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INSTITUTE OF SCIENCE AND TECHNOLOGY

EFFICIENCY IMPROVEMENT OF A MANUFACTURING PLANT LAYOUT

MASTER THESIS

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30.11.2017

Mudheher SABAH

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ABSTRACT

EFFICIENCY IMPROVEMENT OF A MANUFACTURING PLANT LAYOUT

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This research is based on a proposed initial plant of four work stations, each such workstation consists of four departments to manufacture three products. The conditions in this plant are suggested in a way to simplify our discussion. This study focuses on two effective tools to improve the efficiency of any manufacturing plant, the first tool is plant layout design by rearrange the departments of the workstation using the basic of CRAFT method to improve the efficiency of the plant by finding better arrangement of departments which lead to less material handling effort and i.e. reduce the cost of material flow between departments. The lack in this method is not always we reach optimality and just some of the alternatives could be reached, this lack has discussed and a MATLAB program had built to check all possible layouts and find the optimal solution with the list of all alternative layouts which satisfy this optimality. This program could help effectively to find the optimal solution easily and produce more flexibility for the decision maker to choose alternative layout. The second tool concerns on finding the best decision for maximum profit could get from the three products produced in the plant according to the market demand under certain constraints. Lingo and Excel programs are used for simulation and analysis. At the end of this research, we will explain why Lingo is more preferable than excel program in this kind of study.

Keywords: Plant layout, CRAFT, Lingo program, Material handling effort, Operation research.

ÖZET

FABRİKA DÜZENİ OLUŞTURULMASINDA ETKİN İLERLEME

Mudheher SABAH
Fen bilimleri yüksek lisans, Makine mühendisliği bölümü
Danışman:Yardımcı. Prof. Dr. Ibrahim MAHARIQ
Kasım 2017, 59 sayfa

Bu araştırma,dört iş istasyonun tasarlanmış tesisi üzerine kurulu olup,her bir iş istasyonu üç ürünün üretmek amacıyla dört bölümden oluşmaktadır.Bu tesisin kurulumundaki şartlar görüşmemizi basitleştirecek şekilde önerilmiştir. Bu çalışma herhangi bir tesis üretimi etkinliğinin geliştirilmesi için iki etkili araca odaklanmaktadır.Bunlardan ilk araç, materyal taşıma çabası ile bölümler arası material akış maliyetini azaltan daha iyi düzenlemenin bulunulması ile fabrika etkinliğini geliştirmek için CRAFT yöntemi temelinin kullanılarak iş istasyonunun bölümlerini yeniden düzenlenmesi ile yapılan tesis düzen tasarımıdır.Bu yöntemdeki eksiklik daima en iyisine ulaşamıyor olmamız,sadece bazı alternatiflere ulaşabilmemizdir.Bu eksiklik görüşülmüş ve tüm muhtemel tesis düzenlerini kontrol eden ve bu en iyiyi karşılayan tüm alternatif düzenlerin listesi yapılarak en iyi çözümü bulmak için bir MATLAB program yapılmıştır.Bu program daha kolay bir şekilde en iyi çözümü bulmada ve tüm muhtemel alternative düzenler de listeleneceğinden dolayı karar veren kişiye alternative düzen seçerken esneklik sağlamada etkili olarak yardımcı olmaktadır.İkinci araç da belirli sınırlamalarla pazar talebini karşılayacak tesiste üretilen üç üründen elde edilen kazancın en yüksek olması için en iyi kararın verilmesi ile ilgilidir.Simülasyon ve analiz için Lingo ve Eexcel programı kullanılmıştır. Bu çalışmada Lingo programın excel programdan daha fazla tercih edildiğini açıklamak amacıyla araştırma sonucunda kıyaslama yapılmıştır.

Anahtar kelimeler: Tesis düzeni, CRAFT, Lingo program, Materyal taşıma çabası,operasyon araştırması

LIST OF ABBREVIATIONS

CRAFT : Computerized Relative Allocation Facilities Techniques
SLP : Systematic Layout Planning
LP : Linear Programming
TS : Tabu Search
SA : Simulated Annealing
GA : Genetic Algorithm
OR : Operation Research
MS : Management Science

CHAPTER ONE

INTRODUCTION

Improving the efficiency of any manufacturing plant is very important to continue in the competitive market and the key to company survival over years by minimizing the cost of producing its products. There are many studies have been made to improve the efficiency of any manufacturing plant. Two of the most important techniques to reach profit optimality could be: plant layout design technique, which based on the best use of the occupied place, machines, equipment, workers, etc. The second technique to improve the efficiency of the plant is by using operation research (OR) approach, which concerns on scientifically based decisions regarding the best utilization of the plant entities to maximize the profit.

1.1 Plant Layout Design Technique

Plant layout can be defined as the facilities arrangement in the plant. A good placement of different departments, work stations, storage areas, equipment, machines, and the well usage of available areas in a manufacturing plant can effectively reduce the cost, increase the productivity, and improve the efficiency. Plant layout has defined by James More as the configuration of an optimal arrangement of departments, personnel, storing rooms, transportation equipment, work centers machines, and all other supporting services along with the best structure design to contain these facilities in the conversion process that meets the required output quality and quantity most economically.

Although the plan to design plant layout should be made at a high level of corporation, all other challenging factors could be locally solved. Plant design with consideration of less material handling is very important for productivity and profitability in the company, and could have the biggest effect on the plant than any other company decisions. A manufacturing plant design is the key to arrange production functions and processes physically in a way that eliminates unnecessary things such as movement and waiting [1].

We can define Material Handling as materials movement from storage area to the machining zone, and then from machine to another according to the processing sequence of manufacturing. There are four types of plant layout each type has its own approach to optimality:

1.1.1 Product Plant Layout

In this type similar machines are arranged according to the operation sequence required for manufacturing the product and the materials move from one workstation to another sequentially without any backtracking or deviation. Fig 1.1 below represents the operation.

Figure 1.1: Product plant layout

1.1.2 Process Plant Layout

According to this type of layout similar machines are arranged together at one place. The function in each department should performed in such a way that each machine has to do a specific job as possible. Fig 1.2 is an example about the operation:

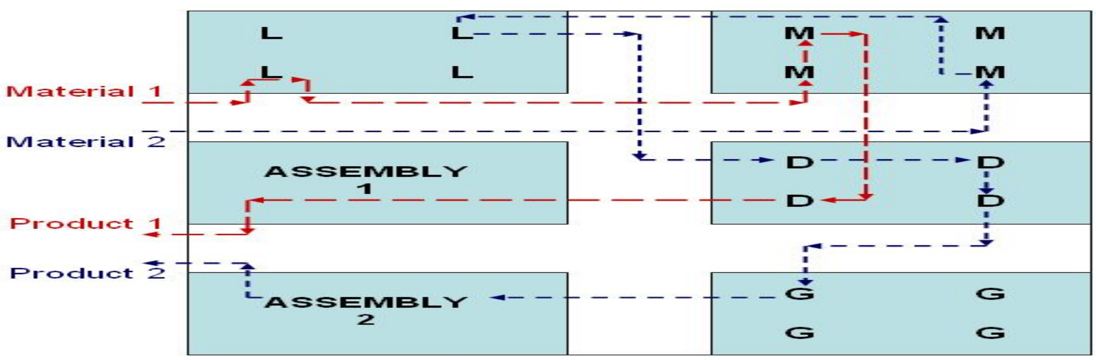

Figure 1.2: process plant layout

1.1.3 Fixed Plant Layout

Major products being produced are fixed at one location, while All other facilities like equipment, machines, tools, and labor are brought and arranged around the work center. Generally this method is suitable for producing big products like ships. The following drawing represents this process fig 1.3:

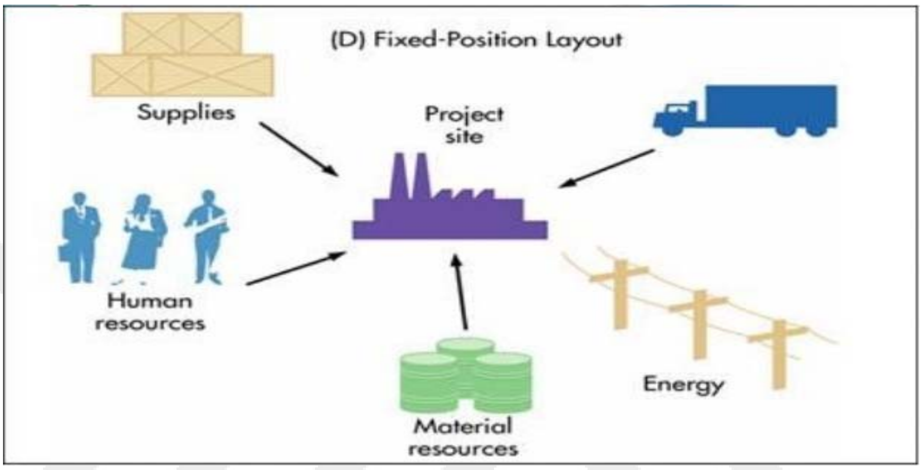

Figure 1.3: Fixed plant layout

1.1.4 Combined (Group) Plant Layout

In many manufacturing units, several products are produced in repeated numbers with no likelihood of continuous production and machines are grouped according to the process requirements for a set of several items which need to similar processing.

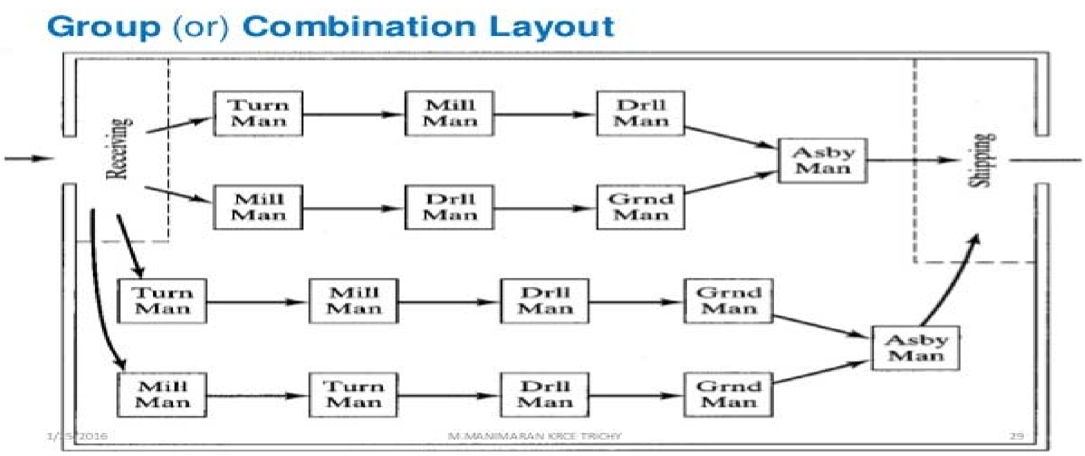

Figure 1.4: Group plant layout

Choosing any type of layouts depends on many factors. One of these factors could be the physical properties like, volume and weight also the capital of the company could affect choosing the type of layout, and also the production volume and the variety of the products in the workstation. For example, if we want to produce more product variety with less production volume, then choosing process layout will be more suitable. The relationship between production volume and product variety and the type of layout shown in fig 1.5.

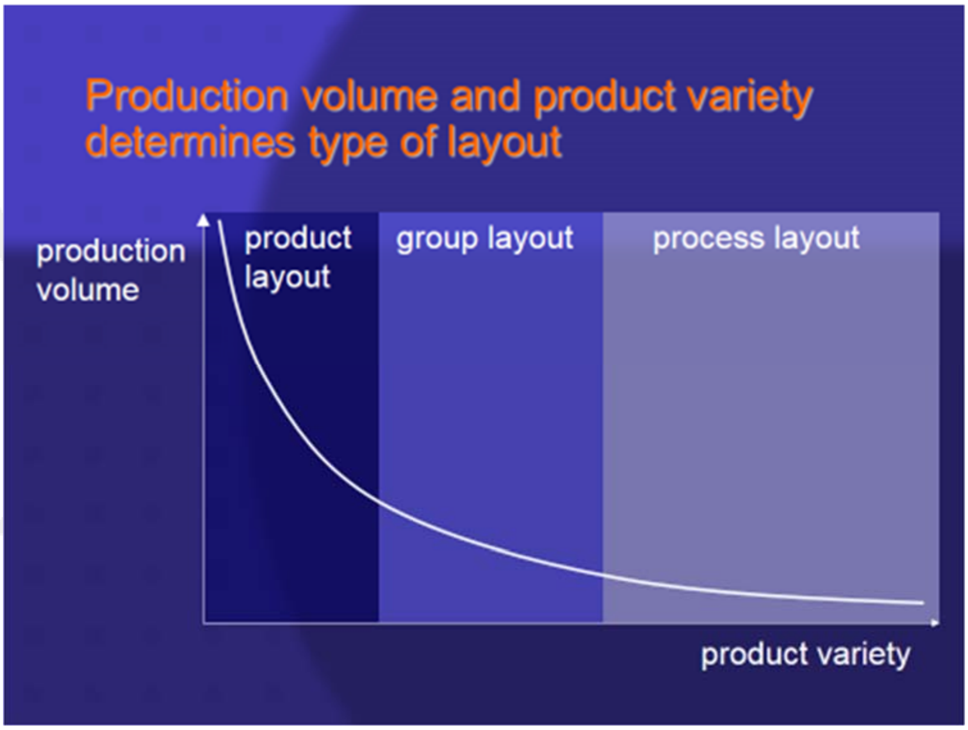

Fig 1.5: Relationship between production volume and variety layout type

In all of the previous layout design types, there are many methods to optimize the efficiency of the plant. One of the most effective factors could affect the cost of manufacturing is the distance of transportation. CRAFT (computerized relative allocating facilities technique) is a well-known algorithm used to improve the initial layout design by reducing transportation distance and accordingly reduces the cost of production.

1.2 Computerized Relative Allocation Facilities Techniques (CRAFT)

CRAFT is an algorithm applied to initial layout to improve productivity by minimizing the total distance of moving between departments by swapping two or more departments and find better design. This technique can be used in different types of layouts. There are various means of material handling that a firm may use in the workshops, which could be manually or motorized. To use CRAFT method for layout improvement, the analyst should provide an initial layout. According to this algorithm, CRAFT will exchange location of department's center pairs by making many iterations and evaluate the solutions to choose the best design which satisfy the best result, fig 1.5 shows a configuration for CRAFT algorithm.

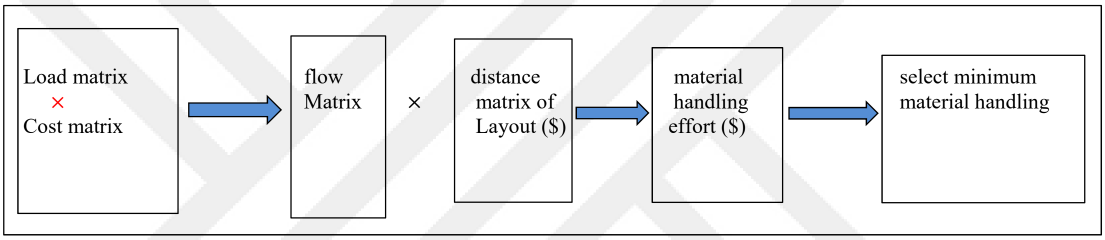

Figure 1.6: CRAFT algorithm

1.2.1 CRAFT Facts

CRAFT only exchanges departments that are**:**

a. Adjacent (share at least one common edge)

b. Have equal areas.

c. Adjacency is a necessary but not sufficient criteria for swapping departments.

d. Quality of final solution depends on the initial layout.

e. Final solution may be locally optimal, not globally optimal.

To start with applying CRAFT on the initial layout, we should collect the necessary information, and data to start evaluating the layout design.

1.3 Data Collection for Evaluating the Layout Design

The first step to start with is to collect data of the company for the existing layout that includes area of each workstation, transportation cost and distance between the departments. Some of these data like the cost depend on information we should gather first like time study, we should deal with these data in a matrix forms to make our calculations easier. The goal from gathering these data and making the necessary calculations on them is to redesign a new layout based on the initial one, which means relocation of different departments in the workstation by making the necessary swap between pairs of departments in the workstation to ensure reaching better or optimal material handling effort (minimize material transportation cost). While making our decision for the best design we should put in our consideration not to disturb the process of producing products or the material movement from process beginning of raw material stage till final process of dispatching. The better layout design will reduce the material movement and thus the waste in time will accordingly be reduced.

Now we may need to have an idea about the necessary data to apply CRAFT Algorithm and exploring them briefly as in the following:

1.3.1 From to Chart

From to chart provides information concerning the number of material handling trips between departments or distance path between centroids of departments. The following table 1.1 is an example of it.

Table 1.1: From to chart

From Departments \ To Departments	A	B	C	D	E	F	G
A		23	12	35	65	16	95
B			37	45	80	40	80
C				18	50	12	67
D					119	63	60
E						49	30
F							79
G							

The above table represents the relationships between numbers of departments. For instance, the number of units between department (D) and E is (119) units, the number of units between departments C and F is (12) units. Rows and columns have same titles with the same sequence. Entries in the matrix may represent the distance between centroids of departments, number of material handling trips made between departments in each day, total material movement represented by weight, cost, quantity etc. The lower triangle has been left blank as it sometimes holds the same data of upper triangle. In case of upper triangles' data differs from lower data, then the trips from B to C as example might not be the same as the trips from C to B, In this case the lower triangle should keep its data. When dealing with distance or trips, it might be useful to add totals columns and rows at the right and bottom of the matrix [9].

1.3.2 Cost Matrix

Cost matrix (Cij) represents the cost of transportation per unit distance from workstation to another or from department to another within the workstation [10].The cost of transportation per unit distance could not be the same between different pairs of departments due to the manner used in transportation, for instance transportation between certain pairs could be motorized and using modern technology in transportation while other pairs of departments may use manual transportation and cost more money, table 1.2 below represents cost matrix.

Table 1.2: Unit cost matrix

From / to	1	2	3	4
1	C_{11}	C_{12}	C_{13}	C_{14}
2	C_{21}	C_{22}	C_{23}	C_{24}
3	C_{31}	C_{32}	C_{33}	C_{34}
4	C_{41}	C_{42}	C_{43}	C_{44}

1.3.3 Distance Matrix

The traveling distance between each pair of departments in the workshop layout is the main factor to reduce the cost of transportation of items, workers, services, etc. The distance should be taken from the centroids of departments and it could be in rectilinear path or Euclidean path. Rectilinear path is more suitable and closer to reality table 1.3 represents an example of distance matrix.

Table 1.3: distance matrix

From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

As we said before the distance should be taken from the centroid of departments, and from table 1.3 shown above we can see for example the distance from department (C) to department (B) is (7), while the distance from department (B) to department (C) is (5), this difference could be due to different path between receiving and departing items.

1.3.4 Flow Matrix

Flow matrix (Fij) represents the flow of material from workstation i to workstation j or from department to another within the workstation. The flow matrix listing the departments to be considered and the number of trips (or flow) between them in a given period as in table 1.4 below [10].

Table 1.4: Flow matrix

From / to	1	2	3	4
1	F_{11}	F_{12}	F_{13}	F_{14}
2	F_{21}	F_{22}	F_{23}	F_{24}
3	F_{31}	F_{32}	F_{33}	F_{34}
4	F_{41}	F_{42}	F_{43}	F_{44}

We can get the flow matrix by multiplying load matrix which represents the number of trips (each trip could transport one item or a specific number of items) between each pairs of departments (counted for a specific time) centroids by the cost matrix (the cost for each trip in a specific distance).

1.3.5 Material Handling Effort

There are many definitions to cover the meaning of material handling, we can say that the material handling is a combination of science and art both of them involving the moving, positioning the material to a storage area or packing. With the raise of technology over decades, manufacturing plants systems continued to evolve over time so no more widely depend on human muscles or animals to do jobs because they have limited power and speed and to do a specific job could cost much money. As the life needs new services that traditional means of handling will not be sufficient or effective, the modern technology become very important to fulfill the appearance of our new life needs effectively with reduction in production cost. Choosing the suitable material handling equipment to do its function will improve the efficiency of the plant improve the, this not because this equipment will produce further products, but by reducing cost of producing these products because of its capacity of loading and velocity to do the trips of transportation.

We can get material handling effort by multiplying the load matrix which mean number of trips per specific time by the cost matrix which list the cost of each trip for a specific distance.

We will now explore another method to improve the plant efficiency as a second step of improvement.

1.4 Operation Research (OR) Technique for Plant Optimization

This field of study which can also referred to it by a term "management science" ("MS") adapts ideas and techniques to improve productivity and efficiency which can applied in any manufacturing plant. It uses a scientific expressions to decision making that leads to best decision and operate the system.

1.4.1 Modeling the Problem in OR

To modeling any problem we should define and investigate the problem. The analyst should specify three important elements to implement this mission: a- description of the decision alternatives, b- specifying the objective of the study, c- identifying the decision limitation under which the model will operate. After defining the problem we should translate this definition to mathematical relationships. If we could reach a model that fits one of the standard models for instance linear programming then we can often find the solution by using the common algorithms. If these mathematical relationships were so complex to find the solution the analyst can simplify the model and use a heuristic approach, or it could be more appropriate to use simulation. In some cases it is more beneficial to combine a mathematical, heuristics, and simulation all together to solve the problem.

1.4.2 Sensitivity Analysis

An important aspect of the model solution is (sensitivity analysis). It provides the analyst additional information about the behavior of the optimal solution when the model undergoes some parameter changes. Sensitivity analysis become more important when the information gathered about parameters were not accurate enough [22].

1.4.3 Methodology of OR

We can list some important tips in solving any problem by using (OR) technique:

1. Formulate the problem by defining the system's problem includes specifying the system's objectives and other organization's parts that must be studied before the problem can be solved.
2. Observing the system and collecting data to specify the values of parameters that affect the system's problem. These values are used to formulate a mathematical model of the problem.
3. Formulate a mathematical model of the problem. There are many mathematical techniques that can be used to represent the system.
4. Verifying the model and use the model for prediction. The analyst after formulating a mathematical model should compare the model with reality, is it close enough to actual problem?
5. Selecting a suitable alternative. After forming the model, analyst can choose the alternative (if there is one) that best meets the system's objective.
6. Put in mind some times that we should select the best alternative that doesn’t violate one or more constraints in the system.

1.5 Thesis Objective

This research is to minimize the material handling effort and maximize the profit using optimization techniques and build a MATLAB program to redesign plant layout in a way to ensure best design for plant layout these goals will be presented by review two of most effective tools for a manufacturing plant efficiency. The first field for this study is the redesign of the plant layout in a way to minimize the material handling effort, the second field is to optimize the profit concerning the best quantity decision of production for three products or more according to market demand.

1.6 Organization of the Thesis

1. Chapter one, gives general overview about two fields concerning manufacturing plant optimization.
2. Chapter two, includes historical review about the studies handled the development of layout redesign and manufacturing plant optimization.
3. Chapter three, this chapter gives information about data collection to improve the efficiency of the plant using layout design technique.
4. Chapter four, includes calculations and result for layout design technique and simulation program to find optimal solution effectively.
5. Chapter five, includes operation research technique to improve the efficiency of the plant as a second step of optimization, necessary data presented to modulate objective function and constraints, calculations and results using programs for simulation: easy lingo, and excel program.
6. Chapter six, includes conclusions and future work.

CHAPTER TWO

HISTORICAL INTRODUCTION FOR PLANT LAYOUT

2.1 Layout Optimization then Simulation or Vice Versa?

Simulation could be considered as an integral part to be applied in planning of any system layout. In this study the researchers try to Figure out which sequence should we start with to get more realistic plant layout, should we start with layout optimization first then simulation or should start with simulation then layout optimization?

And the researchers contrast these two paradigms, with respect to the general assumptions and the types of applications that advocates from each paradigm have used to support their claim. In addition, they propose guidelines on which approach to pursue according to the layout study objectives and the characteristics of the system under consideration. The two of thought could reach the ideas about each sequence as in the table 2.1 below:

Table 2.1: Two schools of thought on whether to start by layout optimization or simulation in facility planning and layout tasks [3]

Paradigm	Layout then simulate	simulate then layout
Belief	Simulation analysis is local, where layout optimization analysis is global	Simulation prior layout study produces layouts that are efficient and realistic
Benefits	Time efficient	Provides accurate estimate of flow for layout optimization from simulation
Application (best for)	• Improving existing layout • Resolving congestion and bottlenecks • In layout • Only minor system's process parameters • Need to be adjusted • Technology embraced requires • Special layout type and simulation • For verification	• Creating a new layout for a system that exhibit • Significant • Stochastic behavior/demand • And /or • Complex interactions • Simulation is used to generate random flow to • Be fed for a layout routine • Solving flow congestions and bottlenecks have higher priority than reducing distances.

In this research, the researchers have compared between the two ideas of what to start with first, simulation or layout design optimization, and they found that the sequence selection depends on many factors based on the function of the facility layout study, the complexity of the plant operations, and stochastic behavior of the system. Starting with plant layout design will be more suitable if the objective is to find the solution with predefined system conditions along with the production strategies, and can applied when the main purpose is to minimize distance of travel and the cost of transportation. While, starting with simulation could be more suitable when applied to problems with uncertainties behavior, and can produce good benefit for improving production and layout operational parameters [3].

2.2 Analysis Plant Layout Design for Effective Production.

In this study the researchers tried to improve the layout design of pulley's manufacturing plant by minimizing the obstructions in work flow to improve productivity. To start in their study they had to investigate the initial plant layout in each section of process i.e. Core ware house, sand mold, disassembly surface finishing, core making, and inspection sections. The faults in each work section in term of material flow was identified. They found that inspection section and disassembly surface finishing should be more specialized to improve their material flow, and so to increase productivity. This research was performed to verify the suitable plant layout design for denture manufacturing. The researchers could produce four models and compared between their efficiency using adjacency based scoring. Also they used for simulation a program called Arena 10 which can be used for personnel allocation to find the increasing productivity of the new improvement layout. According to this study the researchers could specify the obstacles reasons to improve workflow in the plant and thus the productivity. The result of this improvement could minimize the budget of the new layout.

This factory layout has been designed on the basis of process layout and this configuration is shown in Figure 2.1

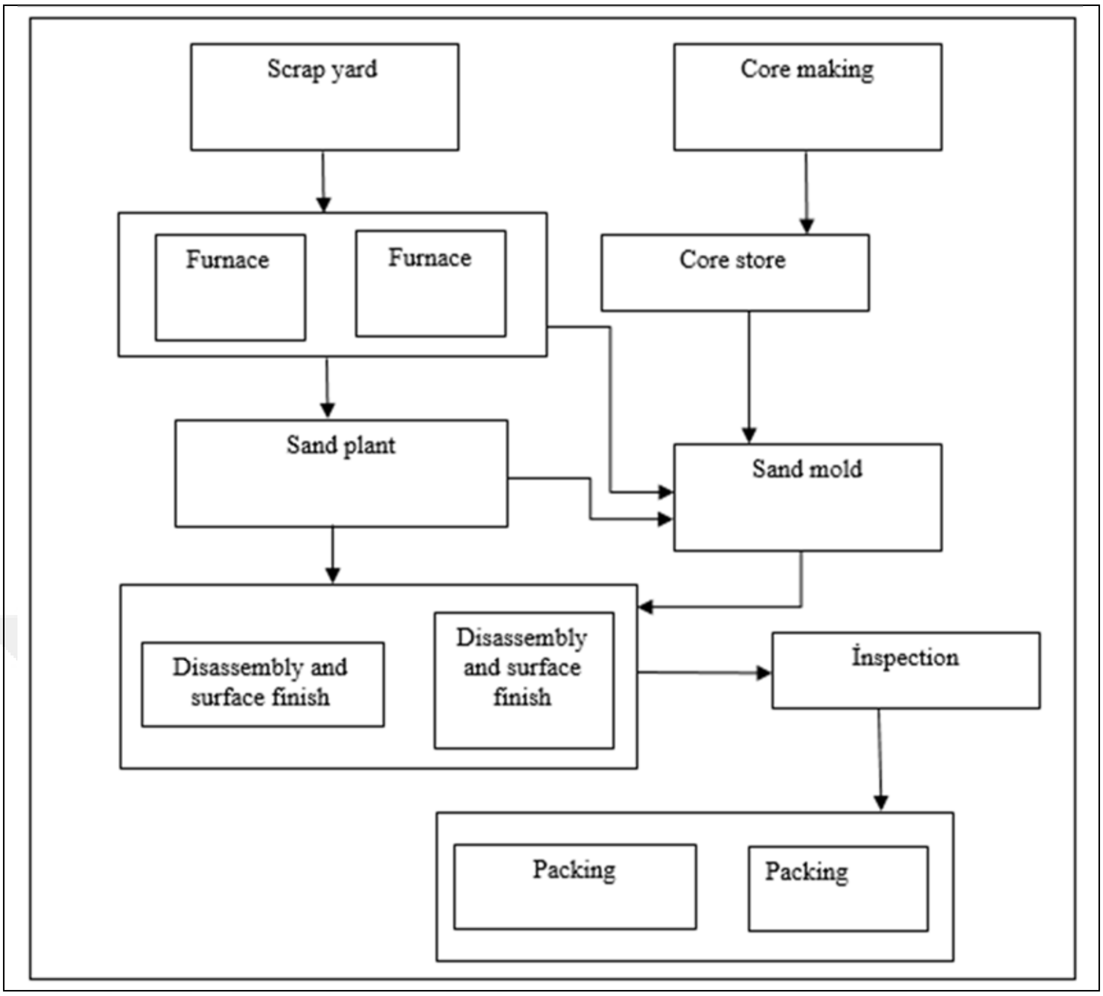

Figure 2.1: Process layout of pulley production [4]

The researchers could improve the initial layout by setting the surface finishing and disassembly sections to be between sand plant section and inspection section as in figure 2.2. Moreover, the inspection section is also improved.

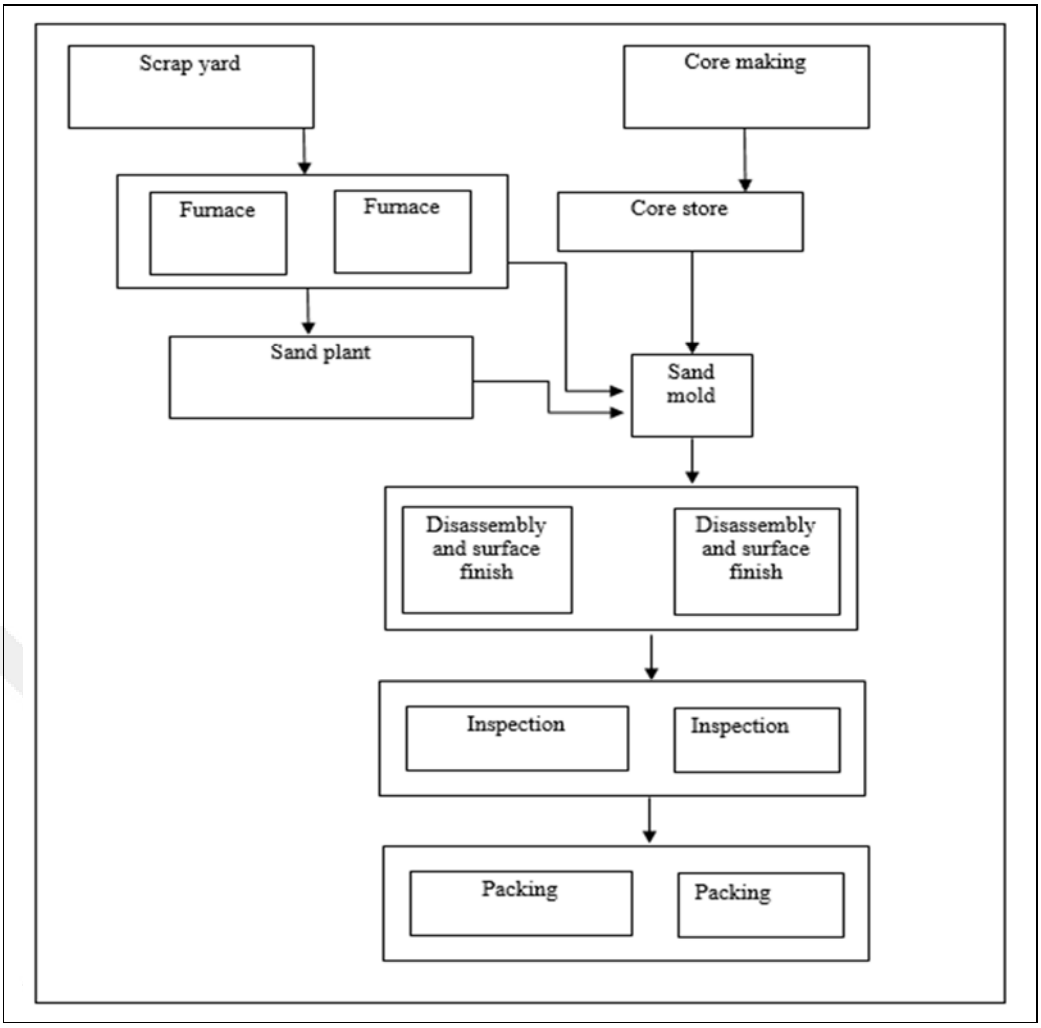

Figure 2.2: Process layout of pulley production [4]

When we analyze the workflow in the plant we can conclude a modification in the size should be made in sand mold, surface finishing, disassembly, core warehouse, and inspection section. The size modification could help to get better work flow and acceptable reduction in transportation between departments. Consequently reducing distance of transportation will minimize accidents [4].

2.3 Analysis of Plant Layout for Reducing Production Cost

In this study the researchers want to improve the efficiency of plant layout of steel flat in a manufacturing factory to optimize the productivity and reducing cost by eliminating obstructions. They have investigated each section of process like, rough rolling, cutting, preheating furnace, intermediate rolling, finish rolling, and inspection. They could identify the problem in each processing section in term of processing time, slack time, distance moved, material handling cost, and processing cost. To improve the initial layout, the work flow should be improved by reducing material movement distance by allocating the machine center rough rolling, cutting machine, intermediate rolling, and inspection sections. This reduction in movement distance will reduce the production cost up to 50% the total operating expenses (Tompkins et al., 1996). The configuration of the process based plant layout is shown in Figure 2.3.

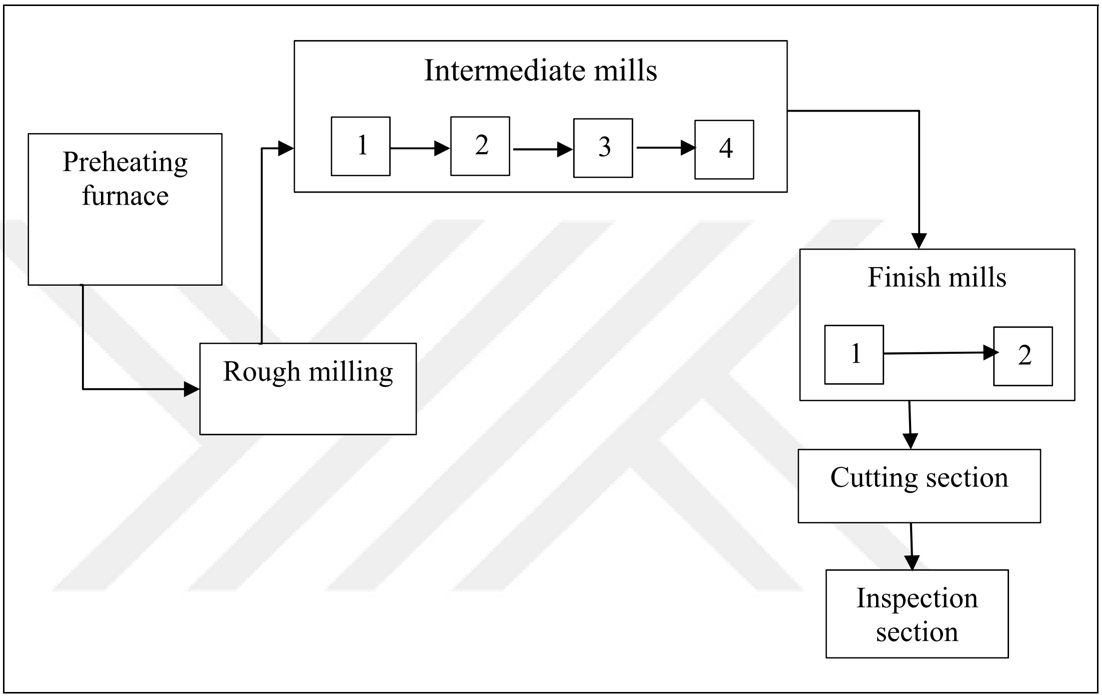

Figure 2.3: Base case (current shop layout: It is multi row layout) [5]

The details of the manufacturing process for plant layout configuration and flow of material from machine center like Preheating furnace, Rough milling, etc. are described in table 2.2.

Table 2.2: description of plant design and flow material according to manufacturing process [5]

s. no	Machine .s	Preheating Furnace	Rough Mill	Intermediate milling				Finish milling		Cutting	inspection	total
				1	2	3	4	1	2			
1	Processing time	300	13	9	7	12	8	8	11	7	9	384 sec
2	Slack time	10	9	12	9	7	12	13	12	370	7	461 sec
3	Distance moved	6.06	3.5	5	121	1.06	1.06	1.27	1.27	9	9	38.43 m
4	Material Handling cost	26	41.77	30.69	4.69	4.69	4.69	4.69	4.69	54.6	62.4	238.9 rs

The new design of the plant layout can be made depending on the previous information as described in table 2.3.

Table 2.3: The new plant layout design information [5]

s. no	Machine .s	Preheat-ing Furnace	Rough Mill	Intermediate milling				Finish milling		Cutting	inspection	total
				1	2	3	4	1	2			
1	Processing time	300	14	11	9	10	7	7	12	7	9	386 sec
2	Slack time	10	7	10	8	6	11	13	12	366	5	447 sec
3	Distance moved	6.06	3.3	4.2	1.26	1.3	1.26	1.4	1.48	5	3.5	28.76 m
4	Material handling cost	26	41.51	29.52	4.69	4.69	4.69	4.69	4.69	15.9	61.25	197.64 rs

Table 2.4: The difference between old and new layout design [5]

s. no	Machine .s	Preheating Furnace	Rough Mill	Intermediate milling				Finish milling		Cutting	inspection	total
				1	2	3	4	1	2			
1	Processing time	0	1	2	2	-2	-1	1	1	0	0	2 sec
2	Slack time	0	-2	-2	-1	-1	-1	-1	0	-4	-2	-14 sec
3	Distance moved	0	-0.2	-0.8	0.05	0.24	0.2	0.13	0.21	-4	-5.5	-9.67 mtr
4	Material handling cost	0	-0.26	-1.17	0	0	0	0	0	38.75	-1.17	-41.35 rs

The resulting layout design can apply to reduce distance of transportation, time consumption, reduce accidents, and increase productivity [5].

2.4 A Typical Manufacturing Plant Layout Design Using CRAFT

In this study, the researchers used (CRAFT) Computerized Relative Allocation of Facilities Technique, which is an improvement algorithm depends in the initial layout design to generate a better layout. To find the optimal solution the researchers have built JAVA program which uses an intermediate file called STEP file as input to JAVA. The STEP file can convert the layout drawn in AutoCAD program into a distance matrix which means the distance from each machine can be recognized by JAVA program. CRAFT takes inputs of the load matrix of interdepartmental flow and transportation costs with a representation of a block layout. The objective function according to CRAFT is to minimize transportation cost. This can be done by reducing distances between pairs of departments which have higher transportation costs by swapping these pairs of departments, Reducing distance can serve to reduce the transportation cost by evaluating the transportation cost of initial layout and compare it with all other alternatives came from departments pair swapping and specify the design of minimum cost to be our optimal solution.

The following results are obtained from the java program where the part flow matrix is varied for different planning periods as shown in the above data. The output of java in table 2.5.

Table 2.5: Result table obtained from the java program [6]

Periods	Initial layout Cost(rs)	Optimal layout Cost (rs)	%reduction in cost of the layout
1	38.71782	17.71495	54.56
2	35.12612	15.27947	56.50
3	40.80588	16.90627	58.56
4	40,870.40	17,037.65	58.31
5	29,100.11	11,094.09	61.84

If we make a comparison between initial and final layout according to the above data we can notice a great reduction in the cost for the final layout. From all above we deduce that the layout cost depends on distance matrix and flow matrix as input data.

STEP file serves to convert the layout design to distance matrix in JAVA program [6].

2.5 Using Systematic Layout Planning (SLP) to Maximize Production

In this study a process type layout of a nacelle production has a problem in wastage movement. The researchers should improve the initial layout design to have a better design which satisfy minimum cost of transportation and movement. Wastage in movement and transportation will increase the cost of production which means inefficient plant layout. SLP technique is used to overcome mentioned problem and to and to find a new layout design with minimum cost. To do such improvement it would be necessary to analyze the initial layout and specify the relationships between different activities in the plant. The dimensionless block diagrams in Figure 2.4 (a, b). Are prepared based on the relationship chart and serves as a basis for two new alternate layouts. The departments are numbered in the same manner as seen in the ARC. The block diagram ignores space and building constraints, and gives us a better idea for designing the optimized layout Figure 2.5 (a, b, c).

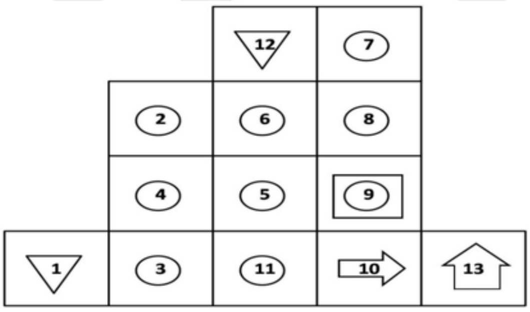

Figure 2.4: (a) dimensionless block diagram of layout 1 [7]

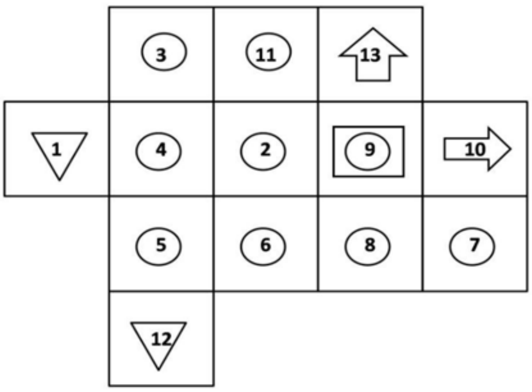

Figure 2.4: (b) Dimensionless block diagram of layout 2 [7]

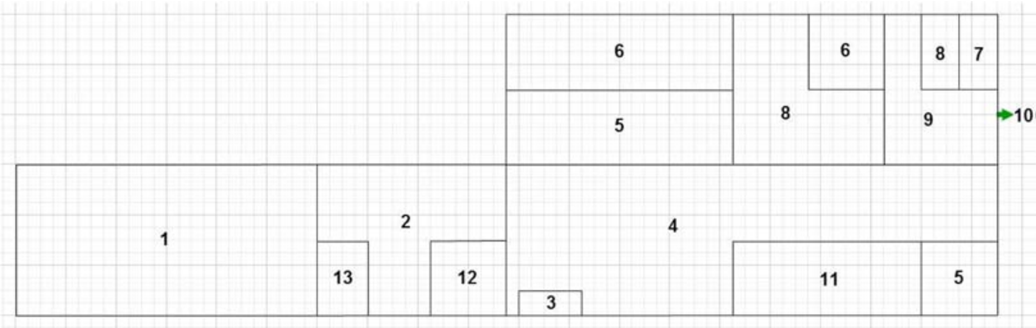

Figure 2.5: (a) Plant layout: original [7]

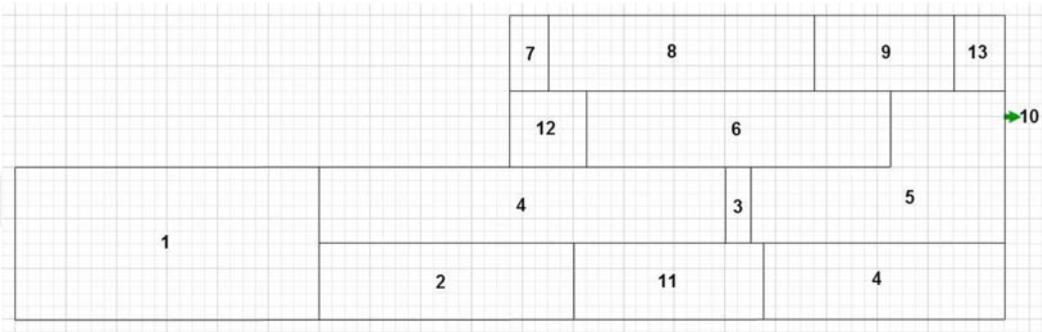

Figure 2.5: (b) Plant layout: proposed layout 1 [7]

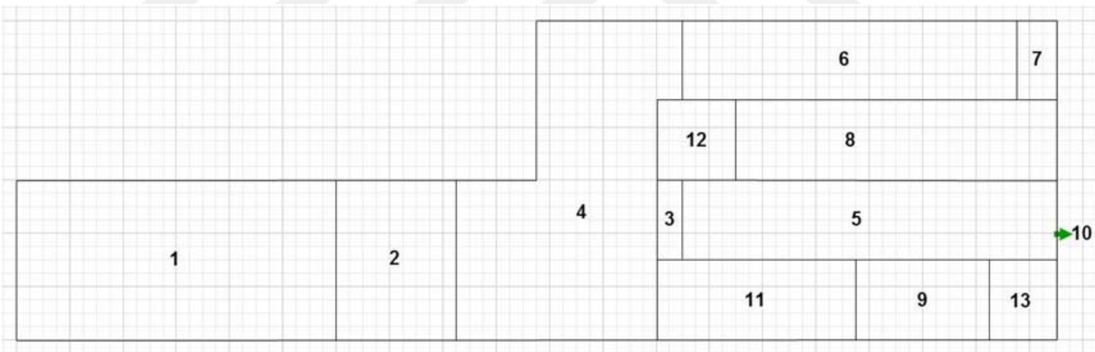

Figure 2.5: (c) Plant layout: proposed layout 2 [7].

The proposed layout 1 was finally selected as the new optimized plant layout. With the new layout all disjoined department Areas were made as one and efficient material flow was achieved. Table 2.6 shows the distances travelled in the proposed layout.

Table 2.6: Distances travelled in the optimized layout [7]

No	process	from	to	Nacelle (m)	Nose Cone (m)
1	Material preparation	Warehouse Warehouse	Material preparation Child parts	64 107	64 107
2	Resin mixing	Warehouse	Mixing gage	121	121
3	Molding	Material preparation Resin mixing Resin mixing Main mold	Main mold Main mold Child parts Mold storage	33.5 42 31 88	90 42.5 31 79.5
4	Wet finishing	Mold storage Resin mixing Child parts Tools area	Wet finishing Wet finishing Wet finishing Wet finishing	31.5 41.5 72.5 78.5	31.5 41.5 72.5 78.5
5	Assembly	Wet finishing Pre-assembly Wet finishing Tools area	Pre-assembly Assembly Assembly Assembly	74 40.5 - 37.5	- - 38 79
6	Dry finishing	Paint mixing Paint mixing Assembly	Dry finishing Child parts Dry finishing	47 75 36	47 75 51.5
7	Final assembly and inspection	Dry finishing Tools area	Final assembly Final assembly	57 83.5	57 -
8	Dispatch	Final assembly	Dispatch	36.5	36.5
total				1197.5	1143

The total reduction in movement for nacelle is 292 m and for nose cone is 47.05 m. Therefore in the optimized layout, the total distance reduced in the manufacturing of one set of nacelle and nose cone is 339.05 m. By the application of SLP for the design of an optimized plant layout we were able to reduce the wastes due motion and transportation, therefore increasing the productivity of the plant [7].

2.6 Efficiency Improvement of a Plant Layout

This study aims to improve the current plant layout and use string diagram for analyzing. The researchers used ARENA software to simulate current and proposed layout. Efficiency of the current & proposed plant layout are calculated. The researchers used the principle of string diagram and simulation software. A string diagram can be used to plot the movements of equipment, material, and essentially when a work study person wants to find out how far the materials travel. A simulation study was under taken to find out the overall efficiency of the plant. To redesign the new layout they use to analyze the current layout all necessary measurements were documented and scaled drawing for the plant were made. M.s office and auto cad used for the purpose. String Diagrams were used to trace and measure the path of material.

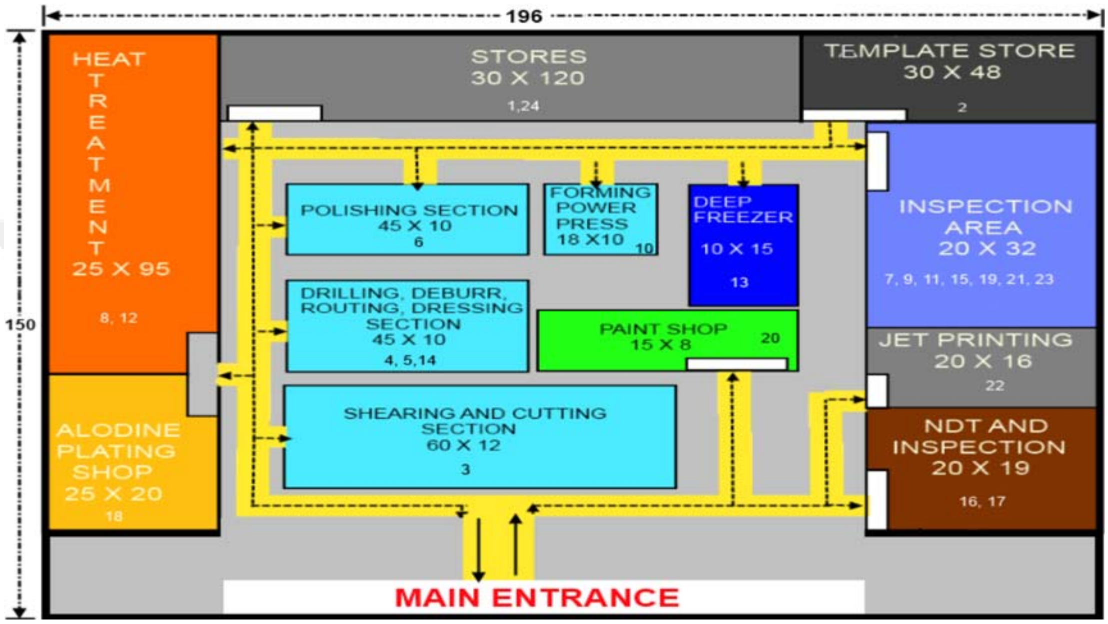

Figure 2.6: Present plant layout [8].

$$\text{Efficiency of the current plant layout (A)} = \frac{\text{prescribed travel length by DGCA)}}{\text{2a current travel length}} * 100$$

$$\text{Efficiency of the current plant layout (A)} = \frac{1500}{2205} * 100$$

$$\text{Efficiency of the current plant layout (A)} = 68.02\%$$

The new layout will be represented as follow:

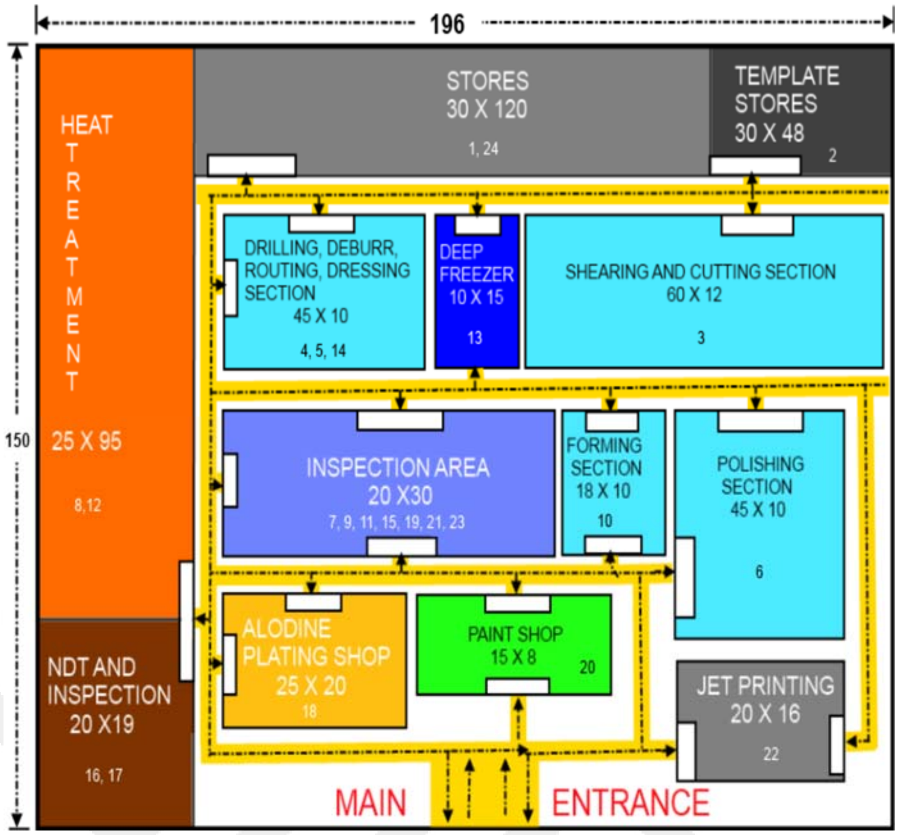

Figure 2.7: The proposed plant layout [8].

Efficiency of the proposed plant layout B = (1500/ 1190) * 100

Efficiency of the proposed plant layout B =126.5%

Percentage improvement: 85.31%

We can notice that a huge improvement achieved using this new plant layout [8].

2.7 Literature Review for Operation Research (OR)

There are many methods for optimization, picking any of these methods depends on the nature of the problem which we want to find the best solution for it which could be linear or not linear. According to the method of optimization and the nature of the problem the solution will be global optimal or locally optimal, the very common methods used for optimization are: Tabu Search method (TS), which a mathematical method used to solve optimization problems to find local optimal solution, this technique based on structural algorithm refers to the problem and the solution which will obtained is called taboo, that mean every problem has its own algorithm [17].

The second well known heuristic search for layout optimization is called Genetic Algorithm (GA) which classified as global search heuristic. It uses techniques which inspire specialists on inheritance, mutation, and crossover [18]. This technique is used to find exact or approximate optimal solution.

The third search is Simulated Annealing (SA). This technique can be more effective in some cases when the search space is discrete and so large we can obtain and acceptable solution in relatively short time when saving in time is important [18].

2.8 Linear Programming

During the World War II, the need to maximize the efficiency in different aspects raised. George Dantzig, a member of the U.S.

Air Force, developed the Simplex method of optimization in 1947 and could use linear algorithm to solve linear problems, mathematicians and economic scientists from different aspects developed his ideas to survey many linear problems and spread the linear applications to the world [23].

Talluri and Narasimhan (2003) have significant participation in this field to become the first researchers could integrate two linear programming models to optimize supplying performance according to the best target measures of the byer with the consideration of the performance variability measures in evaluating alternative suppliers. Both maximum and minimum efficiencies of each supplier would achieve a comprehensive understanding of a supplier performance.

Talluri and Narasimhan (2005) developed a linear programming model to evaluate and select potential suppliers with respect to the strengths of existing suppliers and exclude underperforming suppliers from a telecommunications company’s supply base. The model was compared with traditional and advanced DEA to examine its relative advantages.

2.9 The Systematic Layout Planning (SLP)

This method is developed by (Muther 1970), although this method invented before many decades, but it still important and widely used as a basic procedure to solve layout problems. According to Muther it consists of four phases:

1. Finding the location for the plant to laid out.
2. Establishing the complete layout.
3. Making the layout plan with details.
4. Making the selection of the layout to install.

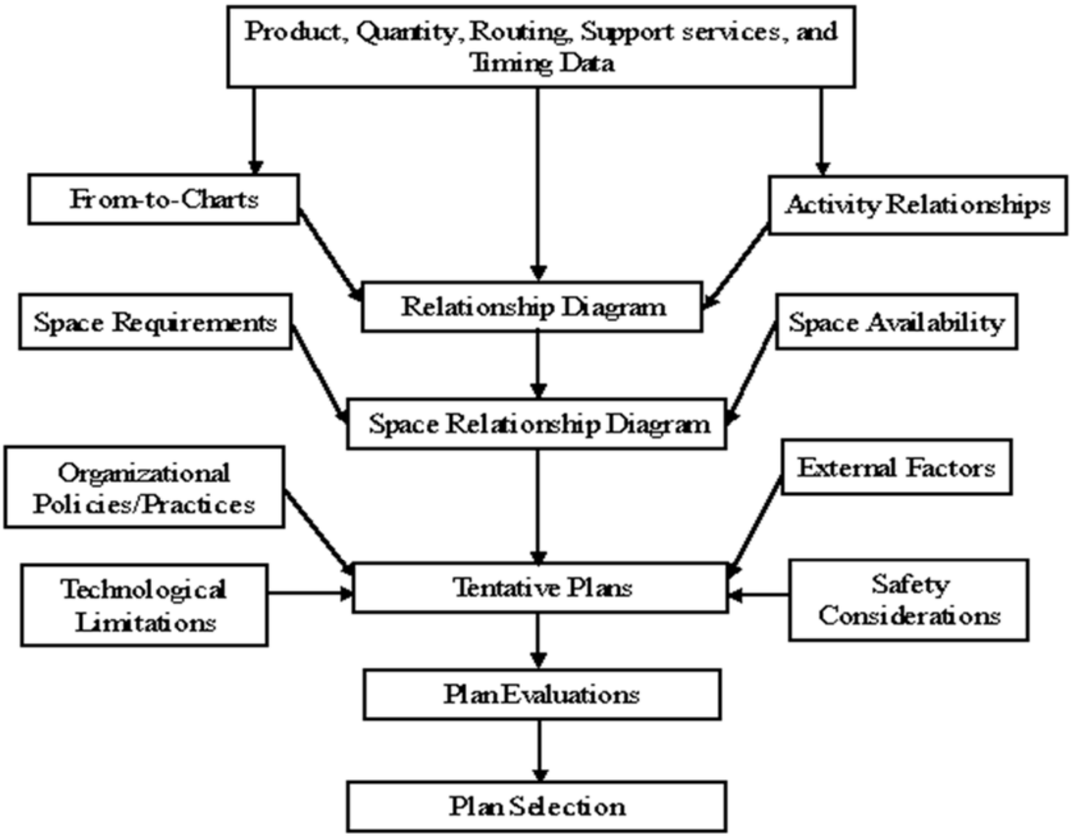

Figure 2.8: stages of SLP.

CHAPTER THREE

DATA COLLECTION AND CALCULATIONS FOR LAYOUT DESIGN TO IMPROVE THE EFFICIENCY OF THE PLANT

3.1 Problem Definition

We have a manufacturing plant consists of four work stations to produce three products, each work station contains four departments.

In this chapter we will focus on layout design technique for efficiency improvement.

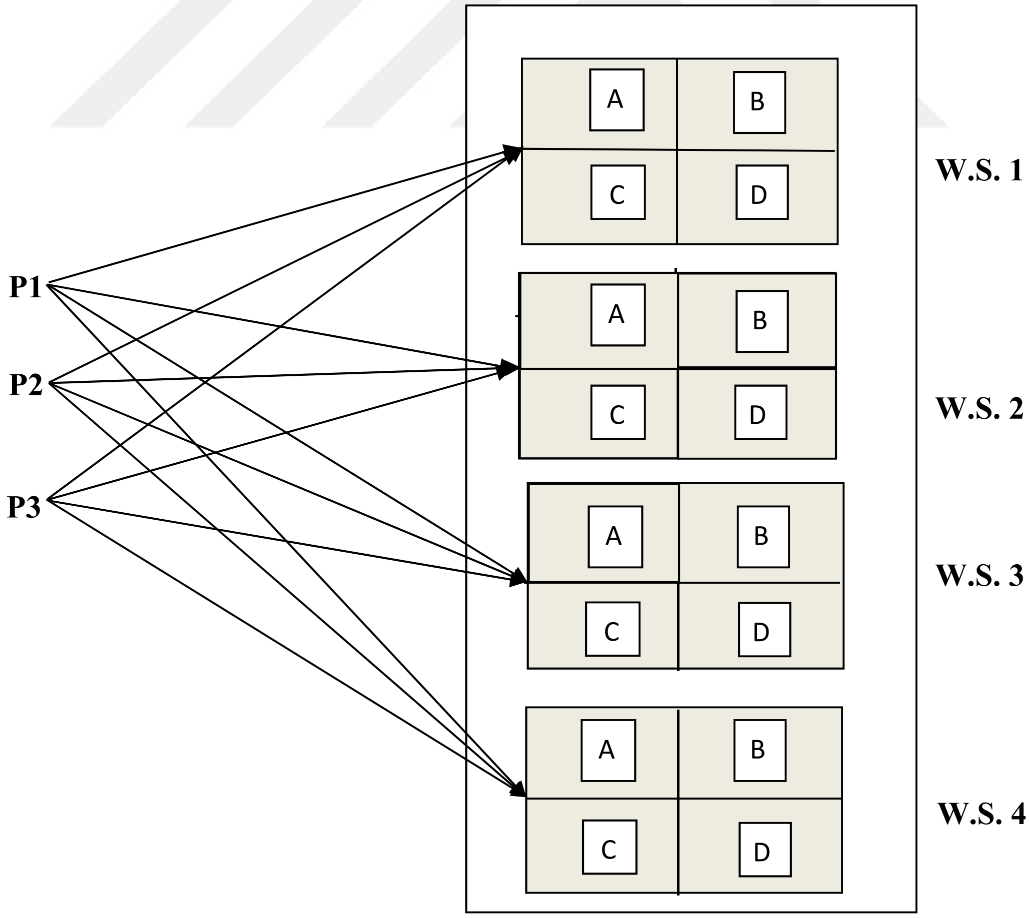

Figure. 3.1: The manufacturing plant.

3.2 Introduction

The manufacturing plant layout in this study has been redesigned by using Computerized Relative Allocation of Facilities Technique (CRAFT) to improve the efficiency. A MATLAB program has been developed to design the optimum plant layout based on minimum transportation cost.

3.3 Input Required For Applying CRAFT Algorithm

1- Number of departments = 4.
2- Initial layout of the machine shop is given as in Figure 3.2 below.
3- Cost matrix = 1$/ meter.
4- Flow matrix (w_{ij}) of the work station which is the result of the product of load matrix by the cost matrix.

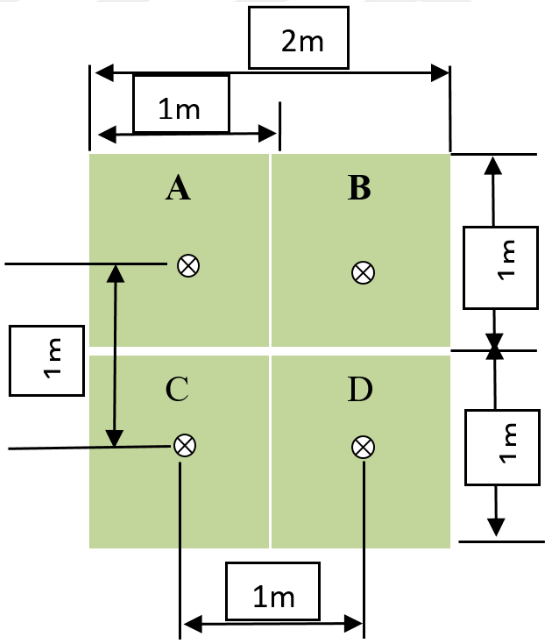

Figure 3.2: department's measurements for initial workshop

In each workshop there are three products to be produced, let's consider a process layout in each work station and try to improve it to increase the efficiency by reducing the handling effort cost, this can be done by rearranging the departments in the initial layout and try to find better layout by making the departments that have more transportation cost close to each other. The procedure we will follow is the basic of

CRAFT program (computerized relative allocation facilities technique), and this will lead to minimizing material handling effort.

The objective function is to minimize the total material handling effort according to the equation below (classified as unconstrained problem):

$$\textbf{Min}\ TC = \sum_{k=0}^{n} D_{ij} * w_{ij} * C_{ij}$$

Where, $\mathbf{D_{ij}}$ is the distance from department I to department j.

$\mathbf{W_{ij}}$ is the interdepartmental traffic from departments i to department j.

$\mathbf{C_{ij}}$ is the handling cost between departments i and department j.

3.4 Steps to Find the Best Alternative Layout Using the Basic of CRAFT

1- Collect the necessary information as input data.
2- Draw the initial layout.
3- Find the distance matrix for the initial layout.
4- Find the relation between departments in the initial layout.
5- List the load matrix for the items.
6- Calculate the items flow matrix.
7- The material handling effort for the initial layout is calculated using flow matrix and distance matrix.
8- The minimum material handling effort for initial layout is done by replacement of the departments.
9- The end of applying this algorithm leads to optimized cost.

We can symbolize CRAFT procedure as an algorithm**:**

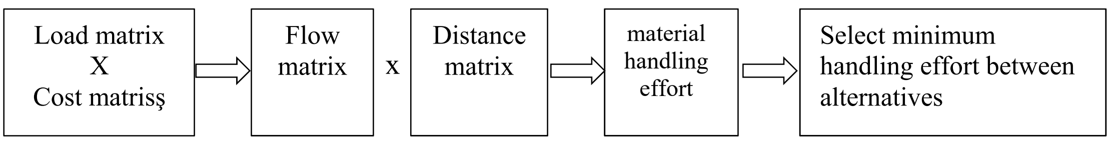

Figure 3.3: CRAFT algorithm to find minimum material handling effort.

3.5 Collection Data and Calculations for Initial Layout Design.

We will start collecting information and make calculations for one of the workstations in the plant, the other work stations will have the same result since they have equal departments size otherwise we should follow the same procedure to find optimal design for each of them. Let's consider our initial layout of the workstation has the following arrangement in Figure 3.4:

A	B
C	D

Figure 3.4: initial layout design

3.5.1 Product, Process and Schedule Data Collection for Initial Layout

In this initial design of the workshop we want to produce products P1, P2, and P3, let's suggest they are subject to the following process sequence to be ready for marketing:

P1: dept. A → dept. B → dept. D → dept. B → dept. C → dept. D.
P2: dept. A → dept. D → dept. C → dept. D.
P3: dept. A → dept. C → dept. B → dept. A → dept. D.

Figure 3.5: process sequence.

The processing sequence for product one as in Figure 3.5 shows that it should first enter department (A), then departments B, D, B, C, and finally department (D) to be ready for marketing. The same thing each, the other products has its special sequence to be ready.

So let's consider our inputs for production quantum, sequence and schedule to be as in the following table 3.1:

Table 3.1: Product, process, and schedule data.

Product	Processing sequence	Daily production	No of items in trolley	Trolley load per day
1	ABDBCD	200	20	10
2	ADCD	100	4	25
3	ACBAD	150	10	15

The table above shows that the company produce three products 1, 2, 3. Product one has processing sequence ABDBCD, the company produce 200 pieces of product one daily, each trolley can handle 20 pieces of product one, that means the number of trolleys per day are (200/20) =10 trolleys. The same way, we can read the information from the table for products two and three.

3.5.2 Distance Matrix for Initial Layout

Now we have to specify the distance matrix as input to our search algorithm using rectilinear method in measurements taken from center to center of each department to another, which depends on our initial layout by assuming square departments for simplicity as in Figure 3.2.

In our initial layout the distance between each adjacent pair is one unit and the distance between each opposite pair is two units i.e. the distance between A and B is one unit while the distance between A and D is two units, the matrix below shows the distances between all pairs in the layout table 3.2:

Table 3.2: Distance matrix for initial layout (assume rectilinear distance) (meter).

From/to	A	B	C	D
A	-------	1	1	2
B	1	-------	2	1
C	1	2	---------	1
D	2	1	1	--------

3.5.3 Load Matrix for Initial Layout

Now we should determine the load matrix which lists the total quantum of trolleys which are moving between all pairs of departments, we can compute the number of trolleys moving between each pair of departments using (product, process and schedule data) matrix. For example if we want to find the number of trolleys between department (A) and (B) we will see (10) trolleys moving for product one between department (A) and (B) (notice that there is no transportation for products two or three between departments (A) and (B) depending on table 3.1 p29). Between department (C) and (D) there are 10 trolleys of product one and 25 trolleys of product two moving between the two departments, so the total trolleys moving between department (C) and (D) are: 10+ 25 = 35 trolleys. We can apply the same procedure for other pairs of departments and we can form the load matrix shown in table 3.3:

Table 3.3: load matrix (trolleys).

From/to	A	B	C	D
A	---------	10	15	40
B	15	-------	10	10
C	-------	15	--------	35
D	--------	10	25	----------

The above matrix give us an idea about the pair of departments that we should make close to each other to minimize the material handling cost, so it is important to make departments A and D close to each other because they have maximum number of trolleys (40 trolleys) moving between them, this is true if we have a unity cost matrix i.e. same means of transportation between all pairs of departments, if this condition is not satisfied, then the cost matrix of transportation along with the load matrix should be considered for the departments rearrangement when plotting the layout design.

3.5.4 Cost Matrix for Initial Layout

Now we should think about the cost of transportation between each pair of departments which could be different between each pair to another for instance we can use motorized transportation between some pairs of departments which cost more than manually transportation, for simplicity we can make the unit cost of manually transportation is (1unit cost) which could be in dollar, while motorized transportation may cost double (2 unit cost). We will suppose motorized transportation between departments B and C which will take value of (2) dollar while other pairs of departments we will suppose manually transportation which will take value of (1) dollar so our matrix as in table 3.4 below:

Table 3.4: unit cost matrix ($).

From / to	A	B	C	D
A	------	1	1	1
B	1	------	2	1
C	1	2	--------	1
D	1	1	1	-------

The above matrix shows that the transportation between department pairs (A,B), (A,C), (A,D), (B,A), (B,D), (C,A), (C,D), (D,A), (D,B), and (D,C) are manual, while transportation between pairs (B,C), and (C,B) are motorized.

3.5.5 Flow Matrix for Initial Layout

To compute material handling effort for the initial layout we should multiply load matrix by cost matrix and then by distance matrix. Now we need to find flow matrix which is the result of multiplying load matrix by cost matrix:

Tables 3.5: (a, b, c) forming flow matrix for initial layout

a- Load matrix

---	10	15	40
15	--	10	10
---	15	--	35
---	10	25	---

×

b- unit cost matrix ($)

---	1	1	1
1	--	2	1
1	2	---	1
1	1	1	---

c- Resultant flow matrix for (load matrix *unit cost matrix)

From /to	A	B	C	D	Total cost of trolleys depart from departments/m
A	----	10	15	40	65
B	15	----	20	10	45
C	----	30	----	35	65
D	----	10	25	----	35
Total cost of trolleys received from departments/m	15	50	60	85	210

Let's discuss the resultant flow matrix in table 3.5.c, the first row values in the table refers to the transportation cost of products to move from department (A) to department (B) and it is (10 $/m), the cost of transportation of products from department (A) to (C) is (15 $/m), and the cost of transportation of products from department (A) to department (D) is (40 $/m), the last value in the first row of the table (65 $/m) represents the total cost of all products to depart from department (A) for one meter, we should be aware that all these costs we got in flow matrix represent the cost of transportation per one meter because unit cost matrix represents the cost of one trolley to move one meter. Also we can notice from the table that the cost of moving trolleys from department (B) to department (A) is (15 $/m). There is no other cost for transporting trolleys to department (A) from other departments, which means all trolleys received in department (A) come from department (B) only, this can be seen clearly in the receiving row at the bottom of the table. We can get values of receiving row by making summation of each column values, for instance, to find the unit cost of receiving all trolleys in department (B) which come from other departments, we should make summation of all the values in the column under department (B): 10 + 30 +10 = 50 $/m.

Finally we can determine the overall unit cost of transportation of all trolleys departed and received between all pairs of departments by making summation of all values on the right column of the table, or by making summation of all the values on the bottom row of the table, this will be valid if all trolleys departed from departments will be received in the other departments. After making summation for the values in the bottom row of the table the result will be the total transportation cost per one meter of movement i.e. 15 + 50 + 60 + 85 = 210 $/meter.

3.5.6 Total Material Handling Effort for Initial Layout

We should put in mind we want to minimize total material handling effort, so for our initial layout, it is necessary to compute the effect of the distances on the cost of the transportation between each pair of department by multiplying distance matrix with the flow matrix. Figure 3.6 (a, b, c) below shows the calculations to get total material handling effort:

Table 3.6: (a, b, c) forming material handling effort for initial layout

a- Flow matrix

----	10	15	40
15	----	20	10
----	30	----	35
----	10	25	----

×

b- distance matrix

----	1	1	2
1	----	2	1
1	2	----	1
2	1	1	----

c- Resulting matrix: material handling effort

From/ To	A	B	C	D	Total cost of trolleys depart from department
A	---	10	15	80	105
B	15	---	40	10	65
C	---	60	---	35	95
D	---	10	25	----	35
Total cost of trolleys entered to department	15	80	80	125	300

The total material handling effort for the trolleys which depart from department (A) to department (B) is (10) dollar, from A to C, is (15) dollar, and from A to D, is (80) dollar, so by making summation for these values, the total cost of departing all trolleys from department (A) will be (105) dollar, and so on for other departments. Also, we can notice from the above matrix that the cost of moving all trolleys which entered to department (A) is (15) dollar, the total cost of moving trolleys which entered to department (B), is (80) dollar and so on. By making summation for the results in the last column in the matrix, or the summation for the results in the last row in the matrix we will get the total cost (300) dollar. So, we can see from the above matrix that the total material handling effort for our initial layout is (300 dollar) which represents the value of the objective function that we want to minimize to increase the profit of the facility.

CHAPTER FOUR

RESULTS AND SIMULATION FOR LAYOUT IMPROVEMENT BASED ON CRAFT TECHNIQUE

4.1 Possible Alternative Designs Based on CRAFT

We can improve our initial layout by rearranging the pairs of departments in the layout, according to CRAFT there are (6) possible alternative layouts can be derived from our initial layout of four departments by applying the following equation:

$$nC_2 = n \times (n-1)/2 \; = 4 \times (4-1)/2 = 6$$

CRAFT can only exchanges departments that are adjacent (share at least one common edge) or have equal areas. The only thing could change by rearranging location of departments is the distance matrix because the load matrix and the cost matrix i.e. the flow matrix will be the same. The six possible alternative layouts can be listed as follows:

Initial layout

A	B
C	D

B	A
C	D

1

C	B
A	D

2

A	C
B	D

3

D	B
C	A

4

A	D
C	B

5

A	B
D	C

6

Figure 4.1: initial and 6 alternative layouts.

We want to find the best design between the above (6) alternative layouts Figure 4.1, which has minimum material handling effort which i.e. minimum transportation cost.

4.1.1 First Alternative Calculation

B	A
C	D

Figure 4.2: first alternative layout

We should form new distance matrix according to first alternative and multiply it with flow matrix which still without change for all alternatives.

Table 4.1: Forming distance matrix for first layout.

from/ to	A	B	C	D
A	-----	1	2	1
B	1	---	1	2
C	2	1	---	1
D	1	2	1	---

Distance matrix

----	1	2	1
1	---	1	2
2	1	--	1
1	2	1	---

×

flow matrix

----	10	15	40
15	----	20	10
----	30	----	35
----	10	25	----

Table 4.2: Total material handling effort

=

From/ To	A	B	C	D	Total cost of trolleys depart from departments
A	---	10	30	40	80
B	15	---	20	20	55
C	---	30	---	35	65
D	---	20	25	----	45
Total cost of trolleys entered to department	15	60	75	95	**245**

For the first alternative layout we see that the total material handling effort is (245) dollar.

It's clear from table 4.2 that the cost of transportation of all trolleys from department (A) to department (B) is (10 $), the cost of transportation of trolleys from department (A) to department (C) is (30 $), and the cost of transportation of all trolleys moving from department (A) to department (D) is (40 $). To find the cost of all trolleys leaving department (A), we should make summation of all previous values in the first row values, so we will get the value of (80 $). The same thing we can interpret the other values in the rest rows, so the values in the right column of the table represent the cost of transportation of trolleys leaving each department. In the same manner we can interpret the values in the bottom row of the table in which each value represent the cost of transportation of all trolleys received in each department, for instance, the cost of transportation of all trolleys reaching department (A) is (15 $), The cost of transportation of all trolleys reaching in department (B) is (60 $), The cost of transportation of all trolleys reaching in department (C) is (75 $). The cost of transportation of all trolleys reaching in department (D) is (95 $). Finally we can obtain the total cost of transportation of all trolleys between all departments we should add every single cost value of transportation in the table, i.e. (10 + 30 + 40 + 15 + 20 + 20 + 30 + 35 + 20 + 25 = 245 $), or directly we can make summation of the values in the right column, or in the bottom row of the table as all trolleys depart from all departments will be received in all departments, i.e. for the right column: (80 + 55 + 65 + 45 = 245 $), or for the bottom row we can get the total cost: (15 + 60 + 75 + 95 = 245 $).

4.1.2 Second Alternative Calculation

C	B
A	D

Figure 4.3: second alternative layout

The only thing will change here is the distance matrix due to departments locations change i.e. the flow matrix still without change.

Table 4.3: forming distance matrix for second layout

from/ to	A	B	C	D
A	-----	2	1	1
B	2	---	1	1
C	1	1	---	2
D	1	1	2	---

Distance matrix (second alternative)

-----	2	1	1
2	---	1	1
1	1	---	2
1	1	2	---

×

flow matrix

----	10	15	40
15	----	20	10
----	30	----	35
----	10	25	----

Table 4.4: total material handling effort for second alternative

=

From/ To	A	B	C	D	total cost of trolleys depart from departments
A	---	20	15	40	75
B	30	---	20	10	60
C	---	30	---	70	100
D	---	10	50	----	60
Total cost of trolleys entered to department	30	60	85	120	**295**

For second alternative layout we see the total material handling effort is (295) dollar.

4.1.3 Third Alternative Calculation

A	C
B	D

Figure 4.4: third alternative layout

Table 4.5: Forming distance matrix for third layout

from/ to	A	B	C	D
A	-----	1	1	2
B	1	---	2	1
C	1	2	---	1
D	2	1	1	---

Distance matrix

-----	1	1	2
1	---	2	1
1	2	---	1
2	1	1	---

×

flow matrix

---	10	15	40
15	----	20	10
---	30	----	35
----	10	25	----

We did the same procedure as before. The resultant matrix is material handling effort for the third layout as in table 4.5 showing below:

Table 4.6: Material handling effort for third layout

=

From/ To	A	B	C	D	total cost of trolleys depart from departments
A	---	10	15	80	105
B	15	---	40	10	65
C	---	60	---	35	95
D	---	10	25	----	35
Total cost of trolleys entered to department	15	80	80	125	**300**

For third alternative layout we see the total material handling effort is (300) dollar.

4.1.4 Fourth Alternative Calculations

D	B
C	A

Figure 4.5: fourth alternative layout

Again we repeat the same procedure as previous alternatives:

Table 4.7: Forming distance matrix fourth alternative

from/ to	A	B	C	D
A	-----	1	1	2
B	1	---	2	1
C	1	2	---	1
D	2	1	1	---

Distance matrix

-----	1	1	2
1	---	2	1
1	2	---	1
2	1	1	---

×

flow matrix

---	10	15	40
15	----	20	10
---	30	----	35
----	10	25	----

Table 4.8: Material handling effort fourth alternative

=

From/ To	A	B	C	D	total cost of trolleys depart from departments
A	---	10	15	80	105
B	15	---	40	10	65
C	---	60	---	35	95
D	---	10	25	----	35
Total cost of trolleys entered to department	15	80	80	125	**300**

For fourth alternative layout we see the total material handling effort is (**300**) dollar.

4.1.5 Fifth Alternative Calculation

A	D
C	B

Figure 4.6: fifth alternative layout.

Again we should form the new distance matrix and multiply it with the flow matrix:

Table 4.9: Forming fifth alternative distance.

from/ to	A	B	C	D
A	-----	2	1	1
B	2	---	1	1
C	1	1	---	2
D	1	1	2	---

Distance matrix

-----	2	1	1
2	---	1	1
1	1	---	2
1	1	2	---

×

flow matrix

---	10	15	40
15	----	20	10
---	30	----	35
----	10	25	----

Table 4.10: Material handling effort fifth layout.

=

From/ To	A	B	C	D	total cost of trolleys depart from departments
A	---	20	15	40	75
B	30	---	20	10	60
C	---	30	---	70	100
D	---	10	50	----	60
Total cost of trolleys entered to department	30	60	85	120	**295**

From the resultant matrix we can see the total material effort for fifth alternative layout is (**295**) dollar.

4.1.6 Sixth Alternative Calculation

A	B
D	C

Figure 4.7: sixth alternative layout.

Repeating previous procedure, forming new distance matrix and make calculations:

Table 4.11: Forming distance matrix for sixth alternative

from/ to	A	B	C	D
A	-----	1	2	1
B	1	---	1	2
C	2	1	---	1
D	1	2	1	---

Distance matrix

----	1	2	1
1	---	1	2
2	1	--	1
1	2	1	---

×

flow matrix

---	10	15	40
15	----	20	10
---	30	----	35
----	10	25	----

Table 4.12: material handling effort sixth layout.

=

From/ To	A	B	C	D	Total cost of trolleys depart from departments
A	---	10	30	40	80
B	15	---	20	20	55
C	---	30	---	35	65
D	---	20	25	----	45
Total cost of trolleys entered to department	15	60	75	95	**245**

For sixth alternative layout the total material effort is (**245**) dollar.

4.2 Layouts Results Comparisons

We can list the results for all alternative layouts: 1- (245) dollar. 2- (295) dollar. 3- (300) dollar. 4- (300) dollar. 5- (295) dollar. 6- (245) dollar.

Now if we compare between all the alternative layouts we will see the best alternative layouts that we can select are layout number one and layout number six which have the minimum value of (245) dollar cost for each of them.

B	A
C	D

Figure 4.8: optimal design (layout 1)

A	B
D	C

Figure 4.9: optimal design (layout 6)

So by using CRAFT method we can find tow alternatives that ensure better layout than initial layout, but not always ensure minimum cost because this way doesn't treat all possible alternatives which should be the factorial of the number of departments (4!) =24 possible alternatives, and it is hard to make calculations for all alternatives because it takes very long time to make previous calculations for all of them, that's why CRAFT can improve our initial design and can get local optimal solution which limited alternatives can be used. To find global optimal solution

4.3 Simulation for Optimal Solution

We can find the best solution effectively and list all the alternative layouts if we build a program make the above calculations for all possible alternative layouts.

To find the global optimal solution we have to make calculations for all alternatives which should be (4! = 24) alternatives, the optimal solution could be the same solution we got before i.e. (245) dollar but not a must which means global optimal and local optimal are the same in this case the only benefit we will get is to list all extra alternative designs which satisfy this optimality. we can list all alternatives we can get from the original layout and try to solve them by using any of available programs, like MATLAB because it will take lot of time to make calculations handily, we can list all configuration distribution for alternative layouts which come from the factorial of departments number as in table 4.12:

Table 4.13: All possible alternative layouts can derived from initial one

Layout 1	A	B	C	D
Layout 2	A	B	D	C
Layout 3	A	C	B	D
Layout 4	A	C	D	B
Layout 5	A	D	C	B
Layout 6	A	D	B	C
Layout 7	B	C	D	A
Layout 8	B	C	A	D
Layout 9	B	D	C	A
Layout 10	B	D	A	C
Layout 11	B	A	C	D
Layout 12	B	A	D	C
Layout 13	C	A	B	D
Layout 14	C	A	D	B
Layout 15	C	B	A	D
Layout 16	C	B	D	A
Layout 17	C	D	A	B
Layout 18	C	D	B	A
Layout 19	D	A	B	C
Layout 20	D	A	C	B
Layout 21	D	B	C	A
Layout 22	D	B	A	C
Layout 23	D	C	A	B
Layout 24	D	C	B	A

4.4 MATLAB Program to Find Optimal Solution

As we said before the solution we got previously (245) may be locally optimal, not globally optimal, because not all alternative layouts (n! =24) calculated. According to CRAFT we calculated just (6) alternatives. To find the globally optimal solution we build a MATLAB program to calculate and compare all possible alternative layouts:

```
clear all
clc
format compact
s=4;   % Departments
% Flow=[0 10 15 40;15 0 20 10;0 30 0 35;0 10 25 0];
prompt={'A:','B:','C:','D:'};
dlg_title='Flow MATRIX';
num_lines=[1 40];
def={'0 10 15 40','15 0 20 10','0 30 0 35','0 10 25 0'};
A=inputdlg(prompt,dlg_title,num_lines,def);

-
-
for k=1:length(P)
   h=zeros(s);
  for r=1:length(row)
    h(row(r),col(r))=D(abcdi(k,row(r)),abcdi(k,col(r))); % x12
  end
  Dist{k}= h+triu(h,1)';
  FD{k}=Flow.*Dist{k};
  Cost{k}=sum(sum(FD{k}));
  cost(k)=double(Cost{k});
%   H=[H;h];
end
MinCost=min(cost)
ABCDind=find(cost==min(cost));
ABCD=[P(ABCDind,:)];
ABCD=['Cost';num2str(MinCost,'%.4d');'****';ABCD];
```

```
Figure('Position', [ 1200 50 200 770 ]);
handle = uicontrol('Style','Text', 'String', ABCD,...
  'FontSize', 30,'units', 'Normalized','Position', [.1.1.9.8]);
```

If we run this program we will get min cost is (245) dollar and we will get all possible alternatives that present the same cost, we can list all alternatives we get as below:

DCAB, DACB, CDBA, CBDA, BCAD, BACD, ABDC, ADBC. And the shape of configuration of these optimal designs will be as in Figure 4.10 (a,b,c,d,e,f,g,h) below:

D	C
A	B

Layout (a)

D	A
C	B

layout (b)

C	D
B	A

layout (c)

C	B
D	A

Layout (d)

B	C
A	D

layout (e)

B	A
C	D

layout (f)

A	B
D	C

Layout (g)

A	D
B	C

layout (h)

Figure 4.10: (a, b, c, d, e, f, g, and h) Optimal alternative designs got from MATLAB.

This program gives the engineers effective way to find the best selection to ensure optimality in minimizing the cost, and more flexibility by selecting any of the possible alternatives. This program could be developed to be used for more department number in which finding the optimality could be very difficult.

CHAPTER FIVE

OPTIMIZATION USING OPERATION RESEARCH (OR) TECHNIQUE

5.1 Introduction

In this chapter we will use operation research technique as a second step of optimization to enhance the efficiency of the plant. We will use this technique to find the maximum profit could get from the three products produced in the plant. The market demand and certain constraints will control the objective function to maximize the profit. Lingo and Excel programs were used for this purpose. Lingo program was used in this study because it provides many analyzable results which can help the decision maker to understand variable limits to predict the system behavior.

5.2 Data Collection

After optimizing the layout design of the work station, we could improve the efficiency by finding the best use of each work station in the company. We should realize the differences in each workstation in term of profit and processing time to supply the market demand for the three product. These differences in each workstation could be due to the manpower or the equipment used in each workstation or any other reasons.

5.2.1 Time Input

Time is very important factor affecting the productivity in any manufacturing plant, processing the products is machines not depend on the machine only but, also depend on the material to process itself, like its size, shape, toughness…etc. Let's consider the production time (in Minutes) / units produced varies from workstation to another (because of the workers skills) table 5.1:

Table 5.1: time (in minutes) / units.

workshop / items	Workshop 1	Workshop 2	Workshop 3	Workshop 4
1	4	5	6	9
2	7	8	4	12
3	9	12	11	14

From table 5.1 we can see that for (item1) it needs (4 minutes) in workshop one to be ready for marketing, (5 minutes) in workshop two, (6 minutes) in workshop three, and (9 minutes) in workshop four. In the same way we can list our readings in a matrix form for product two and three. In the first sight we may decide that it would be more profitable to process all the demand quantity of product one in workstation one which has the minimum processing time value of (4 minutes).This decision will be true if the cost of producing this item is less or same as in other workshops that's why, we need information about the cost of producing each item in each workshop or the profit come from selling each product.

5.2.2 Profit Input

Let's assume the profit in ($) per product varies from workshop to another as in the table 5.2 below:

Table 5.2: Profit matrix ($/product)

workshop / items	Workshop 1	Workshop 2	Workshop 3	Workshop4
1	8	7	5	10
2	10	18	11	16
3	12	14	15	19

Table 5.2 shows that the profit comes from selling one product of item1 processed in workstation1 is (8 $), the profit comes from selling one product of item 1 processed in workstation2 is (7 $), and so on for other values.

5.3 Constraints

Let's consider that there is 40 hours a week available at each workshop, the demand in the market per week is at least 120 units of product 1, 140 units of product 2 and 110 units of product 3.

5.4 Our Goal

Our problem is to know how much of each product should be produced. To find the solution we can formulate this problem as an LP.

5.5 Formulating the Problem as a Linear Program

To start formulating the linear programming model, we should transform the problem to a mathematical form and try to form a function that contain the profit, cost…etc. and try to maximize the profit or minimize the cost by the consideration of constraints given in the problem. If any value satisfy the objective function but violate any of the constraints given will be unfeasible and not acceptable in the solution.

5.5.1 Objective Function

Let X_{ij} be the decision variable which represents the number of product i to be processed in workstation j.

i= 1, 2, 3…

j= 1, 2, 3…..

To maximize the objective function, we should make summation of multiplying each item profit by its decision variable

Max $8X_{11} + 7X_{12} + 5X_{13} + 10X_{14} + 10X_{21} + 18X_{22} + 11X_{23} + 16X_{24} + 12X_{31} + 14X_{32} + 15X_{33} + 19X_{34}$

5.5.2 Constraints

First, we should interpret the conditions given in the problem to a mathematical inequality form with transformation of the time from hours to minutes to comply with the time unit in time matrix:

Limits of the available working hours per week for each workstation:

$4X11 + 7X21 + 9X31 \leq 40$ hr. *60minutes

$5X12 + 8X22 + 12X32 \leq 40$ hr. *60minutes

$6X13 + 4X23 + 11X33 \leq 40$ hr. *60minutes

$9X14 + 12X24 + 14X34 \leq 40$ hr. *60minutes

Constraints of total demand from each product:

$X11 + X12 + X13 + X14 \geq 120$

$X21 + X22 + X23 + X24 \geq 140$

$X31 + X32 + X33 + X34 \geq 110$

5.6 Simulation and Results

There are many programs to solve like this kind of problems which classified as linear problem. In this study, Lingo and Excel programs were used to find optimal profit and, the decision variables values.

5.6.1 Results Using Easy Lingo Program

```
MAX 8X11 + 7x12 + 5x13 + 10x14 + 10X21 + 18X22 + 11X23
+ 16X24 + 12X31 + 14X32 + 15X33 + 19X34
SUBJECT TO
2) 4X11 + 7X21 + 9X31 <= 2400
3) 5X12 + 8X22 + 12X32 <= 2400
4) 6X13 + 4X23 + 11X33 <= 2400
5) 9X14 + 12X24 + 14X34 <= 2400
6) X11 + X12 + X13 + X14 >= 120
7) X21 + X22 + X23 + X24 >= 140
8) X31 + X32 + X33 + X34 >= 110
END
```

When we run the program the results will show up as in table 5.3:

Table 5.3: easy lingo results

(Items) Variables	items production value	reduced cost
X11	**600**	**00.00**
X12	0.00	**4.2500**
X13	0.00	**11.500**
X14	0.00	**2.214**
X21	0.00	**4.00**
X22	**300**	**0.00000**
X23	**600**	**0.00000**
X24	0.00	**0.2857**
X31	0.00	**6.00**
X32	0.00	**13.00**
X33	0.00	**15.25**
X34	**171.00**	**0.00000**

The above table shows that the optimal profit could get is **20057.14** $ and the decision variables which satisfy this optimality should be 600 pieces of product one in workstation one, 300 pieces of product two in work station two, 600 pieces of product two in workstation three, and 171 pieces of product three in workstation four.

5.6.2 Solving the Problem Using Excel Program

After formulating the objective function and constrains the results using Excel Program can be seen in the following:

Forming the objective function as before

MAX 8X11 + 7x12 + 5x13 + 10x14 + 10X21 + 18X22 + 11X23 + 16X24 + 12X31 + 14X32 + 15X33 + 19X34

Constraints:

1- Hours per week should not exceed 40 hrs.

4X11 + 7X21 + 9X31 <= 2400

5X12 + 8X22 + 12X32 <= 2400

6X13 + 4X23 + 11X33 <= 2400

9X14 + 12X24 + 14X34 <= 2400

2- Demand per week from each product:

X11 + X12 + X13 + X14 >= 120

X21 + X22 + X23 + X24 >= 140

X31 + X32 + X33 + X34 >= 110

After using Excel solver we will get the same results:

Optimal profit = 20057.14

X11= 600

X22= 300

X23= 600

X34= 171.428

It's obvious that the results we got from both programs are same except the value of decision (variable 3) in (work station 4) which has the value of (171) in Lingo program while in Excel has a value of (171.4286), this difference is due to the accuracy options.

We can configure our results on the layout design of the company Figure 5.2:

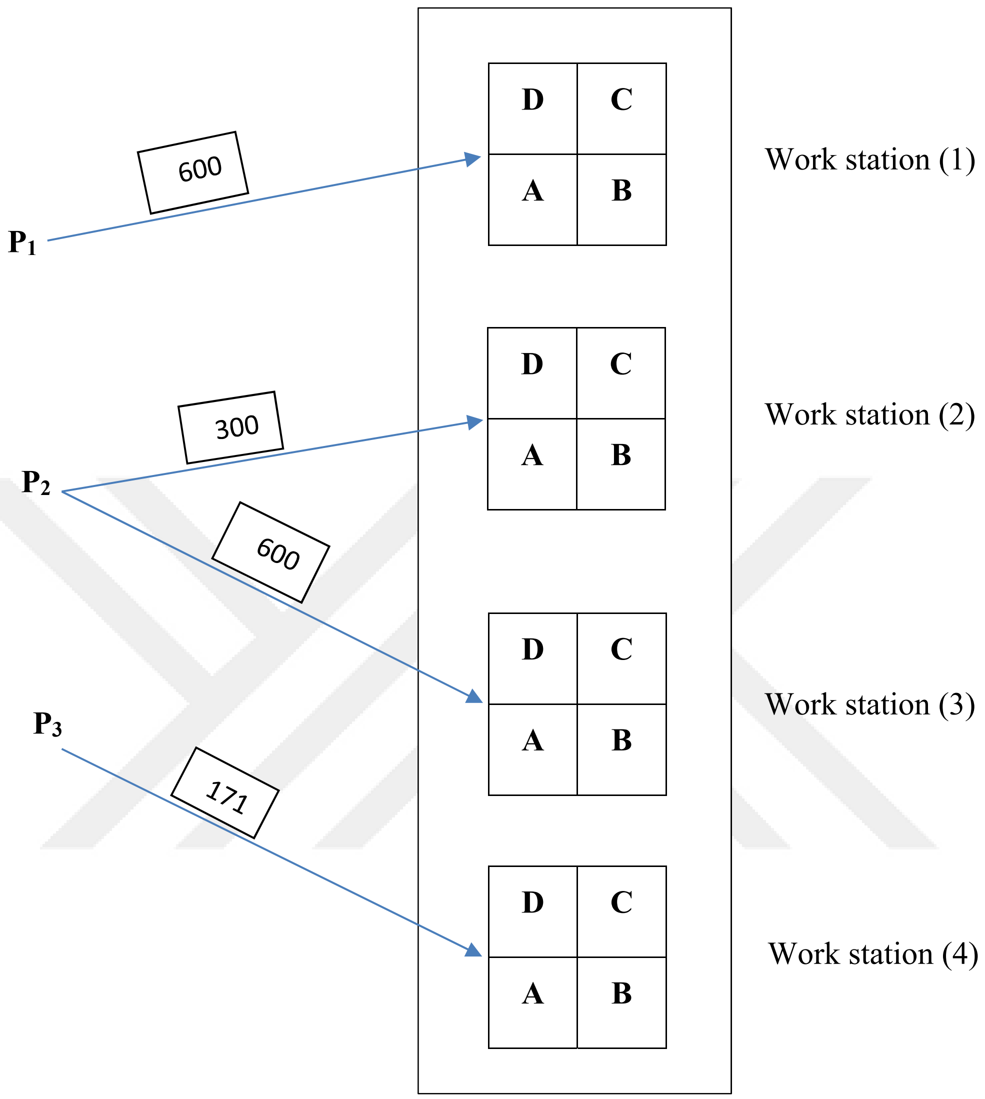

Figure 5.1: results representation

CHAPTER SIX

CONCLUSIONS AND FUTURE WORKS

6.1 Layout Design Improvement Conclusions

1. CRAFT is an improving algorithm depends on initial layout design to find local optimal design solution.
2. Departments' replacement can be done when they have the same area, or sharing the same boundary edge.
3. According to CRAFT we can't make replacement for departments with different size and not adjacent.
4. No improvement in applying CRAFT algorithm will be reasonable, when the initial layout is the optimal design.
5. CRAFT algorithm can be considered as a poor method, because it doesn't consider all possible alternatives, so optimal solution get from CRAFT algorithm is a local optimal solution, but can coincide to be global optimal as in our results shown.
6. We can see from the previous alternative layout results that some of them symmetric.
7. Layout design improvement in our study based on distance between departments.
8. Results based on rectilinear distance between centroids, if Euclidean distances considered, it will may lead to another solution.
9. If the same mean of transportation used between all pairs of departments then, departments of higher transportation trips should be placed close to each other, but this not always true if the mean of transportation between departments is different.

10. MATLAB program was built in a way to evaluate layouts with any number of departments according to the capacity of the computer by changing inputs according to the layout.

6.2 Layout Design Improvement Future Work

It is possible to build a MATLAB program for larger number of departments, it could make the solution highly effective, and it can list all possible alternatives which satisfy optimality. When we dealing with factorial of the number this means large number of alternatives, so the classical methods may be not effective.

6.3 Operation Research Technique Conclusions and Future Works

If we check the results of decision, we will see that some workstations didn't participate in producing a specific products to insure optimality in profit. For example, all the demand from product 1 should be processed and supplied in (workstation 1), the need to involve this product in other workstations arise when (work station 1) is not able to fulfill all the demand from this product. The importance of using Lingo program comes to give us enough information about how to engage this product in other work stations, (reduced cost) in the results of Lingo program shows that the solution will decrease by 4.25 $ for this product 1 in workstation 2 if the value of this variable (X12) increased one unit. Same thing for variable X13, and X14, X21, X24, X31, X32, and X33, all these variables were not engaged in our optimal solution and their benefit is to have information about their effect in the, which have (reduced cost) value to present an idea about how to be enrolled in the solution of optimality. The basic variables which involved in the solution have values of reduced cost equal to zero, this because these variables already involved in the solution and no need to bring them to the solution. Another important privilege for choosing Lingo program is to find a new optimal solution easily when the variables change these limits, this will give more flexibility to make any change if necessary to find the best solution for optimal profit easily, and make specialist engineers more predictable for the system according to the continuous real life changes. There are relatively little multistage optimization studies focusing on layout design optimization and its effect on the other stages optimization.

REFERENCES

1- Philipp Hungerländer, 2014, Semidefinite Optimization, Approaches to Applications in, Facility Layout and Logistics, zur Erlangung des akademischen Grades Doktor der Sozial- und Wirtschaftswissenschaften.

2- Pranavi Yerasi, 2011, productivity improvement of a manual assembly line, master thesis, Submitted to the Office of Graduate Studies of Texas A&M University.

3- Esra E. Aleisa Li Lin, 2005, (Layout Optimization Then Simulation, or Vice Versa?) Proceedings of the 2005 Winter Simulation Conference M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds.

4- Anucha Watanapa, Phichit Kajondecha, Patcharee Duangpitakwong, and Wisitsree Wiyaratn, 2011 (Analysis Plant Layout Design for Effective Production), proceeding of the international multiconference of engineers and computer scientists 2011 imecs, hong kong.

5- Shukla Abhinav*, Vimal Jyoti, Chaturvedi Vedansh, 2013 (Analysis of Plant Layout for Reducing Production Cost) 2013, Available online www.ijsrr.org.

6- Hari Prasad.Na, Rajyalakshmi.Gb, Sreenivasulu Reddy.Ac, 2014, (A Typical Manufacturing Plant Layout Design Using CRAFT Algorithm), 12th Global Congress on Manufacturing and Management,

7- 1 Orville Sutari, 2 Sathish Rao U, 2014, (Development of Plant Layout Using Systematic Layout Planning (SLP) To Maximize Production – A Case Study), Proceedings of 07th IRF International Conference.

8- Vivekanand s Gogi1, Rohith D2, Shashi Kiran K3, Suhail M Shaikh 4, 2014, (Efficiency Improvement of a Plant Layout), International Journal of Innovative Research in Science, Engineering and Technology

9- J L Riggs, Wiley, 1987, Production Systems, https://www.ifm.eng.cam.ac.uk/research/dstools/fromto-chart/

10- Kumar Kasdekar, 3Sharad Agrawal, Nov.-2014, Layout Design and Evaluation Using Computer Relative Allocation of Facilities Technique 1ANNANT Dhawan, 2DINESH International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume- 2, Issue-11,

11- Plant layout design, *August, 2013*, The International Journal of Business & Management (ISSN 2321 –8916) www.theijbm.com /1.BM1307-011.pdf

12- W. Wiyaratn, and A. Watanapa, 2010, "Improvement Plant Layout Using Systematic Layout Planning (SLP) for Increased Productivity", World Academy of Science, Engineering and Technology 72.

13- Kevin So, "Facility layout improvement", (2008), The university of British Columbia 1-37.

14- Amine Drira, Henri Pierreval, (2007), "Facility layout problems: A survey", Elsevier, Annual Reviews in Control 31, 255–267.

15- Stefan Bock, (2007), "Detailed layout planning for irregularly-shaped machines with transportation path design", European Journal of Operational Research 177 693–718.

16- Uttapol Smutkupt, and Sakapoj Wimonkasame, 2009, "Plant Layout Design with Simulation", Proceedings of the International Multi Conference of Engineers and Computer Scientists 2009 Vol II, IMECS 2009, March 18 - 20, 2009, Hong Kong.

17- Arostegui. M, Kadipasaoglu. S., Khumawala. B, 2006, An empirical comparison of Tabu Search, Simulated Annealing,and Genetic Algorithms for facilities location problems. Springerlink International journal of Production Economics 103 (2006) 742–754

18- Balakhrishnan, J., Cheng, C.H., and Kam, F.W.,. 2003. FACOPT: A user friendly Facility Layout optimization System. Journal of Computers and Operation Research. Vol. 30, pp. 1625-1641.

19- Nica, M. Lucian, Ganea, M. Donka, G. 2008. Simulation of Queues in Manufacturing Systems, Anals of the Oradea University, Fascicle of Managament and Technology Engineering, Vol. VII. Page 56-61.

20- Ekren, B.Y., Ornek, A.M., 2008. A Simulation based experimental design to analyze factors affecting production flow time, Simulation Modeling Practice & Theory vol. 16, p. 278- 293.

21- Rieth, D. Gerlach, S., 1996. Planning and controlling of flexible assembly systems for automotive industry. Proceeding of the IEEE International Symposium on Computer-aided Control System Design, Dearborn, September 1996, 15-18.

22- Hamid A. Taha, Operations Research an Introduction, Ninth Edition, p43.

23- E. F. Robertson J. J. O'Connor. George Dantzig. 2003, http://www-history.mcs.standrews. ac.uk/Biographies/Dantzig George.html.

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