

COMPUTERIZED FACILITIES LAYOUT DESIGN

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ABSTRACT

Facilities are crucial as they usually represent the largest and the most expensive assets of an organization. Determining location of machines, workstations, and other facilities are layout problems in a manufacturing plant. Different computerized algorithms have been developed to optimize the flow of materials within a factory. Among others, CRAFT has been developed to improve an already existing layout while algorithms such as CORELAP are used to build new layouts from scratch. This paper hypothesized that better result could be gained by federating these two algorithms rather than their independent applications. The hypothesis is verified by taking layout problems of Kotebe Metal Tools Factory (KMTF). The result obtained by improving the already existing layout using CRAFT is compared with the result obtained through newly developed layout by CORELAP followed by improving it with CRAFT. From the comparison, this study concluded that federated use of computerized layout design algorithms provides better result.

Key words: *Computer Aided Layout Design, Construction Routine and Improvement Routine*

INTRODUCTION AND RELATED LITERATURE

Layout design has been considered as one of the vital areas where business performance improvement can be realized. Facilities are of crucial importance to organizations since they usually represent the largest and most expensive assets of an organization [1, 2, 3]. Effective placement of the facilities is known to have a significant impact upon manufacturing costs, work in process, lead times and productivity. A good placement of facilities contributes to the overall efficiency of operations and can reduce up to 50% of the total operating expenses [4]. Its main concern is reducing cost by maximizing adjacency of highly interacting components of a system or reducing material handling cost or distance between work stations. If facilities are arranged optimally, manufacturers can decrease work in process, material handling costs, total production costs and significantly enhance their system's efficiency [5, 6]. In addition, a good layout brings safe workplace for employees and thereby increases employee morale,

minimize risk of injury to personnel and damage to property [7].

Plant layout design requires diverse field of knowledge. Among others the application and use of computers become an advantage. Computer can perform tedious computations and generate several alternative solutions much more rapidly and effectively than manual procedures [5]. The computerized layout methods, either construction or improvement-type routines are heuristics. Construction-type layout routine generates a block layout based on the relationship between different departments. Commonly used software are Computerized Relationship Layout Planning (CORELAP), Automated Layout Design (ALDEP), and Plant Layout Analysis and Evaluation Techniques (PLANET)[8,9]. Improvement-type routines require an input of a feasible block layout and aim to reduce internal transport cost by attempting simultaneous pair-wise position exchanging among the departments. The most popular improvement-type methods are Computerized Relative Allocation of Facilities Technique (CRAFT) and Computerized Facilities Design (COFAD) [3, 5, 8, 10, 11].

In case of a new layout design construction routine is necessary as there is no initial layout. However, newly constructed layout alone will not be nearly optimal, particularly, when the new construction is evaluated by an improvement routine. Newly established companies in Ethiopia construct layouts without any attention to neither construction nor to improvement with algorithms. This limits the probability of obtaining better sub-optimal new layout. It, thus, initiates the need for other methodology to be devised. This study tried to validate this hypothesis and further proposes implementation of federated construction and improvement algorithms of layout planning routines. It considers federation of CORELAP with CRAFT for improved performance by taking KMTF layout problem as a case. The study however still holds shortcomings of these algorithms such as being restricted to exchange of equal sized sections, restricted to rectangular shape and yielding suboptimal layouts. Yet, the main objective is minimization of transportation cost, which these two algorithms focus to minimize as well.

HYPOTHESIS AND METHODOLOGY

New layout constructions as well as existing layout improvement routines are well studied and proved techniques separately. Result that would be obtained by federating these routines one after the other in comparison with single routine implementation has been given limited attention. This study evaluates benefit that could be obtained from federation of the routines rather than using them independently. The following hypothesis is thus formulated by the study:-

Hypothesis: Developing new layout using construction routine followed by improvement routine is more fruitful than constructing new layout with a construction routine alone or improving a working existing layout using improved routine.

To demonstrate this hypothesis and analyze its implementation, KMTF tools factory data has been collected and analyzed. It is also a good opportunity to validate the significance of facility design to manufacturing industries performance improvement. The reason behind the selection of KMTF is that it has significant number of machines that constitute majority of the company’s investment and their appropriate arrangement is critical for its performance. Primary data was collected through direct observation and measurement to find relationship among different sections of the company which is shown in the next section. Moreover, transport cost and operation time of the main products were also collected. KMTF’s records have been used

as a secondary data source to supplement that of the primary data. By using the data collected, a relationship diagram between the different sections has been developed and computerized layout algorithms CRAFT and CORELAP have been used to evaluate the layouts and validate the proposed hypothesis of federation of algorithms.

KMTF and Data Collection

Kotebe Metal Tools Factory (KMTF), among the first metal industry in the country, was established in 1969 to design and manufacture various hand tools and implements. The factory produces over 40 types of products. From the three years production and sales volume, the following 12 products have been identified as the most critical ones. These are: Stone Hammer (6kg flat), Hammer (3kg), Stone Hammer (1.5kg), Pick Axe (2kg), Axe Congo (4 and 3 lb), Crow Bar (1.5m D 32), Garden Hoe (2 finger), Shovel (No. 5 and 2), Spade Harar (Big), Door Bolt (140mm), Racke (10 finger) and Sickle.

All products except sickle are produced in the tools factory. This factory has seven main sections: Forging, Heat Treatment, Machining, Grinding, Painting, Welding sections and the Raw Material store. Effective placement of these sections significantly affects transportation and handling cost within the factory floor. Based on the production process of the 11 product (except sickle) and material flow between these sections, from-to-chart has been developed to analyze material flow. The following table shows units of material transported to and from the sections listed earlier.

Table 1: From-To chart between different sections

	RM Store	Forging	Machining	Grinding	Heat Treatment	Painting	Welding
RM store		157,205	10,948				
Forging			235,094	3,036	5,783	10,460	
Machining		98,535				10,223	2,175
Grinding					551	4,736	
H. treatment				5,783			
Painting							
Welding			725				

The back-and-forth movement of parts and quantity of material that flows between the sections are also analyzed to make the activity relationship chart and activity relationship diagram shown below (Fig. 1 and 2).

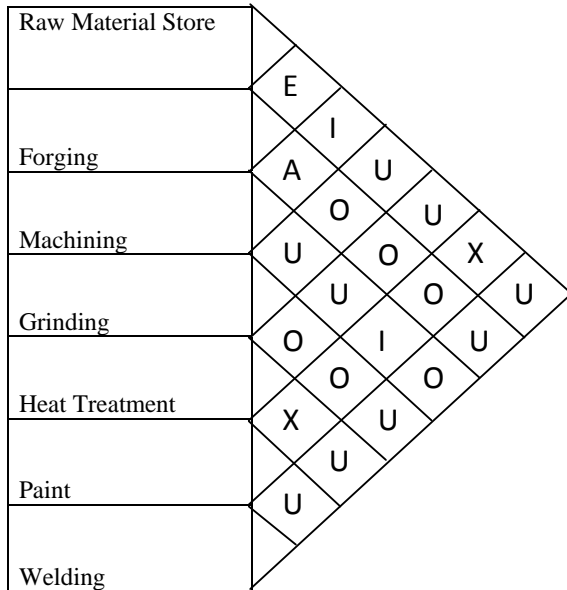


Figure 1 Activity relationship chart

Activity relationship chart (Fig. 1) indicates the closeness relationship between sections. Sections given closeness rating value “A” have *absolutely necessary* relationship and need to be placed very close to one another. Similarly, E, I, O, U and X represent whether the relationship sections is *especially important, important, ordinary, unimportant* and *undesirable* [9, 12]. These values are given based on the amount of material transported to and from one section to another. Material flow between forging and machining is exhibited to be higher (sum of 333,629 units of products) while sections such as heat treatment and painting need not be close to one another resulting in X relationship. The relationship diagram (Fig. 2) mimics the actual relative positions of the sections. The number of lines connecting two sections show the strength of the relationship, more lines represent stronger relationship. The relationship diagram did not include the finished product store because it is located outside the Tools Factory which is out of the scope of this study. From these chart and diagram, the main problem that surfaced out is long distance transportation of materials which resulted in higher transportation and handling cost due to improper placement of the sections i.e. layout problem. Once

the essential problem is identified, it is possible to test the hypothesis for the company under study.

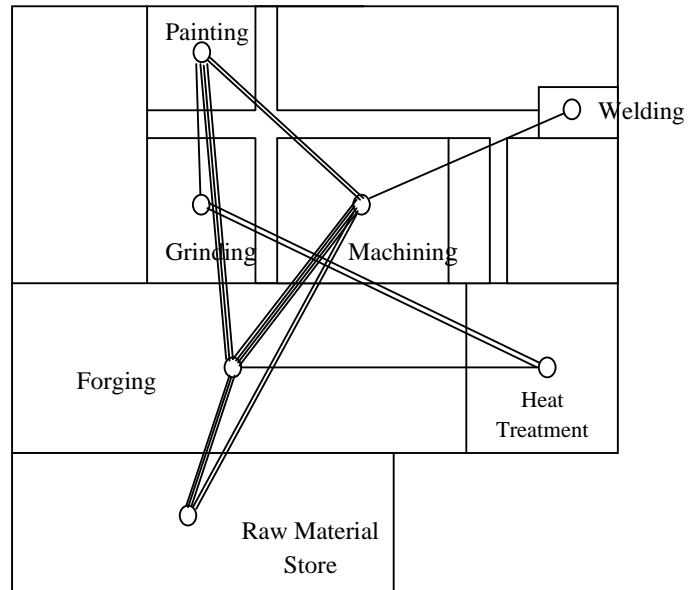


Figure 2 Activity relationship diagram

Improving the existing layout using CRAFT improvement algorithm

Here the current layout is improved by exchanging sections and machines positions. The machine wise improvement considered individual machines arrangement and thus it is more detailed than section wise improvement.

To utilize the CRAFT algorithm an Excel Add-in program has been employed. Facility and section information like facility dimension (length and width), area of each section, from-to flow chart and cost matrix to transport the amount of material are fed into the add-in program. The program assigns the number of cells for each section in the Excel spreadsheet according to the scale selected (e.g. One cell represents 1m²). The actual arrangement is fed manually mimicking the actual relative positioning of sections and machines. In this part, pure CRAFT algorithm with rectilinear distance is used and the cost of this initial layout is calculated with the following formula.

Where

m = Number of departments

d_{ij} = Distance from section i to j (meter)

c_{ij} = Unit cost of transport per unit distance per unit load (Birr)

w_{ij} = Amount of load moved (Kg)

Z = Total movement cost per time period (Birr)

The transport cost is calculated from the operating cost of Overhead Crane used between raw material store and forging sections, and Carts in the rest of the sections. Using this formula the cost of the initial layout is automatically calculated as 4,886 birr per month. An improved layout is developed by applying CRAFT improvement algorithm and exchanging Machining section (represented by number 3) and Grinding section (represented by number 4) in Figure 3 and 4. As a result, the analysis revealed that the improved method reduces the material handling cost by about 25% (i.e. 3648 birr) as compared to the initial cost incurred by the existing layout.

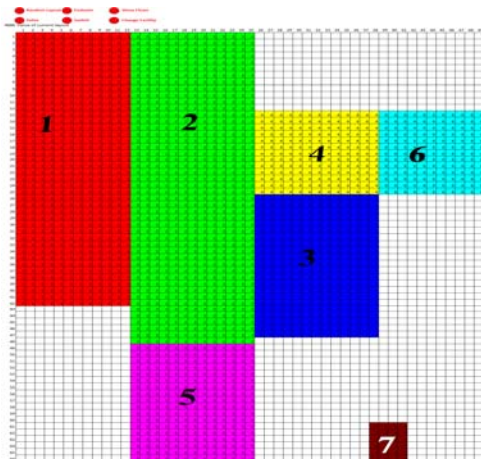


Figure 3 Existing layout

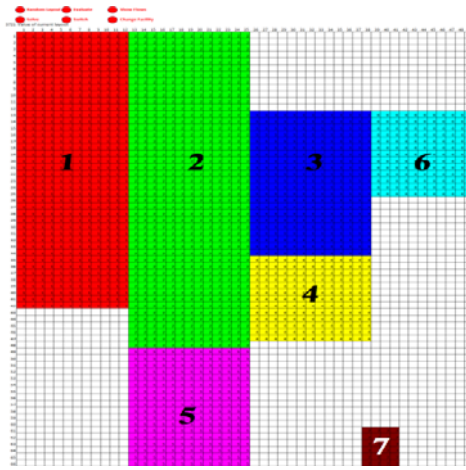


Figure 4 Improved layout

To further obtain efficiency of the layout, machine wise exchange has been made for two cases; the current machines arrangement and arrangements after the section wise exchange. Again CRAFT algorithm has been used with starting layout of the two cases. When the current machine arrangement cost is compared with its machine wise exchange improvement applying CRAFT, 43% cost reduction has been realized. Moreover, when the machine arrangement after section wise improvement is compared with its improved arrangement by CRAFT, more than 42% cost reduction is achieved. The figure representing the machine arrangement in the add-in program has not been presented here due to the large number of machines involved and clarity purpose. However, the improved machine arrangement in the factory floor is shown in the CAD drawing below.

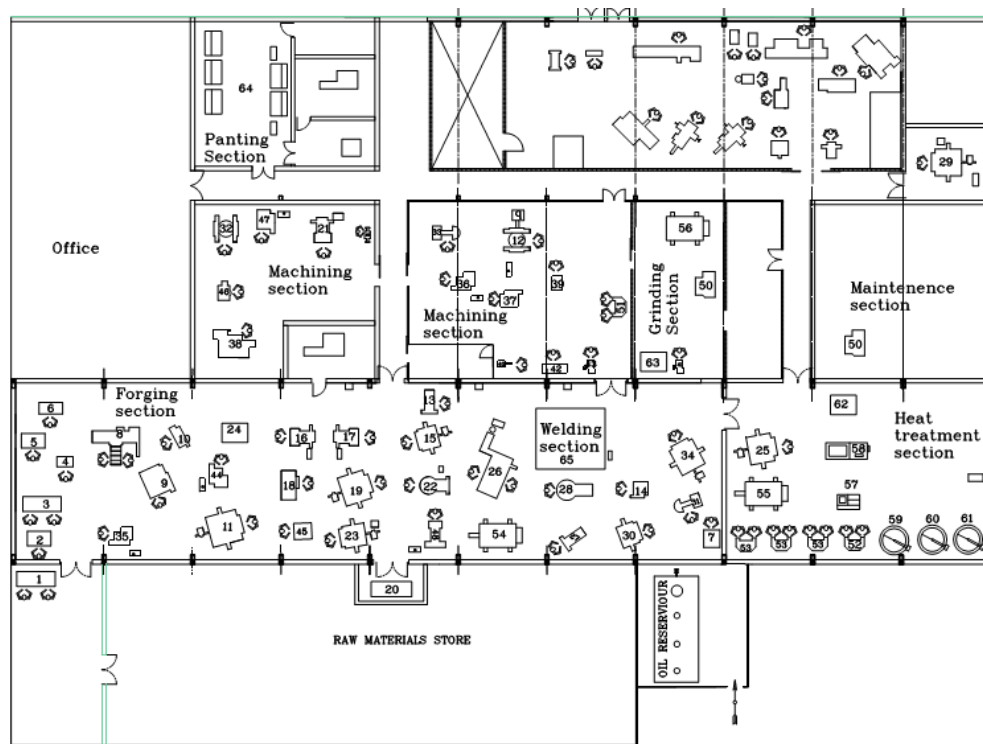


Figure 5 Tools Factory improved layout

CORELAP Construction algorithm federated with CRAFT improvement algorithm

To compare the result and substantiate the hypothesis, CORELAP algorithm alone was used at first. It uses Total Closeness Ratings for selection and placement of departments in the new blank layout space. The closeness ratings values are given different numerical values (6 for A, 5 for E, 4 for I, 3 for O, 2 for U and 1 for X) [9, 12]. By summing these values for the seven section relationship diagram illustrated in Figure 1, total closeness rating (TCR) and Rank of placement for each section has been calculated as shown in Table 2.

Table 4.5: TCR of Different Sections

Name	TCR	RANK
RM	16	3
Forging	22	1
Machining	17	2
Grinding	15	5
Heat treatment	13	6
Painting	14	4
Welding	12	7

Section that has highest rating i.e. forging is placed at the center. The section with the highest closeness rating value with forging is selected to be placed next to it, i.e., machining section. Placement of the sections proceeded until all sections are in place and minor adjustments are made to fit realistic section spacing. After considering alternative arrangements of the section, the one that generates the minimum cost is selected and is 3,806 birr per month. It is evident that result obtained earlier with CRAFT (3,648 birr) is better and, constructing new layout with construction routine alone does not provide better result.

To get better result, as presented in the hypothesis, CRAFT improvement algorithm has again been used. As a result, the cost has been reduced to 3,721 birr per month. Nevertheless, improvement made on current layout by applying CRAFT algorithm alone was better than that of CORELAP construction routine followed by improvement routine methodology. From these results we can deduce that current layout of KMTF was a good starting point for improvement using CRAFT. Therefore, starting improvement from an existing and workable layout is preferable than using construction algorithm, CORELAP alone. If such workable layout is not

present, the construction needs to be followed by improvement routine to have better sub optimality.

This hypothesis is further supported by the Yugoslavian researchers Dinesh, et al. [13]. This study also justified the benefit of utilizing construction routine followed by improvement routine to design an optimal layout. The study concludes advantage of combined usage of these techniques. We can, thus, infer that if the layout design is a new assignment, then federated usage maximizes improvement effort and if there is an existing layout, only improvement routine shall be undertaken and compare its result with newly constructed and then improved layout. This validates the hypothesis of utilization of new layout construction routine followed by improvement routine results better outcome than new layout, with construction routine alone.

CONCLUSION AND RECOMMENDATION

This paper has shown federated usage of construction and improvement routine results better performance of factory layouts. Recently, new companies are being established more frequently in Ethiopia than ever. This study offers benefit that can be achieved with federated usage of construction algorithm of layout design with improvement algorithm. For a new company/facility design, application of construction routine followed by improvement has resulted to be more effective than utilizing new construction alone. On the other hand, if companies' aim to revisit their existing layout, applying improvement routine directly is found to be the right strategy. However, since the performance of existing layout would affect the result from improvement algorithm, constructing new layout and comparing its performance with improved one is prudent. Careful analysis of the current layout of KMTF through computerized layout planning algorithms of CRAFT for improvement routine and CORELAP for construction routine has shown that federated use of computerized layout algorithms would improve efficiency of an organization.

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