Facility Layout Design On The Agricultural Machinery Industry

Nilda Tri Putri, Prima Fithri, and Muhammad Taufik

Abstract—**CV Citra Dragon as one of the medium agricultural machine industry in West Sumatra has a plan to relocate the existing plant to meet customer demand each year. Production capacity enhancement and plant relocation will change the layout of the plant; therefore need to design of facility layout of CV Citra Dragon. By applying Group Technology Layout, design of production layout becomes first step in this research. The initial step is using the Average Linkage Clustering (ALC) and Rank Order Clustering (ROC) to group the machines and part family. To design the layout, Modified Spanning Tree (MST) is used. Next step is, to design layout of warehouses, offices and other production facilities. Activity Relationship Chart methods used to organize the placement of factory facilities has been designed. Based on processing data, total distance of the displacement of material in a single production amounted to 1120.16 m which means need 18.7 minutes of transportation time for one time production. Agricultural Machinery Industry has designed a circular flow pattern with 11 facilities. The facilities were designed consist of 10 rooms and 1 parking space. The wide of plant building is 84 m x 52 m.**

Keywords*—*Facility Layout, Average Linkage Clustering, Activity Relationship Chart, Modified Spanning Tree, Rank Order Clustering

I. Introduction

INDONESIA is an agricultural country which are 39.96 million people in Indonesia are working in the agricultural sector (Central Bureau of Statistics, February 2013). To improve the efficiency and productivity of agriculture, some tools and machines are used. Tools and agricultural machine (alsintan) are tools that used in agribusiness activities. Alsintan used to transform traditional farming systems which are still use manual equipment into modern agriculture which use machine.

Alsintan production in Indonesia is currently supplied from domestic and imports from Korea, Taiwan and China. There are 21 agricultural machinery industries in Indonesia, such as CV Karya Hidup Sentosa in Yogyakarta, PT Agrindo in East Java, and PT Yamindo in South Sulawesi. West Sumatra, Yogyakarta, and East Java became the pioneer in the agricultural machinery industry (alsintan's industry). Based on data from CV Nugraha Chakti Consultant in 2012, West Sumatera has 98 alsintan's industry, but they are still small and medium industries. From 98 industries, that are 74% of household industries, 22% of small industries and 4% are medium industries. CV Citra Dragon in Padang Pariaman and CV Sarana Agro Payakumbuh Cherry are medium industries of alsintan in West Sumatra.

There are several alsintan products frequently utilized by farmers in West Sumatra from alsintan industry. Agricultural tractors, power thresher, rice milling units, and potato grater are product that widely used in West Sumatra. According to CV Nugraha Chakti Consultant [2], until 2012 the use of four types of alsintan are as follows: agricultural tractors as many as 9,210 units, power thresher as many as 6,197 units, rice milling units as many as 4,146 units and potato grater as many 2,908 units.

Based on data, only potato grater can meet the consumer demand, whereas rice milling around 46% can meet the demand. The most commonly products used such as agricultural tractors and power thresher still shortage of 60% and 56%. Based on these data it can be concluded that alsintan industry in West Sumatra has been unable to meet all requirement the needs of existing alsintan in West Sumatera. To solve that problem, alsintan's industry in West Sumatera must increase of the production capacity. And it means that alsintan's industry must have wide plant.

CV Citra Dragon which is one of the alsintan's industries in West Sumatera has planned to relocate the existing plant. According to management, production capacity of the CV Citra Dragon's Factory is located on Sungai Sarik currently has a capacity that is still relatively small at less than 2,000 units per year. The main products of this Factory are hydro tiller and power thresher with capacity production of hydro tiller is 3 units per day and power thresher is 2 units per day. Therefore, CV Citra Dragon will increase production capacity for both of these products at the factory to be built.

Based on the performance indicators of CV Nugraha Chakti Consultant, CV Citra Dragon must reach the production target to meet the requirement hydro tiller and power thresher in West Sumatra is 2,000 units. In addition to produce power thresher and hydro tiller, the management must plan to design the factory that can produce agricultural machinery. CV Citra Dragon has new location for establishment of its new factory which has 70,000 m^2 areas. Trisiafitri [7] has conducted research studies on the feasibility of establishing an alsintan factory on this area and concluded that this area is suitable for establishment of a new factory of CV Citra Dragon.

Based on the existing background, it is necessary to design a new factory for CV Citra Dragon that would

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become one of the large industries in the agricultural machinery industry in West Sumatera.

II. LITERATURE REVIEW

The design of the facility layout is the arrangement of the physical elements of the facility in order to achieve certain goals. There are four different types of layouts that are commonly applied in the design of classic layout which are fixed layout, product layout, process layout and group technology layout [3]. This layout is based on the application of the production process, production capacity and market response to the company. Along with the development of facility layout designers today prefer factory to combine the existing layout in order to gain the advantages of each layout. One type of layout that's often used today is the group technology layout that implements a cellular manufacturing system.

Cellular Manufacturing System is an application of Group Technology (GT), which involves grouping, based on machine components manufacturing and allocation of part families that have the same shape or processes to machine cells. Advantages of Cellular Manufacturing System is the system performance in terms of time for material handling is reduced, reduction of production time, reduction in setup time, the ideal batch size, reduction of work in progress, faster delivery time, high machine utilization, fewer workers, the quality is maintained and the reduction of floor space requirements [6].

Planning the number of machines is one of the first steps in designing the layout of the facility after the plant production capacity planning. Planning this machine is based on the time available and the production process of production targets. The number of machines required depending on production plans, production targets, production capacity, and production time required.

In calculating the number of machines, operations that use similar machines are grouped, with variable operating time, set-up time, and the operation of the production target. Thus the calculation of the amount of machining requirements can be formulated in equation 1 [6]:

$$F = \frac{SQ}{EHR} \qquad (1)$$

Where:
F = Number of machines required (units)
S = Processing time per operation per component (sec)
Q = Output per operation per day (units / sec)
E = Efficiency of the engine
H = Number of machine time available per day (seconds)
R = Reliability engine

The grouping of machine cells and part family is the most important thing in a cellular manufacturing system. Independent machine cells are expected in machine cell grouping. There are several methods in machine cell grouping including clustering method and the method of rank order clustering.

Clustering methods (clustering) is a technique that is used in multivariate statistics for the incorporation of observations into groups or clusters. The goal is to group observations in such a way so that each cluster strived to become more homogeneous cluster variables. In general, clustering procedure based on a very well-known similarity consists of three techniques, namely [3]:

1 Single Linkage Clustering (SLC)

Input for SLC technique can be distance (distance) or similarity (similarities) between pairs of objects. The group was formed through the merger of individual entities nearest neighbors is the smallest distance or largest similarity. For starters must be found is the distance in D = (dij) and combining objects that relate, for example U and V to obtain the cluster (UV) and each cluster W can be calculated as follows:

$$d_{(UV)W} = \min \{ d_{UW,} d_{VW} \} \qquad (2)$$

2 Complete Linkage Clustering (CLC)

CLC can be said to have the same meaning as SLC but with an important exception that each stage of the distance (dissimilarity) between clusters is determined by the distance or similarity between the two elements is the furthest (most distant). CLC guarantee that all items in a cluster are within the maximum or minimum resemblance to each other. Beginning to be discovered is the minimum distance D = {dij} and combining related objects, eg U and V to obtain the cluster (UV) and each cluster W can be calculated as follows:

$$d_{(UV)W} = \max \{d_{UW}, d_{VW}\} \qquad (3)$$

3 Averages Linkage Clustering (ALC)

ALC treat the distance between two clusters as the average between all pairs of items where one member of a pair to each cluster. ALC works starts from the search distance matrix D = {dij} to find the most similar objects, such as U and V. These objects are combined to form a cluster (UV) with the following formula:

$$d(uv)w = \frac{\sum_i \sum_k dik}{N(uv)Nw} \qquad (4)$$

ROC algorithm developed by King in 1980 [6]. ROC is a clustering technique that is known to be quite simple, efficient and effective. This technique was quick in drawing conclusions cell grouping machines and parts family. The ROC technique requires input in the form of binary numbers (0 or 1). ROC algorithm steps are as follows [6]:

Step 1; to rows m = 1, 2 ..., M; calculate the equivalent weight matrix binary cm through the engine and components. The formula to calculate the equivalent weight as follows:

$$c_m = \sum_{p=1}^{P} 2^{P-p} . a_{pm} \; (a_{pm} = 0 \; or \; 1) \qquad (5)$$

Step 2 For the column p = 1, 2,..., P; calculate the equivalent weight of a binary matrix rp through the engine and components. The formula to calculate the equivalent weight as follows:

$$r_p = \sum_{m=1}^{M} 2^{M-m} . a_{pm} \; (a_{pm} = 0 \; or \; 1) \qquad (6)$$

Step 3: If the results of the component machines matrix iteration process does not change again, then stop the iteration process.

In designing the layout of the facility, there are two methods in the layout and the method of quantitative and qualitative methods. There are various methods of quantitative methods modified one spanning tree (MST). Modified spanning tree (MST) is a method for determining the order of the facility. The input of this method is to chart

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the data from symmetric and length of the facility. Completion of the steps of this method as follows:

1. Give the flow matrix [fij], clearance matrix [dij], and the length Li machine. Then, calculate the weighting matrix fij proximity with the formula = (fij) [dij + 1/2 (Li + Lj)].
2. Find the largest element in the matrix weights and denote closeness as a couple i * and j*. Settle fi * j = fj * i = - ∞.
3. Find the largest element and f¬¬j fi * k * i in row i * j * of weights proximity matrix. If fi ≥ fj * k * i, then connect to the i * k, move row i *, i * columns of matrix nearness; and set i * = k. Further, connect 1 to j * of weights proximity matrix and set j * = l. Settle fi * j = fj * i = -∞.
4. Repeat step 3 for the entire facility.

One method that is often used is qualitative Activity Relationship Chart (ARC). Activity Relationship Chart is designing the layout of a manufacturing facility using qualitative techniques. ARC showed the close relationship between facilities. In assessing the relationship between the levels of manufacturing facilities, we need to consider the factors that affect the level of relationship among others [3]:

1. Special demands derived from the specification of activities in each department.
2. The nature or characteristics of the building.
3. Tread building.
4. Facility environment.
5. Expansion

While the assessment system in the ARC using the following types of letters [3]:

A = absolutely necessary adjacent
E = Very Important adjacent
I = Important adjacent
O = No problem
U = It should be far apart
X = Absolute apart

III. Methodology

There are some steps being taken in this research i.e. data collection, designing the layout of the floor production, warehouse design, designing the factory supporting facilities layout, and factory layout design.

3.1. Data Collection

The data was collected in this study consist of: products of CV Citra dragon, production process, bill of materials, process sequence, operating time, specification of machinery and equipment, working hours, raw materials and product dimension.

3.2. Floor Production Layout Design

Processes in designing the layout of the floor production are as follows:

1. Analysis of the production process

Analysis of the production process was used to determine what layout will be used in the design layout. This analysis is based on the production process, how the company responds the market and production capacity.

2. Forming machine cells and part family

Forming machine cells and part family in this study is based on two methods, which are using Average Linkage Clustering (ALC) for first alternative, and using Rank Order Clustering (ROC) for second alternative.

3. Calculation of machine needed to perform the production activities

The calculation needs data such as processing time per machine, production targets, and availability of processing time, the machine efficiency and machine reliability.

4. Design of independent workstation

The design of independent workstations was based on operator's workspace area, space of machinery, and early extensive accumulation and last extensive accumulation. The sum was multiplied by 150% to obtain the size of an independent workstation.

5. Selection of material handling

Types of material handling equipment used are based on the type of production process and the size of the material to be transported. Material handling truck is type of material handling that suitable for use in the production process of job shop. Cube truck and hand truck were material handling equipment is used.

6. Design the layout of the floor production

Designing the layout of the floor production is divided into two kinds, intra cell layout design and inter cell. This second layout is based on the data *from to chart* and the length of the independent workstation or cell as an input of *singlerow.exe* software. Method of preparation of layout is modified spanning tree. The output of the software is then used as the basis for the preparation of the layout of the floor production.

7. Selection of alternative floor production layout

Displacement distance measurements were conducted to compare alternative layouts on the floor production. The layout has good mileage displacement for smaller components. Distance measurements were calculated using rectilinear. The data required in this measurement is the distance from the center point of each facility and the frequency of inter-facility transfer components.

3.3. Designing Warehouse

Designed warehouse is divided into three types, MFG storage, BO storage and finished product warehouse. The design is done based on the size of the warehouse storage media or stored items and the storage time in the shed.

3.4. Designing Factory Supporting Facility Layout

In addition to, the floor production and warehouse facilities were also designed several other production supports. Designing the layout of the plant support facilities based on the needs of the facility. The size of each factory facility adjusted based on those needs and standard provision made by Apple [1] and removal of goods.

3.5. Design of Plant Layout

The design of the overall plant layout used the Activity Relationship Chart (ARC). Having obtained the activity relationship chart then performed a block design template based on the activity relationship chart. Next step is the design of allocating area based on block diagram template and the size of the facility. The final step is to design the layout of a 2D image based on AutoCAD software of allocating area diagram.

IV. DISCUSSIONS

Based on the layout design, it can be analyzed to some process design. The analysis can be done is as follows.

4.1 Analysis of Forming machine Cell and Family Part

Forming machine cells and part family in this study is based on the similarity of the process production of each component. Components and machines in the process production are transformed in the matrix 0-1. Components that have process on a machine will be given by number 1 while the component that is not processed will be given by number 0 in the matrix 0-1. The formation is based on the similarity of this process because many similarities in the manufacturing process for the alsintan product components although the components come from different products.

Method of forming machine cell and part family is the Rank Order Clustering (ROC) method and Linkage Average Clustering (ALC). Both of these methods are equally in need of 0-1 matrices as initial input in the formation of machine cells and part family. ALC is a method of forming machine cell and part family who seek homogeneity of each machine cell with the average distance between clusters (cells). While the ROC is a method that is based on the formation of cell sorting rows and columns equivalent weights are obtained from the conversion of a binary number in the matrix 0-1. Both of these methods will ultimately result in family and arrangement of parts of different machines and ALC is as an first alternative and the ROC is as second alternative. Based on these two alternatives, it can be compared to the best alternatives that can be applied as a layout design on the floor production factory.

Formation of machine cells is using the ALC produces for four cells. One cell contains 16 different types of machines and process 23 components, two cell consists of 12 types of machine and process 39 components, three cell consists of 9 types of machines and process 52 components and four cells consists of 4 machines and process 52 components. Formation of machine cells using the ROC method also produces four cells. One cell contains 13 types of machine and process 57 components, two cell consists of 12 types of machine and process 37 components, three cell consists of 7 kinds of machines and process 38 components and four cell consists of 8 machines and 34 processing components. Judging from the number of cells and the number of machines in the cell, it can be concluded that the design of the cell formation that is used smaller number of larger cells. The design of this type of cell formation is more flexible in case of changes in product and component design. This is consistent with the strategy that applied make the order so if the company changes the product or component designs for consumer want, the company will meet consumer demand quickly.

Good machines cells are machines that are independent cells. Independent machine cells are cells that machines can process components from the beginning to the end of the components manufacture without having exceptional element. Exceptional elements are components which processed more than one cell. Formation of machine cells in both these methods is done by minimizing the number of existing exceptional, with no way to duplicate the machine processes only one component piece. Formation of machine cells with ALC methods produce 3 pieces of exceptional components into the component elements 70 H, 103 H and 14 T. Formation of machine cells with ROC method produces 4 pieces of exceptional components into component elements, namely 1 H, 70 H, 87 H, and 78 T. in terms of the ability of cells in the formation of an independent, it can be concluded that the group of cells with ALC method is better than the cell formation using ROC.

4.2 Analysis of Alternative Selection Floor Production

Designed floor production consists of two alternatives. First alternative is derived from the design of the machine by using the average cell linkage clustering (ALC), while second alternative is derived from the design of the machine by using a rank order clustering (ROC). After the machine cell formation and floor production layout, then the layout is done by comparing the selection of displacement of existing material on both alternatives.

Distance displacement of material obtained from materials mileage that multiplied by the frequency displacement. Floor production of first alternative has a size of 82 m x 33 m and has a displacement distance of 1120.16 m while second alternative of the floor production measures 80 m x 33 m and has a displacement distance of 1291.52 m. Although it has a slightly larger size but the distance moved by the material on the alternative displacement is smaller than the distance of second alternatives that elected an alternate layout as the layout of the floor production.

Displacement of material is a non-productive activity that exists on the floor production. The distance of the farther to be traveled displacement of the production process, more productive wasted time is wasted in the production activities. Assuming the displacement velocity of 1 m / s for each material handling, then the displacement distance of 1120.16 m displacement takes 18.7 minutes to complete one alsintan product.

4.3 Analysis of Layout Flexibility

One of the advantages of the group technology layout is the use of flexible layout in case of change of products. Besides produce the main products namely hydro tiller and threshers, this factory can also produce other alsintan product. Appendix 1 shows the other products that have similar alsintan machines in the production process.

The similarity of the machines used in the manufacture of some alsintan products with hydro tiller products and threshers demonstrate the ability to produce alsintan products layouts other than the main product. This flexible layout capability indicates this layout can still be applicable if there is a demand for other products from consumers than products hydro tiller and threshers.

4.4 Analysis of Plant Facilities Layout

The preparation plant facility layout design is the final step after doing a large set of each manufacturing facility and activity relationship chart (ARC). End mill layout measures 84 mx 52 m, this measurement can be implemented with the size of the land owned by CV Citra Dragon with size 100 mx 70 m. Therefore, this layout can be a factor in the construction of a new factory CV Citra Dragon. Based on the results of the ARC, the design needs to be brought near absolute floor production with three facilities there are MFG storage, BO storage and warehouse. This closeness is based on three factors; the sequence of work flow, the movement of goods or employee and a production support facilities.

When viewed as a whole type of material that is applied to the flow of this layout is the circular type. This type of flow can be seen from the initial movement of the material that originated from the MFG storage that went into the floor production and around the floor production before heading out in the warehouse that has a location adjacent to the MFG storage. Incoming material from MFG storage will process on each machine cell before finally moved to the assembly area. The execution of each component of these cells reduces the displacement distance of the components is done. In addition, this circular flow pattern also makes the floor production size is smaller and more regular material flow.

V. CONCLUSION

Alsintan factory designed by applying group technology layout has a circular flow pattern with 11 facilities. Designed facility consists of 10 room i.e. floor production, office, MFG storage, BO storage, warehouse, leader room, reception room, showroom, mosque, toilets and with 1 parking space. Final layout measures 84 mx 52 m, this measurement can be implemented with the size of the land that owned by CV Citra Dragon with the size of 70 mx 100 m.

APPENDIX

Appendix 1 shows some of the other products that have similar alsintan machines in the production process.

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APPENDIX 1
SPECIFICATION PRODUCTION PROCESS OF ALSINTAN PRODUCT

No	Product / asdasd / Machine	*Hydrotiller*	*Thresher*	*Reaper*	*Handtractor*	*Hammer Mill*	Feed Fish machine	Compost Machine	Corn Sheller	Grass Choper	*Mixer*
1	Sawing Machine	√	√	√	√	√	√	√	√	√	√
2	Cut Grinding Machine	√	√			√	√	√	√	√	√
3	Small Scissors Machine	√	√	√	√	√	√		√	√	
4	Large Scissors Machine	√	√	√				√	√		
5	Cutting Plate Machine	√	√	√	√	√	√	√	√	√	√
6	Hand Cutting Plate Machine	√	√	√	√	√	√	√	√	√	√
7	Iron Concrete Cutting Machine	√	√	√	√	√	√		√		
8	Bending Machine	√	√		√	√					
9	Lathe	√	√	√	√	√	√	√	√	√	√
10	Drilling Machine	√	√	√	√	√	√	√	√	√	√
11	Folding Palte Machine	√	√	√	√	√	√	√	√	√	√
12	Pond Machine	√	√	√		√					
13	Press Machine	√	√	√	√	√		√			
14	Roll Machine	√	√	√		√	√	√	√	√	√
15	Planers Machine	√	√				√	√	√	√	√
16	Grinding Machine	√	√	√	√	√	√	√	√	√	√
17	Screw Machine	√	√	√	√	√		√	√	√	√
18	Welding Machine	√	√	√	√	√	√	√	√	√	√
19	Welding Raft	√	√	√	√	√	√	√	√	√	√
20	Compressor	√	√	√	√	√	√	√	√	√	√