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LAYOUT PLANNING FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper focuses on the modification of the existing layout of a rubberised coir mattress factory using two different approaches viz graph theory and Computerised Relative Allocation of Facilities Technique (CRAFT). The results of the two approaches are compared in terms of the comparative parameters; total distance between departments, total distance travelled per day and material handling cost reduction. It has been found that the Computerised Relative Allocation of Facilities Technique (CRAFT) modified layout could yield highest reduction in all the three comparative parameters. The total distance between departments reduces by 4.5%, total distance travelled per day reduces by 2.4% and the material handling cost reduces by 2.4%.

Keywords: Facility Layout Planning, Facility re-layout, Graph Theory, Computerised Relative Allocation of Facilities Technique (CRAFT).

TABLE OF ABBREVIATIONS

CRAFT Computerised Relative Allocation of Facilities Technique

SLP Systematic Layout Planning

MH Material handling

REL Relationship

1. INTRODUCTION

Layout determines the way in which materials and other inputs (like people and information) flow through the operation. Relatively small changes in the position of a machine in a factory can affect the flow of materials considerably. This in turn can affect the costs and effectiveness of the overall manufacturing operation. Getting it wrong can lead to inefficiency, inflexibility, large volumes of inventory and work in progress, high costs and unhappy customers. A facility layout is an arrangement of

everything needed for production of goods or delivery of services. It may be a machine tool, a work centre, a manufacturing cell, a machine shop, a department, a warehouse, etc. [12]. The layout design generally depends on the products variety and the production volumes.

Layout planning is determining the best physical arrangement of resources within a facility. Layout decisions entail determining the placement of departments, work groups within the departments, workstations, machines, and stock-holding points within a production facility [12]. Facility resource arrangement can significantly affect productivity. Plant layout planning includes decisions regarding the physical allocation of the economic activity centres in a facility, where an economic activity centre is any entity occupying space. To carry out an appropriate plant layout, it's important to take into account the business strategic and tactical objectives.

Most layouts are designed properly for the initial conditions of the business, although as long as the company grows and has to be adapted to internal and external changes, a re-layout is necessary. The reasons for a re-layout are based on 3 types of changes namely, changes in production volumes, processes and technology and product [12]. The frequency of the re-layout will depend on the requirements of the process

In this paper an attempt is made to modify the existing layout of a rubberised coir mattress industry in order to solve the existing problems related to the material movement in the company. It has been found that congestion of materials, unscientific stacking of materials, improper material handling and need for more storage area are affecting the entire production process. The paper discusses the two different approaches that have been used to find a solution which can reduce the material handling cost, total distance travelled per day to the maximum possible extent and also to provide a smooth material movement.

2.LITERATURE REVIEW

The Facility Layout Problem (FLP) is defined as the physical arrangement of the specified departments or machines in a pre-defined area. CRAFT method could be used in case of multi floor facility problems [2]. CRAFT combined with Group Technology (GT) layout with Rank Order Clustering could be used to re design the layout. The performance evaluation of the current and the re designed layout has been done by using ARENA [1]. A comparative analysis of various approaches to find the best layout for a furniture production firm and has found that BLOCPLAN using automated search has given the best result [11]. An illustrative case study on the modification of a plant layout model using CRAFT method has been done and the visualization of the effects of changes introduced has been provided using the ARENA software [9]. A study on the cellular layout, cellular manufacturing system has been done and a case study has also been done to illustrate the benefits of cellular layouts [4]. The travel chart technique could be used to minimize wastes of time, manpower and money and to generate higher profits for the same work from the same resources [6]. Systematic Layout Planning (SLP) procedure has been used to modify the layout of a compressor manufacturing firm to improve the productivity of the firm [7]. An extension of the CRAFT algorithm that aimed to solve complex layout problems has been developed and the results were compared with that obtained from literature [3].

The modification of the existing layout of a production unit to incorporate industrial automation equipment has been done by using systematic layout planning method [5]. For the improvement in process layout, Graph theory can be used with the framework of systematic layout planning methodology .The cost analysis shows a saving of about 62.4% per year in material handling cost by this method [10]. A study on the CRAFT, Quadratic Assignment Problem (QAP), and Systematic Layout Planning (SLP) has been done which provides guidance for efficient facility layout planning [8]. The Systematic Layout Planning (SLP) and the CRAFT method have been chosen from the literature. The methods have been chosen due to its present day relevance and the similarity in the problems addressed in the literature and

case study.

3. PROBLEM IDENTIFICATION AND RELEVANCE OF THE STUDY

The company under study is concentrating on the rubberised coir mattress production with an annual installed capacity of 6000 tonnes, around 4.8 lakh units (an ISO 9001:2008 certified company having strict quality standards and also exports products to many countries). The company has to store sufficient amount of raw materials, work in process and finished products. The company has been facing problems that hinder the smooth material flow and it has also been observed that there is a lack of scientific layout planning.

The study is intended to analyse the existing situation of the factory, to identify the major problems existing in the factory and finally to develop an alternative that could solve the identified problems. The existing layout of the factory has been drawn using AUTOCAD based on the primary data collected from the factory and is given in the Figure 1.

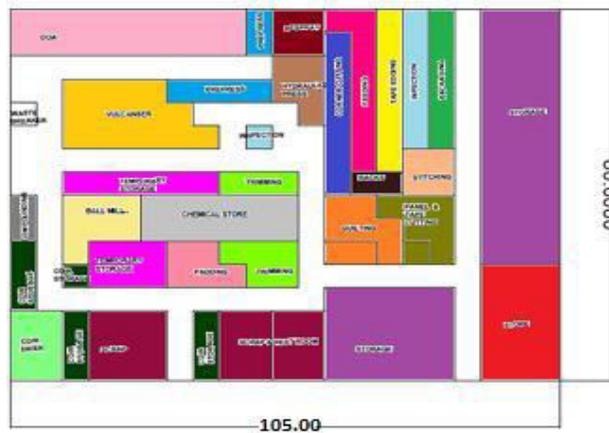


FIGURE 1. EXISTING LAYOUT OF THE FACTORY

The building has a dimension of 105m x 80 m and the various departments are located within the building. The building is divided into two sections namely production plant and the furnishing department. The bare mattress produced in the plant is carried over to the furnishing area for the upholstery works and is finally dispatched out. The study has been conducted on the basis of the assumption that there is a constant demand for the products and the production is carried out to meet the daily target of 800 finished mattresses.

The material handling audit check sheet, interviews with concerned staff and secondary data from the production unit have been used to identify the major issues. It includes the congestion due to low space availability near machines such as Hydraulic press, Vulcaniser, Band saw, 1st Inspection table, chances for easy spreading of fire, unscientific stacking, difficulty to move the bare mattress from production to furnishing on First In First Out (FIFO) basis, need for more warehousing space for furnished mattress and inappropriateness of closeness between departments. Even though there is sufficient space in the building to incorporate all the departments, the improper positioning the departments with respect to the production flow makes the flow of materials complicated.

4. DATA COLLECTION AND SELECTION OF TOOLS

The existing situation has been modeled based on the primary data collected regarding the dimensions of the building, area of each department, distance between departments, number of trips between departments, etc. The company records also have been considered to get vital information regarding production details, production & sales performance, raw material details, price details etc. which

constitutes the secondary data group. The various tools used for layout modification have been identified based on the literature review, from which the Graph theory and CRAFT are found to be the most appropriate and relevant in the particular case.

There are different parameters available to measure the effectiveness of the results obtained. Distances, flows between departments, production time, labour cost, productivity, line balancing efficiency are few among them. The selection of the comparative parameters depends on the uniqueness of the problems that exists in the company. The total distance between departments, total distance travelled per day and the material handling (MH) cost have been selected in this case.

The total distance between departments is taken as the sum of distance between departments. Similarly the total distance travelled per day is the product of distance between 2 departments and the flow between them. The flow may be defined as the number of trips per day. The material handling cost data is not directly available from the company. So the MH cost has been found by taking certain assumptions based on the benchmark data available. The assumption taken is that material handling cost is about 20-30 % of manufacturing cost. In this particular case the average value is taken, i.e. 25% of the manufacturing cost. In this we are using the notations like Total Material Handling Cost (TMHC), Unit Material Handling Cost (UMHC), Material Handling Cost (MHC), Total distance travelled by material (Dt), distance (dij), flow (fij) and unit MH cost (cij) between departments i, j respectively.

$$TMHC = \sum \sum cij \times dij \times fij \quad (1)$$

$$UMHC = \frac{MHC}{Dt} \quad (2)$$

The unit material handling cost for the present system is found to be, cij= RS.3.37/m.

5. METHODOLOGY

The modification of the existing layout has been attempted by using two different approaches viz qualitative method (Graph Theory) and quantitative method (CRAFT). The three comparative parameters have been selected for comparing the alternatives obtained in each case. The graph theory considers qualitative parameters to define the relationship between activities whereas CRAFT uses quantitative data relating to material flow and distance between departments.

6. LAYOUT MODIFICATION USING GRAPH THEORY

Graph theory is SLP based approach. Graph theory approach considers only direct adjacency requirements.

Graph theoretic approaches also handle the unequal area block plan. It's a 2 stage process involving generation of graph followed by development of actual layout. The procedure can be summarized as follows:-

- 1: Construction of Activity Relationship Chart from Precedence diagram
- 2: Construction of Activity Relationship diagram from Activity Relationship Chart
- 3: Development of Block Layout from Activity Relationship diagram
- 4: Development of Modified Plant Layout from Block Layout

The step wise procedure is given in detail below. Step 1: Select a department pair with largest weight

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Step 2: Select a third department based on the sum of the weights with the two departments selected.

Step 3: Select next unselected department to enter by evaluating the sum of weights and place the department on the face of the graph. Here, a face of a graph is a bounded region of a graph

Step 4: Continue the Step 3 until all departments are selected

Step 5: Construct a block layout from the planar graph.

There are certain limitations for using the graph theory. The adjacency score does not account for distance, nor does it account for distance other than adjacent department, even though size is considered in this method, the specific dimension & the length between adjacent departments are not considered, the final layout is very sensitive to the assignment of weights in the relationship chart are few among them.

According to Muther's approach, the desirability of locating a given department next to any other department is rated by one of the following terms: A-Absolutely necessary, E- especially important, I- important, O- ordinary closeness okay, U- unimportant, X- undesirable. The material flow and the activity relationships are integrated to obtain the activity relationship (REL) chart and is used as the primary input. The closeness ratings used are assigned values on the 5 point Likert scale. The ratings are also given numerical weights corresponding to the scale and is calculated by using the equation, numerical weight = 2^n , where n indicates the code. The closeness ratings that are used are given in the table 1[12]. There are certain underlying reasons for assigning the closeness rating and they should also be considered along with the ratings. The relevant reasons have been shortlisted from the literature; the appropriate ones have been selected and is given in the table 2[12]. They are given values, known as code, based on their importance and are also considered for developing the REL chart given in the table 3.

TABLE 1 CLOSENESS RATING

Closeness rating	Numerical Weights	Code
A	16	5
E	8	4
I	4	3
O	2	2
U	0	1

The REL chart is used to develop the relationship diagram given in figure 3 and the final block layout in figure 4 in the subsequent stages to develop the final alternative layout. The numbers used indicate the departments defined in the REL chart.

TABLE 2 REASONS FOR CLOSENESS RATING

Code	Reason
0	Indirect Relationship
1	Better finish
2	Convenience
3	Contact Necessary
4	Flow of Material

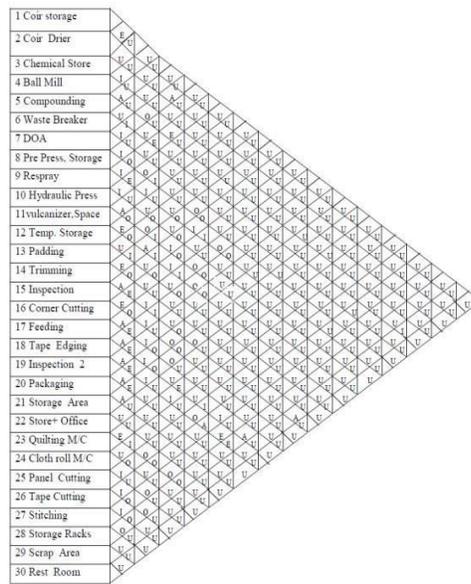


FIGURE 2. REL CHART- CLOSENESS RATING

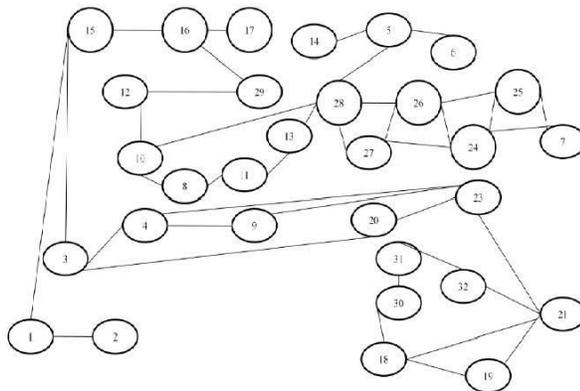


FIGURE 3. RELATIONSHIP DIAGRAM

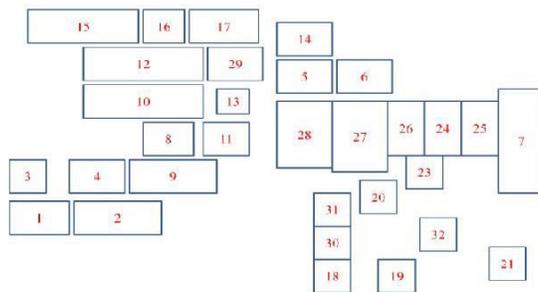


FIGURE 4. BLOCK LAYOUT

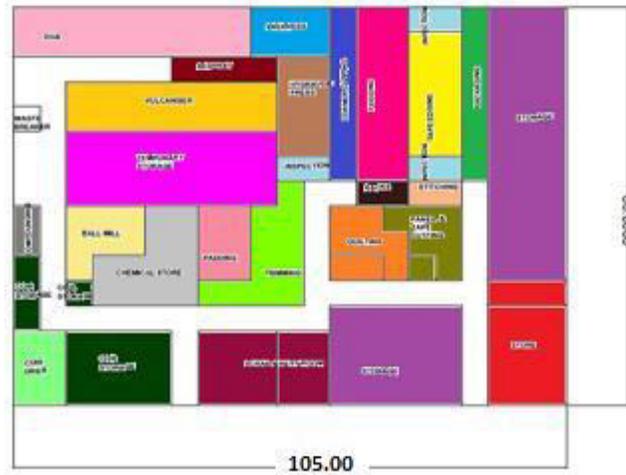


FIGURE 5. BEST ALTERNATIVE USING GRAPH THEORY

The block layout so developed yielded different alternative layouts after integrating the practical limitations existing within the company. The alternatives that have been obtained are evaluated on the basis of the first two selected comparative parameters and the best one is chosen in such a way that it gives the least possible value for the parameter under consideration. The best alternative after evaluation is given in the Figure 5.

The total distance travelled between departments of the existing layout is 730.46m and that of the total distance travelled per day is 95878m. In the case of the best alternative, the total distance travelled between departments is 705m and the total distance travelled per day is 94985.7m. The layout has been chosen as the best alternative since it has lower value than the existing system and is having the lowest value among the available alternatives. It is evident that there is 3.5% provides a user friendly working environment. The add- in button gives an option to design as well as redesign plant layouts. In this each department is divided into different grids which are equal in size. In this case 5m x 5m grid has been chosen for convenience. First of all the basic details regarding size of the company, the number of departments, area requirements, grid size, and flow matrix are given to it whenever corresponding dialog box appears. In this case it is assumed that the material reduction in total distance between departments and 0.1% handling cost is uniform throughout the production reduction in total distance travelled per day for the process. In this case the cost has been taken as 1, since it modified layout has been assumed to be uniform.

7.LAYOUT MODIFICATION USING CRAFT

CRAFT is a heuristic algorithm that takes load matrix of interdepartmental flow and transaction costs with a representation of a block layout as inputs. The block layout could either be an existing layout or, for a new facility, any arbitrary initial layout. CRAFT algorithm is the most widely known algorithm which is developed for situations in which materials handling costs is a major consideration.

The CRAFT algorithm computes the departmental locations and returns an estimation of the total interaction costs for the initial layout. The governing algorithm is designed to compute the impact on a cost measure for two-way or three-way swapping in the location of the facilities. For each swap, the various interaction costs are computed afresh and the load matrix and the change in cost (increase or

decrease) is stored. The algorithm proceeds this way through all possible combinations of swaps accommodated. The basic procedure is repeated a number of times resulting in a more efficient block layout every time till such no further cost reduction is possible. The final block layout is reported as output layout.

The algorithm can be summarized as follows:

Step 1. For any layout describe it in blocks. Then determine centroids of each department. From that calculate the cost = distance (from distance matrix) x unit cost. The distance can be Euclidian or Rectilinear.

Step 2. To make improvements, make pair wise or three way exchanges which have equal area only and are adjacent (generally).

Step 3. If better solution exists; Choose the best, or else go to step 1 and continue the steps or otherwise stop.

The modification of the existing layout using CRAFT is done by using an add-in for Microsoft Excel developed by Jensen & Co. It provides a comfortable platform to work since it is easy to work and it also In the next stage facility is defined. Here traditional CRAFT is used. The existing layout is drawn in the next stage. All the departments that have been specified in the first stage are automatically displayed with suitable colour codes and numbers in a column in this stage. Drag and paste the colour codes in their positions in the company outline that is automatically generated by receiving inputs in the first stage. The existing layout model is created by using this method. The department centroids are automatically updated in the respective columns whenever the layout is completed.

In the next stage there is an option available to evaluate the existing layout. Whenever the pop-up button named evaluate is selected the value of the current layout i.e. the total cost incurred per day for the facility is displayed and it is generated by summing up the value of distance and unit cost for all departments with material flow. The evaluation is done and it shows the value of current layout in terms of total cost incurred per day. Another pop-up button named solve is available which provides option for solving the present layout. On clicking the button, the program automatically checks for solutions by suitable number of iterations. All these iterations are displayed until the best possible solution is obtained. The iteration stops whenever the best result is obtained. There is also an option known as switch which provides manual switching of departments. It can also be selected to cross check if the obtained results are the best available ones. In the final stage, the modified layout has been displayed with the department centroids and its draft.

In this case the plant has been divided into 3 separate sections, since it is impossible to carry out the CRAFT iterations together by incorporating all the parallel activities occurring in the company into a proper sequence. The plant is divided into production, furnishing and the raw material preparation sections. This obtained initial layout is the same as the existing layout described in Figure 1.

Each section is subjected to individual iterations for improvement and the iteration details are given in the table 3. It has been found that the furnishing section hasn't shown any improvements in the CRAFT method.

The initial and final layout of the furnishing section remains the same even after the modification. But the raw material preparation and the production section has showed notable variations from the existing layout. The details of iterations performed are given in table 3 and the term switch in the table has been used to indicate the exchange between departments. The corresponding exchanged departments are shown

in the column titled action and the resultant variation in the cost is given in the final column.

TABLE 3. CRAFT ITERATION DETAILS

Iteration details of production section			
Iterations	Type	Action	Cost
1	Switch:	1 and 12	4906.372
2	Switch:	1 and 12	4899.272
3	Switch:	3 and 15	4892.822
4	Switch:	6 and 7	5399.989
5	Switch:	13 and	5411.522
6	Switch:	11 and 1	5419.522
7	Switch:	13 and	5411.522
8	Switch:	11 and	5419.522
9	Switch:	6 and 7	5399.989
10	Switch:	7 and 14	5327.356
11	Switch:	11 and 1	5318.022
12	Switch:	1 and 12	5291.503
13	Switch:	13 and	5240.637
14	Switch:	11 and 1	4897.939
Iteration details of raw material preparation			
1	Switch:	4 and 5	555
2	Switch:	5 and 3	579

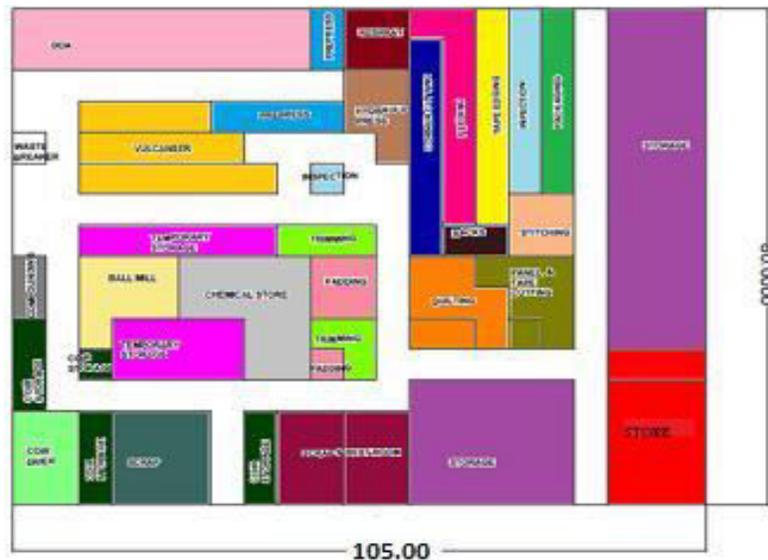


FIGURE 6. BEST ALTERNATIVE USING CRAFT ALGORITHM

The CRAFT considers the best solution as the one which reduces the cost to the maximum possible extent. So integrating the three sections the final modified layout has been obtained and is drawn in the AUTOCAD software for ease of visualisation and is given in the fig 5. In the case of the Computerised Relative Allocation of Facilities Technique (CRAFT) modified layout, the total distance travelled between departments is 697.66m and the total distance travelled per day is 93606.4m. It is clear that there

is 4.5% reduction in total distance between departments and 2.4% reduction in total distance travelled per day for the modified layout.

8. RESULTS & DISCUSSION

The modification of the existing layout using graph theory and CRAFT has yielded two different solutions. A comparative analysis of the two alternatives obtained in each case is necessary to decide the best alternative. The best alternative is the one which has the highest reduction in total distance between departments and total distance travelled per day. The solutions obtained using both methods are found to be acceptable, since there is reduction in total distance between departments and the total distance travelled per day. The comparative analysis of the output of both methods is given table 4.

TABLE 4.EVALUATION OF ALTERNATIVES

Comparative parameter	Existing layout	Graph Theory output	CRAFT output
Total distance between departments (m)	730.46	705	697.66
Reduction in total distance between departments.		25.46	32.8
Total distance travelled per day (m)	95878	94985.7	93606.4
Reduction in total distance travelled /day		892.3	2271.5
Total MH cost per day (Rs.)	3,24,000	3,20,556.6	3,16,294.6
Savings in MH cost per day		3443.32	7705.33
% Savings of original cost		1.063	2.38

The best solution has shown a reduction of 4.5% in total distance between departments, 2.4% reduction in the total distance travelled per day and 2.4% material handling (MH) cost savings. Considering the results of comparative parameters, the Computerised Relative Allocation of Facilities Technique (CRAFT) modified layout is suggested as the best solution to the problem.

9. CONCLUSION

The modification of the existing layout of a rubberised coir mattress factory using two different approaches has yielded two distinct solutions. The qualitative input method (graph theory) and the quantitative input method (CRAFT) have yielded two alternative layouts. The alternative layouts obtained using each method has satisfied the condition that the value of the comparative parameters must be lower than that of the existing layout. A final comparison between the results obtained in each method showed that the CRAFT modified alternative yielded the best reduction for the parameters under consideration. The comparative result showed that there is reduction of 4.5% and 2.4% in case of total distance between departments and total distance travelled per day respectively. It is also evident that the CRAFT modified layout has maximum MH cost reduction by 2.4%.

The layout modified using CRAFT Algorithm is recommended to be implemented in the company. There is a need of some civil work for the implementation and a low initial investment is necessary for it.

The layout alternatives developed are evaluated using the three selected parameters such as total distance between departments, total distance travelled per day and savings in material handling cost. There are various other comparative parameters to evaluate the alternatives like line balancing efficiency, production time, cycle time reduction etc. They are not considered in this study. The present system is assumed to have a constant demand for the products but in practice there are seasonal variations in the demand. The study hasn't yielded an optimum layout. So optimization of the existing layout incorporating the seasonal variation in demand using the advanced tools like genetic algorithm can be considered as further scope of the study.

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