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On Development of Algorithm to Design Layout in Facility Layout Planning Problems

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ABSTRACT

Facility layout refers to the arrangement of physical facilities within the manufacturing system in such a manner so as to have quickest flow of material at the lowest cost. This paper presents a methodology to design a layout considering two factors pick-up, drop-off location and sweep width pattern which differentiate with ALDEP (Automated Layout Design Program) algorithm. ALDEP is a construction type algorithm which develops a layout design by randomly selecting a department and placing in the layout by sweep width only once. In this paper, we designed the layout by the methodology in such a manufacturing system where pick-up and drop-off location are fixed. Also sweep width is taken twice in the proposed layout to form appropriate layout size which is explained by the proper algorithmic approach and numerical example.

Keywords: Pick-up Location, Drop-off Location, Sweep Width, Facility Layout, Layout Design.

1. Introduction

Facility Layout planning is the floor plan of the physical facilities which are used in production. It refers to the generation of several possible plans for spatial arrangement of physical facilities and selects the one which minimize the distance between departments, utilize existing space effectively, and minimize material handling cost and production time. A good design of facilities contributes to the overall efficiency of operations and can reduce until 50% the total operating expenses [11]. Facility layout planning and design plays important role in manufacturing units and also in service outfits. Layout design can influence quality of manufactured products or service delivery as checking or testing locations needs to be incorporated in the integrated system in most befitting manner besides the fact that in certain situations material damages are obviated by reducing its handling requirement.

Computer's aid in plant layout design has its own advantage. Computer can present the computations and create several solutions much more rapidly than manual procedures [15]. The computerized layout methods are heuristics; they do not guarantee an optimal solution. These methods are categorized as either construction or improvement-type routines: Improvement-type layout requires an input of a feasible block layout and desire to decrease movement cost by attempting simultaneous pair-wise (or more) position exchanging among the departments. The most popular improvement-type routines are CRAFT (Computerized Relative Allocation of Facilities Technique) [7] and COFAD (Computerized Facilities Design) [10]. Construction-type routine generates a block layout based on the relationship between different departments. It includes a serial project of each facility to a location until a solution is built [8, 13]. It generates a layout straight from the activity relationship chart, space requirement and shape. However, it provides only one unique layout in the end, which could, sometimes, be far from what was expected [1, 3]. The most popular routines within this category are CORELAP (Computerized Relationship Layout Planning) [14], ALDEP (Automated Layout Design Program) [16] and PLANET (Plant Layout Analysis and Evaluation Techniques) [2, 6]. ALDEP is used when activity relationship is a major consideration. It develops a layout design by randomly selecting a department and placing in the layout [5]. The departments are placed in layout based on its closeness ratings. In a manufacturer system a layout can be designed where the departments of receiving raw materials and deliver the produced goods are in a fixed position. The others department will be arranged according to closeness ratings and for placement of department sweeping pattern is used. In this paper, a single row layout is designed considering pick-up, drop-off location fixed and taking sweep width twice. The illustrated example of methodological procedure is given in the paper.

2. Basic terminology

2.1. Pick-up and drop-off locations (P/D locations)

In a layout, it is often essential to find out the locations from which parts or raw materials enter to process. After entering the raw materials in a department, it needs to be various processed in others department and a department be fixed to deliver the processed goods or leave facilities. The entering position of raw materials is called pick-up location and delivery position of goods is called drop-off location. In proposed layout pick-up and drop-off location is kept in first and last department, although they can potentially be located at various places [9], several researchers restricted their possible location to reduce the complexity [4]. An example is given in Figure 1.

Figure 1. P/D locations in a regular shape facility.

2.2. Sweeping width

Discrete representation systems generally use layout patterns to swap the facility area. These patterns are adjacent curves that visit every grid in the facility area. Several patterns are available in the literature that are used such as the space filling pattern and spiral pattern [12]. They can be seen in Figure 2 and 3.

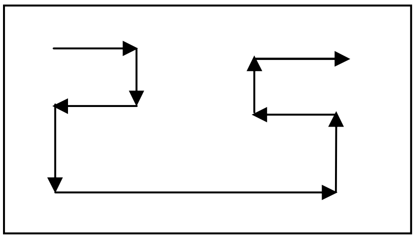

Figure 2. Space filling pattern

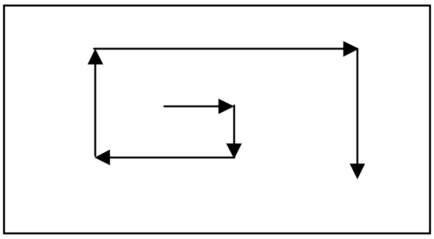

Figure 3: Spiral pattern

The departments in the layout are placed from the upper left corner and moves to the bottom. Then continuous from bottom to upper edge and continue similarly. The placement can be done 1 or 2 or 3 ….. or n columns at a time. This information is called sweep width. In proposed layout, sweep width is taken twice for last position department to give appropriate layout size equal total scaled area of the departments. The sweeping filling of department in the layout is according to the Figure 4.

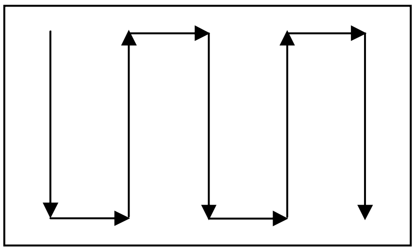

Figure 4. Sweep in filling

2.3. Relationship (REL) chart

A Relationship (REL) Chart represents m (m-1)/2 symmetric qualitative relationships (mainly closeness relationships among the departments of numerous activities), i.e.

r_{12}	
r_{13}	r_{23}

Figure 5. REL Chart

Here, r_{ij} ϵ{A, E, I, O, U, X} where symbols A, E, I, O, U, X are used to indicate the various degrees of closeness. These are A= absolutely necessary, E=especially important, I = important, O=ordinary closeness, U=unimportant, X= undesirable. Closeness Value (CV) between department i and j; r_{ij} is an ordinal values when comparing pairs of departments. Hence, CV (r_{ij}) = arbitrary cardinal value assigned to r_{ij} e.g., CV(U) = 1. In projected algorithm, to design layout by given example, CV(A)=64, CV(E)=16, CV(I)=4, CV(O)=1, CV(U)=0, CV(X)= -1024.

2.4. Total closeness ratings values (TCR value)

Total closeness rating (TCR) of a department is the sum of the numerical values assigned to the closeness relationship between the department and all other departments.

2.5. Requirements of basic data

1. Total number of department.
2. Area of each department.
3. Length and width of layout.
4. Pick-up and Drop-off Location Department.
5. Closeness ratings of various pairs of departments in the form of relationship chart.
6. Sweep width.

3. Proposed algorithm

Step-1 : Fix pick-up and drop-off location to start design layout. As a result the Relationship chart is formed except the department which is fixed for pick-up and drop-off location. It is noted that the layout is designed for unequal areas of facility.

Step-2 : Take the rectangular form of the Relationship (REL) Chart and find the total Closeness values (TCR) for each department.

Step-3 : Select the department with largest TCR values for the first placement and continue the process to make a sequence. If tie occurs, choose the department with the largest area. Two departments which are selected for the pick-up and drop-off location must be included in the sequence.

Step-4 : Make the layout matrix size from given scaled area. It is better to take layout matrix size where length and width is in an appropriate size.

Step-5 : Put the department in the layout according to the sequence.

Step-6 : Place the department in the layout according to sweep width. Only for last department sweep width is also taken one column (if require) with given sweep width to make the layout in a proper size which is the factorization of total scaled area.

4. Numerical illustration

Basic data:

1. Number of departments=8

2. Areas of departments:

Dept.	1	2	3	4	5	6	7	8
Area (sq. m)	17,000	18,000	10,800	20,000	14,000	12,000	24,000	8,000

3. Pick- up and drop-off location dept. 1 and 8.

4. Sweep width =2 columns.

5. REL Chart:

2	-					
3	A	-				
4	O	U	-			
5	E	E	I	-		
6	I	A	U	I	-	
7	E	I	O	E	A	
	2	3	4	5	6	7

Figure 6. REL Chart

CV(A)=64,CV(E)=16, CV(I)=4, CV(O)=1, CV(U)=0, CV(X)= -1024.

Solution: Areas of departments when 1 square for a department=400 sq. m

Dept.	1	2	3	4	5	6	7	8
Area (sq. m)	17,000	18,000	10,800	20,000	14,000	12,000	24,000	8,000
No. of	43	45	27	50	35	30	60	20

Total scaled area= 310 sq. m
Length and width of proposed layout is selected as (10×31)

Hence, Layout matrix size=10×31=310

Sweep width =2 column
Represent triangular matrix in a rectangular form and find TCR values as follows:

Department	Rectangular form of Triangular matrix TCR
2	A+O+E+I+E=64+1+16+4+16=101
3	A+U+E+A+I= 64+0+16+64+4=148
4	O+U+I+U+O= 1+0+4+0+1 = 6
5	E+E+I+I+E= 16+16+4+4+16 =56
6	I+A+U+I+A= 4+64+0+4+64=136
7	E+I+O+E+A= 16+4+1+16+64= 101

Table 1

Department 2 and 7 having same TCR values but area of dept. 7 (24,000 sq. m) is more than the dept. 2 (18,000). Also pick-up and drop-off location is in dept. 1 and 8. So, dept. 1 and dept. 2 is selected for the first and last placement in the layout.
Hence, Layout sequence is 1-3-6-7-2-5-4-8
After placing department the layout is shown below:

1	1	1	1	1	1	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	2	5	5	4	4	4	4	4	4	0	0
1	1	1	1	1	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	2	5	5	4	4	4	4	4	4	0	0
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	5	5	5	4	4	4	4	4	4	0	0
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	4	4	0	0
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	4	4	0	0
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8	8

The above layout matrix size is (10×32).

But layout scaled area is 310 sq.

So we use sweep width one column (fixed) for last department as well as sweep width two column. Therefore, the final layout matrix size is (10×31) which is shown below:

1	1	1	1	1	1	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	2	5	5	4	4	4	4	4	4	8
1	1	1	1	1	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	2	5	5	4	4	4	4	4	4	8
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	2	5	5	5	4	4	4	4	4	4	8
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	4	4	8
1	1	1	1	3	3	6	6	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	4	4	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8
1	1	1	1	3	3	3	3	6	6	7	7	7	7	7	7	2	2	2	2	5	5	5	5	4	4	4	4	8	8	8

Figure 8. Final layout matrix

5. Discussion

5.1. Explanation of using P/D locations department

While for process based firm closeness relationship of a facility with all the other facilities is main concerned in the layout. In the manufacturing firm, there is considered a location of a facility which receives all kinds of raw materials called pick-up location. The pick-up location in the layout is in the first department. After receiving these raw materials, it takes time to process in other closeness department which is represented by REL Chart. And there is location of a department to deliver the produced goods to the customer called drop-off location. The drop-off location in the layout is in the last department. In the layout, departments are placed in a line. In this sense, the layout is single row layout. By the proposed algorithm, each department in the layout may be regular or irregular shape. In proposed layout, only dept. 7 is regular shape and all others irregular shape.

5.2. Explanation of using sweep width twice

It must be noted that, sweep width is taken twice only for last department (Dept. 8). In last dept. sweep width is used 2 columns as well as one column (fixed) and it is used to give appropriate size of the layout matrix. A result is shown below:

In **Figure 7.**

If sweep width 2 column is used layout size is (10×32)

Hence, Total scaled area is 10×32=320 sq. m.

But proposed area of all Department=310 sq. m.

In **Figure 8.**

If sweep width value 2 and 1 column is used only for last department (Dept. 8) layout size is (10×31)

Total scaled area is 10×31=310 sq. m

Therefore, additional area=320-310=10sq. m=4000 sq. m (Since 1 square for a department=400 sq. m) needs which also effect on cost.

6. Conclusion

In the article, a methodology is proposed for selection of optimal facility layout design based on two factors pick-up, drop-off location of department and use of sweep width. This layout design ensures fast movement, make easy to receive raw materials from pick-up and to deliver the product from drop-off position. The methodology also gives appropriate layout matrix size for using sweep width twice where for last department sweep is taken 1 column (fixed) as well as 2 columns. As a result the layout becomes free of using additional area and decrease layout cost.

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