
A REDESIGN LAYOUT TO INCREASE PRODUCTIVITY OF A COMPANY

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Abstract: This project is conducted in Company X, a passenger cars wheel producing company located in Sunter, North Jakarta. With a view of increasing the productivity of the company, the focus of this project will be redesigned the layout of the factory. The main problem encountered is that the goods are not produced in single location, causing a considerable hindrance in terms of time and distance, and hence efficiency. The redesigning layout process will use SLP method and flow analysis while supported by analysis of assembly line balancing to optimize the layout. Regarding the evaluation process, ARENA software will be used to simulate and identify the bottleneck in the production process, and comparing the layout alternatives to decide the best layout. The best chosen layout according to the simulation and SLP method that supported with flow analysis and assembly line balancing will be used as the master draft layout that will be proposed to Company X.

Keywords: *Systematic Layout Planning (SLP), Flow Analysis, Assembly Line Balancing, Productivity, Simulation*

INTRODUCTION

As businesses begin to rapidly emerge and develop in the world, it is impossible to avoid entering a highly competitive business environment. Nowadays, firms can not simply compete only by selling their products and services. They must continuously research and develop their strategies in order to deliver high quality performances to compete with their rivals. By having high quality products, they should be able to dominate the market. One of the factors that contribute to this aspect is a company's plant layout. Not only can a good layout increase a manufacturing process' effectiveness, efficiency and productivity, it can also reduce waste of time and bottleneck, optimize the workflow of material and process, and it can make the monitoring process much simpler.

There are many well-known industry companies in Indonesia that are recognized by their good quality of products and services; one of them is company X. The company specializes mainly on automotive wheel rim manufacturing and produces steel wheel for Jeep, Car, Sedan, and Minibus. To provide their customers these products, the firm needs to be efficient in their manufacturing process. With efficiency, not only will the company be able to provide for their clients, they will also be able to expand their business as they become more productive. A new design

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to the factory's layout can help improve product quality, reduce inefficient time and optimize factory activities.

Problem Identification

The main problem encountered is that the goods are not produced in single location (Figure 1), causing a considerable hindrance in terms of time and distance, and hence efficiency.

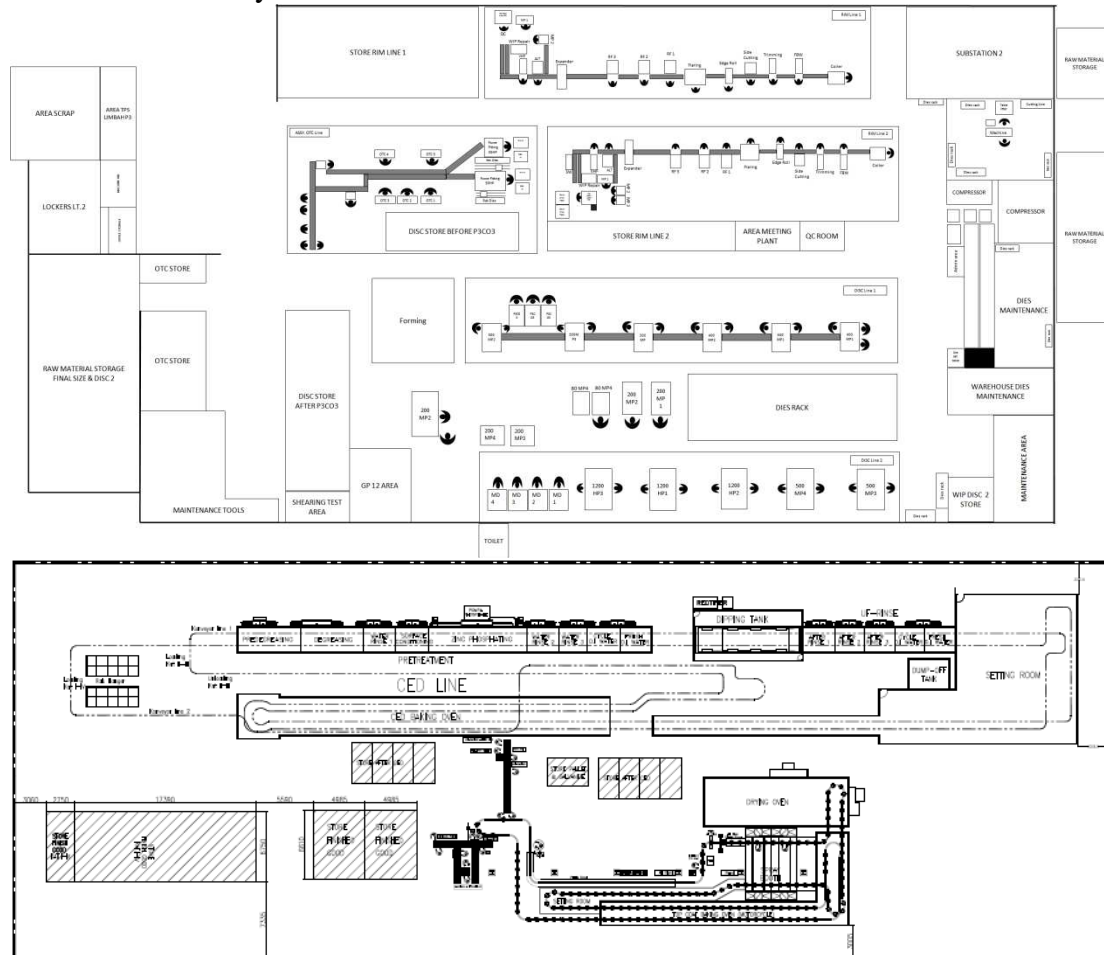


Figure 1. Old Production Line in Company X

It can be concluded that the process of manufacturing in the company would not be efficient. Thus, a redesigning layout of company X is important in order to increase their productivity by minimizing their cycle time and the travel distance between each manufacturing process.

Methodology

To redesigning layout in company X, there are four steps in which contains of several processes in it. Those steps are :

1. **Preliminary study** is the first step to begin the project. This step requires lot of knowledge and resources to obtain the idea that will become the main topic of this project. The next process is seeking for project scope and limitation to define problem identification. Then, hypothesis can be determined and literature review can be used to give explanation about theoretical background of the problem. Next process is to determine the problem statement and define the purpose of the project.

2. **Data Collection** consists of three processes. Those are field observation, interview, and **literature** searching. Purpose of this step is to obtain the data that will be use to do the analysis process.
3. **Analysis data** is the activity which has function to explore the data then make suggested layout. It divided into four sections, analysis product demand, analysis layout, simulation process, and evaluates the suggested layout. Each section has its own procedure to complete the analysis process.

To analyze product demand, it needs to sort the data from the highest until the lowest demand within one year. Next is calculating the cumulative percentage then make a graph based on Pareto analysis. The final process is to analyze the data using ABC analysis to determine the products that will be used in simulation process.

Second step is analyzing the layout. Information related to the layout and visual analysis process in the company is the essential things to begin this process. After analyzing both data and information, there are three aspects that need to be identified. Those aspects are assembly line balancing, number of worker and the activity inside the company; and total productivity production that focus on machine breakdown. After both three aspects are completely done, it should make an Area Relationship Chart (ARC) that explains the relationship between each department and area. Next step is to make Area Relationship Worksheet to give a clearly understanding about the ARC. The final step is to design Area Relationship Diagram (ARD) that will be used as a base to design suggested layout. Both steps are based on Systematic Layout Planning (SLP) methodology.

Simulation step is to simulate and analyze the layout. It consists of several processes, as follow: model conceptualization, model translation, and running the simulation. Model conceptualization is to make some modeling regarding to the problem. After the modeling has been complete, it should be translate into the simulation language. Then, the simulation can start to run. The simulation will be conducted by using ARENA simulation software.

Evaluation process is comparing process between both alternatives layout and makes some decisions regarding to the result of it. It used several parameters to evaluate the result. The most efficient layout will be use as a recommendation layout to the company in order to increase the productivity.

4. **Summary process** contains of the final result of the project which is the recommendation layout which has the most efficient process that can increase the productivity and further developments that needs to be complete to support the layout.

Factory Layout

According Deb and Bhattacharyya (2003), factory layout is the arrangement of area that related to the manufacturing process to allow greater efficiency and productivity. It consists of arrange working areas, storage areas, and location of machines. The arrangement process is related to the process manufacturing, product that will be produce, area of the factory, operational cost, and the specification of machines (dimension). Every single movement will influence the optimization of production. There are some characteristic of good quality factory layout, as follow (Saerang, 2011):

1. Traveling time of workers and material is decreasing
2. Minimum operational cost

3. Zero accident in the factory
4. Employees could work efficiently and effectively
5. Optimize empty space
6. Communication among employee are well organized

Several factors that must be considered to make a good layout are: material, machine used, employee, and material handling (Ailing, 2009). Based on the work flow of manufacturing process, there are four types of layout as follow (Yin, 2009):

1. Process layout: arrangements of machines which have similar function are placed together into one.
2. Product layout: arrangement of machines location based on the production process.
3. Fixed – position layout: arrangement of equipments that used to produce the product are move to the location where the main product is located in the fixed location.
4. Group technology layout or cellular layout: combination of process and product layout.

Systematic Layout Planning (SLP)

Richard Muther (1973) was introduced the idea of Systematic Layout Planning (SLP) method. It is a planning procedure to arrange factory layout. The aim of this method is has a fastest flow of material during manufacture process with a lowest cost. There are several fundamental procedures that must be done in order to have an efficient and effective factory layout. Those are identify, generation of alternatives, evaluation, selection, and implementation. Details procedure of SLP are as shown as figure 2.

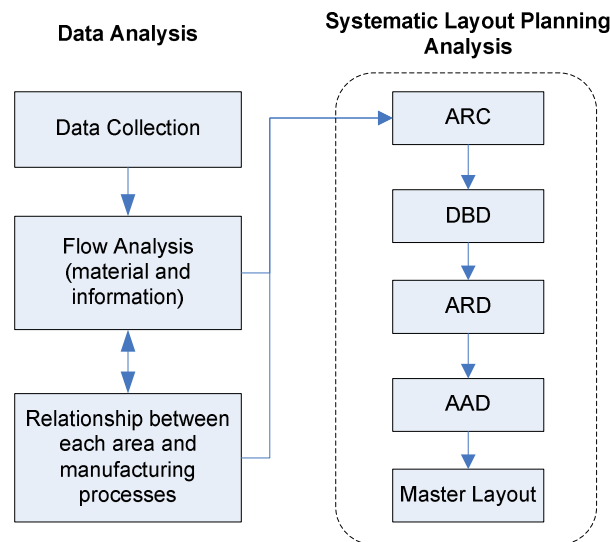


Figure 2. SLP Procedure

Figure 2 shows that the SLP procedure consists of two steps of analysis. The first step is data analysis. To begin the analysis, first process is to collect the data that related to the process manufacturing. Then it continued with the flow analysis (regarding to the material and information flow) and the relationship analysis between each area and manufacturing process. The purpose of data analysis process is to know

the closeness relationship between each area based on the flow analysis and manufacturing process. Result of this analysis will be used as a based to develop the SLP analysis.

After all the data have been identified, SLP analysis can be developed. The process starts from generate the Activity Relationship Chart (ARC), ARC worksheet, Dimensionless Block Diagram (DBD), Area Relationship Diagram (ARD), Area Allocation Diagram (AAD) that already allocated in the proper layout, and the outcome is the Master Layout Drafting.

Simulation

Simulation is an artificial model of process design in the real model system, usually performed on a computer (Shannon, 1975). The aim of it is to study and to analyze the behavior of the real system. Another purpose is to makes some experiments in order to create and determine strategies to implement the proper of system behavior.

Simulation can be used to study about various aspects of facilities planning. The various aspects is about facilities design, capacity planning, inventory policies, quality and reliability systems, warehousing and logistics planning, and maintenance scheduling. By using simulation, analyst can compare the difference between real system and the alternatives scenario. Besides, they also can study why it happens and which proposed alternative is the best solution of it. (Banks, 2005)

There are several reasons why analyst do some practices on simulation modeling, such as (Banks, 2005):

1. **Evaluation.** With simulation modeling, analyst can evaluate the proposed alternative system design and determine which alternatives is the best.
2. **Comparison.** Compare the several options of system designs to analyze the specific function.
3. **Optimization.** In simulation modeling, analyst can do some experiment to optimize the system by develop some factors or combine several factors can produces the best response in system.
4. **Bottleneck analysis.** With simulation modeling, designer can find the characteristics and location of bottleneck that affecting the process in system.

Data Analysis

Analysis Product

To begin the analysis process, first is analyzing the products. The purpose of it is to select the products whose will be used to run in the simulation. This process will start with define the product demand for each type in one year. Then, sorting the data based on the amount number of demand in each products from the highest until the lowest demand. Afterwards, the data will be used to implement ABC analysis as a tool to makes decision which products must be selected as an input for the simulation model.

Table 1. Category Demand Percentage

Category	Cumulative Value Demand (%)	Total Type of Product
A	75.3	6
B	19.7	5
C	4.97	40

ABC analysis is a grouping method based on the highest until the lowest value of data and divided into three categories which are A, B, and C. Based on percentage of total demand, data can be classified each product type into ABC classification.

From ABC analysis, the greatest cumulative value demand which is category A that has six types of product will be selected to implement in the Arena Simulation.

Analysis Layout using SLP Analysis

The next process after analyzing product demand is analyzing layout. Systematic Layout Planning, production line area planning, operation process chart will be implemented as tools to develop new layout of Company X.

Area Relationship Chart

Area relationship is implemented as a basis of recommendation for making new design layout. There are several data needed in order to makes area relationship chart, such as current layout with the dimension in each area and building, steps in manufacturing process, and informal interview with the employees. The purpose of informal interview is to determine the closeness importance relationship between each area. Thus, data of area relationship will be more reliable and accurate for Systematic Layout Planning. Here is the data of area existing in the Company.

Table 2. List of Area Existing in the Company

Area	Area	Area	Area
Raw Material Storage	Toilet	Disc line 2	Machine IBIS
Cutting Raw Material Area	RIM line 1	GP 12 Area	Area TPS Limbah P3
Compressor	Store RIM line 1	Lathe	Area Scrap
Dies Maintenance	RIM line 2	Shearing Test Area	Lockers It.2
Substation 2	Store RIM line 2	Disc Store After P3CO3	Disc store before P3CO3
Warehouse dies maintenance	Dies Rack	Maintenance tools	CED line
Maintenance area	Area QC	OTC area	Top coat line
Die set table	Area Meeting Plant	OTC store	Finished good store
WIP disc 2 store	Disc line 1	Raw Material Storage & Final size	Packaging
Admin area dies maintenance	P3CO3	Office Storage	

Area Relationship Worksheet

After analyze the relationship using area relationship chart, then area relationship worksheet can be generated. It use to make easier in understand and translating the chart from Area Relationship Chart into Dimensionless Block Diagram.

Dimensionless Block Diagram

After Activity Relationship Worksheet has been generated, the dimensionless block diagram can be created. Dimensionless block diagram consist of block that contains of area name in the center and the closeness relationship code at the top and

bottom side of block. Besides, there will also number that determine each area in the workshop written bellow the relationship code.

Area Relationship Diagram

The dimensionless block diagram will be arranged into several designs to find the most optimum layout. To make an optimum Area Relationship Diagram, department or activity which is describe with a box that has A relationship must be placed side by side.

Area Allocation Diagram

The next analysis after all the previous analysis have been done is Area Allocation Diagram which is the technique of placing the areas regarding to the flow of manufacturing process, flow analysis (material and information), and the dimension of each area.

Draft Master Layout

The best AAD will be used as a based to design the Draft Master Layout. The draft layout will be visualized by using AutoCad as it is show in Figure 3.

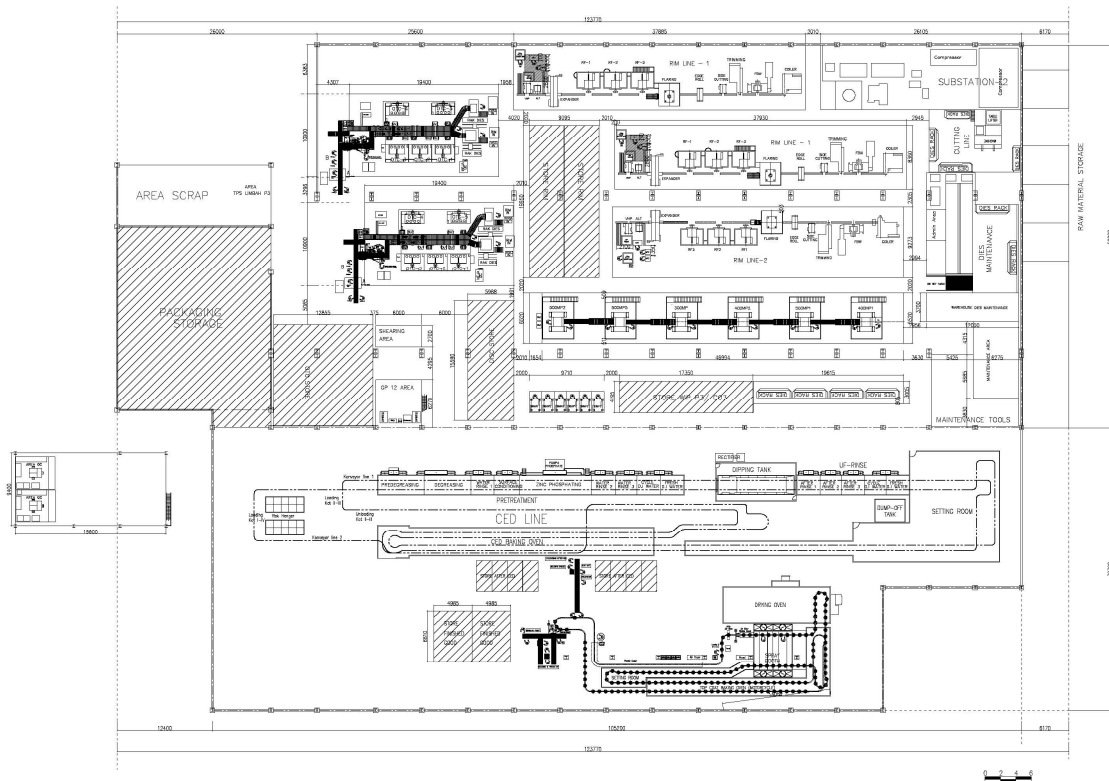


Figure 3. Proposed Layout of Company X

Analysis Layout using Assembly Line Balancing

To analyze assembly line balancing, it needs data regarding the lead time in each operation. Then after obtained the data, it should sum up the time to know the number of stages required. The total lead time divided by the required cycle time to get the required number of stages. Total lead time has different amount in every product types.

Hence, in order to calculate assembly line balancing, the total lead time in all product types assumed to has the same amount and it uses the longest processing time.

$$\text{Number of stages} = \frac{237.76 \text{ seconds/piece}}{12.58 \text{ seconds/piece}} = 18.9 \text{ stages} \approx 19 \text{ stages}$$

From calculation above, Company X should operate 19 stages operation with total lead time 237.76 seconds/piece and target demand 1,080,778 units in a year. In the actual condition they operate 32 stages operation; hence the analysis should carry on with the line balancing.

To start the line balancing analysis, average cycle time must be calculated first from total work content divided by number of required stages. The average cycle time will assist to make decision whether the machine must be duplicated or not in order to make the flow of process balance.

$$\text{Average Cycle Time} = \frac{\text{total work content}}{\text{total required stages}}$$

$$\begin{aligned} \text{Average Cycle Time} &= \frac{230.54 \text{ seconds}}{32 \text{ stages}} \\ &= 7.20 \text{ seconds/stage} \end{aligned}$$

The result above shown that to achieve line balancing or prevent bottleneck during the production process, each operation must spend 7.20 seconds to complete the job. The fact is, there are some operations which take more than 7.20 seconds. To solve the problem, the operation should be duplicated to achieve line balancing.

Table 3. Comparison of Actual and New Total Lead Time

Description	Actual (s)	New (s)
Total Lead Time	230.54	150.27

Based on the assembly line analysis, there are 18 operations that must be duplicated in order to makes the whole processes are balanced. It makes the efficiency of production process is increasing to 34.82%. The calculation of increase of efficiency is:

$$\begin{aligned} \text{Efficiency} &= \frac{(\text{total actual lead time} - \text{total new lead time})}{\text{total actual lead time}} \times 100 \% \\ \text{Efficiency} &= \frac{(230.54 - 150.27) \text{ seconds}}{230.54 \text{ seconds}} \times 100 \% \\ &= 34.82 \% \end{aligned}$$

From the analysis above, it can be concluded that the efficiency of manufacturing process can be increased to 34.82%. Thus, several operations that must be duplicated based on the assembly line balancing analysis will be implemented in the Draft of Layout.

Simulation

Conceptual Model

Generally, the simulation model will contains of input, process, and output. At initial condition, raw material that already arrived will transfer to the next process until it becomes a finished product. Figure 4 is shows the overall conceptual model for six products in current condition.

The purpose of this simulation model is to give a visualization of the manufacturing process and compare the current and proposed layout performance; thus the result of the comparison will be used to make the best layout decision. There are several parameters that used to measure the performance, such as input, output, transfer time, throughput, and total lead time.

To construct the simulation model, there are some assumptions due to the manufacturing process, as follow:

- Total working time within a day is 21.67 hours per day.
- There is no adjustment process in each machine.
- Each machine produces one product only.
- There is no breakdown machine.
- No delay time between each process.
- Each product has a constant demand within a day

Model Translation

In model translation, model is translated and constructed based on the Operation Process Chart for the manufacturing process. The model translation structure consists of six types of product correlating to different cycle of time in each process.

The first creation to translate the conceptual model is using Create Module. This module is used as the starting point for each type or entities in a simulation model. It used only once for the whole processes. The input data of create module is based on the demand of products per day and inter arrival time from raw material storage to the initial process.

After design Create Module, both of entities go to the Station Module. It shows the station state of each workstation. Each station module is named according to the workstation.

Afterwards, each entity flows to Decide Module for decision making process. To decide the processes, it based on the condition. It can be used a percentage true. For example, the percentage true of 80%. The product is acceptable if the percentage true is $\geq 80\%$; then it goes to the next process. However, if the percentage true is $\leq 80\%$; it goes to another process which is repair process before it goes to next process.

Then, the flow of simulation model goes to Assign Module. This module is used for define the attributes; entity types, entity pictures, and lead time for every types of product. Each entity will use each Assign Module separately due to the different cycle time needed for each type. Besides, its also to prevent the chaos between each entity. However, both of entities have same operation resource and step. There will be several Assign Module used according to the each type for the entire processes.

Next, the entity goes to the Process Module. It uses as the main processing method in the simulation. There is one or more Process Module based on the number of machine used in each workstation. The action logic for each module is Seize Delay Release and the resources assigned to the material in the process. Delay type is expression to determine the attribute runs the process in the second form.

Afterwards, the simulation model goes to the Route Model. Its function is to transfer an entity to a specified station, or to the next stations. The module has a transfer time (seconds) to represent how long it takes to transfer from one to the next workstation. In this simulation model, there will be several Route Model due to the several workstations exist in the entire processes.

The entire workstations have almost the same step with the first. The difference is on the number of machines used to produce products.

The next process is an assembly process that rim and disc must being assembled into one produce a wheel. The assembly process is assign in the Batch Module. It used as a grouping mechanism in simulation model. The type in this

module is permanent and batch sizes are two components that present of two components are assembled continuously into one. The rule is any entity which requires the entity that defines rim and disc.

Finishing station is almost the same with previous station. The difference is at the end of process, there are Record Module and Dispose Module. The function of Record Module is to collect the data statistics which is the total time for the entire processes in simulation model. And Dispose Module uses as the ending point for entities.

Model Verification

Model verification is used to confirm whether the simulation model is correctly implemented or not. The procedure is confirm the logic of translated model from the initial until the last module in the simulation model. When the checking process is done and represent the real system in manufacturing process, the simulation model can be run. If the simulation runs well without any error, it considered to be verified.

Model Validation

Model validation is the comparing process between the real condition and simulation model. The purpose is to make sure whether the simulation model runs almost the same with the real condition or not. There are several parameters to be compared; number of input and output, number of throughput, transfer time, and total lead time. Table 4 is the summary of result comparison between the real condition and simulation model.

Table 4. Summary of Result Comparison

No	Parameter	Type of Product	Real Condition	Simulation Model
1	Number of Input (units)	Product A	692	692
		Product B	314	314
		Product C	609	609
		Product D	787	787
		Product E	583	583
		Product F	406	406
2	Number of Output (units)	Product A	692	692
		Product B	314	314
		Product C	609	609
		Product D	787	787
		Product E	583	583
		Product F	406	406
3	Transfer Time (hours/unit)	Product A	1.53	1.53
		Product B	1.53	1.53
		Product C	1.53	1.53
		Product D	1.53	1.53
		Product E	1.53	1.53
		Product F	1.53	1.53
4	Total Lead Time (hours)		21.67	17.29

Table 4 shows there is a different between the real condition and simulation model due to there is no delay time in each process in the simulation model. But the

different is not significant due to almost parameters have the same result. The difference only at the total lead time; and the value is small.

The conclusion is, simulation model is valid and will be used to compare the actual condition and proposed condition layout due to the difference in model validation is not too significant.

Proposed Simulation

Based on the previous analysis, the simulation will be used as a tool to be compared. Simulation model between the actual condition and proposed design is almost the same. The difference is on the several machines that should be duplicated in order to make the entire processes more balanced. Proposed simulation model and the results can be seen in Figure 5. Table 5 shows the summary of the result comparison between the real condition and the optional design layout.

Table 5. Summary of Result Comparison

No	Parameter	Type of Product	Real Condition	Proposed Layout
1	Number of Input (units)	Product A	692	692
		Product B	314	314
		Product C	609	609
		Product D	787	787
		Product E	583	583
		Product F	406	406
2	Number of Output (units)	Product A	692	692
		Product B	314	314
		Product C	609	609
		Product D	787	787
		Product E	583	583
		Product F	406	406
3	Transfer Time (hours/unit)	Product A	1.53	0.44
		Product B	1.53	0.44
		Product C	1.53	0.44
		Product D	1.53	0.44
		Product E	1.53	0.44
		Product F	1.53	0.44
4	Total Lead Time (hours)		17.29	11.6478

It can be concluded, by simulate proposed layout, the transfer time and total lead time are reduced. It is due to the duplication of several machines and rearrangement of the layout.

To analyze the simulation, there are some calculations that need to be done in order to know how the productivity changes after redesigning the layout. The calculations are involved:

- The result of simulation model is shows a big difference in the total lead time between the real condition in the simulation and the proposed layout (the second alternative layout). It can be concluded that the efficiency of the process manufacturing is increasing due to the total lead time is reduced. The calculation is :

$$Efficiency\ increase = \frac{(17.29 - 11.65)\text{ hours}}{17.29\text{ hours}} \times 100\%$$

$$\text{Efficiency increase} = \frac{5.64 \text{ hours}}{17.29 \text{ hours}} \times 100\%$$

$$\text{Efficiency increase} = 32.62 \%$$

- From the calculation above, the required lead time for the entire processes to produce 3,391 products per day can be reduced for 7.07 hours within per day. Thus, it can reduce the shift within a day from three shifts per day it can reduce until two shifts per day. The calculation is as follow :

$$\text{Time reduced} = \frac{32.62}{100} \times 21.67 \text{ hours}$$

$$\text{Time reduced} = 7.07 \text{ hours}$$

Total working time within a day is :

$$\text{Total working time} = 21.67 \text{ hours} - 7.07 \text{ hours}$$

$$\text{Total working time} = 14.6 \text{ hours}$$

- Total product that can be produced within a day if the company requires the number of shift within a day is 3 shifts. The calculation is :

$$32.62\% = \frac{(x - 3,391)\text{products}}{x} \times 100\%$$

$$0.3262 x = x - 3,391 \text{ products}$$

$$0.6738 x = 3,391 \text{ products}$$

$$x = 5,033 \text{ products}$$

x represents a total product that can be produced within a day with 3 shifts. It can be concluded that within a day by performing the proposed layout is able to produce 5,033 products rather than the current layout that only able to produce 3,391 products. Which is the productivity of the proposed layout is increasing 32.62 % from the current layout by the simulation analysis.

Conclusion

The new layout has been generated by using Systematic Layout Planning methodology. Analysis starts by making an Activity Relationship Chart (ARC) based on the closeness relationship between each activity or area. It will uses as a base to arrange the Dimensionless Block Diagram (DBD). The dimensions for existing each area and facilities include the machines, tools, etc are calculated in order to arrange the new layout. Before develop the new layout, assembly line balancing analysis must be obtained in order to make the proposed layouts are more balance than the actual layout. According to DBD, calculated dimension, and assembly line balancing, the proposed layout can be arranged.

The proposed layout has its own characteristic based on the flow of material and area allocation; and also has consequences if the company implements this proposed layout. After designing the new layout, simulation analysis must be accomplished to ensure which layout is the best layout to be proposed. The parameters that will be analyzed are number input and output, transfer time, and total lead time to complete the job within a day.

Based on the analysis process, it can be concluded that Company X will increase their productivity and more efficient during the manufacturing process if they implement the proposed layout. But, it may has several consequences, as follow they must added some new machines to make the process is more balance than before; and makes some expansion in several area of Company X.

Further Developments

According to the observation of layout analysis, these following research needs to be included in further developments, as follow:

1. Company needs to be focused on their inventory in order to minimize their inventory cost and it will make the company more efficient if they have a smaller inventory than before.
2. Line Balancing. The current analysis at this project is only performed with one iteration. There will be a better balancing result by performing more iterations to increase their productivity.

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