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COMPARING ALTERNATIVE PLANT LAYOUTS BASED ON CRAFT AND BLOCPLAN ALGORITHMS

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ABSTRACT

This study compares two proposed layout models for large-scale, single-floor process plant using CRAFT and BLOCPLAN algorithms. These two proposed layout models are both determined from initial layout followed by an iterative improvement procedure. Flow distance, material handling cost, flow time, and saved area spaces are the four criteria to measure the performance of each model. Based on the four criteria, generating the company plant layout using BLOCPLAN layout model has the best performance.
Keywords*: Plant Layout, Iterative Solution Approach, CRAFT, BLOCPLAN.*

1. INTRODUCTION

Since 1960s, many heuristic and meta-heuristic algorithms had been formulated due to the dynamic nature of the plant layout. For years, problems related to plant layout have become more complex due to the increasing competitiveness of today's globalization. Therefore, the study of facilities layout becomes more prominent.

A manufacturing company in Indonesia is used as our case example. FSCM Manufacturing Indonesia is a company specialized in fabricating various types of motorcycle chains. Based on the increasing demand rates, the company has built two separated plants. Existing layout of the first plant shows that the flow of materials is not optimized. This is indicated by the increased flow distance and material handling cost. Hence,an improvement in the layout is needed.

The goals of this paper are to identify the existing layout performance, develop proposed layouts, and then compare the existing layout with the proposed ones.

2. THEORETICAL BACKGROUND

Aleisa and Lin (2005) stated that a facility layout problem (FLP) is analytically formulated according to a classic model in discrete optimization which works by enumerating different layout configurations until the best plan is obtained.

Due to combinatorial aspects of solving the best facility layout problem, analysts have developed various heuristic algorithms instead of using the blind search methods. These are categorized as construction or improvement-type layouts.

- Construction-type generates a block layout based on the relationship between departments.
- Improvement-type aims to reduce movement cost by attempting simultaneous pair-wise exchanges among the departments.

Tompkins et al. (2003) defined an improvement-type starting with an initial layout and seeking to improve the objective function through "incremental" changes in the layout while construction-types generally develop a new layout "from scratch."

Among the most popular algorithms within the improvement-types is CRAFT. CRAFT (Computerized Relative Allocation of Facilities Technique) is one of the earliest algorithms presented in the literature and was first introduced in 1963 by Armour, Buffa, and Vollman. It uses a from-to chart as input. Layout 'cost' is then measured by distance-based objective function shown in Equation 1 (Tompkins et al., 2003).

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{if} c_{ij} d_{ij} \qquad (1)$$

Since CRAFT is an improvement-type algorithm, it starts with an initial layout. CRAFT begins by determining the centroid of the department then calculates the rectilinear distance between the centroid pairs and stores the values in a distance matrix. The initial layout cost is determined by multiplying each entry in the from-to chart with the corresponding entries in the unit cost matrix and the distance matrix. It then considers all-possible two or three-way department exchanges and identifies the best exchange; the one that yields the largest reduction in the layout cost.

Burkard and Stratman (1978) proposed a heuristic algorithm which used concepts of a branch and bound algorithm and an improvement algorithm. An initial solution is obtained using branch and bound which terminates after a preset time limit. The initial solution is then improved by using an improvement algorithm. This mixed-type algorithm was classified by Bazaraa and Kirca (1983) as algorithms which have the characteristics of optimal and suboptimal algorithms. It is then studied by Heragu and Kusiak (1987). These algorithms are known as hybrid algorithms.

BLOCPLAN is one of the most frequently used hybrid algorithm. BLOCPLAN uses a relationship chart as well as a from-to chart as input data for the 'flow'. Layout 'cost' can be measured either by the distance-based objective (see Equation 1) or the adjacency-based objective (see Equation 2 below).

$$\max z = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij} x_{ij} \qquad (2)$$

BLOCPLAN offers the analyst a variety of options for improving the layout. The analyst may try some two-way exchanges simply by typing the department indices to be exchanged, or select the "automatic search" option to have the algorithm generates a specified number of layouts. BLOCPLAN may also be used as a construction algorithm. In doing so, the layout planner may indicate the location of certain departments a priori. Therefore, BLOCPLAN may be used both as a construction algorithm and an improvement algorithm (Tompkins et al., 2003).

3. RESEARCH METHOD

The research method used for this experiment is done by identifying the performance of the existing layout using MHPS table. For comparison with the existing one, CRAFT and BLOCPLAN algorithms are used to generate several alternative layouts. The best layout is then selected based on its effectiveness and efficiency in four selected criteria.

4. RESULT AND DISCUSSION

4.1. Result

In order to process the existing layout, a software program is used; the complex shape of each department in the existing layout is simpified by converting it into a block layout diagram. The result is shown in Figure 1.

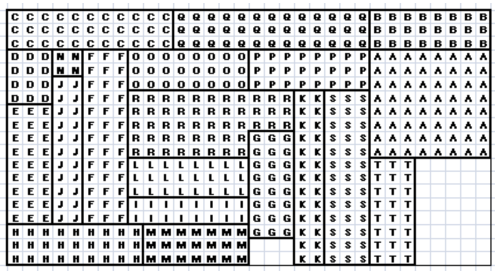

Figure 1. Block Diagram of Existing Layout

To measure the flow distance, material handling cost, and flow time of the existing layout, an MHPS calculation is used (see Table 1.).

Table 1. MHPS Calculation Table

Move			*Material Handling*					*Cost*				
From	*To*	d (m)	Component	MH	Moved Units	*Unit Load* (kg)	Freq.	Flow Time	Total Usage Tiem of MH	Movement Cost	Movement Cost / Day	Total Cost
WH	*Pin Cutting*	5,5	*Pin*	*Big Hoist*	139,008	3.000	5	3,38	73,25	1.563,78	7.818,88	
WH	*Bush Forming*	16,3	*Bush*	*Small Hoist*	55,2374	500	8	8,52	68,16	3.568,25	28.545,96	
WH	*Press Komatsu*	10,5	*OLP*	*Big Hoist*	82,0632	3.000	2	4,63	73,25	2.142,95	4.285,91	
WH	*Press Dobby*	18,5	*ILP*	*Big Hoist*	121,6286	3.000	3	6,63	73,25	3.069,64	9.208,91	
WH	*Press Dobby*	18,5	*ULP*	*Big Hoist*	0,0091	3.000	2	6,63	73,25	3.069,64	6.139,27	73.948,86
WH	*Barrel A*	28	*Roller*	Container	1.372,24	400	4	11	761,88	2.865,79	11.463,15	
WH	*Press Komatsu*	10,5	*OLP-A*	*Big Hoist*	0,0077	3.000	1	4,63	73,25	2.142,95	2.142,95	
WH	*Pin Cutting*	5,5	*Joint Pin*	*Big Hoist*	0,0599	3.000	1	3,38	73,25	1.563,78	1.563,78	
WH	*Press Chin Fong*	16	*Clip*	*Big Hoist*	0,0049	3.000	1	6	73,25	2.780,05	2.780,05	

The following are formulas used to form the MHPS calculation table:

$$Distance\ (Rectalinear) = |\Delta x| + |\Delta y| \qquad (3)$$

$$Moved\ Units = \frac{Prepared\ units\ (destination)}{Accepted\ units\ (kg\ per\ unit)} \quad (4)$$

$$Frequency = \frac{Moved\ Units}{Unit\ Load\ Capacity} \quad (5)$$

$$Flow\ Time = Load - unload + \left[\left(\frac{1}{Average\ Speed}\right) \times \left(\frac{Distance}{Effectivity}\right)\right] \quad (6)$$

$$Total\ Usage\ Time\ of\ MH = \sum \begin{pmatrix} Handling\ movement\ time\ \times \\ frequency\ per\ day \end{pmatrix} \quad (7)$$

$$Movement\ Cost = \left[\begin{matrix} \left(\frac{Flow\ time}{\sum Usage\ Time\ of\ MH}\right) \times \\ (MH\ Quantity\ \times\ Inventory\ Cost) \end{matrix}\right] + \left[Flow\ time\ \times \left(\frac{Fuel\ + Labor\ Cost}{60}\right)\right] \quad (8)$$

$$Movement\ Cost\ per\ Day = Movement\ cost\ x\ Frequency\ per\ day \quad (9)$$

'Saved spaces' criteria of the existing layout can be determined by manually measuring the engineering layout drawing in AutoCAD software.

For the existing layout, the total flow distance is 463.1 meters; total MH cost is Rp 1,047,678.49 per day; 89.74 m^2 of spaciousness; and 1,617.24 minutes of total flow time. These results will be compared with the performance of the proposed layouts based on CRAFT and BLOCPLAN.

For the CRAFT algorithm, we are using the WinQSB software which exchanges each department one by one in pairs until the optimum state. After reaching the 7th iteration, the layout is in its optimum condition (see Figure 2.)

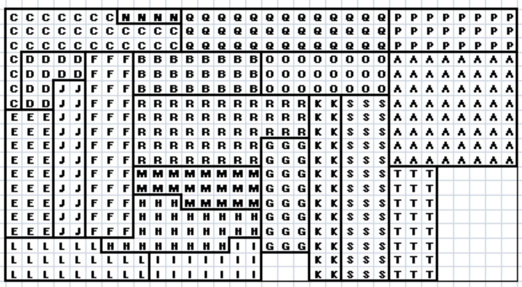

Figure 2. Block Diagram for CRAFT Optimum Layout

Based on the MHPS calculation table of CRAFT layout result, it is known that the total flow distance is 446.88 meters with Rp 1,035,636.87 per day of total material handling cost, 57.8 m^2 of spaciousness, and 1,549.27 minutes of total flow time.

A comparison from the results of BLOCPLAN algorithm utilizing the BLOCPLAN For Windows software is also done. Among twenty generated layouts, only the 14th layout is chosen due to its efficient nature for the whole production system (see Figure 3).

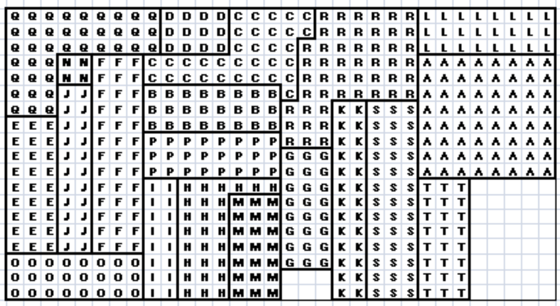

Figure 3. Block Diagram for BLOCPLAN Optimum Layout

For the total flow distance criteria, CRAFT layout could reduce 3.5% of total flow distance from the initial layout. However, BLOCPLAN gives the most significant minimization for which the total flow distance will be 434.62 meters (reducing 6.2% from the initial state). The comparison for these three results is depicted in Chart 1.

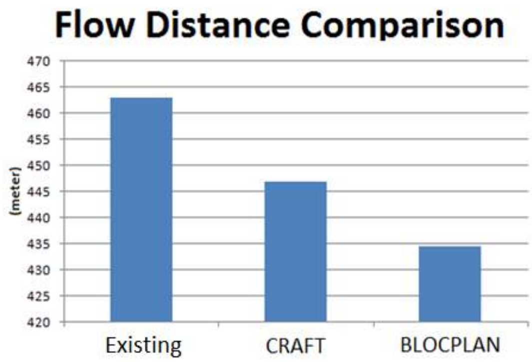

Chart 1. Flow Distance Comparison Chart

For the total material handling cost, CRAFT layout gives a total of Rp 1,035,636.87 per day which means a decrease of 1.15% from the existing state. Actually, the cost can still be minimized using the optimum layout from BLOCPLAN. The result shows a maximum reduction of the total material handling cost of Rp 1,022,419.91 per day (reduced 2.4% from the initial state). The comparison chart of total MH cost is presented in Chart 2.

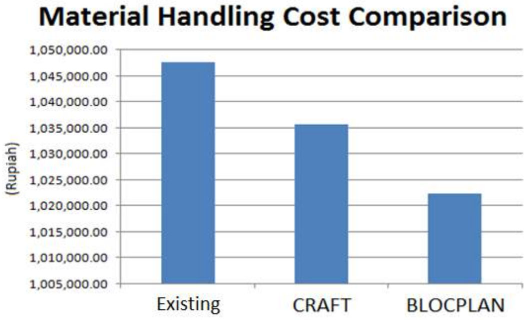

Chart 2. MH Cost Comparison Chart

For the flow time criteria, CRAFT layout is capable of reducing 4.20% of the flow time from the initial state. However, a better result is from the BLOCPLAN layout which gives a total of 1,506.23 minutes (reduced 6.86% of flow time from the initial state). A comparison chart of total flow time is presented in Chart 3.

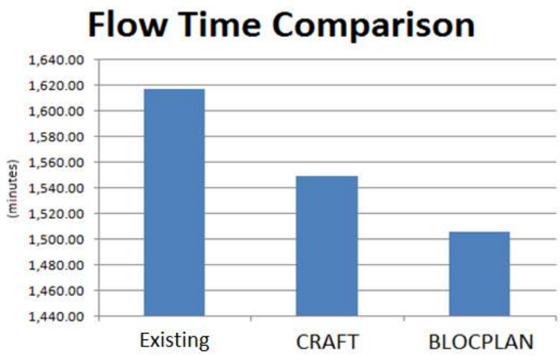

Chart 3. Flow Time Comparison Chart

Lastly, for the saved areas criteria, the existing layout can save five empty spaces consecutively: 12.51 m^2, 33.11 m^2, 17.13 m^2, 5.17 m^2, and 21.82 m^2 with the total of all spaces is 89.74 m^2. This is much better as compared to the BLOCPLAN result; it could save up six areas with each consecutively valued: 19.97 m^2, 9.51 m^2, 29.88 m^2, 10.9 m^2, 16.04 m^2, and 24.44 m^2 and a total of 110.74 m^2. CRAFT algorithm does badly with a total saving of only 57.8 m^2. Each area valued 17.21 m^2, 21.69 m^2, and 18.9 m^2.

A comparison chart for saved area criteria is presented in Chart 4.

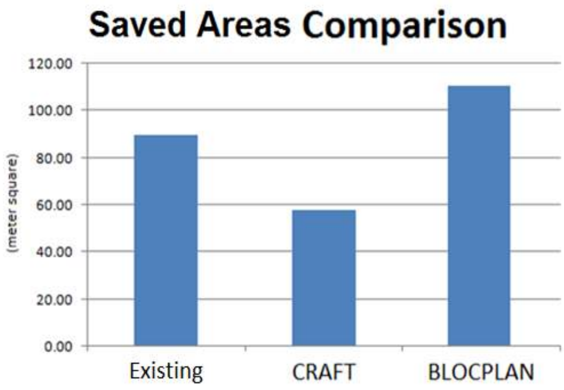

Chart 4. Saved Areas Comparison Chart

4.2. Discussion

Based on the presented results, the layout from BLOCPLAN algorithm is eventually chosen as the proposed one because of its capability to offer the most efficient performance as compared to both the existing layout design and the CRAFT layout design.

The reason why BLOCPLAN gives the most effective layout is because it considers all possibilities when exchanging the positions of all departments. CRAFT is restricted to make changes on departments that are adjacent to each other as well as facilities having the same sizes. This kind of certitude limits the CRAFT algorithm to acquire the most effective layout composition.

To measure the performance of every layout generated by CRAFT and BLOCPLAN, this paper uses a modified MHPS calculation table. In the past, most studies regarding the movement costs in facility layout problem did not consider any MH variations, unit load capacity, and overhead costs.

Due to the complexity of those affecting factors, the movement cost variable is often generalized so that it causes losses. The distance-based objective which is presented in Equation 1, shows there is only one variable of cost (c_{ij}). This cost variable (c_{ij}) is usually being equalized or assumed to be constant.

Each component in MHPS table has their own formulas and input data. For example, in order to determine the total movement cost, we have to consider the types of material handling that is used, the durations of MH usage, fuel cost,

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depreciation, and so on. This is why the formulas for the modified MHPS calculations are so complex and need more observational data on the shop floor.

5. CONCLUSION

Two proposed plant layout models based on CRAFT and BLOCPLAN algorithm are compared in this study. They are previously determined from initial layout improved by iterative improvement procedure. Based on the four comparing criteria, the result shows that BLOCPLAN layout is chosen due to its capability to offer the most efficient performance for the system.

This paper embraces the usage of modified MHPS calculation in order to derive more accurate results. Future research can be done using meta-heuristic algorithms to generate more layout results.

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