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Development of a Suitable Plant Layout using Computerised Relative Allocation of Facility Techniques

Priyaranjan Mallick, Kamalakanta Muduli, Jitendra Narayan Biswal, John Pumwa, Peter Oyekola

Abstract: ***In contemporary technological developed scenario, the distinctive manufacturing industry involves large number of diversified accomplishments such as administration office, design office, sales & marketing office, production or manufacturing shops, inspection and assembly departments, and security office etc., organized as a unit with essential communication amenities. The ultimate goal of facility plan or layout problem is to reduce the cost of material flow by locating the office and departments within specified location. In this paper, the layout of a casting industry has been designed by means of Computerized Relative Allocation of Facilities Technique (CRAFT). The results shows that a reduction of 34.9% in the total distance travelled could be achieved with the new layout design that was developed using CRAFT algorithm.***

Keywords: ***Facility Layout, CRAFT Algorithm, Plant Layout, Manufacturing, production***

I. INTRODUCTION

Plant layout involves arrangement of physical equipment and facilities for more efficient operations resulting from changes in time, cost of production, material handling etc. in order to attain maximum efficiency, the factors of production must attain effective co-ordination and efficiency. Plant layout combines space allocation and equipment rearrangement as such that total operating cost is minimised [1].Plant layout is the floor plan used for the arrangement of equipment and machineries in a plant irrespective of whether it is established or contemplated in order to allow quickest flow possible at minimal cost and material handling in processing the product from receiving raw material to the final shipment of finished product[2]. In plant layout design, major factors considered are the location, capital investment etc. poor layout yields substantial financial loss which might affect the company in the long run hence the need for proper plant layout planning[3]. The purpose of planning is to reduce the distance flow between stations for space optimisation. Basically, two plant planning algorithms are widely used. The first is graph based methods (i.e. ALDEP, CORELAP, and PLANET). While the other is improvement algorithm (pair wise exchange i.e.CRAFT, MCCRAFT)[4]. Computerised relative allocation of facility technique (CRAFT) algorithm is based on matrix of interdepartmental flow and cost[5]. Material handling cost if the major consideration hence main factor is the floor area given the recent advancement in technology, there is a constant need to change equipment and processes for more optimum output also cost of land close to source of materials with sufficient access to electricity, water etc. is on the rise hence space efficiency to give maximum output with limited space constraint. Although CRAFT algorithm is widely used, its result is not optimum in terms of minimising cost of transportation, but its result is close to optimum in majority of its applications which is why we are implementing it in this paper. Inefficient plant layout design result in maximisation of transportation cost hence reduction in work efficiency. 'According to process' means the processes are back-to-back and should be assigned in a line of which processes will be handled systematically and hence reduction of handling cost and efficient material flow[6]. For huge facilities with numerous inter departments, manual calculations cannot suffice, in this situation, CRAFT is used because it a pair wise exchange algorithm that may give an optimal solution because final results depend onexisting layout. In getting the best layout, multiple input solutions are accessed and optimum is determined. CRAFT uses departmental switch for those with common scope of work.

II. LITERATURE REVIEW

The objective of this section is to summarise existing literature on plant layout efficiency design and CRAFT algorithm as it relates to the paper. Plant layout involves arrangement of machines, tools and process in order to minimise the cost of material handling cost and increase material flow maximally which is of utmost necessity in manufacturing companies.

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* Correspondence Author

Priyaranjan Mallick*, Department of Mechanical Engineering, College of Engineering and Technology, Bhubaneswar.

Kamalakanta Muduli, Department of Mechanical Engineering, Papua New Guinea University of Technology.

Jitendra Narayan Biswal, Department of Mechanical Engineering, DRIEMS, Odisha, India.

John Pumwa, Department of Mechanical Engineering, Papua New Guinea University of Technology.

Peter Oyekola, Department of Mechanical Engineering, Papua New Guinea University of Technology.

Although the aim is to reduce cost, we also have to take into consideration possibility of future change such as expansion or change in technology. For instance, a factory that produce florescent tubes have to constantly change their manufacturing process and machines in other to meet up the ever dynamic industry which is past fluorescent tubes to energy saving bulbs that consumes less
than 20 watt or even LED flood lights which consumes 10 Watts.

The reason for a re-layout are based on three major types of change [7]

- Change in production volume
- Change in process and technology
- Change in product[8]

Graph theory and CRAFT system was used in the modification of an existing rubberised coir mattress factory by G Elizabeth, R. Sasikumar[9] By using Graph theory, material handling cost was reduced to 0.1% hence, CRAFT method was adapted. The modification using CRAFT was done using add-in for Microsoft Excel developed by Jenson and Co. This new layout yielded a reduction of 4.5% and 2.4% for total distance between department and total distance travelled per day respectively. The material handling cost also reduced by 2.4% R.R Hombal, R Drshobha[10]proposed to improve metro coach using CRAFT methodology. On comparison of results, there was a considerable reduction in material transportation cost the departments were relocated in a way that flow of material is smoother and it was determined that 21.1% of cost could be saved as compared with the present system.V. Hedau[11] also proposed how craft algorithm was used to minimize the travel route and transportation cost of inter department activities, the topic named on improvement of plant layout using CRAFT -here, the study was based on density and distance based process layout (DDBPL). This research was done on a manufacturing industry situated in Indore, Madhya Pradesh which produces variety of products. The problem of the existing plant layout was the difficulty in modifying the existing plant layout.The complexity of the work was increased due to a variety of products manufactured in the organization. For reduction of the complexity, the density based criteria was taken to optimize overall performance of the organization layout. Products that were contributing 75% of total production in a year were chosen as a dense product for the work. The research also concluded that the industry will interchange some of the departments then inter- department material transportation cost will be reduced. CRAFT methodology was also employed in RMG alloy steel where V.A. Deshpande et al [12]Worked on selecting the most effective arrangement in any manufacturing environment, which influences the work efficiency and reduces Material handling cost namely Plant Layout Optimization using CRAFT and ALDEP methodology. RMG alloy steel industry in Barouche deals with rolling mill making RCS bar. First, it changed departments in pair wise inside the layout Using CRAFT which resulted in only 0.1027%. So it further goes under ALDEP which involved checking all the flows possible in the layout accompanied with optimized cost of transportation. Finally, it chooses the optimized one which results 23% saving of material handling cost, with increased productivity, low cost of product and reduction in efforts by production workers. Saving in material handling is such a huge amount of saving results 23% saving of material handling cost, with increased productivity, low cost of product and reduction in efforts by production workers.

Y.Deokar et al[13]workedon the simulation and optimized layout of sheet metal manufacturing plant which produced components for major automobile and transport equipment manufacturer. The major issue was the variation in production volumeas the firm was not meeting its production schedule of75 to 80 assemblies per month. The paper majorly focused on designing a modified layout of which the outcome productivity increased by 91% and net profit increased by 91% per month. Also D. Back [14] proposed an application of simulation to show the improvement of the new layout named on A model for effective developments of plant layouts and material handling systems. Results of this research showed 10% reduced manual material handling improved environment, 76% decrease of manual travelling distances, reduced risk of stock out etc. In addition, O.Cchikwendu and C. Okechukwu (2017) [15]researched on efficiency inlabourutilization, manufacturing and maintenance ease, enhanced productivity,manufacturing flexibility, machines, materials and equipment as well as reduction of accidents, hazards and inventory handling cost. It resulted in enhancement of overall performance as in the case of Vishnu Narayanan A, Rakesh Pillai R, Surendran A(2017)[16]who proposed a study conducted at Steel and Industrial Forgings Ltd, Thrissur a Govt.of Kerala undertaking established in 1983 the new design for plant layout means to achieve remarkable improvement in efficiency, manufacturing cost , lead time, travelling distance and overall production cost and it is done by reallocating the equipment's positions in the layout named on optimization of manufacturing plant layout design in SIFL using CRAFT. The research was a combined study of plant facility reallocation with the help of computerized relative allocation of facility technique (CRAFT) and simulation study carried out by using ARENA simulation software. The conclusion of the research paper is reduction of cost of 14% by changing the position of work stations. The less operational cost value represents an optimized factory layout that performs in the economical manner. This study is proposed to improve production plant layout efficiency by suggesting an improved modified plant layout. A well planned department provides the fundamental for a profitable production. The production rate and the utilization of machines depend on how well the various machines and production facilities are located in a plant.

In this paper the present plant layout is modified to obtain a new layout that saves cost of transportation between the workstations, reduces total time of production and distance moved by the product within the facility.

III. PROBLEM DESCRIPTION

A sand-casting factory operating in Bhubaneswar, Odisha, which produces crusher jaws plates, impact bars, tooth ring hammer etc., experiences high material handling cost. High material handling cost of the company could be attributed higher labour cost, time and intra-departmentaltransportation of materials due to faulty plant layout. The case company has six (6) operational departments as shown in figure 1 below.

The final material processing (Finishing) is strategically placed at the entrance which is preceded by material removal department. Both last two departments share common borders. The pattern making department where sand moulding is done follows and next is furnace a heat treatment department which are side-by-side. The furnace is where pouring and moulding operation is done. Finally, the scrap cutting department. Scraps from the finishing departments are transported through cranes to this department. This has an adverse effect on transportation cost and material flow. Adopting a new plant layout to significantly reduce this associated cost and time to transport materials with less effort, increase production rate and minimise material flow is necessary.

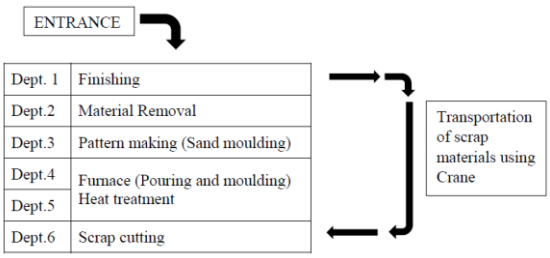

Figure 1: Layout of the case company

IV. METHODOLOGY

CRAFT is widely used than ALDEP and CORELAP as it is an improved algorithm. It begins with an initial layout which is subsequently improved by interchanging the departments pairwise so that the transportation cost is minimized[14]. The algorithm runs progressively until no further changes in cost reduction is achieved. The result given by CRAFT is not optimum in terms of minimum cost of transportation. But the result will be good and close to optimum in majority of applications. Hence, CRAFT is mainly a heuristic algorithm[10]. Heuristics are methods that start from the empty solution and iteratively extend it until the full solution is constructed. Unfortunately, plant layout problem comes under combinationalcategory hence usage of efficient heuristic methods is inevitable for such problem. CRAFT method requires initial layout, flow data, cost per unit distance, total number of departments, fixed departments number of such departmentslocation of those departments and area of departments.

The steps of CRAFT algorithm are summarized below.

Step 1: Input:

1. Number of departments
2. Number of interchangeable departments
3. Initial layout
4. Cost matrix
5. Flow matrix
6. Area of departments

Step 2: Compute the centroids of all departments in the present layout. The left side of the layout is assumed as X and bottom side of the layout is assumed as the Y axis.

Step 3: Form distance matrix using the cancroids. The distance between any two departments is represented by rectilinear distance between the centroids of the two departments.

$$Dij = xi - xj + yi-yj[6]$$

Where (Xi, Yi), and (Xj, Yj) are the centroids of the Department *i* and *j* respectively.

Step 4: Give data on flow, distance and cost, compute the total handling cost of the presentlayout.

$$\text{Total cost} = \sum_{i=1}^{n}(\text{Fij} * \text{Dij} * \text{Cij})[6]$$

Where, Fij is the flow from department 'i' to the dept. 'j'

Dij is the distance from dept. 'i' to the dept. 'j

Cij is the cost/unit distance of travel/trip

Step 5: Find all the probable pairwise substitutions of departments based on mutualmargin or equivalent area criterion. For each possiblesubstitution compute centroids and approximate costs. Considering various departmental interchanges for improvement.

Departmental interchanges that are possible are given below.

- Departments having common border.
- Departments having equal area.

Step 6: Find pairs of departments which gives minimum handling cost from among allpossible pairs of interchange.

Step 7: Is the cost in the previous step less than the total cost of the present layout? If yes, go to 8
Else If not, go to step 11.

Step 8: Interchange the selected pair of departments. call this as the NEW LAYOUT. Compute centroids, distance matrix and total cost.

Step 9: Is the cost of new layout less than the present layout?

If yes, go to step 10. If not, go to step 11.

Step 10: The new layout is here after considered as the PRESENT LAYOUT. Its data oncentroids, layout matrix and the total cost is retained. Go to step 5. Step 11. Print the present layout as the FINAL LAYOUT.

Step 11: Stop.

V. RESULT & DISCUSSION

Data was collected for ring hammer and jaw crusher plate. The total process timing with lead time, total flow of material throughout the process and the distance covered by the material in the whole process were evaluated.

Several material flow possibilities of existing layout and analysis of total material handling cost of alternating departments inside the present layout was done. The layout with the least cost of material handling was selected for the new plant layout.

Table 1: time taken to fully produce ring hammer and jaw crusher plate

Process	Time (Min)	
	Ring Hammer	Jaw crusher plate
Pattern making	270.2	985.67
Scrap cutting	69	134
Furnace and molding	1623	4992
Material removal	22	37
Heat treatment	1477	1477
Finishing	537	689

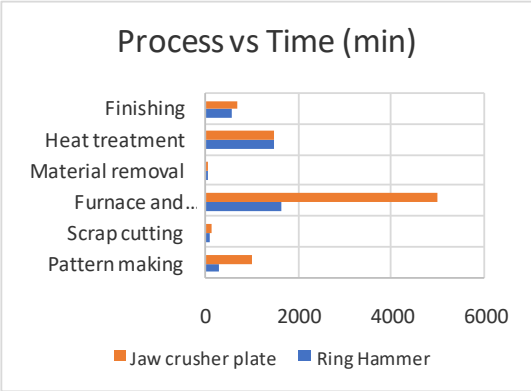

Table 2: Coordinates of plant layout

		Existing Layout		New Layout	
Department		X	Y	X	Y
Pattern making	1	46	14	46	14
Scrap cutting	2	9	5	61	5
Furnace and molding	3	29	16	29	16
Material removal	4	61	9	9	5
Heat treatment	5	9	19	9	19
Finishing	6	63.9	16.7	63.9	16.7

Table 3: Flow matrix of plant layout

Existing Layout							New Layout						
From/ To	**1**	**2**	**3**	**4**	**5**	**6**	**From/ To**	**1**	**2**	**3**	**4**	**5**	**6**
1	-	0	1	0	0	0	**1**	-	0	1	0	0	0
2	0	-	1	0	0	0	**2**	0	-	1	0	0	0
3	0	0	-	1	0	0	**3**	0	0	-	1	0	0
4	0	0	0	-	1	0	**4**	0	0	0	-	1	0
5	0	0	0	0	-	1	**5**	0	0	0	0	-	1
6	0	1	0	0	0	-	**6**	0	1	0	0	0	-

Table 4: Distance matrix of plant layout

Existing Layout							New Layout						
From/ To	**1**	**2**	**3**	**4**	**5**	**6**	**From/ To**	**1**	**2**	**3**	**4**	**5**	**6**
1	-	46	19	20	42	20.6	**1**	-	24	19	46	42	20.6
2	46	-	31	56	14	66.6	**2**	24	-	1	52	66	14.6
3	19	31	-	39	23	35.6	**3**	19	43	-	1	23	35.6
4	20	56	39	-	62	10.6	**4**	46	52	31	-	14	66.6
5	42	14	23	62	-	57.2	**5**	42	66	23	14	-	57.2
6	20.6	66.6	35.6	10.6	57.2	-	**6**	20.3	14.6	35.6	66.6	57.2	-

In analysing the handling cost, equipment's involved and operators' salary as well as cost of operating machinery were considered

Table 5: Cost matrix of plant layout

Existing Layout							New Layout						
From/ To	**1**	**2**	**3**	**4**	**5**	**6**	**From/ To**	**1**	**2**	**3**	**4**	**5**	**6**
1	-	0	28.5395	19.6595	29.1655	28.5395	**1**	-	0	28.5395	25.8925	29.1655	28.8225

2	0	-	25.8925	29.1655	13.7395	35.242	**2**	0	-	31.8125	29.1655	29.322	16.543
3	0	0	-	34.7725	28.696	40.849	**3**	0	0	-	28.5395	28.696	40.849
4	0	0	0	-	32.282	19.503	**4**	0	0	0	-	16.6995	38.202
5	0	0	0	0	-	38.3585	**5**	0	0	0	0	-	38.3585
6	0	0	0	0	0	-	**6**	0	1	0	0	0	-

Table 6: Total Cost matrix of plant layout

Existing Layout							New Layout						
From/ To	**1**	**2**	**3**	**4**	**5**	**6**	**From/ To**	**1**	**2**	**3**	**4**	**5**	**6**
1	-	0	542.2505	0	0	0	**1**	-	0	542.2505	0	0	0
2	0	-	792.9645	0	0	0	**2**	0	-	1367.9375	0	0	0
3	0	0	-	1356.1275	0	0	**3**	0	0	-	884.7245	0	0
4	0	0	0	-	2001.484	0	**4**	0	0	0	-	233.793	0
5	0	0	0	0	-	2194.1062	**5**	0	0	0	0	-	2194.1062
6	0	0	0	0	0	-	**6**	0	1	0	0	0	-
Total	0	0	1335.215	1356.1275	2001.484	2194.1062				1910.188	884.7245	233.793	2194.1062

% saving in MH cost per annum = 24.16%

Total saving in MH cost per annum=17189784.02 Rs/yr-13036138.00 Rs/yr. =4153646.02/yr.

Table 7: Total plant area

From	**Existing Layout(Sq. meter)**	**To**	**Existing Layout**	**New Layout**
1	336	3	19	19
2	180	3	31	43
3	704	4	39	31
4	180	5	62	14
5	324	6	57.2	57.21
6	724	2	66.6	14.6
Total distance travelled			274.8	178.8

Total distance travelled in existing plant layout is 274.8 meter while the total distance travelled in theproposed layout is 178.8 meter hence percentage reduction is 34.9%.

VI. CONCLUSION

The Present work employed CRAFT algorithm to develop a new plant layout for a casting company. The idea of developing the new layout is to reduce the material handling cost along with distance travelled by the material and material flow time from one department to other department over the existing plant layout. It was observed that the proposed layout developed using CRAFT reduces distance travelled by the jobs by 34.9% in comparison to the existing plant layout design. Further, this reduction in distance travelled would result a reduction of material handling cost by 34.9%.

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