation system, and project management. Therefore the power of assembly of products, fabrication, including the manufacturing process, can be simulated through the computer. The simulation way is very useful to pressurized SMEs (Small Business Enterprise) because many SME businesses face the shortage problem in resources to complete a particular order on time (Danny, 2003). Currently, process and product design are needed to combine the design between manufacture and assembly together with the ability to simulate the actual or as-is situation. Danny stated that coupled with simulation, animation, and 3D techniques can be virtually displayed on computers for examination.

This study selects the simulation program as a tool for measurement and evaluation of the new facilities layout. Computer simulation is the method for studying various methods in the real world by applying simulation software designed to simulate the system's operations or characteristics, often over time (Danny, 2003). The simulation model is time based and takes into account all the resources and constraints involved. Due to its ability in dealing with very complicated models of correspondingly complicated systems, as well as the obvious improvement in performance/price of computer which have advanced simulation software power, flexibility, and ease of usage, which contribute to the variety and popular usage of simulation. Simulation can be considered more powerful than just using a normal study. For example, a simulation model can deal with complex problems such as layout model, transportation model as well as air traffic control. The model also builds in the randomness seen in production line reality. To use this tool, the company has to invest money to buy a simulation program. But there are benefits of simulation. In this study the administration of simulation output can show bottleneck problems. The program can show which process has a bottleneck that makes the management level find the root cause of this problem, and find the result calculated in simulation program. Besides, a simulation program can show the output in the production rate, machinery utilization, resource utilization, throughput time, and waiting time. The software automatically collects the performance from the model which can get accurate results. Therefore the simulation model can develop effectively and efficiency a plant layout, and can be improved by the addition of a plant layout rearrangement. All the above details of simulation can prove that a simulation program is suitable in this study.

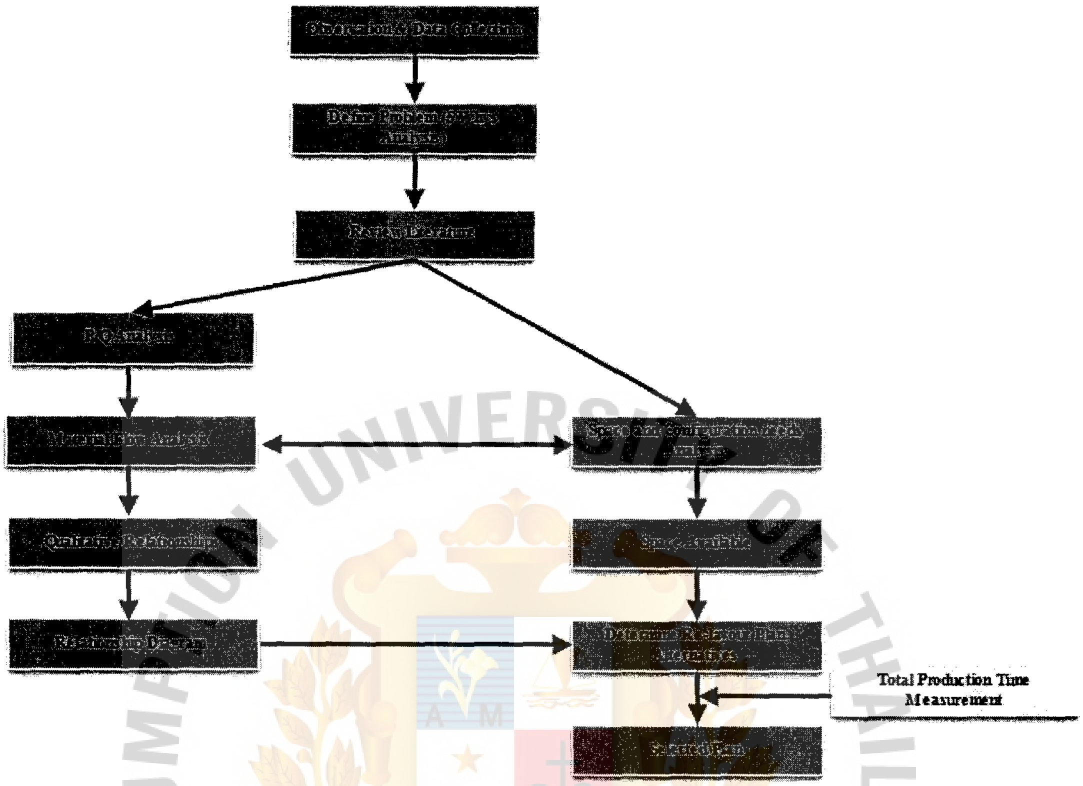
The last step is the selected layout plan. In this final step, the planner can draw the selected layout plan and mark comment on individual detailed features or equipment. The detailed plan should show adequate data to enables the management level to make a decision. The data permits the proper installation of machines and equipment. After that, the company makes a decision to select a plan that is appropriate for the company layout and enables maintenance people to complete the project. Finally the company has proper placement of machines, equipments, utilities, and aisles distance that become the optimal facilities layout.

CHAPTER III

RESEARCH METHODOLOGY

Chapter III refers to the methodology used in this study in order to find the best solution. According the to the literature review which refer to the method in layout arrangement, it can be concluded that it is valid to use the observation study method to observe the social setting, and physical and human behavior. Social observation is observing the company workflows, manufacturing operation and culture, while physical observation is used for observing machines and layout. Also, human behavior observation means observing the working style and movement. After conducting three observations, information such as workflows, transportation route, and manufacturing process, is collected. These observations and information collection make us face the problem of transportation waste that makes long distances. Another problem is the long total production time because of transportation waste. Figure 3.1 shows the research framework. The observation and data collection begins, until a plan alternative is selected. Chapter I explained the determining problem by using 5 Whys Analysis. The literature review was in Chapter II. This chapter will show the methodologies to find the solution for layout arrangement by adapting the layout theories and adjusting the Simplified Systematic Layout Planning (SLP) techniques.

Figure 3.1: Research Framework



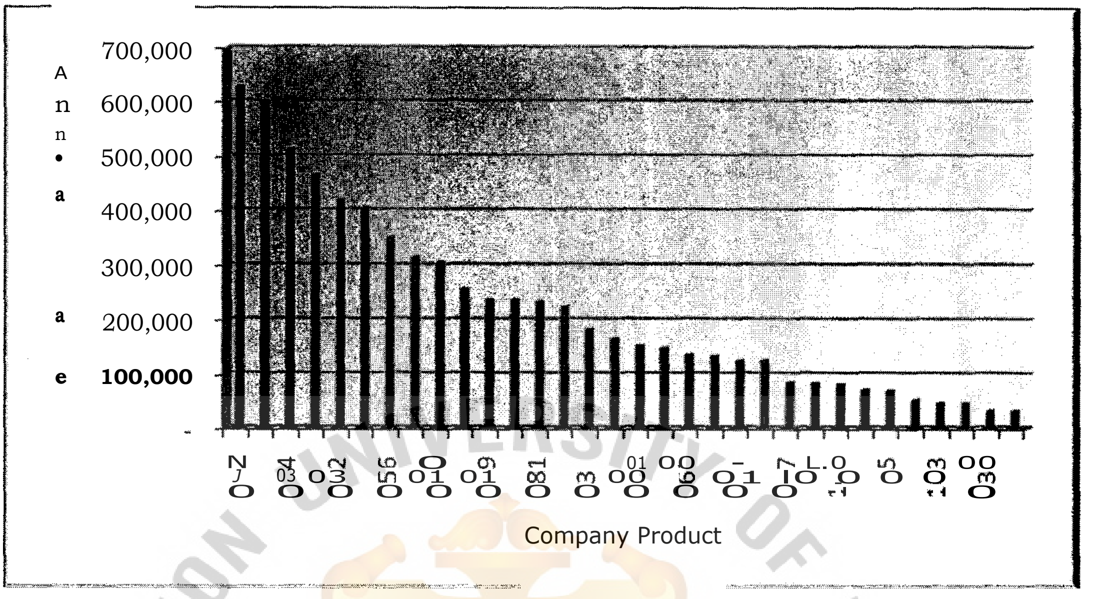
Source: Author

Following the research objectives, this research has methodologies, step by step, as in the following:

3.1 Selecting One Production Line to Plan for Determining Layout Arrangement:

The company has produced many products to the customers' requirements. This research selects one production line to consider the facilities layout by using P/Q Analysis with data collected from the historical data. The annual quantity requirement of each product, and example of data of one brand, are shown in a chart in Figure 3.2. This chart means the company should not focus on every product, but should focus only the top three company products.

Figure 3.2: The Annual Quantity in One Brand Customer of J.S.T. Company

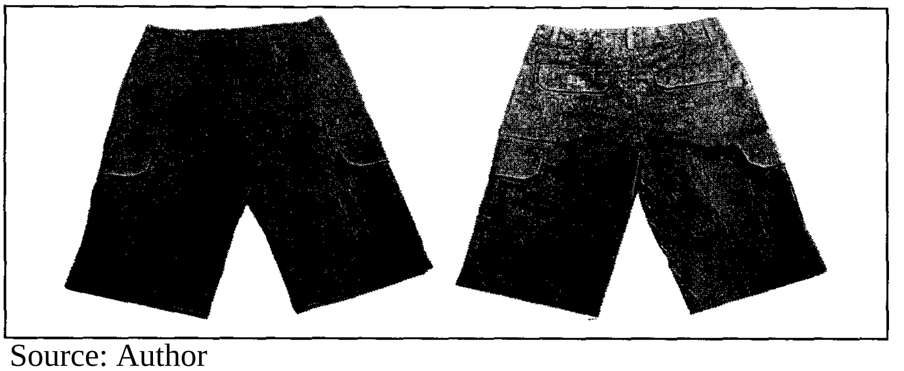


Source: Author

According to Edward (1997), "20/80 rule- where 80 percent of the annual quantities of goods manufactured involves only 20 percent of the number of products produced." Therefore 20 percent of the number of products are numbers 047, 100, 064 (the top three company products). This study selects one company product. The reason is that this product model has the highest annual sales and the longest production process. In this case, this product has the longest path in the process, the longest process time, and a complicated manufacturing process. This study uses a spreadsheet technique to calculate the total production time. Product 047 approximately takes 4,458 seconds (per one batch production) in average production time. Furthermore, the process has transportation time between one station to another one station of 1,674 seconds or 38 percent of the percentage of the total production time.

This product model was frequently ordered by customers, approximately four times per year. Therefore, this product model is an appropriate product to consider in determining the layout arrangement.

Figure 3.3: Company Product No. 047

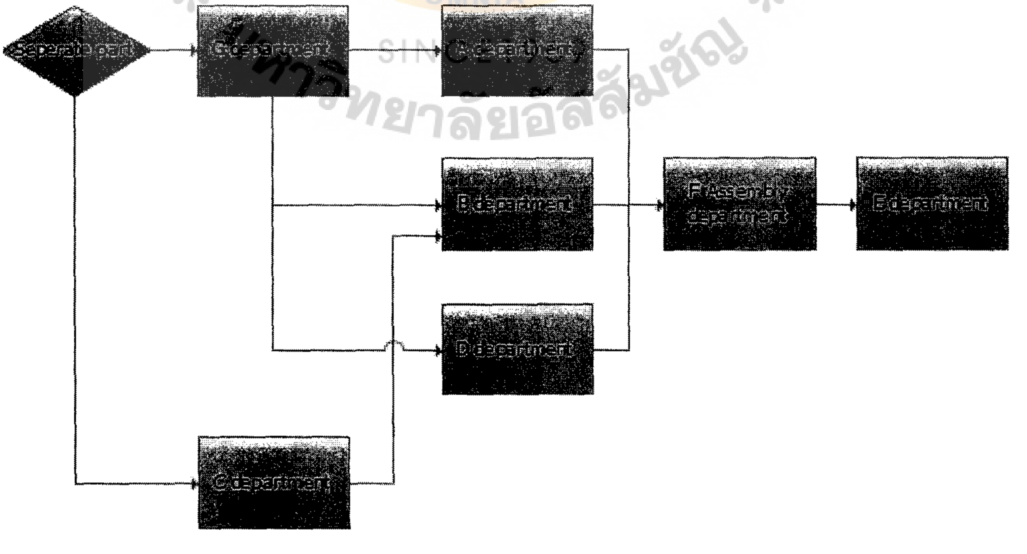


Source: Author

3.2 Determining the Layout Arrangement:

The characteristic of J.S.T. Company's product is high variety and low quantity. High variety of product comes from the customer's order which has several styles, especially fashion products which have a high change rate. Therefore this research sketches the process layout which has high flexibility for equipment or manpower allocation for specific tasks (Francis et al., 1992). The layout process is shown in Figure 3.4.

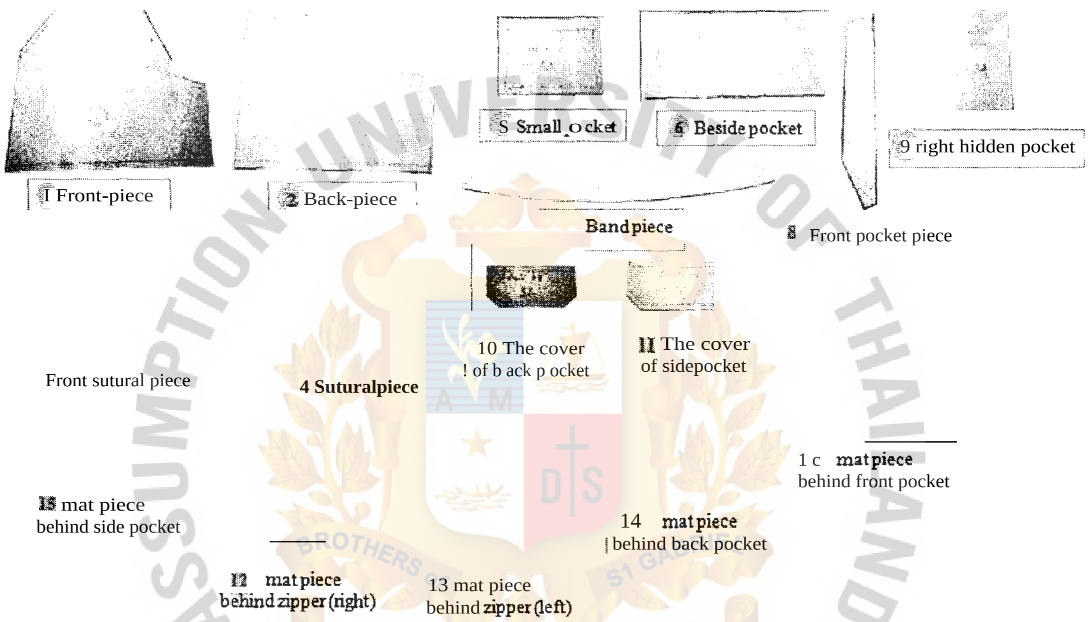
Figure 3.4: Layout Process of J.S.T. Company



Source: Author

Determining the facilities layout arrangement from the layout process is to match it with the characteristic of company operations. The analysis of operation flow is very necessary to determine the new facilities layout. This product model has 42 processes to operate. There are sixteen block patterns or twenty-five cloth pieces per one pant. The operators will combine these cloth pieces together to become one product pant.

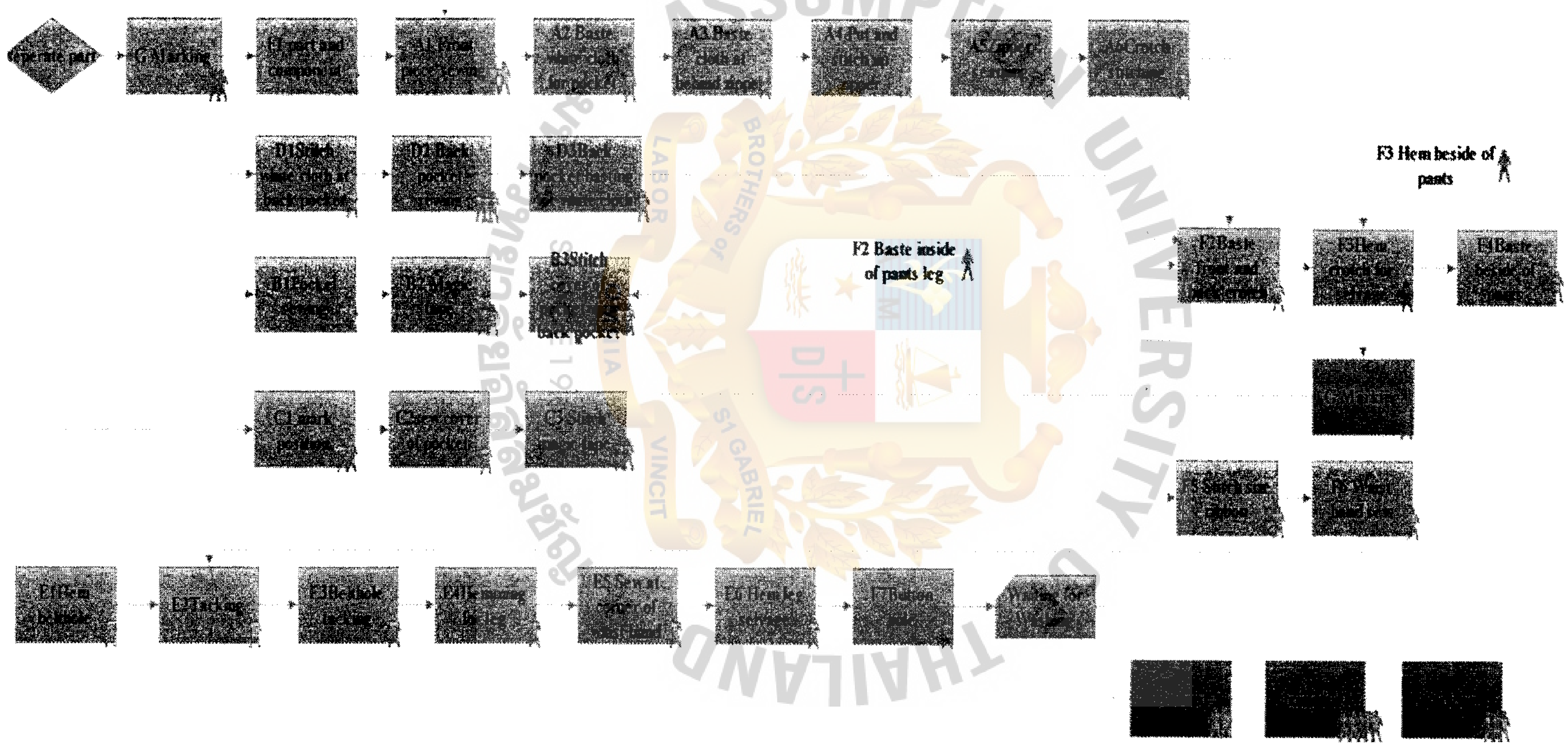
Figure 3.5: Sixteen Block Pattern of Product Style No.047.



Source: Author.

The problem comes from the second floor of the plant layout because of the problem of inconvenient routing and bottleneck process, especially at F assembly department. On the second floor, the plant divides into seven departments, which are the front-piece (A), pocket piece (B), cover of pocket piece (C), back-piece (D), tacking (E), assembly (F), and marking (G) department. The overall process is shown in Figure 3.6 in great detail.

Figure 3.6: Production Processes



Source: Author

The operation processes for this product style are shown in Table 3.1:

Table 3.1: Operation Processes of Selected Product Style.

	Process	Explanation
3.2.1.	Pattern	One pattern operator created "block pattern" when the sample was gotten.
3.2.2.	Paste created pattern toping on fabric sheet	When the order was received pattern operator calculated and planned for using fabric to save the area on fabric for using the least cloth as much as possible. Therefore batch size production depends on the customer order and calculation from this process.
3.2.3.	Spread the fabric on the cutting table	This process depends on the customer order for color requirements.
3.2.4.	Cutting fabric by pasted block pattern on fabric	This product style has 16 blocks pattern or 25 fabric cutting pieces. The characteristic of each block as shown as Figure 3.5.
3.2.5.	Marking person marked on cut sheet	As Figure 3.5, fabric piece no.1, 2, 3, 4, 5, 6, 7, 8, 9,12, 13, 14, 15, and 16 into standard form in order to facilitate sewing processes.
3.2.6.	Distributed the marked cut sheet to each work stations	There are four station areas consist of front-piece, back-piece, cover of pocket piece, and pocket piece.
3.2.7.	Part and component basting	As Figure 3.5, baste right hidden piece and mat piece behind front pocket around for selvage.
3.2.8.	Front-piece sewing	As Figure 3.5 sewer stitches fabric front piece (2 pieces; left and right) with front pocket piece for front pocket and then stitches piece no. 9 and 16. And sewer will combine with front sutural piece
3.2.9.	White cloth sewing	To baste white fabric piece for front pocket to protect selvage.
3.2.10.	Baste on fabric piece at behind zipper	To baste mat piece behind zipper left and right to protect selvage.
3.2.11.	Zipper Assembly	To put a zipper and stitch up with mat piece behind right zipper and combine fabric mat piece behind left zipper piece together.
3.2.12.	Zipper seaming	To sew on top of the cover piece of zipper in order to show thread line.
3.2.13.	Crotch stitching	To assemble 2 front pieces together and sew inside at front crotch
3.2.14.	Front crotch and thigh basting	To baste front crotch and thigh in order to show thread line by setting in special machine.

Table 3.1: Operation Processes of Product Style No.047 (Continued).

3.2.15.	To hem front crotch	To hem on front crotch for thread clinching and avoid fabric selvage by special machine. After this process, WIP inventories will be waiting for assembly pants process.
3.2.16.	To put white cutting piece for back pocket	This prcess makes for back pocket, to stitch white cutting fabric piece with cloth back piece (2 pieces; left and right). And then sewer combines sutural piece together.
3.2.17.	Back pocket sewing	To cut and sew on back piece in order to follow marking line and stitch up with mat piece behind back pocket.
3.2.18.	Back pocket basting for white cloth	To baste white cloth fabric for selvage on two sides of back pocket.
3.2.19.	Back crotch basing	To combine 2 back pieces in order to baste crotch inside by special machine.
3.2.20.	To hem back crotch	For thread clinching avoid Fabric selvage by the special machine and then to be waiting for assembly pants process.
3.2.21.	Mark position on cover of pocket sewing	For cover of pocket department, at first put block pattern cover of back and side pocket on the cover of pocket fabric piece.
3.2.22.	The cover of pocket sewing	According to the precede process, sewer sews the cover of pocket follow the line that was marked.
3.2.23.	To stitch 2 magic tapes on the cover of pocket	Stitch magic tapes on the position at cover of pocket.
3.2.24.	Pocket sewing	This style has three pockets (one small pocket piece and two beside pieces), sewer makes pockets before stitch at pants.
3.2.25.	To stitch two magic tapes	Stitch magic tape up and wait for stitching with pants
3.2.26.	Basting at beside of pants	This process uses special machine and bastes inside of the fabric.
3.2.27.	To hem at beside of pants	This process avoids the fabric selvage and use special machine.
3.2.28.	Marking position at pockets	To mark a postion for stitching three pockets.
3.2.29.	Pocket stitching at pants	To stitch three pockets at beside and front, and two covers of pocket at the back. And then sewer sews back piece behide side pocket inside of two side pockets.
3.2.30.	Basting at beside of pants	This process uses special machine, basting at pant beside is needed to assemble the pants.
3.2.31.	Stitching for size ribbon	To identify size for product separating sewing to follow the thread line. special machine to be faster.

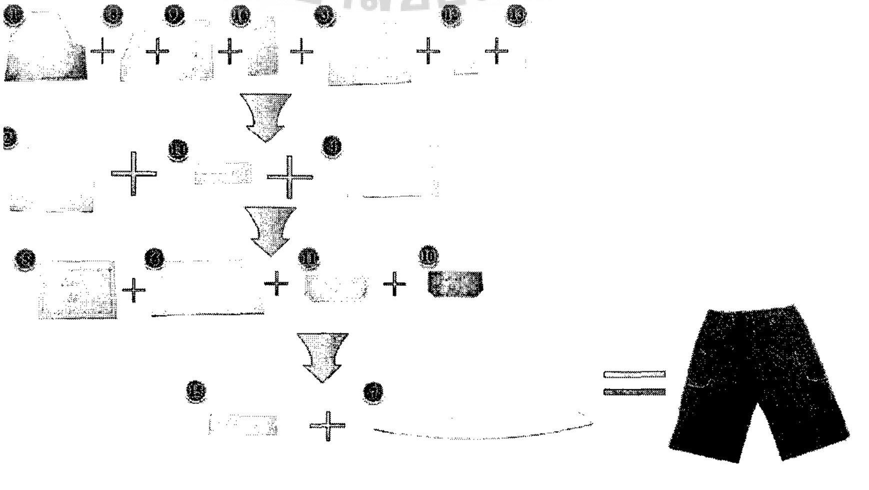
Table 3.1: Operation Processes of Product Style No.047 (Continued).

3.2.32.	Waist band sewing	This process, sewer uses one special machine that enable roll the fabric edge from block pattern band piece and control machine for sewing to follow the thread line.
3.2.33.	Pants tacking	This style was tacked sixteen points on product by using one special machine to be faster.
3.2.34.	Belt hole tacking	Belt hole material was hemmed from preparing and sewer tacks belt hole on pants.
3.2.35.	Hemming at tag extremity	This process has one machine to hem at extremity.
3.2.36.	Sewing at the waist band corner	This process needs high skill of labor to sew at the waist band corner to be nice and tiny.
3.2.37.	Hemming at extremity	According to process 3.2.35, one labor hem at extremity again to avoid selvage and damage.
3.2.38.	Button hole	This process uses special machine for button hole. This machine is usable for countersinking to insert the button.
3.2.39.	Washing	This process, company uses the outsource company for washing process. Lead time spends one day to operate.
3.2.40.	Button stitching	To stitch a button at pants.
3.2.41.	Trimming	To trim and inspect for quality checking.
3.2.42.	Packing	Prepare the finished goods and delivery to customer.

Source: Author.

The above operation processes detail is explained in Figure 3.7, which is a diagram of the overall block pattern to understand the overall processes clearly. From sixteen block patterns, twenty five fabric pieces are combined into one pants product.

Figure 3.7: Process Diagram of Product Style No.047.



Source: Author

In additions, Figure 3.6 shows that F and G departments have the most relationships with other departments. F department is an assembly line to combine two pieces of fabric together and the type of machinery in this department is special machinery. Another problem in this department is that it uses material handling equipment for movement of material and WIP inventories. In this area occurs the traffic problem because of A, B, and D departments' resources movement. Therefore the appropriate methodology in this case is SLP or Simplified Systematic Layout Planning method. Actually, SLP has six steps (Muther & Wheeler, 1973). SLP consists of a framework of phases, a pattern of procedures for alternative planning, rating the various activities and relationships in the layout. But in this case researcher will adapt this method to solve the problem of an appropriate solution for the company.

3.3 Simplified Systematic Layout Planning Method:

The statement of the problem identifies the problem of transportation waste in the current layout. This problem was found in an inappropriate facilities layout on the second floor of the plant. Figure 3.8 has shown the routing and transporting movement of resources and material. This figure shows the current situation of motion movement, with complex routing and traffic. Also, the aisle width between machines is too broad when distributing from one station to another station. This figure shows a top view of the company layout in its current state. The number in Figure 3.8 is the count of resources movement travel. The least travel of resources is two times (green color) and the most travel is 14 times (red color). Red color shows the traffic routing of the movement of materials, resources, and personnel. The calculation for finding the total distances comes from the spreadsheet technique that resources take 702 meters per one batch of production. In the current production, the company approximately produces 230 pants per day in reality. The work time per day is 8 hours. The total production time takes 4,458 seconds per one batch of production. The explanation is in the following:

Process time = 1,664 seconds → 37 percent

Waiting time = 1,120 seconds → 25 percent

Transportation time = 1,674 seconds → 38 percent

When comparing percentages, travel time is 38 percent of total production time. The observation in the current facilities layout significantly vividly shows inappropriate machine positions and routing. Moreover, if the company can solve this problem or find the optimal layout, top management can easily control facilities.

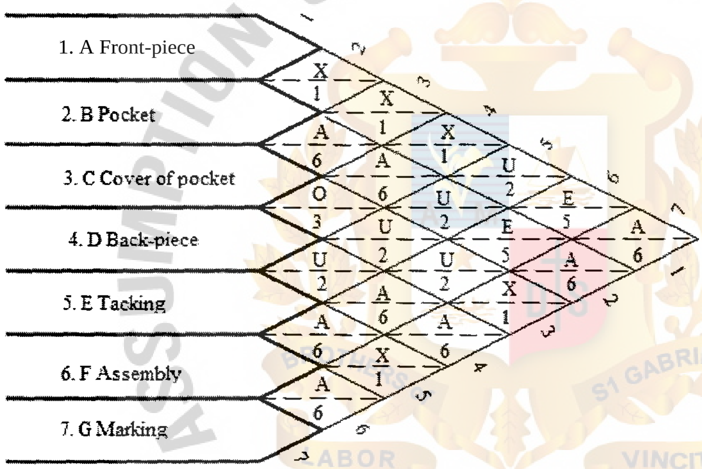
Figure 3.8: Plant Layout's Transportation Route.

Source: Author

However the current layout has a weakness, which is the wrong position of departments. For example E department has to relate with F department but they are not close to each other. Therefore the SLP method is an appropriate way to adapt this theory in this case, in order to rearrange the layout by considering the relationship diagram.

At first, studying the activities relationship analysis has to use a tool to understand the process and try to find the optimal solution for layout arrangement. The tool is called "Diagram Activity Relationship" (Muther & Wheeler, 1973), as in Figure 3.9. This is one method that supports company to clearly see the material flow, and the relationship diagram helps to identify the relationship between each department. In the literature review, there are six values or vowel letters to represent the closeness desirability in order to rank from A "most value" to X "least value", such as A means absolutely necessary and its rating number is equal to 6. For example, in Figure 3.9 front-piece activity (A) has an "A" relationship with the marking department (G). Because A and G departments have the movement of material and resource between each other. E means especially important and its rating number is 5. I means important, and its rating number is 4. 0 means ordinary closeness, and its rating number is 3. U means unimportant, and its rating number is 2, and X is not desirable, with a rating number of 1.

Figure 3.9: A Relationship Chart of Seven Activities



Value	Closeness desirability	No.. of ratings
	Absolutely necessary	
E	Especially important	5
I	Important	
O	Ordinary closeness OK	3
U	Unimportant	2
X	Not desirable	

Source: Author

The way to understand the relationship diagram is to follow the direction of numbers (1 →2 →3 5 —+6 →7). The Rating Number shows the way of calculating TCR (Total Closeness Rating) that relate seven activities (Francis et al., 1992). This chart counts the number following the no. of rating and calculates it into a TCR value of each activity. The following is the TCR calculation which we get from the relationship chart. The number one of TCR value will be focused first.

A front-piece = X + X + X + U + E + A = 1 +1 +1 +2 +5 +6 =16

B pocket piece = X + A + A + U + E + A = 1 +6 + 6 +2+5 + 6=26

C cover of pocket = X + A + O + U + U + X = 1 + 6 +3+2 +2 +1=15

D back-piece = X + A + O + U + A + A = 1 +6 +3 +2 + 6 +6=24

E tacking = U + U + U + U + A + X = 2 +2 + 2 +2 + 6 +1 =15

F assembly = E + E + U + A + A + A = 5 +5 +2 +6 +6 +6 30

G marking = A + A + X + A + X + A = 6 + 6 +1 +6+1 +6=26

F assembly department has the highest value, which means that the company should focus on F department first. F activity has a relationship with every activity except C activity. Therefore F activity should be the center. The second area that will be focused on is G marking activity. G activity has relationships with D, B, A, and F activities.

According to the process flow and analysis of relationships among each activity, it was found that A front-piece activity has relationships with G and F activities by movement of resources and WIP inventories. B pocket piece activity has relationships with C, D, F, and G activities by movement of resources and materials. These relationships are useful for plant layout arrangement. Not only the relationship among activities but the material flow also. Figure 3.5 has explained the manufacturing flow of this product model. In this research, the study of material flow will use a spreadsheet technique for the as-is process. The as-is model is created in the spreadsheet to calculate the total distance in layout. Chapter I referred to the problem in the as-is model. The drawing shows the flow of material and personnel. As the current layout has aisle width between machines equal to two meters, the movement of personnel and material flow is not smooth but complicated. Besides, some processes share resources and need space available for keeping WIP inventories. Therefore the next step should establish the space requirement for a plant layout rearrangement.

3.4 Establishing Space Requirement:

After consideration of the relationship diagram and flow of material, the space requirement is established. The current space on the second floor is 896 square meters, divided into seven departments. Table 3.2 explains the details of each activity.

Table 3.2: Seven Activities Details

Activity	Area (sq m.)	Labor	Machine	Comment
A	75	7	7	This area operates front-pieces and needs high skill level of operator.
B	72	6	6	This process spends long time and to be a bottleneck.
C	76	5	5	This area has inappropriate position of machine and unsmooth workflow
D	93	8	8	This area operate es and needs high skill level of operator.
E	91.5	6	6	This area has 4 special machines for tacking and two simple machines.
F	96	7	7	This area consists of 7 special machines. This area is the main problem of plant layout because of traffic in personnel and material movement.
G	8	2	-	This area. 2 labors have to operate 21 fabric cutting pieces

Source: Author

The total of seven departments is 511.5 square meters; the rest of the area is two restrooms, elevator, and fire exit. In Table 3.2, (B) activity consists of six machines with six workers. This area operates pocket fabric pieces and has the problem of material flow. The machine was put in an inappropriate position that means the flow cannot run continuously; and the involvement of personnel movement is not smooth. These problems lead to the traffic which occurs around this area. (C) activity operates the cover of pocket fabric pieces. The same as (B) activity, this area has inappropriate position of machines and unsmooth material flow. For G activity, operators have to operate 21 fabric pieces, and moreover this area has WIP inventories so needs more space available to store these WIP inventories. Table 3.3 explains the way for establishing space requirement, but this Table shows the current area of each department.

Table 3.3 shows each activity area that the company has in the current layout. The above details give an idea of how the company establishes the space requirement at optimal space by studying each activity detail. The calculation for space requirement divides the total area into each activity or each portion area.

Thereafter, determining the main area for each portion area includes storage, WIP inventories area, aisle routing, machine area, and working area.

Table 3.3: Form of Machine and Equipment Space for As-Is Model

Machine And Equipment Space Form

Plant J.S.T. Garment Company Floor 2nd floor

	Data	Area								
Machine Code	Description	ht le t	r t-back	machine area	s ea	Working area	Aisle Routing	No.of machine	Total space	Comment:
Total department space		m.	m_	sq.m.	sq.m.	sq.m	sq.m.		sq.m.	
A	Front-piece	5	15	1	14	14	46	7	75.0	
B	Pocket piece	6	12	1	12	12	47	6	72.0	
C	Cover of pocket piece	4	19	1	14	10	51	5	76.0	
D	Back piece	6	15.5	1	20	18	54	8	910	
E	Tacking and Elements	7	13	1	30	12	48	6	91.0	
F	Assembly line	12	8	1	30	27	38	7	96.0	
G	Marking	4	1	0	0	4	4	0	8	

Source: Author

In this step, study shows what physical features each activity requires. Configuration of space will help to give shape in order for each activity's space and reduce the waste area that is not necessary. The current layout is not an appropriate layout. Each activity area has too much space for WIP inventories and aisle routing, that make the layout inflexible. Some processes have no need for storage area for WIP inventories. Also, some processes have over-long aisle routing. Lean and layout theories are very useful in this case and can find the optimal solution for rearrangement. Finally, the company will get the optimal space requirement.

After analysis of the relationship diagram and space requirements, the next step is to plan the layout style. This section has three plans for layout style, and selects the optimal layout for the company. The optimal layout should save total distance as much as possible by using a spreadsheet technique for calculations.

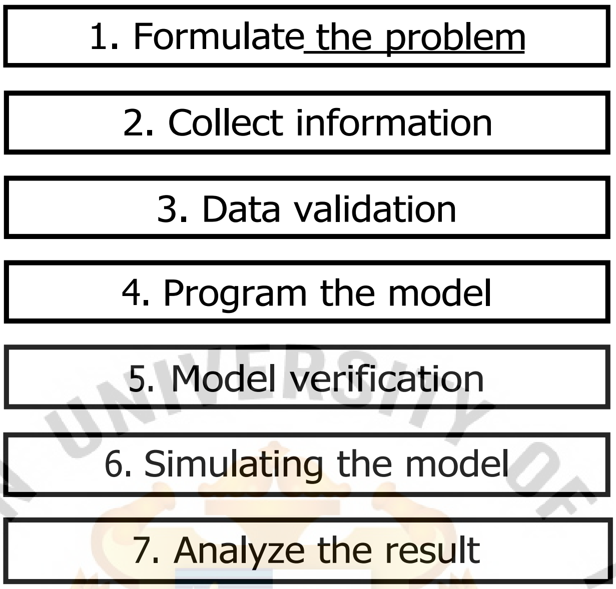
3.5 What-If Analysis:

In the methodology section, to find the optimal plant layout rearrangement, this study expects that the solution can be achieved in reducing total distance. This research uses a spreadsheet technique as the tool for calculating the total distance and developing alternative plans for making worthy decisions. The selected layout should eliminate the bottleneck problem and the What-if analysis will play an important role in analyzing the bottleneck problem. In order to test whether the selected layout will aid in wiping out the bottleneck, simulation play a visual role in simulating the flow of the selected layout before real implementation. A simulation tool can be considered as "simulation system analysis" that will simulate elimination or not. This section will use a tool to support the answer. "Simulation system analysis" will simulate the manufacturing process, number of employees, machines, travel time, WIP inventories, and material.

3.5.1 Simulation Process: Simulation is only a tool to simulate the input data, in other words, simulation can generate millions of possible situations that could be taking place. However, the accuracy of output data or result perfectly depends on how accurate is the input data. Therefore this study verifies the input data by comparing between realistic data and selected distribution data. The data found that there is no significance between the two groups of data. Besides, the result from verification is done by comparing existing output with simulation. Also the error between two groups shows indifference between two groups of data.

The study applied a seven step approach for conducting a successful simulation study (Law and Kelton, 1999) which are shown in Figure 3.10.

Figure 3.10: Seven Steps in Conducting Successful Simulation.



Source: Author

Step 1: Formulate the problem, observe the problem, of which full details are illustrated in Chapter 1 by using five why analysis.

Step 2: Collect information, study the social setting with physical, and human behavior observation to obtain the data.

Step 3: Data validation, study validation of the input data comparing the percentage error between real data with represented distribution data which will be used as input data to the simulation model. With study criteria, results will be accepted to be validated only when error is below 5 percent. In a real process, workflow also has people as an operation unit. Human process time, however, could not perform the same output over time. Thus, error below 5percent could reasonably be allowed.

Step 4: Program the model. Study programming the model via a simulation program. The simulation model represents the current actual model, as simulation models mimic the real operation.

Step 5: Model verification, Comparing performance measures from a simulation model of the existing system with the comparable performance measures collected from the actual existing system. It is important that the model be checked to see whether it is working properly and providing a good representation of the real world situation or not. The assumptions of the model should also be checked to see that the appropriate probability distribution is being used. When the results are consistent with how they perceive the system should operate, then the simulation model is said to have face validity.

Step 6: Simulating the model. The model was simulated according to real operation time per day, that is 8 Hours. The study simulates up to a certain point that data were present at steady-state. This means the number of simulations of the model is tested up to point that a similarity of result is established.

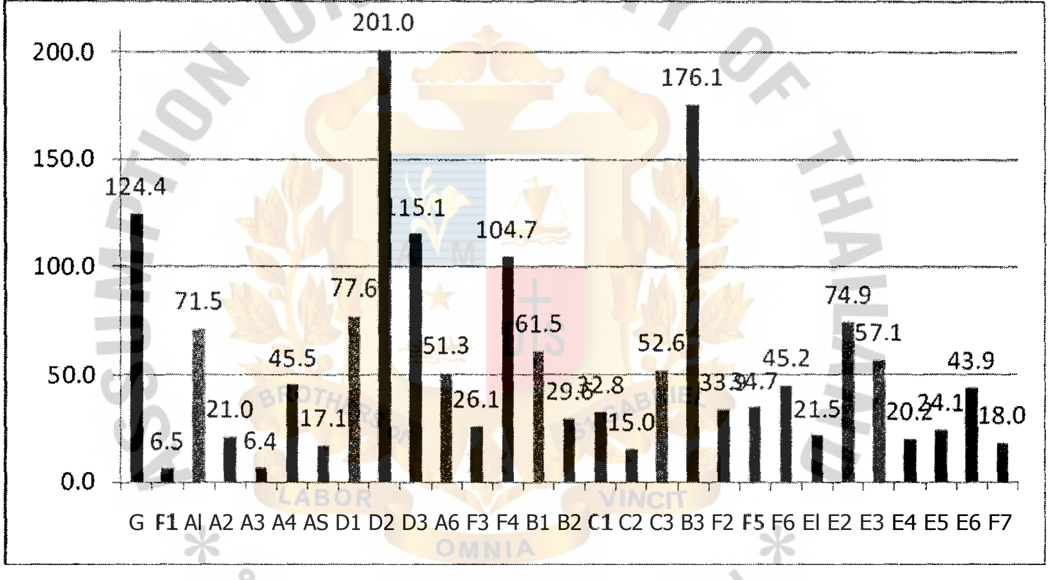
Step 7: Analyze the result. The number of finished products, total waiting times, as well as total distance are the indicators on which the study is focused

After simulating the existing model (As-is scenario), this study realized that bottleneck occurred at process G marking, Al, D1, D2, D3, F4, and B3. In the spread sheet, the bottleneck process can also be observed because of the intensive traffic in those work centers. This jumbled routes are caused by incorrect machine arrangement, process time, high frequency of resources movement, and inconvenience of facilities layout. Especially in G the marking process has two workers to operate it. Bottleneck occurred because two workers have to distribute the marking piece to many processes (process of Fl, Al, D1, B1, and B3), and they are unable to respond to the others process needs immediately. The result found that the process has a high percentage of working utilization, 91.92 percent. Especially in F 1 process which has 91.42 percents for the percentage of waiting time from the G marking process.

Therefore, the main idea of what-if analysis is that new facilities layout can eliminate these bottleneck processes. In other word, eliminating bottleneck processes will lead to significantly reducing the waiting time. Another point is production time, which is the root cause of problem, to answer why congested traffic at bottlenecks is taking place.

After monitoring the process time among work centers, empowered by simulation, this study found that total time among bottleneck process as shown as Figure 3.10, shows as 124 seconds in G, 201 seconds in D2, 115 seconds in D3, 105 seconds in F4, and 176 seconds in B3. These are only five from twenty nine work centers which show up to 721 seconds or 43 percent of total production time.

Figure 3.11: Process Time Bottleneck Detection From Simulation Program.



Source: Author

Hence, if this research can reduce these process times, the waiting queue can be significantly minimized.

After bottleneck processes are indentified, the study will apply the concept of lean theories, and line balancing, as well as simulation to detect, and then diminish the bottleneck process.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

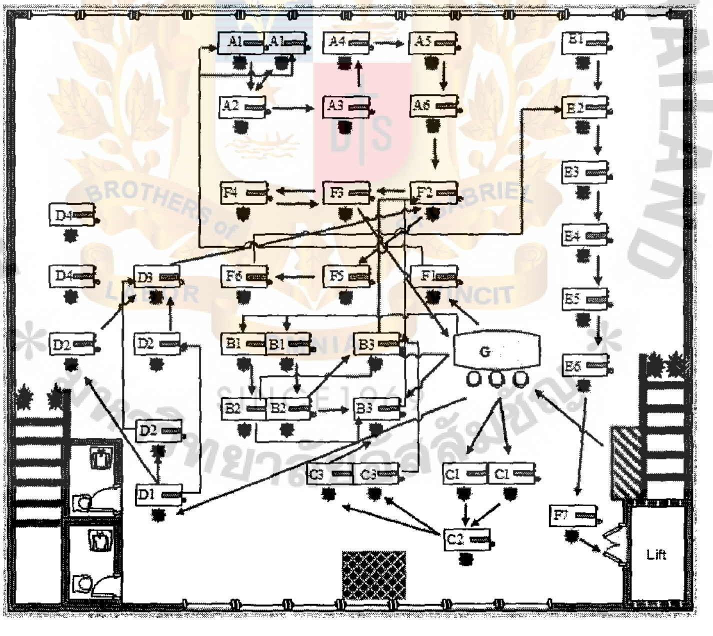
The root cause of the problem is that the company has an inappropriate facilities layout, as the current-state does not consider the relationship between different departments. Chapter IV will also present the analysis obtained from results of the methodologies. The research adopted the Simplified Systematic Layout Planning (SLP) method to analyze the relationship among department, and a spreadsheet technique to calculate the total distance and transportation time in order to develop the alternative facilities layout plans. Thereafter, applying a simulation program simulates each alternative facilities layout plan for measurement, and aids making a decision to select the appropriate facilities layout for the company.

4.1 Develop Alternatives Layout Plans:

The Activity Relationship Diagram tool helps the company to analyze the relationship among different departments. The result of this tool is that the company should focus on F department first for the new facilities layout. F has the highest value of total closeness rating (TCR). Therefore, the study of that relationship should start at F department as the center. The first plan for the new facilities layout is followed by an activities relationship diagram as in the following:

4.1.1 Plan A: This plan is focused on F department as the center, or the first department of a new layout design. This layout style depends on the relationship of each department. The relationship diagram found that F department should be focused as the first area as its TCR is 30. This area has the movement of resources, personnel, and materials which relates to A, B, D, G, and E departments. Therefore this layout style puts F department on the configuration as the first area, as shown as Figure 4.1. In this Figure, F department has seven machines; these machines are special machines and are used for a special process. Six machines are placed together and the distance between machines is two meters. Another machine is put near the elevator for the end of the process, for convenient routing. And then to find the next area which has a relationship with F. The G marking department should be second, because G has a relationship with F department, so G is near to F. This style can reduce the traffic around G marking when comparing the as-is state. This means that traffic in G department disappears. Moreover F and G have a relationship with B department, and B has a TCR rank in the second position. Therefore, B department is near to G and F departments. B department has six machines with six resources. Some processes have the same operation but have more than one resource, so these processes are close together for sharing materials, and do not need a storage area. A, D, C, and E departments are placed around the layout style concept in which processes which have a relationship to each other will be close; and processes which do not relate to each other will be far away.

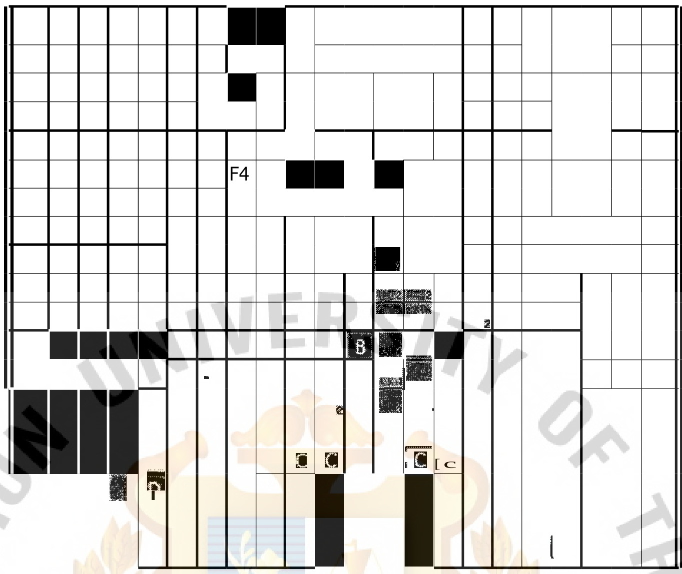
Figure 4.1: Layout Arrangement by Analysis of Activities Relationship In Plan A.



Source: Author

This study uses the spreadsheet technique to help to calculate and analyze the first plan. The measurement of this layout style is the total travel distance which is calculated from the spreadsheet technique. The total distance is 312 meters per one batch production. The movement of resources takes 744 seconds for transportation time. The workflow of materials and resources are better as shown in Figure 4.2. The complicated movement of personnel is reduced.

Figure 4.2: The Workflow of Materials And Resources Of Plan A.



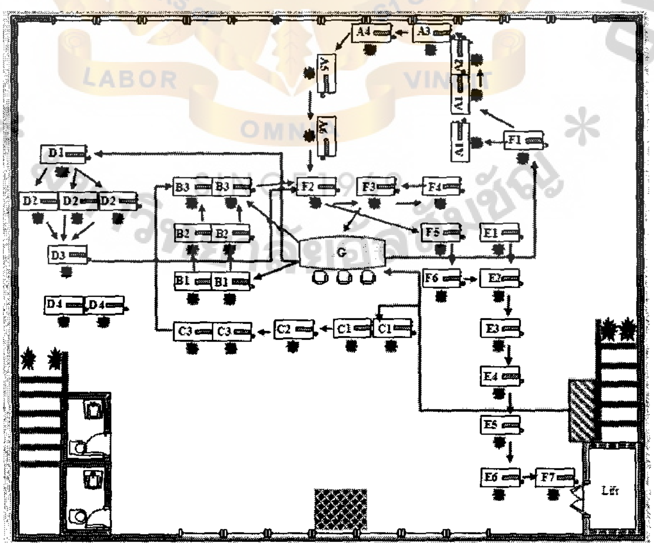
Source: Author

When comparing between the as-is model and this plan, this style is better. The company can reduce the transportation time. On the other hand, in this figure still occurs the problem of traffic in the area of F department, which comes from the movement of materials and personnel. When traffic happens, the movement of personnel is dangerous. Therefore the layout theory should be applied in this case and try to eliminate the traffic problem.

4.1.2. Plan B: The second planned layout design will adopt another type of layout, "Product layout". This type is useful when the production process is organized in a continuous or repetitive way (Jakanathan, 2003). The design will combine process and product layout together, which applies the other plant layout theory in the model, such as U-shape, L-shape, and I-shape layout design. In the process consideration, F department is the assembly line for combining the components from other departments to be semi-products. In this area, there is movement of personnel and materials that lead to traffic and bottleneck problems. Therefore, this layout plan has to eliminate the traffic point around F department, as shown as Figure 4.3.

Designing starts from F department, that uses the L-shape layout design. The correct operations flow is reached through the layout design, and equipment, and machinery specifications. F department is the area of machinery specification and the flows are related to each other, especially F2, F3, and F4 machines. Therefore F2, F3, and F4 should be as close as possible to link them together in order to support the operators which have no motion. From the operation process, F5 and F6 machines are the next process, and F6 continuously sends work to E2. The advantage of L-shape in F department is there is an available workspace that can be adjusted for G marking department to support to other parts and be located at the center. This location of G department can reduce the travel distance and transportation time for distributing work. For A department, U-shape is applied, the workers of A department will sit face to face to improve the communication and have less travel distance. Besides, the U-shape flow is useful for A department as the starting process and ending process of A are in the same position. Another department (E) uses I-shape layout because I-shape is the best flow pattern for continuous flow. The process of E department goes from El until E6.

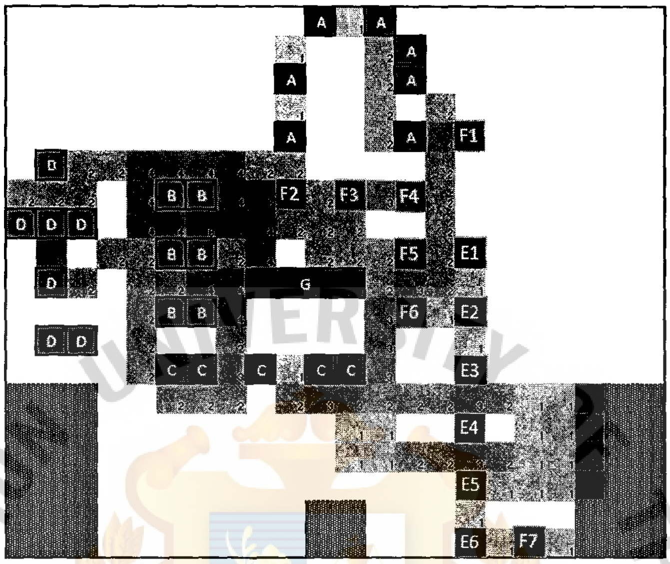
Figure 4.3: The Facilities Layout For Plan B.



Source: Author

This model is appropriate for continuous workflow. The result of measurement shows that this model can reduce the travel distances to 224 meters per one batch production and take 534 seconds for transportation time. The operation and material flow is shown in Figure 4.4 in the spreadsheet technique.

Figure 4.4: The Workflow of Resources And Materials For Plan B.



Source: Author

There is no traffic problem in this model after adopting the product layout theory. The workflow and transportation routing are smooth, to avoid accidents.

The resulting conclusion of each alternative layout is shown in Table 4.1.

Table 4.1: The Conclusion of Each Alternative Layout.

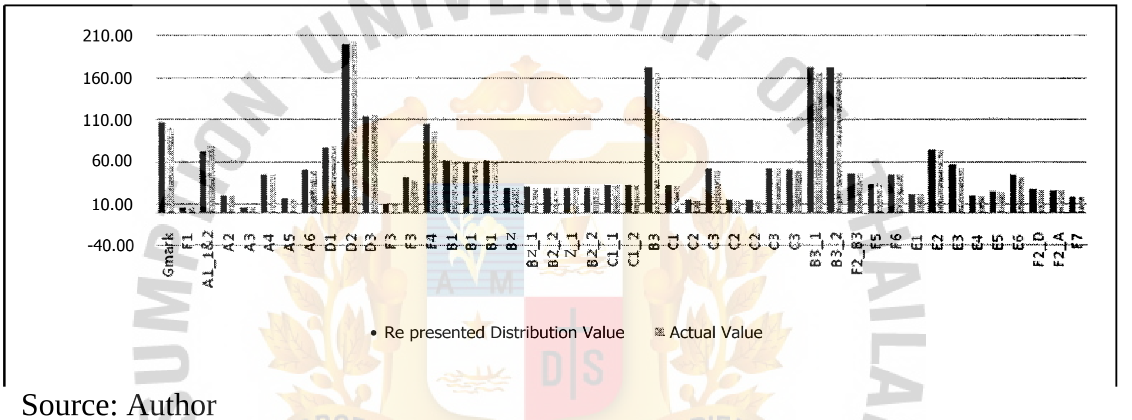
	Travel Distance	Total Transportation Time
Current-state	702 meters	1,674 seconds
Plan A	312 meters	744 seconds
Plan B	224 meters	534 seconds

Source: Author

Table 4.1 explains that Plan B is the appropriate layout for the company, but this plan should be proved by using the simulation program before making a decision. The reason why a simulation program is needed, is because simulation can possibly detect bottlenecks and determine which process has the high number in the queue.

In order to obtain the accurate results, simulation needs accurate input data. Thus, data and model validation need to be conducted. According to steps in conducting successful simulation, data validation is very important before input of actual data to the simulation model. This study compares actual data to the represented distribution data. The gap between the two sets of data is data error, 3.54 percent in error. Thus, we could accept this represented distribution to be used as input data to the simulation model, since, less than 5 percent is less than the criteria, as mentioned in Chapter III.

Figure 4.5: The Difference In Seconds Among Work Centers Between Actual Data And Represented Distribution.

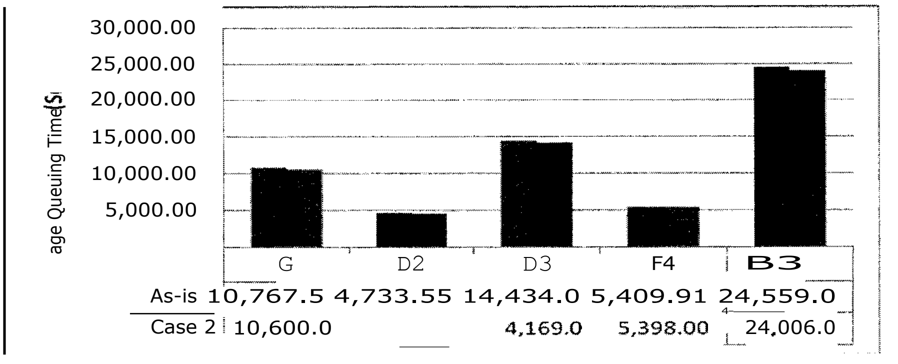


Source: Author

After Data validation, model verification is conducted in order to make sure that simulation model is correct and reflects reality. The simulation result shows 234 batches as finished product at the end of day, while the actual output rate averages 230 batches per day. This is only 1.73 percent difference, thus the simulation model is failed to be rejected for invalidation.

3.1.2.1 Result Analysis: as mentioned in Chapter III, regardless of process time bottleneck, the result shows that work centers G, D2, D3, F4, and B3 also have the largest queuing time. However, after plan B was developed and tested via simulation, the result shows a significant difference between the as-is model and Plan B in terms of average queuing time.

Figure 4.6: The Average Queuing Time In Seconds Between As-Is And Plan B.



Source: Author

The result shows only 1.64 percents difference in Plan B from the As-is model. Obviously, processes still have to be future analyzed to obtain a better result, thus Plan C is developed accordingly.

4.1.3. Plan C: This plan is a development from Plan B which has a weakness from bottleneck processes. These processes occurred because of an unbalanced production line. Therefore, this plan is developed by using line balancing, to eliminate the bottleneck processes in order to improve productivity. Therefore the line balancing concept can be adopted in this case. This study would like to adopt line balancing theory in the case study as in the following:

<u>The Study of Line Balancing Concept:</u> This case will use a combination of processes. Analysis of the production line is needed to analyze every process in each department. The observation found that the process time in each department is not equal, and quite different.

A department (from Al until A6) = 228 seconds

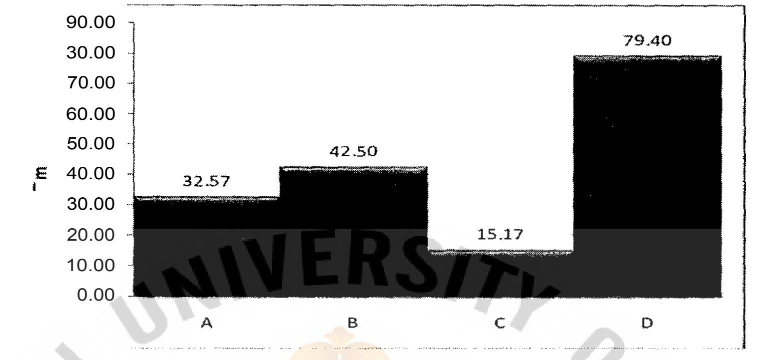
B department (from B1 until B3) = 255 seconds

C department (from C1 until C3) = 91 seconds

D department (from D1 until D3) = 397 seconds

The process time of C department takes the least, or 5 times of D department as shown in Figure 4.7. In the current-state, this department has 5 machines and 5 operators. These are C1, C2, and C3 processes. These three process can combine together to be one process (C1+C2+C3) and need 2 operators. Besides, the observation found that these processes have no complex operations. When combining process C, there are 3 operators left who can help other departments.

Figure 4.7: Process Time Among Work Centers For As-Is Model.



Source: Author

These three operators can support the processes of D3, B3, and D2, but resources are needed to spend time in training the operators. In the current-state, D3 has only 1 operator, 2 in B3, and 3 in D2. Therefore the new production line D3 has 2 operators, 3 operators for B3, and 4 operators for D2. When changing resources is input into the simulation program, the result is that the bottleneck from D2 process has disappeared and G department cannot submit the parts and materials to F 1, Al, and B1 processes under their requirements at the right time. B1 has to wait for G which affects B2 also (B2 is received WIP inventories from B1). Besides, D2 has to wait for D1 because G cannot respond to submit WIP inventories to D1 immediately. This situation G needs more resource to operate and distribute to other processes at the right time. If the company adds more resource, it means the company has to pay more wages or spend more money. Therefore, how can the company add more resource in G but without increasing wage payments?.

Actually the manufacturing process started at G department. If resource is added in G, the distribution to other processes will be at the right time. Besides, another idea can support the production process effectively, by changing the working time for G department. In the current-state, the working time is 8:30 A.M. until 5:30 P.M. In this case G department should start work at 7:30 A.M. until 4:30 P.M. to prepare for parts and materials to others immediately.

However, the company has to find more resource in G in order to submit parts and materials to others at the right time.

The observation and data collection found that other processes can be combined together: process of A4 combined with A5, and B1 combined with B2. This combination can reduce the transportation time that moves from one station to another station. When combining the process of A4 and A5 and using one resource and machine to operate, the process of A5 takes 15 seconds and has 1 operator. A4 takes 44 seconds. When combined together, the process time is equal to 59 seconds. Even though process A4 and A5 were combined and have only one resource to operate, they can send to the next process (A6) at the right time. After A4 and A5 are combined together, the company will have 1 operator to support others.

Other processes, B1 and B2, can combine because these processes submit WIP inventories to B3 too fast, that makes B3 have high numbers in the queue. B1 and B2 have 4 operators for pocket pieces. B1 process takes around 59 seconds, and B2 takes 29 seconds. When these processes are combined together, the operation takes around 88 seconds. They still submit WIP inventories to B3 at the right time and the company has 2 operators to support others also.

The combination of process A4 with A5 and B1 with B2, means the company has 3 operators that can support the processes of G, D1 and D3. These three processes have high numbers in the queue and need more resource to operate. Therefore, the new situation is changed, G has 3 operators, D1 has 2 operators, and D3 has 3 operators. This case can conclude that the number of resource for each process is as in Table 4.2.

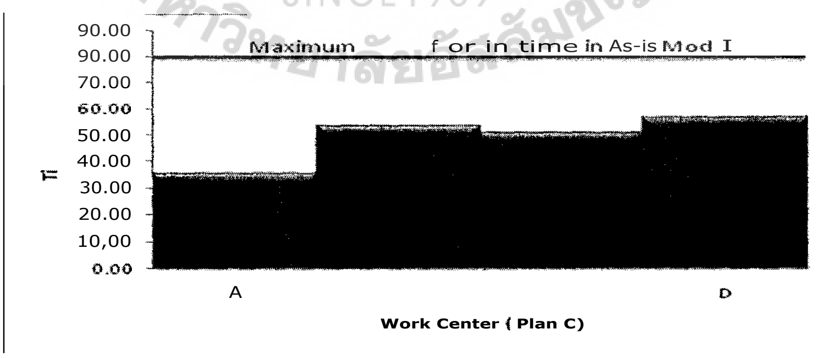
Table 4.2: The Number of Resources In Each Department.

Process	A1	A2	A3	A4 (A4+A5)	[illegible]		
No. of Resource	2	1	1	1	1		
Process	B1 (B1+B2)	B2 (B3)					
No. of Resource	2	3					
Process	C (C1+C2+C3)						
No. of Resource	2						
Process	D1	D2	D3				
No. of Resource	2	4	3				
Process	E1	E2	E3	E4	E5	E6	
No. of Resource	1	1	1	1	1	1	
Process	F1	F2	F3	F4	F5	F6	F7
No. of Resource	1	1	1	1	1	1	1
Process	G						
No. of Resource	3						

Source: Author

After moving resource between each process, the processes of A, B, C, and D departments can balance process time, as shown as Figure 4.8. When inputting this information into the simulation program, the numbers in the queue from G, B3, and F4 has disappeared.

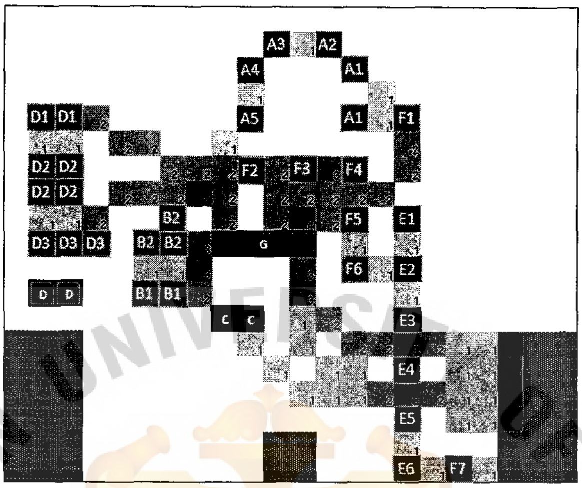
Figure 4.8: Process Time Among Work Centers For Plan C.



Source: Author

Hence, adopting the line balancing concept can eliminate the bottleneck problem from 5 work centers, where this concept can reduce the transportation time that the company has in the facilities layout and increase the productivity from 234 pants per days to 267 pants. The new facilities layout is shown in Figure 4.9.

Figure 4.9: The Workflow of Resources And Materials of Plan C.

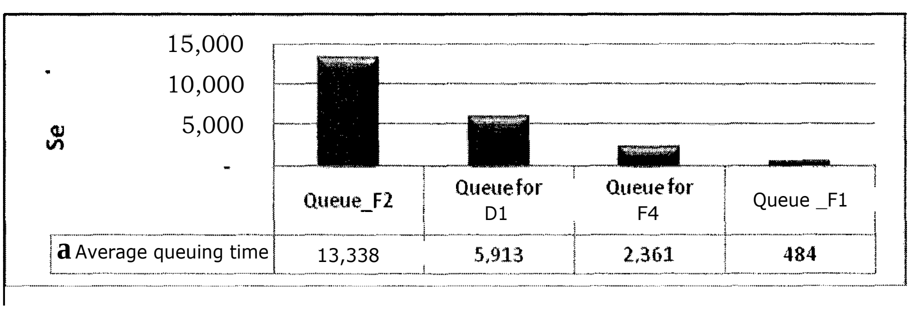


Source: Author

This plan can reduce transportation time by adopting the line balancing concept to 122 square meters. The transportation time takes only 291 seconds per one batch production. Thereby, the layout is useful for the company to increase productivity, and reduce transportation time and travel distance. Inevitably, this facilities layout could be the appropriate facilities layout for the company.

In simulation, the result shows that average number in the queue only occurred in F2, D1, F4, and F1. However significant queuing time would affect the overall working line in F2, whose value shows up to 13,338 seconds per 8 hours, or 1,199 seconds per one batch production, as shown in Figure 4.10.

Figure 4.10: The Average Queuing Time in Seconds Among Bottleneck Process.



Source: Author

Although, plan C can eliminate bottleneck processes from 5 work centers (G, B3, D2, D3, and F4), there is a new bottleneck process which is due to adding of resources in G, B, and D processes. These processes lead to more numbers in the queue in F2 process. The new bottleneck process shifts to F2, as this process has been using the special machine with one operator for controlling. F2 has to operate 3 processes for front crotch basting, back crotch basting, and basting at side of pants. These three processes have only one operator and one machine, so the process takes much time. F2 process takes around 104 seconds. The operator of F2 has to take turns among these three processes that depends on first-in first-out priority.

The solution for the F2 process should eliminate the bottleneck from F2:

Machine Investment: For this option, the company needs to invest in one more machine for F2 process and hire one operator to control this machine. The machine cost is approximately BHT 290,000 and wage cost for one operator is BHT 203 per day. If the company invest in a machine and hires one more operator, the productivity will be increased to be 392 pants per day. Increasing productivity can deliver the product to the customer at the right time. Therefore the company can produce 392 pants per day; and the company has no need to pay the late penalty anymore which can save approximately BHT 300,000 per year. Besides, the company has an ability to increase the profitability also, as in the following:

As-is:

230 * 1 month = 5,980 pants per month → profit = BHT 299,000 per month

profit = BHT 3,588,000 per year

To-be:

392 * 1 month = 10,192 pants per month → profit = BHT 509,600 per month

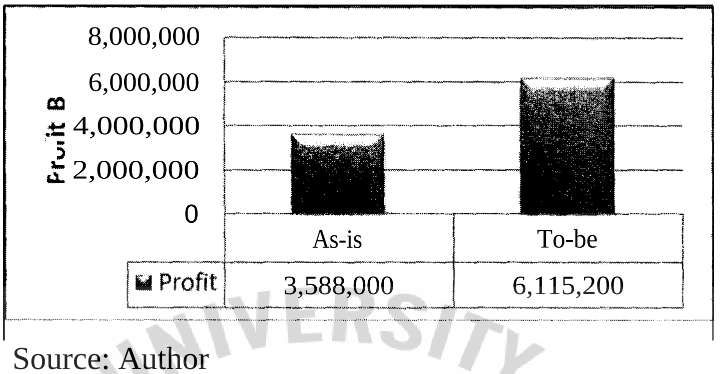
profit = BHT 6,115,200 per year

Add: Late penalty = 300,000 per year

Total: To-be facilities layout is equal to BHT 6,415,200 per year.

Profit includes the late penalty cost of BHT 300,000 because the productivity of plan C is 392 pants per day. Actually customer demand is approximately 2,000 pants per week or 333 pants per day. Hence, with machine investment, the company can produce the products in accordance with customer demand at the right time.

Figure 4.11: Profit Comparison Between As-Is Layout And To-Be Layout.



Source: Author

In this option, the company will get a profit of BHT 6,415,200 per year. When calculating the percentage, it is about 79 percent increase in profit.

When comparing between the as-is layout and to-be layout, it was found that the company can reduce the transportation time, total distance, and waiting time as follows:

<u>As-is layout:</u>

Process time = 1,664 seconds

Waiting time = 1,120 seconds

Transportation time = 1674 seconds

<u>To-be layout:</u>

Process time = 1,664 seconds

Waiting time = 1,199 seconds

Transportation time = 291 seconds

The rearrangement of the facilities layout can save transportation time, reduced from 1674 seconds to 291 seconds, or the company can save 82.6 percent from the current-state. While plan C cannot reduce the waiting time because this plan has added resource and a machine in B, D, and G departments. The resource and machine changes in these departments leads to an increase in the number in the queue in F2 process which depends on the first-in first-out priority. The waiting time in F2 process is 1,199 seconds per one batch production to wait for F2 machine. If the company invests in one more machine in F2 process, this waiting time will be reduced as follows:

Process time = 1,664 seconds

Waiting time = 789 seconds

Transportation time = 291 seconds

The total production time will be 2,744 seconds. The productivity will be 392 pants per day. The machine and resource investment can increase the productivity and deliver the product to customers at the right time.

4.2 The Configuration of Space Requirement:

This part is the study of space requirement after selecting the appropriate layout from part 4.1. The space requirement is shown as Table 4.3. This Figure shows that the company uses 157 square meters from the total area of 896 square meters. The development from the current-state is in G department. Because in the current-state, G occupies 8 square meters and this area is the obstacle for transport routing and they have no space requirement to store the WIP inventories. Therefore plan C has more space for G department at 25 square meters. This presents no obstacle and G has storage area for WIP inventories. Beside, the company has more space available for storage of raw materials also. Because of the current-state, the company has no space available to keep raw materials, which makes company to stock the raw materials on the first floor. In this situation it is a waste of time to bring the raw material, as the operator has to go to downstairs. Therefore the to-be model is useful for the company to stock the raw materials on the second floor, which is convenient for every operator and saves much time.

Table 4.3: The Configuration of Space Requirement for To-Be Layout.

Machine And Equipment Space Form

Plant J.S.T. Garment Company   Floor 2rd floor

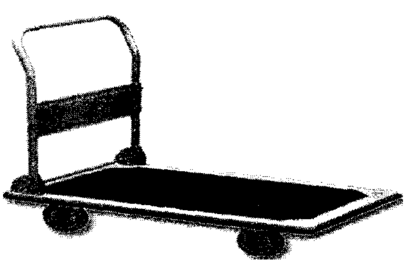
	Data	Area								
Machine Code	Description	[illegible]ght-left	[illegible]	machine area	[illegible]	Working area	Aisle Routing	No of machine	[illegible] space	Comment
Total department space		m.	in.	sq.m	sq.m	sq.m	sq.m.		sq.m.	
A	Front-piece	7	5	1	23	6	6	6	35.0	
B	Pocket piece	4	4	1	2	5	9	5	16.0	
C	Cover of pocket piece	4	2	1	1	2	5	2	8.0	
D	Back piece	3	9	1	7	11	9	11	27.0	
E	Tacking and Elements	2	11	1	11	6	5	6	22.0	
F	Assembly line	6	4	1	7	7	10	7	24.0	
G	Marking	5	5	0	4	8	13	0	25.0	

Source: Author

4.3 Material Handling Analysis:

This part analyzes the material handling that should be used in the factory. The material handling is needed for batch production that can move the WIP inventories from one station to another station easily. However the effectiveness of material handling depends on the dimension, capacity, weight, and size (Edward, 1997). This study required material handling in F and E departments because these departments operate for the semi-product. The movement from one station to another station is hard to do, so material handling is needed for the new facilities layout. The material handling should use the trolley, as shown in Figure 4.12. The dimensions are 740 * 480 millimeters. These dimensions are suitable for the company's aisle routing. The capacity is 150 kilograms. The cost is about 800 baht per trolley. This material handling is suitable for transportation routing and saves time in movement.

Figure 4.12: Trolley.



Source: Author

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

According to the statement of the problem, the company coped with the problem of late delivery. The penalty is approximately BHT 300,000 per year per customer. The main reason derived from a poor facilities layout on the second floor of the factory. The rearrangement of facilities layout is considered as a good way to solve the problem. The poor facilities layout came from inconvenience transport routing that led to transportation waste of resource motion. This reason affected waste in the total distance and total production time. Therefore the main objective of this study is diminishing the total distance and transportation time within the factory in order to deliver the product to customers on time.

5.1 Conclusion:

This study selected one production line by adjusting P/Q analysis, following the assumption and Pareto rules. One product model was selected and determined the facilities layout arrangement. The reasons for selecting this product are because this model has the most annual sales, most complex operations, and highest repeat orders from customers. The next step, the material flow analysis of this product model is necessary, to analyze the flow of material, resource, transportation routing and personnel in the production line. The analysis of the current state detected the complex and inconvenience routing. Especially around G and F departments were found the congested traffic problem. Besides, bottlenecks were detected in five work centers; B3, D2, D2, F4, and G departments. Both traffic and bottleneck problems were from non-consideration of relationships among different departments. Therefore, this study adopted the activities relationship diagram. This step analyzed the relationships among different departments which consist of A, B, C, D, E, F, G departments. This study has adopted the activity relationship diagram to support the analysis. The diagram helps to manage the rearranged relationships among seven departments; the main concept is for calculating the total closeness rating (TCR). The result of the diagram shows F department has the highest values of TCR, so the company must focus on this department as its first priority for determining the new layout design.

The activities relationship diagram is not sufficient in this study. Lean layout theories can help the company, such as U-Shape, L-Shape, and I-flow. These flows support the company layout in reducing transportation distances within the company. However, the appropriate facilities layout should be proved and tested in a simulation program. Simulation programs can simulate the bottleneck process, numbers in the queue at each process, resource utilization, and queuing time of each process.

The appropriate facilities layout selection is to select an appropriate facilities layout which can reduce the transportation time as well as increase productivity. The study has developed three alternatives plans, as concluded in Table 5.1.

Table 5.1: The Conclusion of Each Alternative Plan.

	Travel Distance	Total Transportation Time	Output per day
Current-state	702 meters	1,674 seconds	234 pants
Plan A	312 meters	744 seconds	234 pants
Plan B	224 meters	534 seconds	234 pants
Plan C	122 meters	291 seconds	267 pants

Source: Author

Finally, the appropriate layout is plan C, since company can save much in total production time. Plan C can reduce transportation time to 291 seconds per one batch production, so total production time is reduced from 3,075 seconds to 4,458 seconds, per one batch production. Besides, plan C increases the productivity to 267 pants per day, and the bottleneck processes in the current-state disappear. The bottleneck problem is tested and validated via a simulation program. However if the company invests in one machine for process F2, the productivity will be increased to 392 pants per day and total production time will be decreased to 2,744 seconds from 4,458 seconds.

Therefore, the approach to increase the productivity and deliver the product to customers on time without a late penalty lies in implementing Plan C.

After selecting the appropriate facilities layout, the configuration of space requirement is the calculation of space requirement in the factory. In the current-state, G department has no space available for storage of WIP inventories. The study has a form to show the space requirement for each department, including machine area, WIP inventories area, and aisle routing. When determining the layout arrangement, this form helps to calculate the space requirement of each department to check the space utilization. Finally, the selected facilities layout uses 157 square meters. This layout can reduce the traffic and inconvenience problem around G department. Since G has more space available for storage, there is no obstacle for transport routing, and the company has more space for raw materials storage.

Determining a layout arrangement in this study includes the analysis of material handling to support the movement of resource and materials. The efficiency of material handling depends on size, dimension, capacity, and weight. The study applied a trolley cart to help the material movement which is appropriate to the aisle width and transportation routing.

5.2 Managerial Implication:

This study can help the company to reduce the transportation time and total distance within the company in order to deliver the products to customers at the right time. The company has no need to pay the late penalty, which was approximately BHT 300,000 per year. Besides, this study can increase the productivity to be 392 pants per day which is sufficient for average customer demand. This productivity improvements means that the company can increase its annual profit to be six million. However the condition is machine investment which the company has to pay for the machine cost. The machine investment has a high return in profit. However, it is necessary to train the operator with practice in using the machine in order to avoid accidents with its operation. More time is needed to learn to operate this machine.

5.3 Recommendation:

This study focuses on a facilities layout re-arrangement to reduce the transportation time in order to deliver the product to customers on time. However, a good facilities layout should have smooth workflows. In addition, the best workflow smoothing should also have work standardization, especially if the operation process depends on people, who vary. Work standardization is important to avoid NVA (non-value added activities). The management level should set the standardized time for each process. Standardized work is an agreed set of work procedures that establishes the best method and sequence for each manufacturing process. Standardized work provides a basis for consistently high levels of productivity, quality, and safety. Therefore, the organization should develop standardized work to increase productivity. The effectiveness of this idea should build a culture within the organization to force the operators to follow the work standardization. When the organization has a good layout and work standardization, it means that the organization can eliminate the transportation waste and non-valued added activities. Therefore a future study should deepen the of work standardization to help the new facilities layout effectively. Another important idea is how to increase productivity which is more than 392 pants per day. The company should plan its production schedule effectively or extend the overtime for each day in order to increase the output per day. On the other hand, training for operators makes them have more skills, to be ready for every operation in order to support every department.

Ultimately, for simulation, the consequence of reviewing input data should be periodically conducted. Data such as working time could be changing when workers have more skills, or there is investment in new machines. Inevitably, input data to simulation is very important, since a simulation program is only a tool for simulating possible outcome for events.

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APPENDICES

APPENDIX A

Simulation Result of Current-State

Process	In second
Queue for D1	10141.42454
Queue for B3 (After B2 done)	9185.20532
Queue_A1_2F	7231.63618
QueueA1_1F	7226.00021
Queue for C2	7211.04946
Queue for B1_2	5713.90355
Queue_B1_1	5537.34554
Queue for F4_A	5081.13078
Queue for D3	4591.00182
Queue for El	4277.60711
Queue for B3 (After C3 done)	3461.74303
Queue_F2_A6	1394.14668
Queue_A1_2	61.32781
Queue A1_1	61.3236
Queue for F2 (3rd)	39.12028
Queue for C3	32.8137
Queue for B2	28.25178
Queue for A4	21.21064
Queue_F2_D3	18.97311
Queue for F4_D	15.1475
Queue for F3	8.33643
Queue for A2	3.73599
Queue_Fl	1.88589
Queue for F3 (After F4 done)	1.0095
Queue for B3 (After G marking 2 done)	0.42893
Queue for A6	0.25143
Queue for E3	0.1365
Queue for E6	0.01256

APPENDIX B

Available Average Queuing Time of Plan C

Queue_F2	13,338
Queue for D1	5,913
Queue for F4	2,361
Queue _Fl	484
Queue for F2 (3rd)	60
Queue for A2	46
Queue for B1_2	24
Queue_B1_1	21
Queue for C3	13
Queue for D3	9
Queue for F3	8
Queue for B2	7
Queue for F3 (After F4 done)	1

APPENDIX C

The Operation Process Time

G (for Al)	20
G (for Fl)	12
G (for B1)	4
G (for D1)	27
Fl	6
Al	87
A2	20
A3	6
A4	44
A5	15
A6	50
D1	78
D2	203
D3	116
B1	59
B2	29
B3	167
C1	32
C2	14
C3	45
F2 (from A6)	21
F2 (from D3)	21
F2 (from B3)	46
F3 (from F2)	10
F3 (from F4)	39
G (from F3)	37
F5	34
F6	44
El	22
E2	74
E3	53
E4	20
E5	24
E6	41
F7	18