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THE USABILITY OF CRAFT LAYOUT DESIGN METHOD WITH THE EXAMINATION OF SIMPLIFICATIONS

FRUZSINA BÓSA[1] – PÉTER VERES[2] – AZIZBEK KYDYKOV[3]

Abstract: Logistics optimization has been gaining attention continuously by companies in recent decades, but due to the current situation, such as the pandemic, recession, and supply chain reorganizations, manufacturers have to resort to more serious tools. One of these is layout redesign, which fundamentally changes a material flow process. One of the most well-known methods is the CRAFT method, which uses two very serious simplifications. In this work, we will examine how much difference the simplifications make in a system close to reality, and can we safely use the CRAFT method.

Keywords: Layout planning, Layout redesign, CRAFT method

1. INTRODUCTION

Within the life of manufacturing companies, it is an inevitable event that some machines or even entire production lines have to be reorganized from time to time. Ideally the companies innovate, the technology improves, they have more machines, the product range expand or change, or the production volume of existing products is increased. Logistics processes are primarily meant to serve production processes; therefore logistics systems must also keep up with the changing and developing technology [1], [2].

There are not always positive reasons behind the reorganization of plants. The past few years have caused enormous problems for many companies due to the pandemic situation [3], [4]. The supply chains were weakened, even several suppliers could not fulfil their orders. Due to the weakened market and problems caused by the supply chain, it was not possible or necessary to manufacture some products, which had a great impact on the companies. Downsizing and reorganization came forward, and alternatives appeared on the markets [5]. Even in the disadvantageous situation thus created, it was necessary to rethink the function of the factories that had been worked until then, and one way to do this is to transform the layout of the whole production and/or storage system. If production lines fail due to a lack of labor or because they cannot produce due to lack of materials, and the situation cannot be remedied in the long term, it may be worthwhile to consider and implement other arrangements [6], [7].

In this work, we will use a simple example to test the efficiency of one of the best-known layout organizing method: the CRAFT method. After a little introduction, we want to answer if the simplification of the method is affecting the result and, if so, how much deviation can we measure. If the deviation is not significant, the CRAFT method can be safely used in its original form for layout planning.

[1]BSc student., University of Miskolc, Institute of Logistics
fruzsibosa@gmail.com
[2]PhD., University of Miskolc, Institute of Logistics
peter.veres@uni-miskolc.hu
[3]PhD., Kyrgyz State Technical University, Institute of Logistics
azizbek.kydykov@gmail.com

2. DESCRIPTION OF THE CRAFT METHOD AND THE TEST LAYOUT

We usually encounter the installation problem of objects with a given floor area and shape as an internal plant layout task. The most often used solution method is the CRAFT method, which classifies as a heuristic algorithm, meaning that there are no specific mathematical relationships on the basis of which we can find an optimal solution. Based on a guiding process, the possible versions must be examined, and then a solution must be chosen from among them, which may not be the optimal solution, but it is suitable for us given these circumstances [2], [6], [8].

In order to apply the method, we have to lay down the basic rules, which are as follows:

- The shape of the floor area of the workshop, in which the layout is carried out. This cannot be changed or rotated, as this does not happen in reality either.
- The shape of the machines cannot change either, but they can be rotated, just like in reality.
- The base area of the machines is taken into account, and the centre of gravity is assumed to be the source and sink. This is the simplification we wanted to test.
- The movement between the machines takes place according to the Cartesian coordinate system. In reality most of the routes in a factory are designed this way, so this can generally be considered realistic [6], [9], [10].

First of all, we record the position of the starting layout, based on this the route matrix between the individual points can be calculated [2], [6]:

$$L = \sum_{i=1}^{s}\sum_{j=1}^{s}\left|(x_{si} - x_{sj}) + (y_{si} - y_{sj})\right| \tag{1}$$

where:

- x_s is the x coordinate of the centre of gravity of the object
- y_s is the y coordinate of the centre of gravity of the object
- i,j are the objects

The material flow matrix is considered as given, and it can be used to calculate the material handling work [2],[6]:

$$W = \sum_{i=1}^{s}\sum_{j=1}^{s} q_{ij} l_{ij} = Spur(Q_{11} L_{11}^{T}) \tag{2}$$

After this, we have to look for all the possible exchanges, so that 1 object can be exchanged with only 1 other object or set of objects at a time. We have to calculate every distance matrix for all the possible exchanges. After we got the new material flow values, we pick the smallest, and we fix this exchange. Now we repeat the previous set of instructions [8]:

- define the new set of exchanges of the objects (be careful not to get back a previous configuration),
- calculate the new distance matrices,
- calculate the new material flow matrices,
- pick the lowest value of material flow number,
- fix that exchange of objects as the new starting position.

We repeat these instructions until we have no more possible exchange, the material flow numbers only get bigger (we pick the lowest number in all branches), or we think we find an optimal solution [6],[8].

2.1. The testing layout

We create a simple, but somewhat realistic starting layout. There is no new equipment we want to insert, we only need to optimize the current layout. The system consists of 6 machines (1-6) that can take 3 different shapes. From a raw material warehouse (Ra), a finished product warehouse (Rk), an empty area (0) where objects can be placed freely, and a closed area (black tile) where no objects can be installed. The red dots are the exit points of the objects and the green dots are the enter points. The grey dots are the grid points, they only here for visuals, and ease the computation. A grid in this layout is 4x4m=16m^2.The staring layout can be seen in Figure 1.

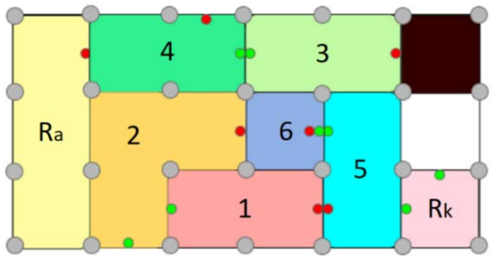

Figure 1. Starting layout of testproblem

The next important data is the material flow matrix. This doesn't change over the whole testing, but in the CRAFT method the enter and exit points are on top of each other, which is in the centre of the objects. The material flow table can be seen in Table I.

Table I.
Material flow matrix, that represents the connection between the test objects

Qk	Ra	1b	1k	2b	2k	3b	3k	4b	4k	5b	5k	6b	6k	Rk1	Rk2
Ra	0	30	0	6	0	10	0	0	0	10	0	2	0	0	0
1b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1k	5	0	0	18	0	0	0	0	0	5	0	0	0	0	0
2b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2k	0	1	0	0	0	21	0	0	0	0	0	0	0	0	0
3b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3k	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0
4b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4k	3	0	0	0	0	1	0	0	0	0	0	10	0	0	0
5b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5k	1	0	0	0	0	0	0	0	0	0	0	15	0	5	0
6b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6k	0	1	0	0	0	0	0	1	0	0	0	0	0	25	0
Rk1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rk2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3. TESTING OF THE CRAFT METHOD

We can represent the whole layout as coordinate points. In the CRAFT method, we calculate the distance between two objects, by simple subtracting the X coordinates of the two objects in absolute value, and do this for the Y coordinate also, and then add them together. This eliminates the physical routes that connects them and ignore any other object this route goes through. In a more realistic way, we can only use roads or routes between objects. Table II shows the CRAFT method's simplified distance matrix where object 7 and 8 are the raw material and finish product warehouses, and Table III shows the real distance matrix, where all grid points are shown and calculated by Dijkstra algorithm [11], [12].

Table II.

Distance matrix in CRAFT method

L [m]	1	2	3	4	5	6	7	8
1	0	10	12	12	8	6	12	8
2	10	0	14	6	14	8	2	18
3	12	14	0	8	8	6	16	12
4	12	6	8	0	16	10	8	20
5	8	14	8	16	0	6	16	4
6	6	8	6	10	6	0	10	10
7	12	2	16	8	16	10	0	20
8	8	18	12	20	4	10	20	0

Table III.

Distance matrix with realistic calculation

	Ra	1b	1k	2b	2k	3b	3k	4b	4k	5b	5k	6b	6k	Rk1	Rk2	S1.1	S1.2	S1.3	S1.4	S2.1	S2.2	S2.3	S2.4	S3.1	S3.2	S3.3	S3.4	S4.1	S4.2	S4.3	S4.4	S5.1	S5.2	S5.3	S5.4	S6.1	S6.2	S6.3	S6.4	S7.1	S7.2	S7.3	S7.4
Ra	0																																					0,5	0,5				
1b		0																														0,5	0,5										
1k			0																					0,5	0,5																		
2b				0																									0,5	0,5													
2k					0																											0,5				0,5							
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6b												0													0,5	0,5																	
6k													0												0,5	0,5																	
Rk1														0						0,5	0,5																						
Rk2															0		0,5				0,5																						
S1.1																0	1			1																							
S1.2															0,5	1	0	1			1																						
S1.3																	1	0	1			1																					
S1.4																		1	0				1																				
S2.1														0,5		1				0	1			1																			
S2.2														0,5	0,5		1			1	0	1																					
S2.3							0,5											1			1	0	1			1																	
S2.4							0,5												1			1	0				1																
S3.1			0,5								0,5									1				0	1			1															
S3.2			0,5							0,5	0,5	0,5	0,5											1	0	1			1														
S3.3										0,5		0,5	0,5									1			1	0				1													
S3.4																							1				0				1												
S4.1																								1				0				1											
S4.2				0,5																					1				0	1			1										
S4.3				0,5		0,5		0,5																		1			1	0	1			1									
S4.4						0,5		0,5	0,5																		1			1	0				1								
S5.1		0,5			0,5																							1				0	1			1							
S5.2		0,5																											1			1	0										
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S5.4									0,5																						1				0				1				
S6.1					0,5																											1				0	1			1			
S6.2																																				1	0	1					
S6.3	0,5																																	1			1	0	1				
S6.4	0,5																																		1			1	0				1
S7.1																																				1				0	1		
S7.2																																								1	0	1	
S7.3																																									1	0	1
S7.4																																							1			1	0

For every step, and exchange of objects we have to calculate or modify the previous two tables. This is very time-consuming for the realistic method, even for this simple problem. Since the entire calculation of the two methods would take nearly 100 pages, we will only show the final solution and the tree of exchanges. The total tree of CRAFT method can be seen in Figure 2. In the nodes of the tree (squares) in the first row we can see the name or the exchanges of the node, and in the second row there are the value of total material handling work, where the lower is better.

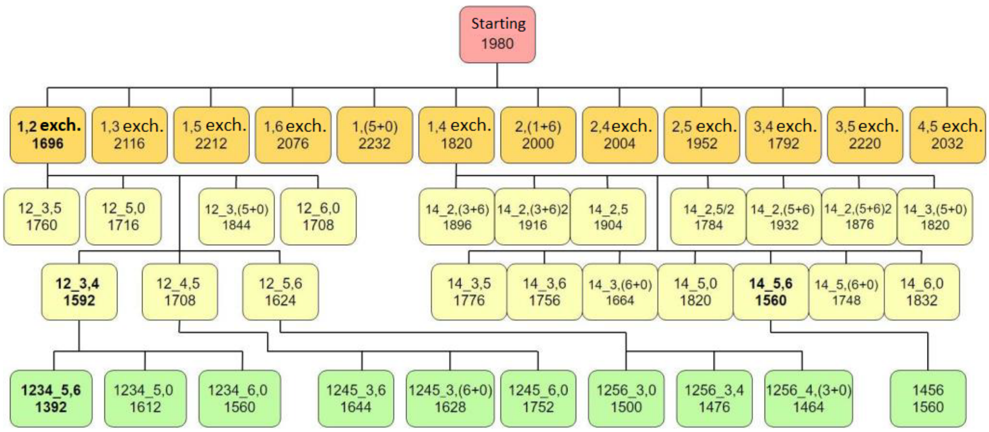

Figure 2. Tree of exchanges of CRAFT Method

When we calculate the values of the realistic method, there are several sub-solutions, because, in the CRAFT method, the orientation of object doesn't matter, because we work with their centre, but in the realistic method most of the time there are 2 or even 4 rotations can be possible for every object. We can't eliminate this problem automatically, because it creates numerous similar layouts, so we address it by manually picking the most sensible orientations for the objects. With this the trees are completely identical only the values changes. Table IV contains the values compared between the two methods.

Table IV.

Deviation between the two methods

Exchange name	CRAFT Method		Realistic method		Deviation between methods
	Value of material handling work (W_L)	Improvement from Start layout (%)	Value of material handling work (W_L)	Improvement from Start layout(%)	
Start layout	1980	0,00%	2080	0,00%	5,05%
1,2 excange	1696	14,34%	1764	15,19%	4,01%
14_5,6	1560	21,21%	1626	21,83%	4,23%
12_3,4	1592	19,60%	1688	18,85%	6,03%
123_5,6	1392	29,70%	1488	28,46%	6,90%

In Table IV we examined 5 important layouts (they are highlighted in Fig. 2), both the improvements are similar, and the deviation between methods are in a very narrow value limits (4…7%). With this finding we can assume, that the simplifications of CRAFT method is acceptable, because we can find clear quasi-linear connection between the models. With this knowledge we can recommend the usage of the CRAFT method for layout planning.

4. SUMMARY

In this paper, we proved that the CRAFT method does not affect the result as much as we originally suspected, despite the fact, that it uses simplifications: the enter and exit points of the installable objects are in the centre, and their transport path is practically a straight line. From the data we can see that the connection between the CRAFT and realistic method is quasi linearly proportional, so we can safely say that the CRAFT method can be successfully applied to layout design tasks.

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