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The Application of CRAFT Algorithm for Increasing Material Flow Efficiency: A Case Study of Wooden Door Panels Manufacturing Factory

Chayut Bunterngchit

Division of Industrial and Logistics Engineering Technology, Faculty of Engineering and Technology, King Mongkut's University of Technology North Bangkok, Rayong Campus, Rayong 21120, Thailand

chayut.b@eat.kmutnb.ac.th

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Abstract. Flow without efficiency is a critical problem of the production processes. This research aimed to apply plant layout techniques in order to improve the layout of a wooden door panels manufacturing factory. The goal was to shorten the distance of material flow and, hence, the total cost of the system can be reduced. The research was to study the route of material flow and apply CRAFT algorithm to shuffle the workstations within the plant. Main input data of this study were From-To Chart, Cost Matrix, distances and initial layout. The performance indicators were the cost of material handling per day and total distances of material handling. The results of this study were as follows: the cost of material handling was reduced from THB 3,356.73 per day to THB 3,016.29 per day (10.14 percent) and total distance of material handling was reduced from 134,376.5 meters per day to 119,361.5 meters per day (11.17 percent).

1. Introduction

The wooden door panels' demand of the case study factory has been increased continuously as shown in Table 1. Therefore, the factory decided to buy more machines to place at the bottleneck department for increasing the capability to 4,000 units per day. However, there were critical problems about the space and the layout of the factory. As a result, machines could not be worked at their full capacity and the flow efficiency of the materials was low. In conclusion, the factory has faced the problem about the management of the department arrangement and the material flow efficiency. Plant re-layout techniques must be applied to solve these problems.

Table 1: Demand of the wooden door panels from January to July 2017

Month	Demand [Units]				Total [Units]	Production needed [Units/day]
	Pattern A	Pattern B	Pattern C	Pattern D		
January	21,625	9,340	17,955	14,080	63,000	3,000
February	24,800	8,005	24,650	17,545	75,000	3,000
March	34,730	6,315	33,615	19,840	94,500	3,500
April	29,240	10,070	28,890	15,400	83,600	3,800
May	30,675	12,350	29,775	26,000	98,800	3,800
June	29,645	10,780	29,590	24,985	95,000	3,800
July	32,090	15,275	31,470	25,165	104,000	4,000

2. Literature Review

The meaning of plant layout is the arrangement of machines and the flow of materials from one department to others, which have minimized material handling cost and maximize material flow efficiency [1]. Plant layout is very important activity; proper layout can save a large amount of production cost of the factory [2]. However, if there is a critical change in factory the layout is needed to be revised or it can be called as plant re-layout. The reason for a re-layout are based on 3 types of changes which are changes in production volumes, changes in processes & technology and changes in product [3]. The case study factory also had one of the reason that was change in production volumes. Therefore, plant re-layout was required to increase the capability of the process.

The techniques and algorithms used for plant re-layout can be called as Facility Layout Problem (FLP). Meller, Narayanan and Vance [4], summarize the different algorithm to solve FLP. Exact solution methods based on the Mixed Integer Program (MIP) are very difficult to solve large problems because the majority of FLP is on heuristic approaches. The famous construction algorithm such as Computerized Relationship Layout Planning (CORELAP) and Automated Layout Design Program (ALDEP) can gain the solution without initial layout [5]. Improvement algorithms such as Computerized Relative Allocation of Facilities Technique (CRAFT), Micro CRAFT (MCRAFT) and BLOCPLAN are applied to the initial layout and try to improve it by shuffling departments.

A main objective function is to minimize material handling costs. The total material handling cost is expressed as Eq. (1) [6].

$$Min\ \ C = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}c_{ij}d_{ij} \tag{1}$$

Where C is total material handling cost, m denote the number of departments, f_{ij} is the flow from department i to department j, c_{ij} denote the cost of moving a unit load one distance unit from department i to department j and d_{ij} is the distance from department i to j which measured rectilinearly between department centroids.

Based on literature survey [3,7], CRAFT algorithm is suitable for the factory that has many adjacent departments. So, I selected CRAFT algorithm for the re-layout of this case study plant which also has many adjacent departments as shown in Fig. 1.

Prasad, Rajyalakshmi and Sreenivasulu [5] and Hedau and Sharma [8] improved plant layout by using CRAFT algorithm which can reduced cost more than 50 percent and 27.7 percent respectively.

3. Research Methodology

CRAFT starts with an initial layout and begins by determining the centroids of the departments in the initial layout. Then calculate the rectilinear distance between pairs of department centroids and stores the value in a distance matrix. The initial layout cost is determined by multiplying from-to chart, unit cost matrix and distance matrix. Next, CRAFT considers all possible two ways (pairwise) exchange and identify the best exchange which is the one that yields the largest reduction in the layout cost. Then, CRAFT updates the layout according to the best exchange and compute the new department centroids as well as the new layout cost to complete the first iteration. The next iteration continues until no further reduction in layout cost can be obtained.

CRAFT input requirements are the existing layout as shown in Fig. 1. There are 20 departments in the factory. The analysis will be divided into 2 parts, part 1 is called “wood group” which is department 1 – department 12, and part 2 is called “manufacturing group” which is department 13 – 20.

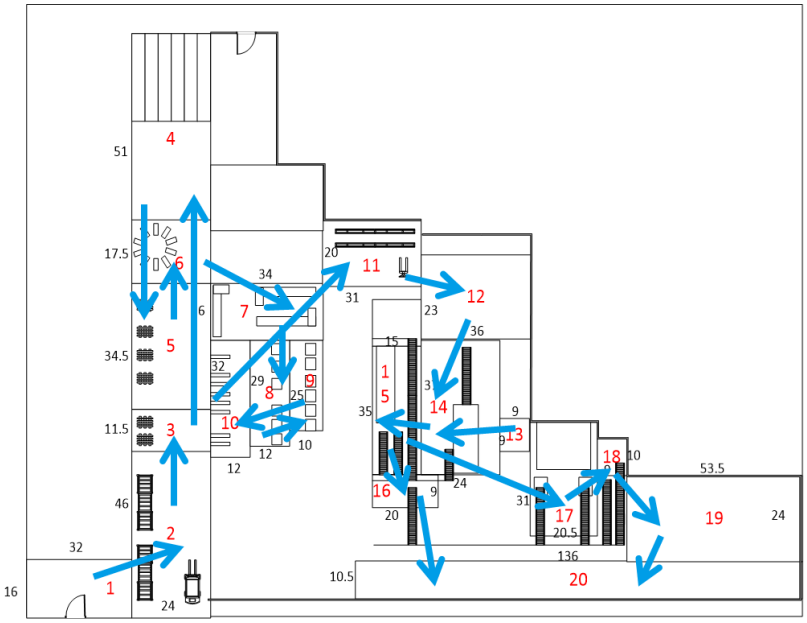

Fig. 1. Initial layout

The important inputs from CRAFT are distance matrix, from-to chart and unit cost matrix. Distance matrix as shown in Table 2 was calculated by the rectilinear distance between pairs of department centroids. From-to chart as shown in Table 3 showed the frequency of the material flow between departments. Unit cost matrix as shown in Table 4 was calculated by gasoline cost of forklift and the labor cost of moving material between departments.

Table 2: Distance between departments of wood group [m/times]

Department	1	2	3	4	5	6	7	8	9	10	11	12
1		43	71.75	155	112.25	86.25	133	99.5	112.5	120	183.5	205.5
2	43		28.75	112	69.25	43.25	90	56.5	69.5	77	140.5	162.5
3	71.75	28.75		83.25	40.5	14.5	61.25	27.75	40.75	48.25	111.75	133.75
4	155	112	83.25		42.75	68.75	80	91.5	100.5	115	94.5	139.5
5	112.25	69.25	40.5	42.75		26	37.25	48.75	57.75	72.25	71.25	96.75
6	86.25	43.25	14.5	68.75	26		46.75	22.75	31.75	46.25	97.25	119.25
7	133	90	61.25	80	37.25	46.75		33.5	20.5	35	50.5	72.5
8	99.5	56.5	27.75	91.5	48.75	22.75	33.5		13	23.5	84	106
9	112.5	69.5	40.75	100.5	57.75	31.75	20.5	13		14.5	71	93
10	120	77	48.25	115	72.25	46.25	35	23.5	14.5		63.5	85.5
11	183.5	140.5	111.75	94.5	71.25	97.25	50.5	84	71	63.5		45
12	205.5	162.5	133.75	139.5	96.75	119.25	72.5	106	93	85.5	45	

Table 3: From-to chart of wood group [times/day]

Department	1	2	3	4	5	6	7	8	9	10	11	12
1		120	0	0	0	0	0	0	0	0	0	0
2	120		120	0	0	0	0	0	0	0	0	0
3	0	120		120	0	0	0	0	0	0	0	0
4	0	0	120		120	0	0	0	0	0	0	0
5	0	0	0	120		120	0	0	0	0	0	0
6	0	0	0	0	120		86	0	0	0	0	0
7	0	0	0	0	0	86		86	0	0	0	0
8	0	0	0	0	0	0	86		86	0	0	0
9	0	0	0	0	0	0	0	86		120	0	0
10	0	0	0	0	0	0	0	0	120		120	0
11	0	0	0	0	0	0	0	0	0	120		75
12	0	0	0	0	0	0	0	0	0	0	75	

Table 4: Unit cost matrix of wood group [THB/m]

Department	1	2	3	4	5	6	7	8	9	10	11	12
1		0.03	0	0	0	0	0	0	0	0	0	0
2	0.03		0.03	0	0	0	0	0	0	0	0	0
3	0	0.03		0.03	0	0	0	0	0	0	0	0
4	0	0	0.03		0.03	0	0	0	0	0	0	0
5	0	0	0	0.03		0.03	0	0	0	0	0	0
6	0	0	0	0	0.03		0.03	0	0	0	0	0
7	0	0	0	0	0	0.03		0.03	0	0	0	0
8	0	0	0	0	0	0	0.03		0.03	0	0	0
9	0	0	0	0	0	0	0	0.03		0.03	0	0
10	0	0	0	0	0	0	0	0	0.03		0.013	0
11	0	0	0	0	0	0	0	0	0	0.013		0.013
12	0	0	0	0	0	0	0	0	0	0	0.013	

After multiplying distance matrix, from-to chart and unit cost matrix, the initial material handling cost of wood group was THB 2,706.72 per day.

4. Results

To improve the layout of wood group, department 5 and 6 were shuffled to have the shorter flow distance and also department 8, 9 and 10 were shuffled to have smooth and shorter flow. The layout after shuffling the wood group is shown in Fig. 2. After multiplying distance matrix, from-to chart and unit cost matrix, the proposed material handling cost was THB 2,482.44 per day, which was less than the initial cost.

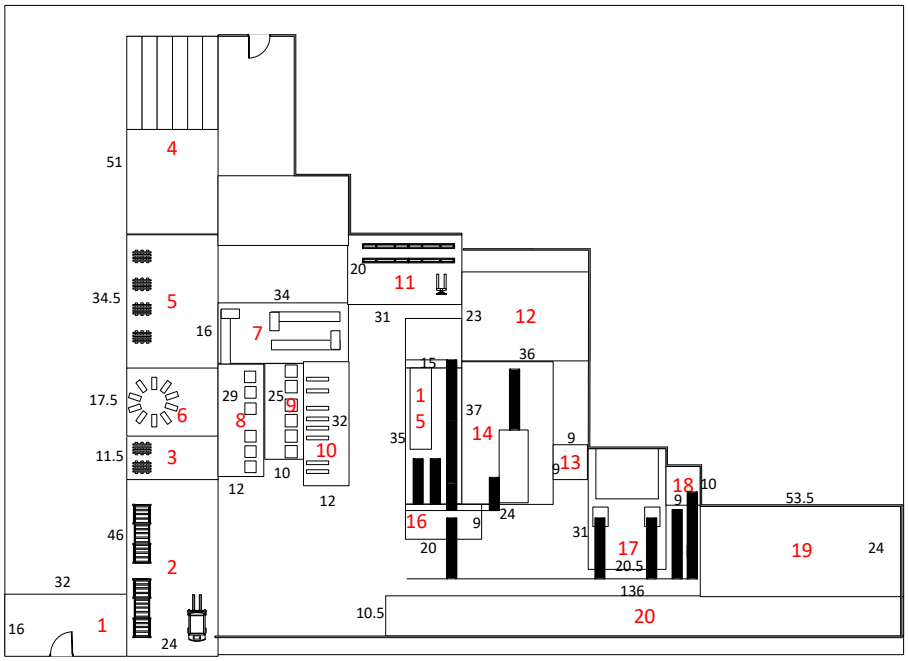

Fig. 2. Layout after wood group improvement

To improve the layout of manufacturing group, CRAFT algorithm was applied, the initial cost of manufacturing group was THB 650.01 per day. Then, considered all possible pairwise exchange for the first iteration and calculated the material handling cost as shown in Table 5.

Table 5: Material handling cost of manufacturing group by using CRAFT with all iterations

First Iteration		Second Iteration		Third Iteration		Fourth Iteration	
Pairwise	Cost [THB per day]	Pairwise	Cost [THB per day]	Pairwise	Cost [THB per day]	Pairwise	Cost [THB per day]
13 - 14	663.51	13 - 14	629.67	**14 - 15**	**600.96**	14 - 16	616.05
14 - 15	642.81	14 - 15	608.97	14 - 16	665.1	15 - 17	618.51
14 - 16	709.47	14 - 16	675.63	14 - 17	622.74	13 - 19	643.8
15 - 16	668.49	15 - 16	634.65	15 - 16	626.64		
13 - 17	642	**13 - 17**	**608.16**	13 - 19	651		
17 - 18	700.71	17 - 19	737.43				
18 - 19	**616.17**						

From the first iteration, department 18 and 19 were the best exchange. The cost was reduced to 616.17 THB per day. Then, repeated the process for the second iteration. From the second iteration, department 13 and 17 were the best exchange. The cost was reduced to 608.16 THB per day. Then, repeated the process for the third iteration, which department 14 and 15 were the best exchange. The cost was reduced to 600.96 THB per day. Then, repeated the process for the fourth iteration, which could be found that none of the pairwise could generate the lower material handling cost. Therefore, CRAFT algorithm has stopped. The total material handling cost of manufacturing group was 600.96 THB per day. The improved layout is shown in Fig. 3.

CRAFT algorithm could reduce total material handling cost from both wood and manufacturing group, which was THB 3,356.73 per day to THB 3,083.4 per day (8.14 percent).

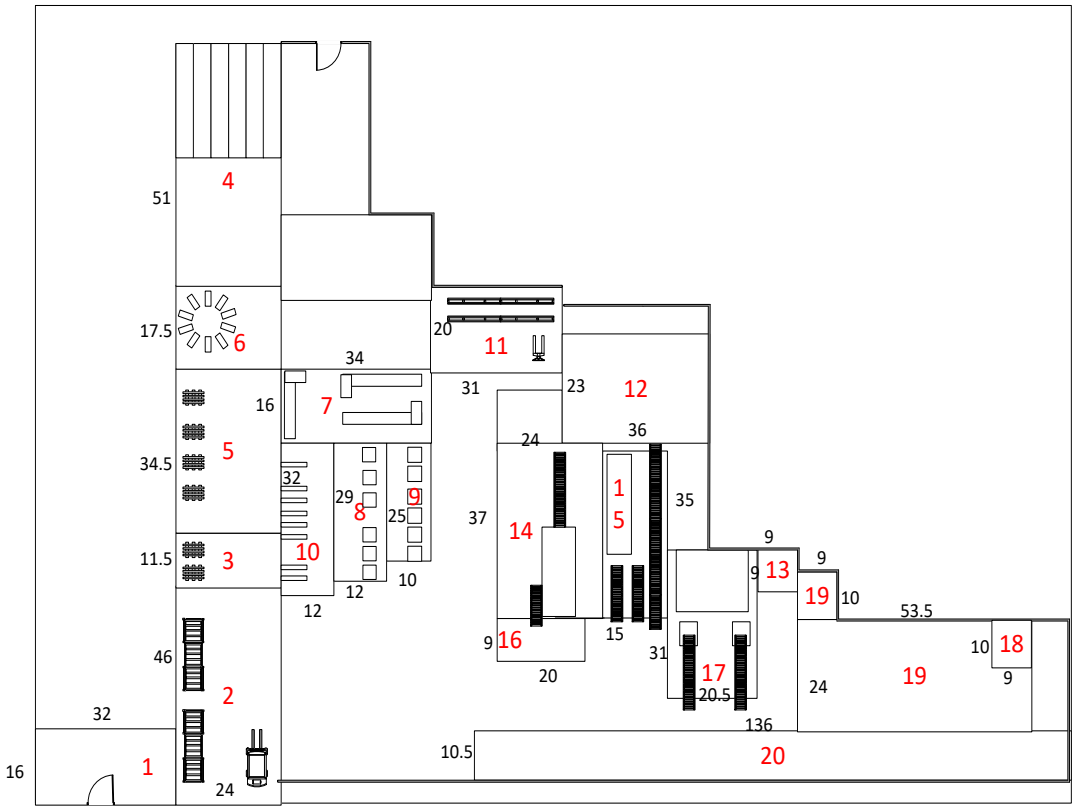

Fig. 3. Layout after manufacturing group improvement

5. Conclusion and Discussion

CRAFT algorithm could reduce material handling cost. However, there were some weaknesses. According to Fig. 3, the different size of the department would be very hard to exchange the location such as department 18 and 19. Material flow from 17 to 18 would be farther than material flow from 17 to 18 of the initial layout.

Therefore, more improvement needed to be made. Department 13-14, 17-18, 19-17, and 16-15 were adjacent according to the flow. The final layout after improvement is shown in Fig. 4 and the total material handling cost of manufacturing group reduced to THB 533.85 per day. The total material handling cost of the whole factory was reduced from THB 3,356.73 per day to THB 3,016.29 per day (10.14 percent) and total distance of material handling was reduced from 134,376.5 meters per day to 119,361.5 meters per day (11.17 percent).

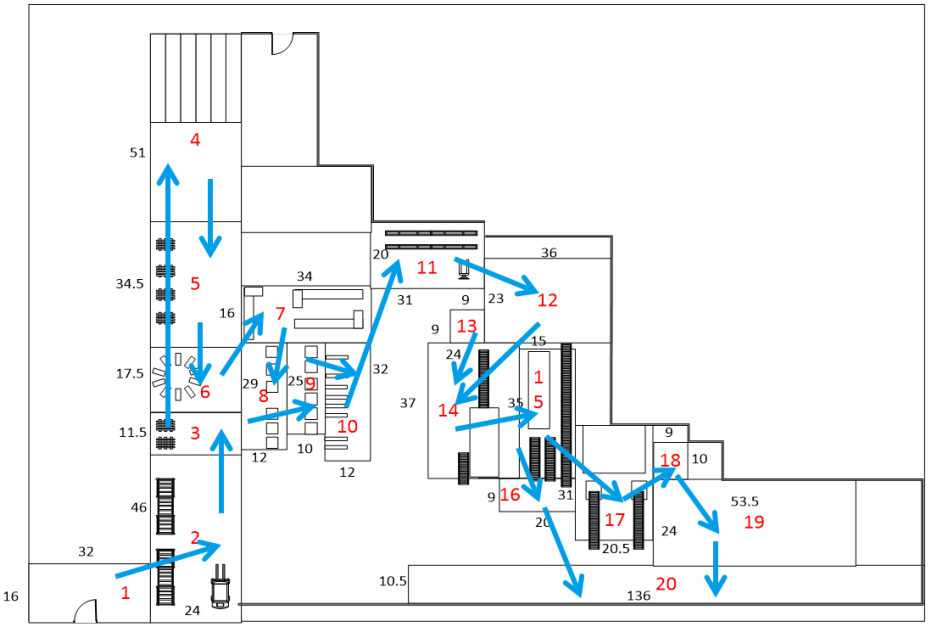

Fig. 4. Final layout

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