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A PERFORMANCE COMPARISON OF DISCRETE REPRESENTATION-BASED FACILITY LAYOUT ALGORITHMS: A CASE STUDY

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by

Sema BAYRAK

April 2015

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Istanbul, Turkey

APPROVAL PAGE

This is to certify that I have read this thesis written by Sema BAYRAK and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Industrial Engineering.

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April 2015

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M.S. Thesis – Industrial Engineering
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ABSTRACT

The Facility Layout Problem (FLP) is generally focused on the manufacturing system, which is the critical component of each production system. In other words, FLP is related to material flows. Therefore, the basic aim of FLP is to find an optimal arrangement of manufacturing or service facilities which minimize the moves of workers and which can complete the material-handling operations in the shortest time possible. Determining the physical organization of a production environment can be given as an example for FLP.

The existing Facility Layout Algorithms are based on a flow which occurs from the centroid of one department to the centroid of another department. However, this principle cannot be applied in real cases. Therefore, the Spiral Facility Layout Algorithm (SFLA) has been developed by Eldemir & Sanli (2010) as an alternative for FLP. SFLA begins with putting a department at a center point and proceeds by placing each department from the center to the outside. With this algorithm, the adjacency between related departments can be provided and the total material handling cost can be reduced.

In this thesis, a case study will be used in order to compare the performance of the available facility layout algorithm, MCRAFT, versus the proposed algorithm, SFLA. This study will be applied by using real data which is obtained from a company in the metal industry.

Keywords: Facility Layout Problems, Discrete Representation Type, SFLA, Mcraft, Facility Algorithms

AYRIK TABANLI TESIS YERLEŞIM ALGORITMALARININ BIR PERFORMANS KARŞILAŞTIRILMASI: BIR VAKA ÇALIŞMASI

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ÖZ

Tesis Düzen problemleri (FLP), genellikle her imalatın kritik bir unsuru olan üretim sistemine odaklanır. Diğer bir deyişle, FLP malzeme akışı ile ilgilidir. Bu yüzden; tesis düzenleme problemlerinin temel amacı, işçilerin hareketlerini en aza indirmek ve en kısa sürede malzeme taşıma işlemlerini tamamlamak için imalat veya hizmet verilen tesislerde uygun düzenlemeyi bulmaktır. Bir üretim ortamının fiziksel organizasyonu belirlenmesi FLP için bir örnek olarak verilebilir.

Mevcut algoritmalardaki ortaya çıkan akış, bir bölümün merkezinden başka bir bölümün merkezine doğru oluşur. Ancak, bu ilke gerçek durumlarda uygulanabilir değildir. Bu nedenle, Spiral Tesis Yerleştirme Algoritması (SFLA) FLP için bir alternatif olarak Eldemir ve Sanlı (2010) tarafından geliştirilmiştir. SFLA bir merkez noktasına bir bölüm koyarak başlar ve her bölümün merkezden dışa yerleştirerek ilerler. Bu algoritma sayesinde, ilişkili bölümler arasındaki yakınlık sağlanarak toplam malzeme taşıma maliyeti düşürülmesi hedeflenmiştir.

Bu tezde, tesis düzenleme algoritmalarından olan mevcut Mcraft'a karşı yeni geliştirilen SFLA'nin bir vaka çalışması yapılarak performansları kıyaslanacaktır. Bu çalışma, metal sektöründeki bir şirketten elde edilen gerçek verileri kullanılarak uygulanacaktır.

Anahtar Kelimeler: Tesis Planlama, Tesis Planlama Algoritmaları, SFLA, Mcraft, Ayrık Tabanlı Tesis Yerleştirme Algoritmaları

To my parents

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I dedicate my master study to my beloved husband, Salih Reis BAYRAK, my little son, Serhat Ahmed BAYRAK, my parents and sister Mehmet, Sevim, and Selma BICIMVEREN who pray for me, support me, trust in me, and show an endless patience to make me able to complete this dissertation.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION

CRAFT: Computerized Relative Allocation of Facility Technique
CTC : Centroid to Centroid Distance
DCTC : Distributed Centriod to Centroid Distance
FLP : Facility Layout Problems
GT : Group Technology
GA : Genetic Algorithms
MIP : Mixed Integer Programming
SFC : Space Filling Curves
SA : Simulated Annealing
SFLA : Spiral Facility Layout Algorithm
TS : Tabu Search
QAP : Quadratic Assignment Problem

CHAPTER 1

INTRODUCTION

In today's world of global competition, manufacturers and businesses in the service sector must find ways to reduce their costs in order to survive. Businesses, determining the location of the appropriate factory organizations, stock to minimize the possible waste of the production system, while part of the optimal placement is to make cost reduction efforts at as many stages of the logistics as possible. Reducing costs also aims to increase productivity and efficiency.

1.1 INITIAL STATEMENT

Studies conducted to date indicate that business activity consists of many unnecessary costs. Departments/machines made from extra material, as well as information and document flow, lead to unnecessary transport, thus increasing costs. This is usually due to the unnecessary transportation departments as well as failure to appropriately place them in the machine factory. It is revealed that while the work done in the production system creates 35-70% of the cost of a product, the material may be associated with transport costs (Heragu, 1997). Tompkins & White (1984) studied a company engaged in the manufacturing of material handling activities, which corresponds to 20-50% of the total operating budget. Thus, if you place the company in accordance with this section, you may reduce production costs and increase the firm's competitive strength.

1.2 PROBLEM DEFINITION

The departments in a business or optimal placement of equipment are called "facility design" or "plant design." Plant design is one of the sub-titles of the Facilities Planning issue.

Facility planning determines how best to support the activities of objective material-fixed assets (Tompkins et al., 2010) for a manufacturing company planning production of a manufacturing facility which deals with the best way to support a hospital, the hospital facility is concerned with how to support the medical services provided to patients.

Facility planning, facility location, and facility location selection are concerned with issues such as plant design. However, the terms facility planning, facility location, and facility location selection should not be synonymous with plant design terms. Facility planning, facility location selection, and facility design can be divided into sub-topics. In this study, “Facility Design Problem" will be discussed as one of the sub-topics of plant planning.

1.3 PURPOSE OF STUDY

The machine in an office and the department areas cover information, materials, and resources, and so on by considering optimal placement defined as a planar area (Bozer & Meller, 1997). The problems are the change of the product design, the manufacturing line of the factory after removal of a product from a new product added or from the production line, the demand for a product significantly increasing or decreasing, the changes in process design, the displacement of one or more pieces of equipment, the adaptation of new safety standards, and/or the organizational changes that can occur in the company due to the decision to build a new factory. There are some goals in a facility design study: (Tompkins et al., 2010)

- Minimizing software investment
- Minimizing the duration of the total production
- Getting the best layout from existing fields
- Effectively utilizing people, equipment, and energy

• Ensuring the continuity of operation regulation
• Minimizing materials handling costs
• Maximizing the speed of customer response
• Facilitating the production and organizational process
• Providing for employee safety, job satisfaction and environmental responsibility

Based on the definition and purpose of the above, effective and appropriate workplace arrangements are very important for a business. This is the origin of the importance of workplace regulations which have focused on the problem and are often optimal for solving this problem, using intuitive, developed computer algorithms.

1.4 THESIS STRUCTURE

The following sections are organized as follows: chapter 2 will explain the basic concept of the Facility Layout Problem and the required data. Chapter 3 will compare the layout planning model from the past to today's traditional and modern techniques with the mentioned literature survey. Chapter 4 will explain in more detail the computer-aided facility algorithm which is used in chapter 5. In chapter 5, a factory which is active in the metal industry will be presented. Real case data will be applied to the algorithm while used discrete representation will be discussed and performed. Algorithms MCRAFT and SFLA are compared with the real case data which has 2 levels. The first one is management level, and the other one is production. A heuristic layout that produces the algorithms as an alternative layout will be described in this section. Evaluation of all alternative layouts will be made. Finally, in chapter 6, the thesis will analyze the result of the study and the scope of this study will discuss once again the importance of facility layout design.

CHAPTER 2

THEORETICAL BACKGROUND

In a factory or business, one of the most effective methods of increasing productivity and lowering costs is to eliminate unnecessary activities. In a plant design, these objectives should be performed in terms of personnel and equipment usage, material handling, and inventory reduction.

A good workplace layout which minimizes the cost of human movement needs the data base to calculate these costs (Heragu, 1997)

- Equipment/facilities between material flow
- Shape and area information for machine
- All machines will be placed in the available space
- -if- Placement constraints for machines
- Proximity requirements between machine pairs

All of the above data is not indispensable. However, in order to define material flow between machines, it is necessary to draft a settlement. This is used to determine the relationships between machines. Furthermore, the space requirement of each plant must be known.

The designer does not have the data numerically -— you can create subjective information for the machine flow from high, medium, and low.

In a plant, machine, or workstation, the space requirement should be calculated taking into account the necessary space to run around the workers and the corridor to move the material.

2.1 LITERATURE REVIEW

Layout problems are found in a few types of manufacturing systems. Typically, layout problems are related to the location of facilities in the factory or plant. They greatly impact the system performance. A lot of research related to facility layout has been published. The recent literature analysis is given here.

The placements of the departments in the facilities in the plant area are often referred to as "facility layout problem." It contains manufacturing cost, times, and productivity. But researchers do not agree on a common and exact definition of the layout problems. Tompkins et al., 1996 said that good placement of facilities supports the overall efficiency of operations and can reduce the total operation expenses up to 50%. Aleisa & Lin (2005) found that simulation studies are used to measure the benefits and performance of a given layout. In addition, layout problems are known to be complex and generally NP-Hard is written in Garey & Johnson (1979).

Koopmans & Beckmann (1957) were the first to consider this class of problems. They defined the facility layout problem as a common industrial problem in which the objective is to build facilities, so as to minimize the cost of transportation material between departments or facilities. Meller, Narayanan, & Vance (1999) considered that the facility layout problems are formed in finding a non-overlapping planar orthogonal arrangement of rectangular facilities so as to minimize the distance-based measure. Azadivar & Wang (2000) defined the facility as the determination of the relative location for, and allocation of the available space among, a given number of facilities. Lee (2002) reported that the facility layout problem consists of arranging unequal area facilities of different sizes in the total area; it can be bound to the length or width of the site area to minimize the total transportation cost and slack area cost. Shayan & Chittilappilly (2004) defined it as an optimization problem that tries to make layout and material handling systems more efficient while designing layouts.

Several design and topic clearly affect the nature of the problems,n particular, the production variety and volume, different material handling systems, different possible flows, number of floors, and facility shapes are affected. Some researchers selected these important factors to study.

Production variety and volume affect the layout design. Dilworth (1996) discussed that four organizations have fixed product layout, process layout, product layout, and cellular layout. Also, Proth (1992) and Hamann, & Vernadat (1992) studied different subjects in this area.

Facilities' shapes are often distinguished as regular or irregular in Kim & Kim (2000) and Lee & Kim (2000). Chwif, Pereira, Barretto & Moscato (1998) mention that a facility can have its given dimensions as length and width. Meller et al. (1999) also gave the ration in a fixed-shape block case.

When dealing with a material handling system, two dependent design problems are considered: finding the facility layout and selecting the handling equipment. Devise & Pierreval (2000) and Heragu & Kusiak (1988) mention that the types of material handling types determine the pattern to be used for the layout of machines. Layout design types which consider the material handling devices are the single row layout, multi-rows layout, loop layout, and open-field layout, as explained in Yang, Peters & Tu (2005). Djellap & Gourgand (2001); Ficko, Brezocnick & Balic (2004); Kim & Bobbie (1996); Kumar, Hadjinicola & Lin (1995) — all these studies used the single row layout when the facility had to be placed along a line. Loop layouts are studied by Chaieb (2002); Cheng & Gen (1998); Cheng, Gen, & Tosawa (1996); Nearchou (2006); Potts & Whitehead (2001). Chen, Wang, & Chen (2001); Ficko et al. (2004); Kim et al. (1996) studied multi-rows layouts. Yang et al (2005) studied open-field layout.

Johnson (1982) first addressed a multi-floor layout problem. Then other researchers focused on this type of problem, like Bozer, Meller, & Erlebacher(1994); Meller & Bozer (1997); Patsiatzis & Papageorgiou (2002); Lee et al.(2005); With elevators Matsuzaki et al.(1999); Lee, Roh, & Jeong (2005).

Layout evaluation can be separated into two basic types: static and dynamic layout. Most article are dealing with static layout problems; in other words, they assume the production remains constant over a long period of time. Recently several researches introduced the dynamic layout problems like Balakrishnan, Cheng, Conway, & Lau (2003); Braglia, Zanoni, & Zavanella (2003); Kouvelis, Kurawarwala, & Gutierrez, (1992); Meng, Heragu, & Zijm (2004).

There are several ways of mathematically the layout problems & solving them. Some researches consider it an optimization problem, or single or multiple objectives. Generally, problems are formulated through discrete or continuous formulation. In literature, the most commonly encountered formulation is the Quadratic Assignment Problem found by Koopmans & Beckman (1957) or Mixed Integer Programming found by Kaufman & Brocekx (1978), is modeled using this method in Izadinia et al (2014).

Discrete formulation is mentioned by Kouvelis & Chiang (1992) and Braglia (1996). The facility or departments are divided into the rectangular blocks with the same area and each block is assigned to the facility. This method is used by Fruggiero, Lambiase, & Negri (2006). If a facility has unequal areas, it can be made using a different block, found Wang, Hu, & Ku (2005). Discrete representation is commonly used for dynamic layout problems. The methods addressed are related to equal size facilities; Baykasoglu & Gindy (2001); Lacksonen & Enscore (1993). Budget constraints can be added to make the reconfiguration of facilities on the floor plant; Balakrishnan, Robert Jacobs, & Venkataramanan (1992); Baykasoglu et al (2006). In a real case, the rearrangement costs must not exceed a certain level on the budget.

Some algorithms use the discrete representation layout. MATCH is one of the discrete representation types developed by Montreuil, Ratliff & Goetschalckx (1987). SHAPE is another algorithm which is developed by Hassan et al. (1986). CRAFT is an improvement algorithm is developed by Armour & Buffar (1963). MULTIPLE is also an improvement type algorithm which is developed by Bozer, Meller, & Erlebacher (1994) for single- and multi-floor facilities. It uses space-filling curves. SABLE is developed by Meller & Bozer (1996) and uses space-filling curves. It is able to solve single- and multi-floor facility layout problems and helps the simulated annealing algorithm to find the best solution. Mcraft is an extended version of CRAFT which is a continuous representation type. It is developed by Hosni, Whitehouse, & Atkins (1980). The program divides facility area into bands and assigns the bands to departments and then applies the pair-wise exchange method to find the optimum solution.

The continuous representation type is found more relevant by several researchers like Das (1993); Dunker, Radonsb, & Westkampera (2005); Lacksonen (1997). It is based on the Mixed Integer Programming found by Kaufman & Brocekx (1978); Das (1993). All the facilities or departments are placed anywhere within the planar site and must not overlap each other, Das (1993), Dunker et al. (2005), Meller et al. (1999). The distance between two facilities can be calculated in rectilinear form as in Chwif et al (1998). The pick-up and drop-off points are generated constraints in the layout problem formulation mentioned by Kim & Kim (2000); Welgama & Gibson (1993); Yang et al (2005). The P/D stations are processed by Chittratanawat & Noble (1999); Aiello, Enea, & Galante (2002). The overlap was studied by Welgama & Gibson (1993) and Mir & Imam (2001).

Some algorithms use the continuous representation. They also generally define construction heuristic approaches under the approximated approaches. This is because improvement methods start from one initial solution and try to improve the solution with the new solution. SPIRAL is a continuous representation which is a construction-type algorithm developed by Goetschalckx (1992). It uses the adjacency -based objective function and is based on a theoretical approach graph. BLOCPLAN is developed by Donaghey & Pire (1990). It is both the construction and improvement algorithm types. This program can solve the single- and multi-floor problems. Qualitative and quantitative data types are used for program input. LOGIC also uses continuous representation. It is both the construction and improvement types of algorithms which are developed by Tam (1992). The program forms horizontal and vertical cuts that slice the area to divide the plant area into the departments. The program uses the distance-based objective function.

Exact approach methods were developed by Kouvelis & Kim (1992) which suggested the branch and bound algorithm for the undirectional loop layout problem. Meller et al (1999) also used this approach to solve the problem with a given rectangular available area.

The approximated approaches based on metaheuristic methods are divided into two sections: search methods (tabu search and simulated annealing) and evolutionary approaches (genetic and ant colony algorithms).

Chiang & Kouvelis (1996) developed a tabu search algorithm to solve the problem. They used a neighborhood based on the two exchange departments in the floor and included a long memory size, a dynamic tabu list size etc. Chwif et al (1998) is developed the simulated annealing to solve the problem with the ratio facilities’ sizes.

Mckendall et al (2006) suggested two simulated annealing approaches for the dynamic layout problem with same-size departments. Genetic algorithms have been researched to use this method. For static layout, studies are published; Banerjee & Zhou (1995), Mak, Wong, & Chan (1998), Wu & Appleton (2002), Dunker, Radonsb, & Westkamper (2003), and Wang et al. (2005); Sadrzadeh (2012); Pierreval et al (2013). For dynamic layout problems, genetic algorithms are published; Balakrishnan & Cheng (2000), Balakrishnan, Cheng, Conway, et al. (2003), and Dunker et al. (2005); Sahin et al (2010). Ant colony optimization has been used recently for solving layout problems. Solimanpur, Vrat, & Shankar (2005) enhanced an ant algorithm for a sequence-dependent single row machine layout problem. Baykasoglu et al. (2006) recommended an ant colony algorithm for solving the unconstrained and budget-constrained dynamic layout problems. Komarudin & Wong (2010); Ulutas & Kulturek-Konak (2012); Moosa et al (2013) have also studied this method.

The hybrid approach is the other metaheuristic method. It also solves facility layout problems. Mahdi, Amet, & Portman (1998) recommended a hybrid approach for minimizing the material handling cost. They used a simulated annealing algorithm to solve the geometrical part of the problem, a genetic algorithm to make decisions about the material handling cost, and Hitchcock's method to minimize the total material handling cost. Mir & Imam (2001) offered a hybrid approach for a layout problem which is an unequal area of department in the facility. Lee & Lee (2002) studied a hybrid genetic algorithm for fixed shape and unequal area facility layout problems. First tabu search and simulated annealing are used to find the global solution, then genetic algorithms are used for a local search process to search for the best solution. And Hernández et al (2015) also studied on hybrid approach (Drira et al., 2007) (Hernández et al., 2015).

In this section, we have tried to represent a recent survey related to the facility layout problem. Recent papers include more and more complex and/or realistic characteristics of the manufacturing systems. The usage of metaheuristics has more articles than other approaches. Evolutionary algorithms also have large coverage in literature. Also, in recent studies the hybrid method has been popular in optimizing the layout.

2.2 MEASURING FLOWS

Flow systems are very important to the facility planner. The planner views flow as the movement of goods, materials, information, or people. If the flow of materials orparts within a manufacturing facility is to be the subject of the flow process, then the process is called a material flow system. The subjects of material flow systems are the materials, parts, and supplies used by a firm in manufacturing products. The resources of material flow systems include the production control, quality control, manufacturing, assembly, and storage departments, material handling equipments, and factory storage.

The material flow system includes work order or bar codes or some warehouse records to follow the flow of materials. Communication types differ between departments (Tompkins et al., 2010).

The first step in designing a workplace engaged in manufacturing materials and parts is to determine the overall flow patterns formed by the business process inventories. Flow models, i.e. from start to finish, begin by processing the raw product, from the semi-final to the semi-finished products,containing the entire flow process (Heragu, 1997). Flow models, the "flow of workstations", "flow within the section" and "flow between departments," would be more accurate to describe them separately.

2.2.1 Flow within Workstation

When creating this flow, the movement of workers and ergonomics should be considered. The flow workstations, symmetrical, simultaneous, and natural, must be rhythmic and regular.

2.2.2 Flow within Departments

The flow in the section depends on the type of section. A production department monitors the flow of workflow products. The product flow is typically like the model shown in Figure 2.2.

Sections in a process flow between parts of the workstations should be small. Flow typically occurs between workstations and corridors. Flow patterns are formed depending on the direction of the workstation according to the corridors. Figure 2.1

shows three types of workstations-aisles arrangements and the results. The determination of the suitable workstation-aisle arrangement pattern is dependent on the workstations' occupied areas, available space, and the amount of material to be moved.

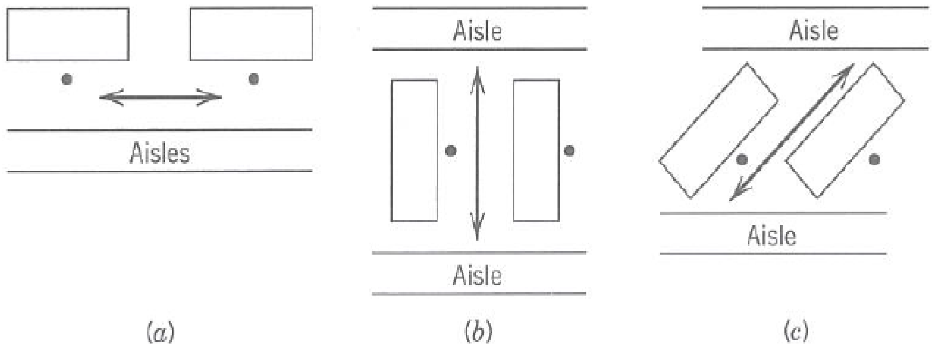


Figure 2.1 Flow within process departments (a) Parallel. (b) Perpendicular (c) Diagonal (Tompkins et al., 2010).

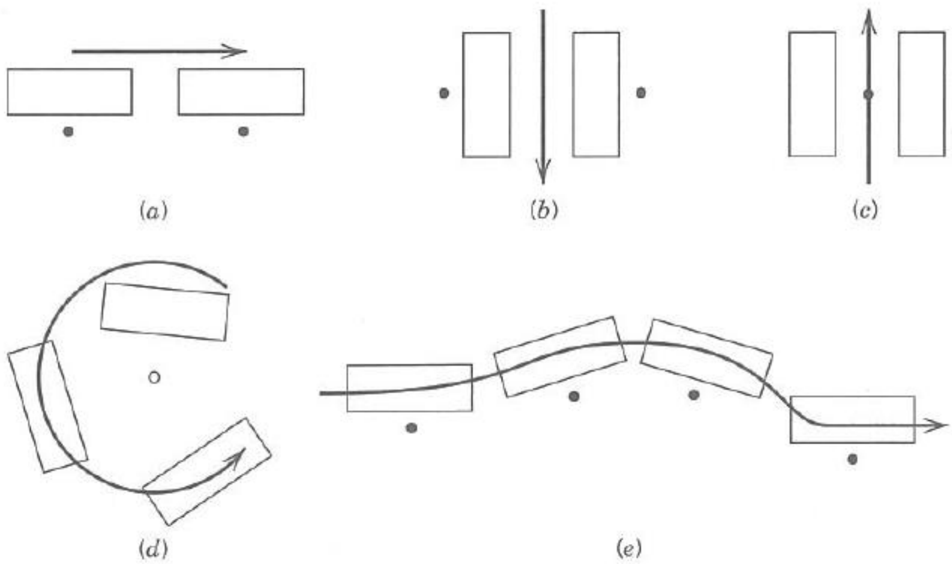


Figure 2.2 Flow within product departments (a) End to end (b) Back to back (c) Front to front (d) Circular (e) Odd- angles (Tompkins et al., 2010)

2.2.3 Flow between Departments

Flow between the regions is a measure commonly used to evaluate the entire stream in a facility. Flow usually consists of a combination of four types of flow patterns, shown in Figure 2.3. An important consideration in the flow between departments is the location of the entry and exit stations for each department. The locations of the entry and exit stations are often fixed because of the facility layout.

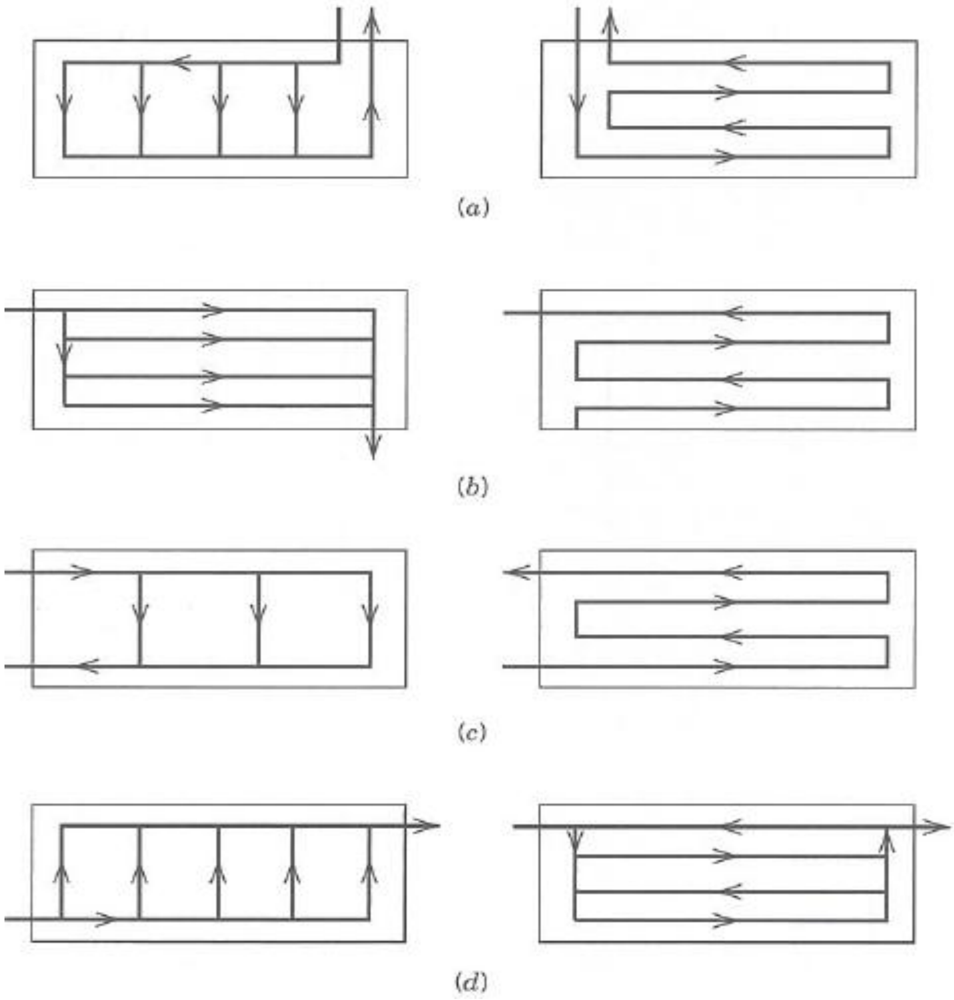


Figure 2.3 Flow within a department considering the location of input/output points.
(a) At the same location. (b) On adjacent sides (c) On the same side (d) on opposite sides. (Tompkins et al., 2010)

2.3 TYPES OF FACILITY LAYOUT

After deciding on the type of facility to be used in the production, workflow is determined by the position of the department and the machine. For positioning departments and machines, use the trial and error method. There may be many possible solutions to the object according to its own characteristics, but the problem is trying to make the most appropriate placement order. According to the evaluation objectives and constraints, it is possible to choose the advantage of the various calculation methods on some of them. Kumar & Suresh (2009) separated the layout group in 5 categories:

1. Process layout
2. Product layout
3. Combination layout
4. Fixed position layout
5. Group layout

2.3.1 Process Layout

According to the procedure, mass production placement is recommended. All machines performing similar type of operations are grouped at one location in the process layout. All lathes, milling machines, etc. are grouped in the same process. Thus, they are grouped together according to their placement in the facility by order of function. The material flow from a process line also changes from product to product toward the other. Usually the line is long and it is possible to have backflow. As long as there is not enough time for settlement, by-settlement is normally used according to the amount of products. Usually placements are used because of the variety of products produced according to the process workplaces and lower production volumes.

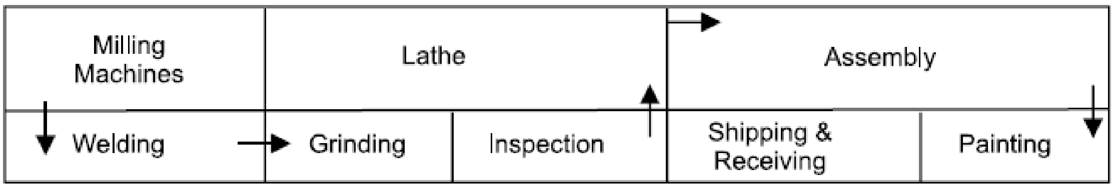


Figure 2.4 Process Layouts (Kumar & Suresh, 2009).

Advantages

1. Machines should be used better and less machines ued.
2. Labor and hardware flexibility are possible.
3. Fewer machines must be less than the cost of investment and general purpose machinery.
4. The increased use of production facilities.
5. A high degree of flexibility is provided in the machine and workers' job distribution.
6. Diversity work of the mission and work of the differences makes engaging and interesting.
7. Managers would be very knowledgeable about the work in their own department.

Limitations:

1. In material handling, long-distance movements may have a backward flow and material handling costs could rise.
2. Material handling is not mechanized.
3. Backwards flow inventory increases and the raw product inventory increase production time is extended.
4. Efficiency drops depending on the number of installations.
5. Output time (time interval between the processing input and output) will be extended.
6. Earnings and space are connected by the semi-finished stock.

2.3.2 Product Layout

These machines and ancillary services are placed in the order of items in the layout process, to make one or more products to reduce the cost of the production amount greater than the volume flow and the productive facilities arranged. They are used to perform fast and reliable work which requires special-purpose machinery. Product placement is used when one requires a separate production line for manufacturing production quantities of a product. A machines' layout based on a complete product cannot be shared with different products. Therefore it should be sufficient to ensure the efficient use of production volume equipment.

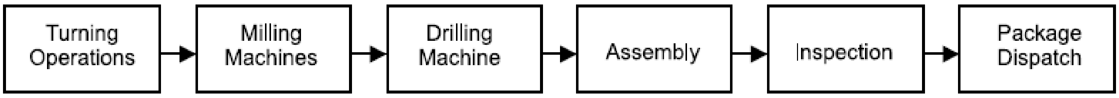


Figure 2.5 Product Layout (Kumar & Suresh, 2009).

Advantages

1. The flow of the production should be smooth and logical.
2. Semi-finished stock is small.
3. Total production time is short.
4. Material handling costs are minimal.
5. It is possible to simplify the planning and control systems.
6. Less space is occupied by work transit and for temporary storage.
7. Smooth flow and mechanical handling systems and material handling costs are reduced.
8. A good line balancing eliminates excess capacity and bottlenecks.
9. Production cycle is short because of the continuous flow of material.
10. The raw product inventory is low. Unskilled workers are able to work and learn the job.

Limitations:

1. A failure of one machine on the production line may cause interruption of the flow line from the machine after.
2. A change in the layout may require major changes in product design.
3. The rate of production determines the bottleneck machine.
4. High investment in hardware is required.
5. Not flexible; requires a change including rearrangement of the product.

2.3.3 Hybrid (Combination) Layout

According to placement and combination of products, the process of the settlement also includes the advantages of both types. Combined placement can be produced in different types and sizes. The machine is regulated by the settlement process, but is grouped in order to produce products of different types and sizes. It should be noted that the sequence remains the same in various products and sizes.

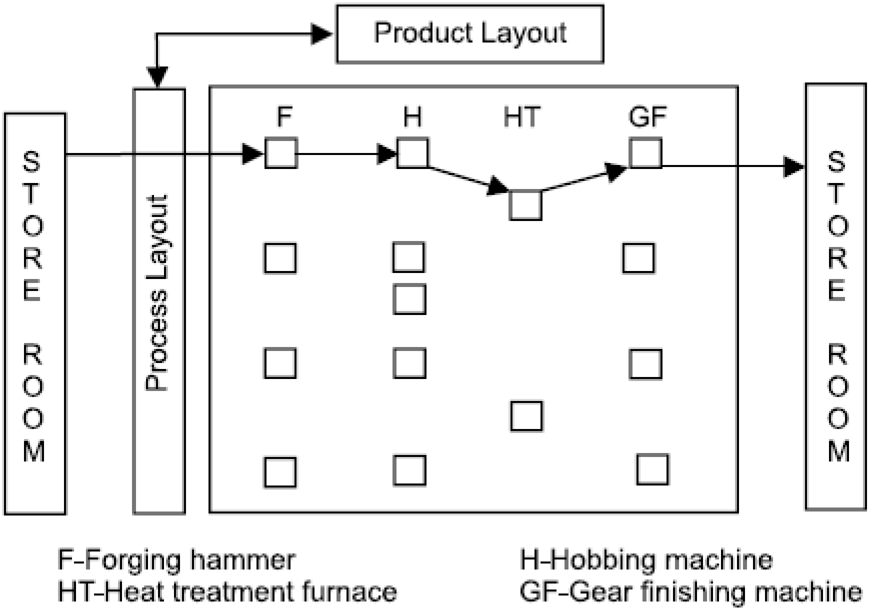


Figure 2.6 Combination layout for making different types and sizes of gears.

2.3.4 Fixed Position Layout

This is also called the project type of layout. In this layout, materials, or basic elements, are fixed by means of standing in a residential area. Machines, workers, and other materials are moved to this area. In this layout type, one or more in the production of heavy products and assembly of a large number of transport costs are suitable if they contain high heavy components. The biggest advantage of this type of layout includes:

1. Business spread and helps to increase the ability of workers.
2. Workers identify themselves with a product they are interested in doing the job.
3. This type of layout is largely flexible.
4. Less capital investment for the settlement arrangements.
5.

2.3.5 Group Technology based Layout

Group Technology (GT) separates a part and analyzes and compares it to similar features in the family group. GT can develop only with a mixture of layout by the product according to the process flow. These small batches are for technical business because they have the advantages of suitability and the flow lines to the economical production of various products are very helpful. GT application includes two main steps. The first step is to select a part of the family or group, and the second step is to edit the hardware domain in which specific components are used to process the family. They appear as small facilities on site. GT production planning cycles time, reducing the work and installation time. Thus, the cellular manufacturing layout (group settlement) is joining the layout of the product and the process. This placement also allows the advantages of both types. The main objective is to minimize the total production at the cellular transport and equipment costs. For this reason it is called a multi-purpose layout (Kumar & Suresh, 2009).

Advantages:

Group technology layout can increase:

1. Component standardization and rationalization.
2. Reliability of estimates.
3. Effective machine operation and productivity.
4. Customer service.

It can decrease the:

1. Paper work and overall production time.
2. Work-in-process and work movement.
3. Overall cost.

2.4 MATERIAL FLOW SYSTEMS

The arrangement of departments in a plant is due to flow between the departments. To create an alternative layout you need activity relationship data. Activity relationships can be classified in quantitative and qualitative data. In a facility with a large number of materials, information, and people moving between departments, quantitative flow measurements will be the basis of the settlement of departments. In communication, the establishment of organizational relationships is important and qualitative measure of the flow is used for designing the layout of departments. Mostly, a facility will need to use quantitative and qualitative flow measures.

2.4.1 Quantitative Flow Measurement

Depending on the amount of inter-departmental flow calculated as quantitative moved. These measures often used from-to-chart for recording as it can be seen in figure 2.7. (Tompkins et al., 2010)

		TO								
		Blanking	Stores	Milling	Press	Flashing	Machine Cleaning	Assembly	Packing	Storage
FROM	Blanking		20	45	60	32	4	78	60	
	Stores			40						
	Milling				50				78	
	Press						60			
	Flashing	8							50	
	Machine Cleaning			3						
	Assembly		5							
	Packing						34			90
	Storage									

Figure 2.7 From-to chart.

2.4.2 Qualitative Flow Measurement

This measurement was developed by Muther. Flows may be measured using closeness relationship values. These values indicate the reasons for the closeness charts obtained using the relationship diagram with values (Tompkins et al., 2010).

Value	Closeness
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness Okay
U	Unimportant
X	Undesirable

Figure 2.8 Closeness of Relationship Charts.

Code	Reason
1	Frequency of use high
2	Frequency of use medium
3	Frequency of use low
4	Information flow high
5	Information flow medium
6	Information flow low

Figure 2.9 Reasons of Relationship Values.

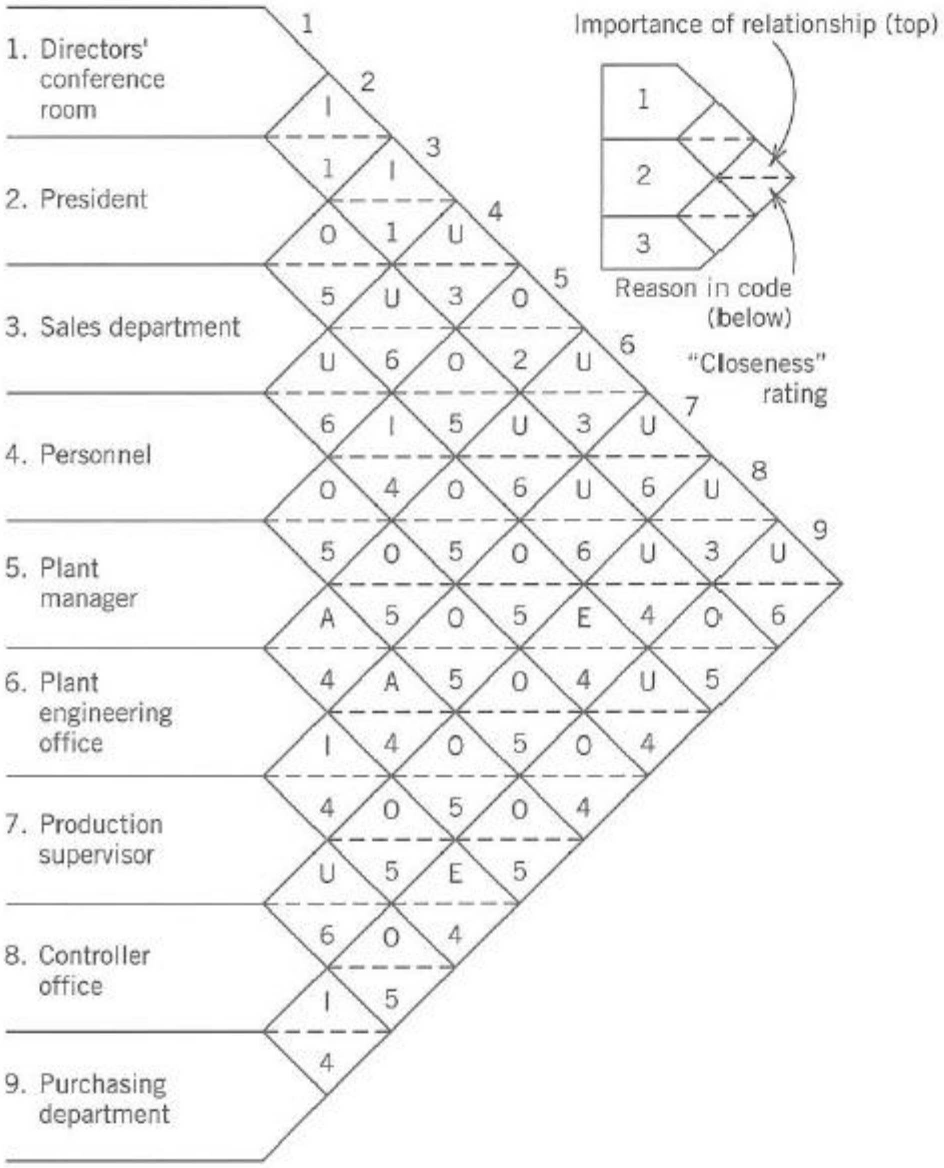


Figure 2.10 Relationship Chart.

2.5 SPACE REQUIREMENT

The amount of space required in the facility is the most difficult determination in the facility planning.

Space assignment can be stated as part of the process of allocation, since space in the building is simple. For assignment, the area of departments should be noted considering the required area. The shape and overall size of the factory building is designed to be predicted. Space requirements of each departments of the draft need to be processed and analyzed regarding the total area.

Warehouse activities, inventory levels, storage units, storage methods and strategies, equipment requirements, building constraints and personal requirements must be considered when determining the space requirement.

In manufacturing and office floors, space requirements can be defined by identifying workstations and departmental requirements respectively (Tompkins et al., 2010).

CHAPTER 3

LAYOUT PLANNING MODELS AND SOLUTION METHODS

Facility layout designs are interested in the arrangement of departments in the facility. Evaluation of the Department, with the adjacency matrix, can be shown between departments of the trip (round trip) and is based on the number. An interdepartmental trip can define the number of departments which can be used to decide the placement next to each other. Problems in the given partition scheme, inter-departmental relationships based on closeness, and distance of an optimization function are to find a layout that provides (Bhowmik, April 2008).

3.1 DESIGN PROBLEM

Facility design problem includes both design and optimization problems. Here, the problem of dealing with workplace regulations as a design problem will be referred to using the two traditional approaches. These are systematic layout planning and engineering design problems.

3.1.1 Systematic Layout Planning

Systematic layout can be said to have been developed in the late 1960s and isstill a popular approach. The systematic layout planning (SLP) is a tool used to arrange a workplace in a facility by locating two areas with high frequency and logical relationships close to each other. The process permits fast material flow in manufacturing the product at the lowest cost and with the least amount of handling. The SLP technique consists of 4 steps (Heragu, 1997).

Step 1: Decide The Location of Departments: This step includes the identification of locations for departments. For example, the area on the north side of the building or adjacent to the western side of the old building could be in another building.

Step 2: Establishment of the General Layout: At this stage, the flow between departments, closeness situations, and space requirements for each department is determined by considering the relationship between hands and is used as budget constraints and decisions layout type. The generated plans cost and non-cost factors are developed and selected for general work areas.

Step 3 : Creation of Detailed Layout : In step 2, the actual position of the designated department, layout of the department, and each machine and its auxiliary equipment is not provided with details about the location and layout of support services such as rest rooms and cleaning and inspection stations. While step 2 deals with the issue of the layout of the department, in step 3, the placement within each department and the layout details are considered.

Step 4: Establishing Selected Placements: Detailed layout of the affected employees and the appropriate layout after approval by an authorized person (such as administrative staff and managers) are selected. These plans and sketches should show all details, because these plans are used for the transport or installation of new facilities. In step 4 is the transport of plant/installation and capital for the transportation of the machine and the time allocated.

The most important steps are 2 and 3. The input data required for SLP has five classes:

Product (P): types of products to be produced
Quantity (Q) of the production volume of each part type
Routing (R): a sequence for each part type
Services (S): Support services, cabinets, inspection stations and so on
Timing (T): Part types which will be used when the machine will be produced during production

P-Q-R gives a matrix from where the material flow is created (from-to chart). This matrix shows the flow intensity between each pair of machines. Similarly, the relationship diagram with P-Q-S data is generated. Then, the relationship diagram is generated utilizing the flow matrix and the relationship diagram. The next step is to define the space requirements and qualifications. With these two pieces of information, taking advantage of the relationship diagrams, the space-relationship diagram is created. At this stage, thereusually form two or three alternative layouts. Finally, each layout option is considered, depending on cost and other intangible factors, and between them the best is selected.

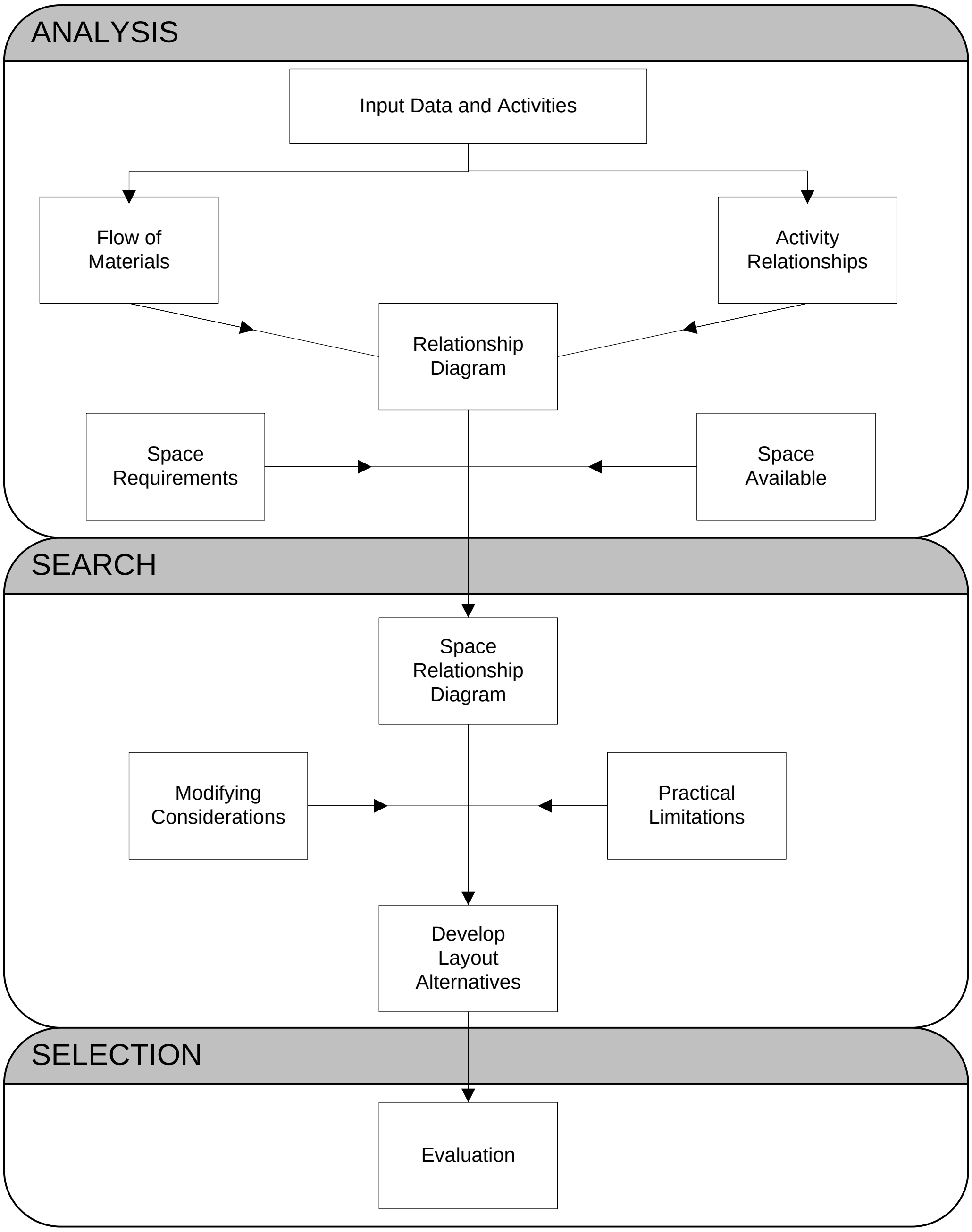


Figure 3.1 SLP Procedures (Muther 1961).

3.1.2 Engineering Design Problems

Engineering design problems consist of six steps listed below: (Tompkins et al., 2010)

1. Define the problem
2. Analyze the problem
3. Create design options
4. Evaluate the options
5. Select the preferred design
6. Create the selected design

In the traditional engineering design process, these are the process steps when applied to facilities planning: (Tompkins et al., 2010)

Define or redefine the objective of the facility: It should be noted by the business service in a production facility that quantitative products are to be produced or services to be provided. The volume or level of activity, if possible, shall be defined.

Specify the primary and support activities to be performed in accomplishing the objective: Main and supporting activities and requirements must be met; operations, equipment, personnel, and material flow must be defined and considered.

Determine the interrelationships among all activities: They support the activities within the facility boundaries which must determine interrelationships or how they affect each other. Both quantitative and qualitative relationships must be defined.

Determine the space requirements for all activities: While determining the space requirement for each event, all materials and equipment and personnel requirements must also be taken into account.

Generate alternative facilities plans: Options include both option plans, including the option to plant design facilities within organizations. Options include design and residential design options to include structural design and material handling systems.

Evaluate alternative facilities plans: For each alternative plan, the subjective factors determine and assess whether these factors include the facilities and operations that affect and influence efficiency level.

Select a facilities plan: Which alternative plan, goal and objectives of the facility meet the best criterion to select what it provides?

Implement the facilities plan: Once the plan is selected, the next step is to perform it. Analysts held responsible for this performance can be a good idea. As known, employees often show resistance to change. If a new work order is created, priorities are approved by the employee and must be supported. If there should be changes, the employee is required to achieve these changes and should be instructed about what desired outcomes shall be.

Redefine the objective of the facility: If new requirements will take place on the property, all property must have the updated plan. Changes in product design or transport equipment due to the changes of the flow model or the facility shall be updated.

3.2 ALGORITHM CLASSIFICATION

This can be examined under two main headings: objective function and representation type.

3.2.1 The Objective Functions

Facility layout algorithms can also be classified according to the objective function. The objective function’s purpose is to find the optimum cost of the layout design. There are two main purposes: one aim is minimization of the sum of flows times distances; the other aim is maximize the adjacency score.

3.2.1.1 Distance-Based Objective Function

Distance-based objective function — which is similar to classical quadratic assignment problem (QAP) — usesdata as a form-to chart. Distance-based objective function is calculated by multiplying the cost, distance, and flow between department 'i' and 'j'. The aim of the function is to minimize the cost per unit of moving time between departments. This cost is related with the material handling principle. Material handling costs increase with the distance unit loading cost.

$$min\ Z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij}\ c_{ij}\ d_{ij} \tag{3.1}$$

Let m denote the number of departments

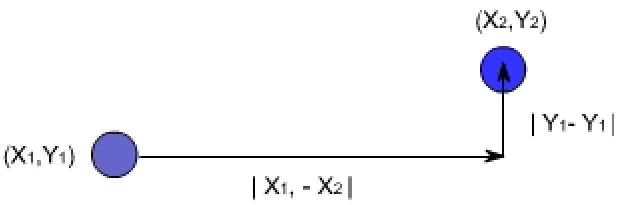
f_{ij} is the flow between department i to department j
c_{ij} is the cost of moving a unit load one distance unit between department i to department j
d_{ij} is the distance from department i to j

The distance measure involved in a facility location problem is an important element in formulating a function. There are two ways to measure the distance between two facilities or departments. First is centroid to centroid, and second is distributed centroid to centroid distance. These methods are commonly used in facility design.

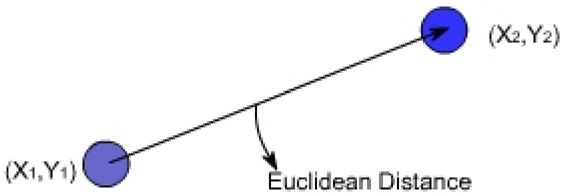
3.2.1.1.1 Centroid To Centroid Distance Approach

The distance between two department's centroid is called centroid to centroid distance (CTC). General assumption is that the flow is between the centers of departments. There are two ways to measure the distance between two facilities or departments. The first one is rectilinear and second one is euclidean distance.

When distance between two facilities is measured along paths that are orthogonal to each other, then that distance is termed rectilinear distance. Suppose two facilities are located at points represented by (X 1 , Y 1) and at (X 2 , Y 2) , then the rectilinear distance between the facilities will be : $d_{ij} = [\ |x_i-x_j| + |y_i - y_j|\ ]$.



When distance is measured along a straight-line path between the two facilities, then that distance is termed euclidean distance. Suppose two facilities are located at points represented by (X 1 , Y 1) and at (X 2 , Y 2), then the Euclidean distance between the facilities will be $d_{ij} = [(x_i-x_j)^2 + (y_i-y_j)^2]^{0.5}$.



3.2.1.1.2 Distributed Centroid To Centroid Distance Approach

Another distance measurement approach is distributed centriod to centroid distance (DCTC). This approach was used by (Bozer & Meller, 1997) firstly.

Normally CTC approach accepts that the flow of departments can only be from the center of one department to the center of another department. In practice, the flow can be anywhere in the department to anywhere in the other department. In DCTC, study assumes a second idea. Departments are divided into sub-departments and assume that flow occurs between these sub-departments. So, flows occur from every part of a department to the appropriate part of other departments. The function is below (Bozer & Meller, 1997).

$$min\ Z = \sum_i \sum_{k \in s(i)} \sum_j \sum_{l \in s(j)} \frac{f_{ij}}{a_i a_j} c_{ij}\ d_{ij} \qquad (3.2)$$

Where

f_{ij} is the flow between department i and j
c_{ij} is the cost of moving between department i and j
d_{kl} is the distance between sub-department k and l

a_i and a_j are the areas of department i and j

In general, CTC method is used because of the simplicity. But SFLA and Mcraft algoritms are used with the DCTC method to calculate the distance.

3.2.1.2 Contour Distance

Contour distance is also called 'free flow' in some papers. This approach allows travelling throughout the boundaries of the departments and follows the shortest way to reach other suitable departments. (Arapoglu et al., 2001)

This positive side of the measure is that the measured distance is correct. The disadvantage of the correct measure is that through the block layout design level one does not know the exact connection point of the departments' flow. These are to become clearer by the end of the design (Liu, 2004).

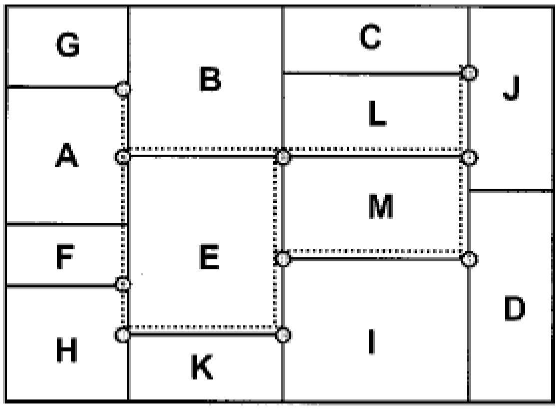


Figure 3.2 Contour Distance Layout (Arapoglu et al.,2001).

3.2.1.3 Adjacency-Based Objective Function

When the data is like a relationship chart, adjacency=based objective function is more suitable to use. The aim of the mathematical model is expressed through the following equation: (Tompkins et al., 2010)

$$max\, Z = \sum_i \sum_j \; r_{ij}\, x_{ij} \qquad 3.3$$

With the objective function, the sum of the flow values between neighboring sections to each other (neighboring points) is calculated. Where xij = 1 if i and j are adjacent sections, sharing a common border; otherwise xij = 0. r is the numeric value given, according to the strength of the relationship letters A,E,I,O,U and X used for the letter representation.

3.2.1.4 Weighted Cost Function

The logic of the method is the combination of the adjacency-based and distance-based objectives. Both objectives have disadvantages and also advantages. Some researchers have combined these two functions under weighted criteria approach for getting the optimal solution, but may not give a good solution. This method has some disadvantages in formulas (Liu, 2004).

$$min\ Z = \sum_i \sum_j \ f_{ij}\, c_{ij}\, d_{ij} + \sum_i \sum_j \ (w_{ij}\, x_{ij})\,(1 - x_{ij}) \qquad (3.4)$$

Where the parameter wij is the weighing factor between 0 and 1, rij is the numeric value of the relationship, xij is the adjacent score (Meller & Gau, 2007).

3.2.2 Layout Representation

The presentation of an FLP occurs with the basic mathematical model. This representation method provides the application of optimization algorithms more efficiently. There are several kinds of FLP presentation models, but there are two commonly used main types: discrete representation and continuous representation (Liu, 2004).

3.2.2.1 Discrete Representation

In the discrete representation method, the plant area is divided into rectangular blocks with the same area and shape, and each block is assigned to the facility. This type of representation reduces the problem in FLP (Facility Layout Problem). At the same time it removes some possible solutions. If the smaller sized rectangular (block size) is chosen, the number of removed solutions can be decreased. If the smaller rectangular size is selected, the computational effort will be increased (Drira et al., 2007) (Liu, 2004). In literature, most of the facility algorithms often use a discrete representation.

Some algorithms also use discrete representation. Match, Shape, Craft, Multiple and Sable are illustrated for usage type. The Quadratic Assignment Problem was first modeled for using the discrete representation type by Koopmans & Beckmann (1957). Then mixed and linear integer programming problems were used in discrete representation by in Kusiak & Heragu (1987), (McKENDALL et al., 2010).

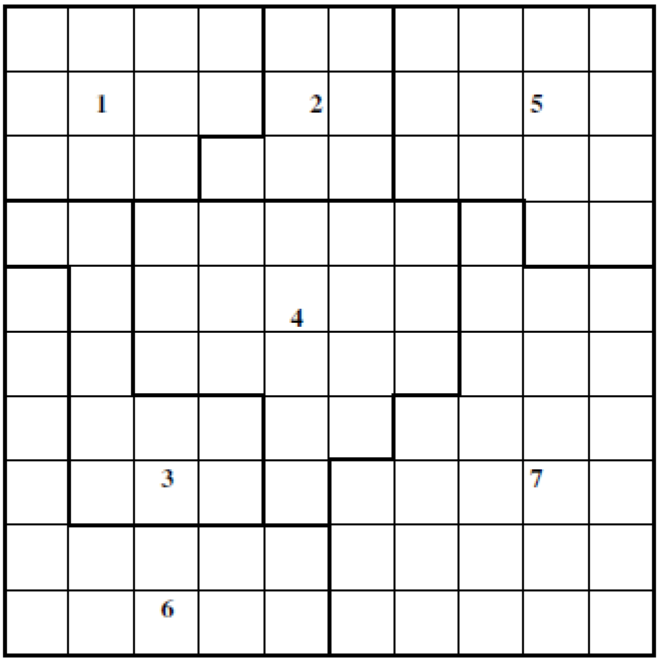


Figure 3.3 Discrete Representation Type.

For discrete representation, a famous solution for programming layout is based on Space Filling Curves (SFC). If the facility area is being divided into blocks (grids), a space filling curve defines a continuous sequence by the way of all neighbored squares in the used layout. SFC guarantees that a facility is never divided. However, this technique requires many rules to verify the connection of all location of a layout (Wang et al., 2005).

3.2.2.2 Continuous Representation

In a continuous representation, the facility area is not divided into the rectangular blocks. This uses the centroid, area (or perimeter) and width (and/or length) of a department to determine the exact location of the department in the floor of facility

(McKENDALL et al., 2010). But this type of representation raises the difficulty of the FLP. Some algorithms which use the continuous representation type accepted that the department shape is rectangular and also use a lot of variables to calculate the formulas. This affects the real optimal solution of the algorithms (Liu, 2004).

A few algorithms are used in the continuous representation type. Montreuil (1990) used the Mixed Integer Programming with continuous representation type. And also Heragu & Kusiak (1991) formulated the linear integer programming using the continuous representation type. In time, algorithms improved through research (Meller & Liu, 2007). And also some computer-aided algorithms programs use the continuous representation type. For example: Spiral, Blockplan, and Logic.

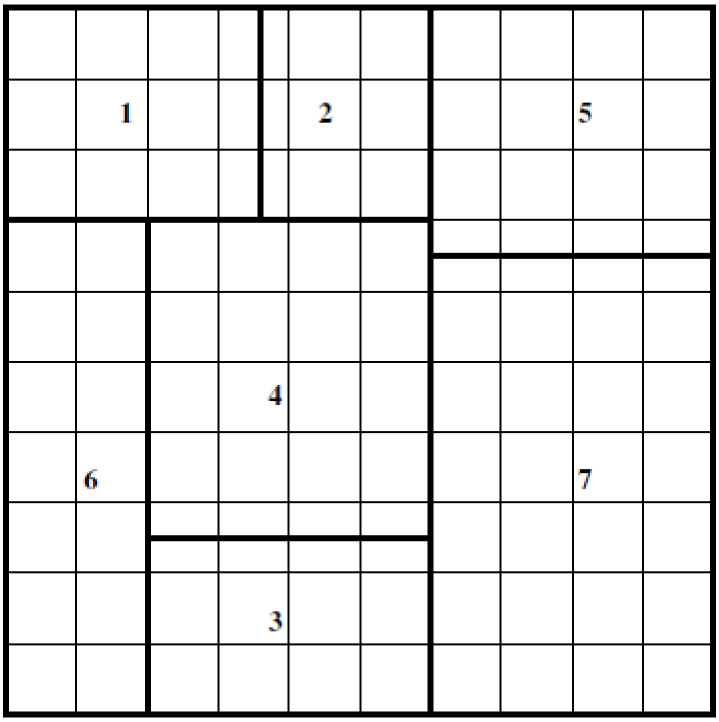


Figure 3.4 The Continuous Representations.

3.3 FLP SOLUTION PROCEDURE

Many literature sources of facility design methods are divided into two major categories, including algorithmic and procedural (Yang & Kuo, 2003).

Algorithmic approaches often simplify design constraints and objectives in order to reach a function that holds the place of the objective function which can be derived from the solution. The majority of existing literature describes algorithmic approaches (Heragu, 1997). Algorithmic approaches, especially commercial software, for example Spiral® (Goetschalckx, 1992) and Layopt® (Bozeret al., 1994), can efficiently the settlement alternatives. Nevertheless, the quantitative targets to be reached most of the time do not realize all of the design goals.

Muther (1973), according to the procedural approaches, can combine qualitative and quantitative objectives in the design process(Yang & Kuo, 2003). With these approaches, the design process has several steps divided and solved sequentially. A procedural approach to the application of qualitative success is usually provided by an experienced designer design and depends on the emergence of alternatives. Therefore, such an approach is personal (subjective) and robust science can produce a good solution because of the non-fundamental shortcomings. Therefore, personalization (subjectivity) and inefficiency prevent the possibility of settlement design of my adaptation’s procedural approach to solving the problem.

Facility location creation and evaluation require internal struggle because of the very nature and purpose of collecting information and its time-consuming process. Research effort in the past is revealed and a new methodology is aimed to develop solutions to meet these needs. Nevertheless, our algorithmic approaches were focusing mainly on minimizing the cost of the material handling. On the other hand, procedural approaches relied on the experience of experts. Neither algorithmic nor procedural residential design methodology are a necessary activity which can be applied to the solution of design problems (Yang & Kuo, 2003).

3.3.1 Traditional Methods

Some quantitative methods of analysis will be examined under the traditional methods topic.

3.3.1.1 Pairwise Exchange Method

The Pairwise Exchange method is the improvement heuristic method. The majority of layout problems involve the redesign of an existing facility. This method is not guaranteed to find the optimal layout. The final layout solution is dependent on the initial layout and this method does not consider the size and shape of departments. For finding the final layout, additional work has to be rearranged within the departments if size and shape are not suitable.

This method can be used with both the adjacency-based and distance-based objectives. The aim of the method is to minimize the total cost of transporting material among all departments in a facility. Generally researchers accept that the distance between departments is rectilinear and is measured form the centroids and all departments' areas are assumed to be of equal size.

The pairwise exchange method simply states that for each iteration, all feasible exchanges in the locations of department pairs are evaluated and the pair that results in the largest reduction in total cost is selected. If the lowest total cost of next is greater than the total cost of previous iteration, the calculation is finished. Thus, final layout is determined.

3.3.1.2 Graph Based Method

The Graph Based Method approach assumed the importance of layout property adjacent pairs. Areas and shapes of the first section are ignored, and each section is shown as a dot in the graph. The method uses a graph (nodes connected by arcs) to represent departments and their adjacencies to other departments. The objective function is a graph of the equation regulating the maximization of the rate of maximum adjacency between departments, using the adjacency based objective. Departments are nodes (Meller & Gau, 1996).

The adjacency score does not account for distance, nor does it account for distance other than adjacent departments. Although size is considered in this method, the specific dimension is not considered, and the lengths between adjacent departments are also not considered. The final layout is very sensitive to the assignment of weights in the relationship chart.

3.3.2 Optimal Algorithms

Many different optimal algorithms have been enhanced to find out the QAP. Optimal algorithms can give the optimal solution. Beside, all worksheet algorithms have high memory and computational time requirements. Generally categories are branch and bound algorithms and cutting plane algorithms.

In branch and bound algorithms, the solution procedure is continued on the basis of step-by-step single assignment of facilities planning. Trackback also occurs at every stage, except for certain assignments and advanced search will be carried out. The main difference between these algorithms is they can solve the potential lower bounds and problem size. It is observed that cutting plane algorithms can solve eight facilities' layout problems optimally. The process of branch and bound algorithm is faster than cutting plane algorithms in small number facility problems.

3.3.2.1 Quadratic Assignment Problems

Koopmans & Beckman (1957) were the first to model the problem of designing plants with material flow in equal area by using Quadratic Assignment Problem (QAP). QAP urban planning, including the control panel layout and wiring design, is used in a wide field of application. The aim of the QAP is minimizing the transportation distance in the facility. That all departments have equal space , and are assumed to be in a constant place, and all the priorities of layout, are known(Meller & Gau, 1996).

The reason for taking this name: objective function is a function where quadratic variables and constraints are linear functions of the variables. Placed in a residential area is a group of plants with the aim to minimize the costs associated with the flow problem, and area distances between a group are considered. The QAP has been often used to design the facility layout problem. Besides, this does not mean that all facility design problems can be solved by QAP (Shouman et al., 2001).

Mathematical expression of this type of problem:

$$min\ Z = \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{\substack{k=1 \\ i \neq k}}^{n} \sum_{\substack{l=1 \\ j \neq l}}^{n} f_{ik}\ c_{jl}\ x_{ij} x_{kl} \tag{3.5}$$

$$\text{Subject to} \quad \sum_{j=1}^{n} x_{ij} = 1 \qquad i=1,2,\ldots,n$$

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad j=1,2,\ldots,n$$

$$x_{ij} = 0 \text{ or } 1 \qquad i,j=1,2,\ldots,n \tag{3.6}$$

Where;

n	total number of departments and locations
a_{ij}	net revenue from operating department i at location j
f_{ik}	flow of material from department i to k
c_{jl}	cost of transporting unit load of material from location j to l

$$x_{ij} = \begin{cases} 1 \text{ if department } i \text{ is assigned to location } j \\ 0 \text{ otherwise} \end{cases}$$

3.3.2.2 Mix- Integer Programming Algorithm

A mixed-integer programming formulation for facility problems work was presented in 1990 by Montreuil. Model uses distance-based objective and is not based on traditional discrete structures (QAP). Instead, the permanent representation of a layout (continuous representation) is used. See the article for variable, formulas and notations (Gau & Meller, 1996).

3.3.3 Heuristic Approaches

Rosenblatt (1979) developed a heuristic algorithm that mixed the qualitative and quantitative direction of the facility layout design problem into minimizing the total material handling cost and maximizing the total adjacency rating. He built an efficient combination of alternatives from randomly generated new alternative layouts, and then specified different weights for these objectives to get optimal best layout solution (Chen & Sha, 2005).

Many applications produce an optimum, if not a reasonable solution close to the optimum of the problem, but are not guaranteed to be optimal algorithms of this solution. Maybe it can obtain the optimum solution, but it cannot be proved mathematically. Therefore, the heuristic algorithms are designed to give near the optimum solution. Heuristic algorithms, although they are not an optimum solution to the problem of known methods or conventional methods, are not economical when the solution is used in cases where the near-optimal solution is satisfactory. With heuristics, they found good results in large size samples. In a wide range of problems, what may be considered an acceptable cost performance is allowed to obtain data. Heuristic algorithms can also be divided themselves as follows (Heragu, 1997).

1. Construction Algorithm
2. Improvement Algorithm
3. Hybrid Algorithm

3.3.3.1 Construction Algorithm

Construction algorithms form a particular purpose to the extent addressed by individual departments which are taking place starting from the zero solution and which ultimately aim to implement the format layout plan. Many more construction algorithms are presented. These algorithms are named as:

- ALDEP (Automated Layout Design Program)
- CORELAP (Computerized Relationship Layout Planning)
- PLANET (Computerized Plant Layout Analysis and Evaluation Technique)
- LAYOPT (Layout Optimizing Program)
- CASS
- COLO2
- COMP1-COMP2-COMSBUL
- DOMINO
- GENOPT
- IMAGE
- LAYADAPT
- LSP

- MST (Modified Spanning Tree Algorithm)
- MUSTLAP2
- FATE
- RMA
- INLAYT
- MAT

The common objectives of these nominated construction algorithms are minimum total flow between departments or facilities, minimum total transportation cost, and adjacent desirability (Shouman et al., 2001).

CORELAP (Computerized Relationship Layout Planning) was first proposed in 1967 by Robert C. Lee and James M. Moore and subsequently developed by R. Sepponen. To run, the program needs some data. These are the number of departments, areas of departments, relationship diagrams, and relations weight matrix for entries (adjacency score). Generally must all of this basic data must be used for the algorithm (Adiguzel, 2012).

PLANET (Plant Layout Analysis and Evaluation Technique) was developed by Apple and Deisenroth in 1972. It is used to generate and evaluate plant layout. It does not limit the final layout to a uniform shape, nor does it permit fixing departments to certain locations, resulting in unrealistic layout. The advantage is used for generating an initial layout, which can be used as an improvement procedure. The measure of feasibility is defined as a total handling cost. Algorithms which accepted the flow between departments are the same in both directions (Diaz & Smith, 2007).

ALDEP (Automated Layout Design Program) was developed by Seehof & Evans in 1967. It is basically the same as Corelap. It differs in the way the first department is selected. The other difference that Corelap tries to generate one good layout, while Aldep generates up 20 different layout, rates them, and gives the opportunity to choose to the user (Diaz & Smith, 2007).

3.3.3.2 Improvement Algorithm

Such algorithms examine primarily existing plant layouts. The whole section is examined and placements are replaced with each other to improve the design format. It takes as input the layout of the existing layout, to get placement organization plans improved by changing the location of each of the sections on the plan. Hence the solution optimality of the improvement algorithms depends on the initial layouts. Examples of improvement algorithms are below:

- CRAFT (Compurized Relative Allocation of Facilites Tecnique)
- COFAD (Computerized Facility Design)
- COSFAD
- OPT Algorithms
- REVISED HILLER

These algorithms also need some data to run and solve. These are number and location of fix department, initial facility layout, transportation cost, distance matrix, arrival-departure matrix (from to chart) and relationship chart (Adiguzel, 2012).

COFAD (Computerized Facility Design) was developed by Moore in 1974. It is essentially a changeover of Craft to incorporate material handling alternatives. It aims to jointly select a layout and a material handling system. It will result in a minimally reduced transportation cost (Diaz & Smith, 2007).

LOGIC (Layout Optimization with Guillotine Induced Cuts) was developed by Tam (1992). It is a continuous-based algorithm. The algorithm is both a construction and improvement type algorithm. It uses the from-to chart and is measured by the distance-based objective function. The main subject is dividing the layout into smaller parts by executing successive guillotine cuts. These cuts are straight lines which go from one side to the other side of the building. Each cut is either vertical or horizontal. In a vertical cut, a department can be positioned to either east side or west side of the cut. In a horizontal cut, a department can positioned to either the north or south side of the cut. The program implements a series of horizontal and vertical cuts. Then appropriate subsets of the departments are assigned to these cuts (Tompkins et al., 2010).

MULTIPLE (Multiform Plant Layout Evaluation) was developed by Bozer, Meller, & Erlebacher (1994). It is like Craft. It uses the same data as Craft; the input data is the from-to chart and the objective function is distance-based. The algorithm starts with initial layout. Algorithms are done through two-way exchanges, and in each iteration the exchanges that make the largest cost reduction can be selected. The program is made of space filling curves which are used to reconstruct a new layout when any two departments are exchanged (Tompkins et al., 2010).

SPIRAL is an interactive program developed by Goetschalckx (1992). It creates regularly shaped layout adapted from a hexagonal grid structure. Input data is a flow matrix. The generated layout is converted to BlocPlan (Diaz & Smith, 2007).

3.3.3.3 Hybrid Algorithms

Algorithms that use multiple solution techniques are described as hybrid or combined algorithms. The solution of QAP is determined by using a combination of two heuristic algorithms. These combinations of algorithms are important in some cases to enhance the solution of the algorithm. Under this section, the hybrid algorithms are examples BLOCPLAN, FLAC and DISCON. Some hybrid procedures are characterized by their ability to give optimal quality results (Shouman et al., 2001), (Drira et al., 2007).

BlocPlan was developed by Donaghey and Piraeus in 1991 and generates placements on the block type. The algorithm uses both the relationship chart and data to flow from-to chart as input. The cost of the layout can be calculated using the distance-based objective function calculated or adjacency-based objective function. BlockPlan is determined by the number of program blocks and is limited to two or three blocks. Moreover, it is allowed to change the bandwidth (Tompkins et al., 2010).

Algorithms inputs are:

1. number of departments (max 18)
2. departments names and areas
3. relationship chart or from-to chart
4. length-width ratio of the facility floor

5. production information: number of product, number of unit loads, department sequence
6. information of any department with fixed location

The output is layout and points of the layout shown with a graphically corresponding score. It is a very impressive layout design program. The program is used as a construction and improvement algorithm, providing great flexibility to the user. It can be used for both single-storey and multi-storey residential layouts (Diaz & Smith, 2007).

3.3.4 Metaheuristic Approaches

Metaheuristic methods are methods based on the realization of the deep search of the most favorable regions of the solution space. Metaheuristic methods' quality of these solutions is higher than those obtained by conventional heuristic approach.

A metaheuristic is defined as an iterative generation operation which directs a traditional heuristic by intelligently exploring and exploiting the search space. Strategies are used in structure to find effective near-optimal layout solutions (Osman & Laporte, 1996). The meaning of the word is that Meta means an upper level, while heuristic is to find/discover.

The metaheuristic approach has four components: initial space of solution, search engine, learning and guideline strategies, and management of information structures; as well as four separated classifications: guided construction search process, guided local search process, population search process, and hybrids of the processes (Osman, 2001).

3.3.4.1 Genetic Algorithms (GA)

Genetic Algorithms (GA) is a search technique used to solve optimization problems that are adaptable. Individuals in the nature of food are in competition for resources such as water and shelter. At the same time, every individual wants to continue their lineage. Here in these conditions, the race winners (strong individuals with the best adaptation to the environment) will get the chance to continue the lineage. New individuals produced by the individual race winners also receive properties from ancestors.

GA, like the above mentioned "natural selection and adaptation," is an approach inspired by the principles laid out. Individuals represent the solutions of problems related to the gain. Individuals' (i.e. chromosomes) environment adaptation and survival status (i.e. the individual "fitness value") represents the ability to solve problems. GA selects the most appropriate for the current number of solutions and seeks to obtain new solutions from these solutions.

In general, GA is a simulation of the environment competition in natural life. It is a parallel processing in searching for solution space. For this reason, it enhances the potentiality to achieve global solutiosn without falling into the local optimal solution. It has been commonly implemented to solve mixed optimization problems (Wang et al., 2005).

In fact, numerous researchers are using this approach like Banerjee & Zhou (1995), Mak, Wong, & Chan (1998), Tam & Chan (1998), Azadivar & Wang (2000), Wu & Appleton (2002), Dunker, Radonsb, & Westka¨mpera (2003), and Wang et al. (2005) for the static layout problems, and Balakrishnan & Cheng (2000), Balakrishnan, Cheng, Conway, et al. (2003), and Dunker et al. (2005) for the dynamic layout problems. (Drira et al., 2007)

3.3.4.2 Simulated Annealing Algorithms (SA)

In Simulated Annealing (SA) a metal cools down; in freezing, the minimum energy turns into a crystal structure (annealing process) and takes advantage of the similarity between the minimum investigated in a more general system. It is heated to melting point and then rides over any solid when cooled to solidify. The cooling rate varies depending on the structural characteristics of the solid. As seen, the material is heated and then cooled rapidly. The best attempt to reach a certain format can be obtained from the annealing process SA perceives, such as particles in a system. So the algorithm is motivated from a physical annealing process used to get low-energy states of solids.

SA is a randomized local search procedure where small changes to current solution counseling to an increase in solution cost can be accepted with some probability (Gendreau, & Potvin).

SA was first introduced to optimization problems by Kirkpatrick (1983) and widely applied in many different areas. In electronic circuit design, image processing, routing problems, travel problems, material physics simulation, and cutting and packing problems, SA was successful in solving the flow scheduling and job scheduling problems.

The SA algorithm is an algorithm that improves step-by-step. During this improvement there are not only better solutions but also bad solutions with a certain probability. This is called the probability to accept the possibility. SA and other heuristics (these genetic algorithms are tabu search and neural networks, etc.) have strengths and weaknesses. The advantages of the SA are that it applies to the problem easier than other methods and is capable of providing good results for many combinatorial optimization problems. The disadvantages are that it requires high computer time and parameter selections must be careful for the solution of the problem. SA depends largely on performance parameters.

Kirkpatrick, Gelatt, & Vecchi (1983) applied the simulated annealing approach to the solution of a circuit board layout and wiring problem, and to the traveling salesman problem. Burkard & Rendl (1984) presented some computational results from the application of simulated annealing to QAP's (Wilhelm & Ward, 1987). Chwif et al. (1998) used a simulated annealing algorithm to solve the layout problem with facilities' sizes. Two neighborhood procedures are proposed: a pairwise exchange between facilities and random moves in the four main directions (upwards, downwards, leftwards and rightward). McKendall et al. (2006) studied two simulated annealing approaches for a dynamic layout problem with equal size facilities (Drira et al., 2007).

3.3.4.3 Tabu- Search Algorithm (TS)

The proposed high-level for the solution of combinatorial problems by Glover is an algorithm techniques called tabu-search (TS).

TS is usually prevalent in neighborhood solutions in searching for an optimal solution. It is so dependent on values of the algorithm's control parameters. TS techniques were examined before a certain number of solutions, keeping a list called the tabu list (creating a memory function). It is a search procedure that prohibits a while to return to the solution, and thus leads to a better point of the search solution space (Glover, 1989).

TS is used to enhance the layout plan. Glover (1986) was the first to enter the TS heuristic. Since then, TS has been successfully used to solve many types of combinatorial optimization facility layout problems. Skorin-Kapov (1990) used TS to solve the static facility layout problem using the discrete representation of the layout. Similarly, Taillard (1991), Battiti & Tecchiolli (1994), Chiang & Kouvelis (1996) used QAP to solve the FLP, and Chiang & Chiang (1998) presented effective TS heuristics for the discrete static facility layout problem. However, Kaku & Mazzola (1997) offered the only TS heuristic for the discrete (equal-area) dynamic facility layout problem (McKendall & Hakobyan, 2010).

3.3.4.4 Other Approaches

Other approaches which are also commonly applied to FLP are Variable Neighborhood Search, Particle Swarm Optimization, Ant Colony Optimization, Artificial Neural Network, and Hill Climbing Algorithm. Also, neural network, fuzzy logic and expert system are used when needed. In the following part of is given some information about commonly used algorithms.

Variable Neighborhood Search (VNS) was developed in by Pierre Hansen and Nenad Mladenovic (1997). VNS is aimed to change the neighborhood structure within a local search heuristic. The local minimum points of a neighborhood structure, according to another structure of the neighborhood, do not have to be a local minimum. According to all, the local optimum is a global optimum neighborhood structure. For many local minimum problems, one or more neighborhoods are close to each other (Gendreau & Potvin).

Particle Swarm Optimization (PSO) algorithm was put forward for the first time in 1995 by Kennedy and Eberhart. A lot of birds have been inspired by the movement "metaHeuristic" (communicating with neighboring iteration solutions that are close to the best results) algorithm. Such algorithm representatives are Ant Colony Optimization, Genetic Algorithms, Neural Networks, Evolutionary Algorithms, Simulated Annealing, Tabu Search. In the literature, a lot of plant layout has been studied using PSO and QAP applications although Liu & Abraham (2007) used the hybrid-fuzzy neighborhood structure by a PSO algorithm working on solving the QAP problem; Rezazadeh et al. (2009) studied the PSO with the regulation by dynamic plant layout; Wang & Zhang (2007), belonging to the owner who can give examples of the unequal area facility arranging work placements with PSO (Adiguzel, 2012).

Ant Colony Optimization (ACO) by Dorigo et al in 1992 was making a study based on the team work behavior of ants. Ants are able to find the shortest way to food source using the special chemical pheromone path left by other ants foraging for food. The same rule was applied for solving optimization problems. Ants while moving around for food keep the excretion of pheromones on their path. As the ants that took shortest path to find food start returning, followers of the pheromone path on the trail increase. Ants who move later, foraging for food, follow the trail. So, the concentration of pheromones increases. This can show the shortest path to all ants. The same principle is applied in the optimization problem to get the best solution (Gogna & Tayal, 2013). In the literature, many studies used the ACO algorithm to solve the facility layout design. Merz & Freisleben (1999) did a QAP study and comparison of heuristics; Gambardella et al. (1999) is running a QAP algorithm for ACO; Kendall & Shang (2004) are examples of hybrid made by a dynamic plant layout work (Adiguzel, 2012).

The Hill Climbing Algorithm method is an iterative improvement (local call) method. The basis of this method is defined according to certain rules to reach a neighboring solution from the solution. The importance of choosing a good neighborhood structure on the effectiveness of the TT method is great. The absolute good does not have to be the best.

A metaheuristic algorithm can give the best results in every problem. Meta-heuristic algorithms are all different application areas. Facility layout algorithms that can give you the best results for the design are: simulated annealing and ant colony optimization (Gogna & Tayal, 2013).

CHAPTER 4

COMPUTER-AIDED FACILITY LAYOUT ALGORITHMS

Computer-aided layout techniques save flow between departments and can be classified by the method of producing a variety of placements. The relationship between the section is from where the schema can be saved to a quantitatively or qualitatively relationship diagram. Two computer-aided layout techniques require quantitative flow entries which are CRAFT and COFAD. PLANET accepts as input streams both qualitative and quantitative, and ALDEP CORELAP wants qualitative flow entries.

A settlement can mean the development of an existing residential settlement or creating from scratch by making a settlement. A procedure is creating a new layout by developing an existing one in this "algorithm development." If an empty floor is creating a layout from the beginning then that "organizations algorithm" is considered. CRAFT and COFAD development are algorithms of the organization, the other three algorithms are PLANET, CORELAP, and ALDEP. Needed input from computer and aided layout technique is the same as those required in the manual layout of art.

This section only explains the used programs which are Craft-Mcraft and SFLA. Others are explained in chapter 3.

4.1 CRAFT (Computerized Relative Allocation of Facility Technique)

In 1963 by Armour & Buffa, this has been proposed as the first computer-aided placement algorithm. It was developed by E. S. Buffa, G. C. Armour and T. E. Vollman. Using flows, distances and unit transport costs for the transport, CRAFT is developing a layout with the aim of multiplying the cost minimization. CRAFT, wants as input costs "a unit of displacement from each unit". In this context, the following assumptions are needed to enter the transportation costs (Tompkins et al., 2010).With Craft the entries are as follows:

- The dimensions of the building
- The dimensions of the facilities
- Flow data between facility pairs
- Fixed facilities if they exist

CRAFT procedure begins by determining the center of the sections in existing layout. Then, it calculates the distance between the other linear and records the distance to a distance matrix. Transportation costs are from where the entries in the chart are calculated by multiplying the cost matrix of displacement and distance matrix (Tompkins et al., 2010).

We can say that distance-based objective function use craft calculating costs. Then, Craft, equal in size to or part of the common border, attempts to reduce the cost of transport replacing them. The following types of changes can be taken into account:

- Binary Exchange
- Three-way exchange
- Binary exchange following a three-way exchange
- Three-way exchange following binary interchange
- Two or three-way exchange of best

Each section is calculated from the change in the cost of transporting, and which handling interdepartmental change provides the greatest decline in cost is determined as the layout. With CRAFT, this procedure also applies to the new layout. The procedure of displacement of the part takes to achieve any reduction in transportation costs of providing the layout.

Dummy departments are other departments do not have a relationship with the flow, but who occupied parts. Dummy departments:

- To fill the building irregularities
- The facility area with the inclusion of departments (stairs, escalators, rest rooms, etc.)
- Used to help in the final determination of the corridor layout.

For the first two sections use of dummy with CRSFT,all departments are square or rectangular and there are no requirement stems from the space inside. With the use of dummy in the third section, the resort craft, the planner allows you to use to develop practical available layouts.

With CRAFT, what i and j facility costs every time you change the location of the accounts is a drop that much. In this cost reduction account, i and j coordinates are replaced with each other, including two plants, makes the following equation: (Heragu, 1997)

$$\sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{ik} + \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{jk} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{ik} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{jk} \tag{4.1}$$

Where:

f: the flow between facilities

d : the distance

The first two terms in the equation, i and j, in the previous case of binary interchange are part of its contribution to the cost of material handling; the last two terms indicate expressions to calculate the contribution from the binary interchange on the next situation.

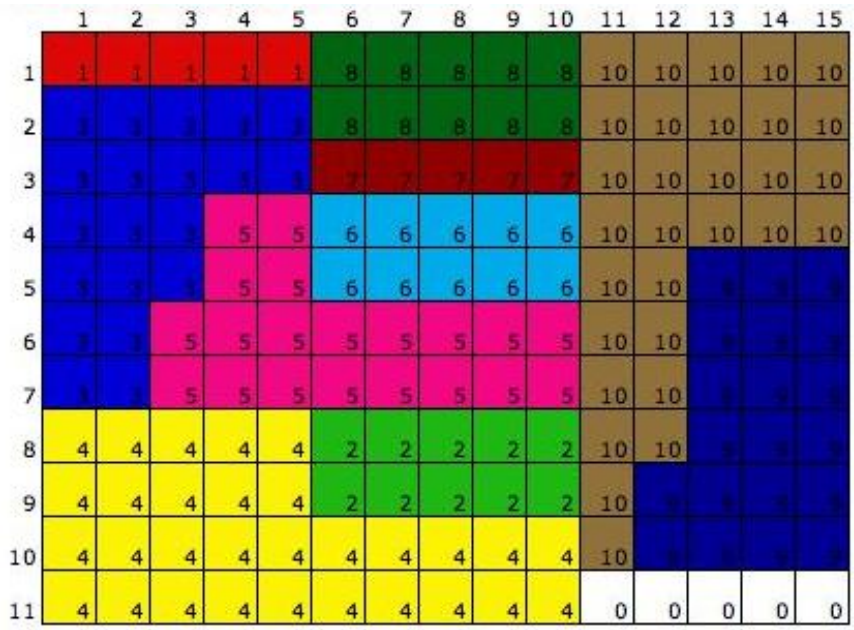


Figure 4.1 Craft layout solution design.

4.2 MCRAFT

Mcraft was presented by Hosni, Whitehouse & Atkins (1980). Mcraft is an enhanced version of Craft. Mcraft separated the facility area into bands and allocated the band to one or more departments. The number of bands in the facility layout is determined by the user.

The sweep method is used in Mcraft. So the band width is accepted to be the same for all the bands. As a result, Mcraft is not effective like Craft in fixed departments. This condition makes a very big complication to ing the optimum solution (Tompkins et al., 2010).

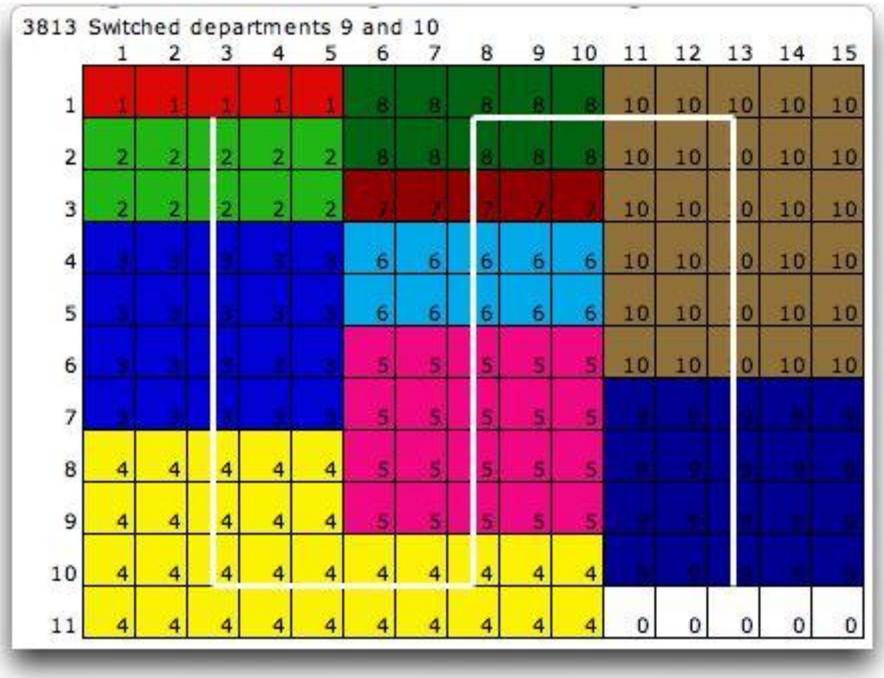


Figure 4.2 Mcraft layout solution design.

4.3 SFLA (Spiral Facility Layout Algorithm)

Spiral Facility Layout Algorithm is one of the newest programs developed by Eldemir & Sanli (2010).

This algorithm is presented in construction and improvement types of algorithms. The representation type is discrete and the objective function is distance-based objective function. Quantitative data are used, which are flow matrix and cost matrix. Three parameters are required to run the program. Also in the facility area, departments' area and x-y coordinated of centroid and facility length and width are entered. SFLA uses the pairwise exchange algorithm. The used route is a spiral pattern. The aim of using spiral pattern is that it centralizes the flow and collecsd the most related departments at the center of the facility for reduction of the distance between them for feasible material handling.

This program is inspired by Mcraft. All these properties are similar to Mcraft. However they have some differences between each other. Mcraft uses the sweeping pattern to find the layout. But SFLA uses the spiral pattern. Mcraft requires a bandwidth to make a block for routing the flow. SFLA requires both bandwidth and length to form the block size. The block size is calculated by giving the width and length of the facility. Suggested block size calculating formula is below: (Sanli, 2010)

$$Width = \sqrt{\frac{totalarea}{(\sqrt{\#of\ departments})^2}} \times \frac{facility\ width}{facility\ length} \tag{4.1}$$

$$Length = \sqrt{\frac{totalarea}{(\sqrt{\#of\ departments})^2}} \times \frac{facility\ length}{facility\ width} \tag{4.2}$$

This formula is used because the block size affects the total area‘s length and width. To keep the total facility area in suitable ratio, it uses this ratio formula to reach the appropriate size. Also, the user can give the band width and length values.

Initially the facility area, length, width and number of departments are entered as input. And also in the same step, flow matrix, cost matrix, and coordinates of the departments are entered. Or you can create a random problem to run the program. This filled the row randomly.

Second is that though block width and length are calculated or entered by user, the algorithm can define the space filling curve for layout. Firstly the number representation spiral curve is formed. According to initial layout, letter representations are formed by symbolizing the departments assigned to blocks with respect to their area. Then layout is formed.

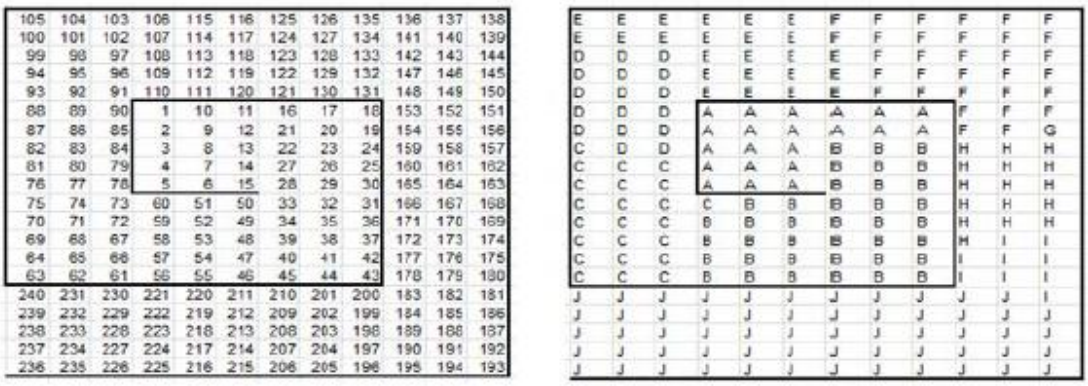


Figure 4.3 Numbers and Letters Representation of a Layout.

Then the improvement layout section can run. Making improvement layout can be developed by taking the random layout or entering the department manually into program. And also in this step, department cost and sequence of departments are shown.

The layout design process goes on with the pairwise exchange optimization for improvement. When the program finds the minimum cost from the initial layout cost, the program is terminated. In addition, the final layout is dependent on the initial (starting) layout. Optimum solution can be affected from the initial layout, so selection of first layout is important. Users can try a lot of different initial layouts then choose the best of them. When the user decides the initial layout, the layout improvement step can be run. So optimum layout sequence and cost can be calculated and final optimum layout can be formed (Sanli, 2010).

CHAPTER 5

APPLICATION AND COMPUTATIONAL STUDY

Rosenblatt (1986) defines the dynamic layout problem until today that many researchers have developed various approaches to solving the problem. Considering the resources available in the literature testing the identified problem-solving algorithms, the best known of the results of the study were able to reach the solution or solutions compared with the references that have been identified. However, the methods developing dynamic layout problems may be encountered in real life to be used as a study on what has not been reported yet.

In this thesis, computer-aided layout and especially the newly developed algorithms will be evaluated as SFLA algorithms. In making this assessment made only ever with literature, data taken from real-life problems has been applied. And compared with each other, the results suggested the availability of optimal solutions is aimed interpretation.

In this context, editing and getting the data for implementing computer-aided algorithms, and the evaluation and comparison of solution alternatives, can be interpreted in conjunction with newly developed SFLA.

5.1 INDUSTRY AND COMPANY INFORMATION

The general approach in the manufacturing sector to regulation of facility design during installation location of the identification and location of the workstation and the machine is not to be changed. For example, the company will be implementing heavy presses, changing the position of those presses, and excavating for new foundation.

This causes the rise in the cost and production disruptions. Therefore, changes are made at once.

On the other hand, the displacement is less than the cost of transport between the more important of machine tools, and the business is done by arranging placement in a certain period. In this way, it is possible to provide high gain.

The size of companies in the metal industry affects their production and machines are diversified. Small machines are used for detailed work, large machines are used for large jobs. Therefore, the products manufactured according to the occasional change in the settlement are performed.

In the present, our company is engaged in the manufacturing metal industry. The company has been active for more than 33 years, initially focused on the domestic market and for the last 4-5 years directed to exportation. The managers have accomplished the building of a factory which has almost 200 employees. This company has a wide range of customer portfolios all around the world and in Turkey as well. Monthly production average is above 150.000 pieces and our turnover is more than 10 million dollars.

They follow the new trends and technology and also try to spot the needs of kitchens to meet the market demands beforehand. They are aware of what change there is in kitchen fashion and they implement the changes immediately. They have a research and development department and one of the owners is the head of the department. With that they are sure that everything about the production and development is shambled by the superior’s control.

They export goods to more than 25 countries although their main market is North Africa and Middle East, Iran, Azerbaijan, Kazakhstan etc. They are also exporting to European countries. In terms of export figures, export volume is more than10 million USD and increases every year.

It has a five-floor building. Their production is focused mainly on cookware utensils. Production is carried out in four different product groups. These are pot, pressure cooker, samovar, and ceramic series. They offer many different types of products so they can be able to meet their customers’ demands. A point they would like to remark is that they are able to produce private labels so customers can have their requested products. Currently available products are based on layout and the most intense production process, which are positioned close to each other.

As a result of company review, a layout design will be applied to the production and management floors of the building. Information flows of management floor and labor force of production floor are increasing. It was observed that the existing order is not enough. The results of this study are expected to provide benefits to the company.

5.2 DATA COLLECTION AND ARRANGEMENT

5.2.1 The Plant's Current Placement Scheme

It is built on an area of 10000 m^2 and five-floor builds. There is need for all departments within the factory. Loading area is located in the outside of the building.

Factory layout according to the process has been set for the same or similar machines. Departments have been shaped by these groups.

Factory production and management of existing floors of the layout is like that:

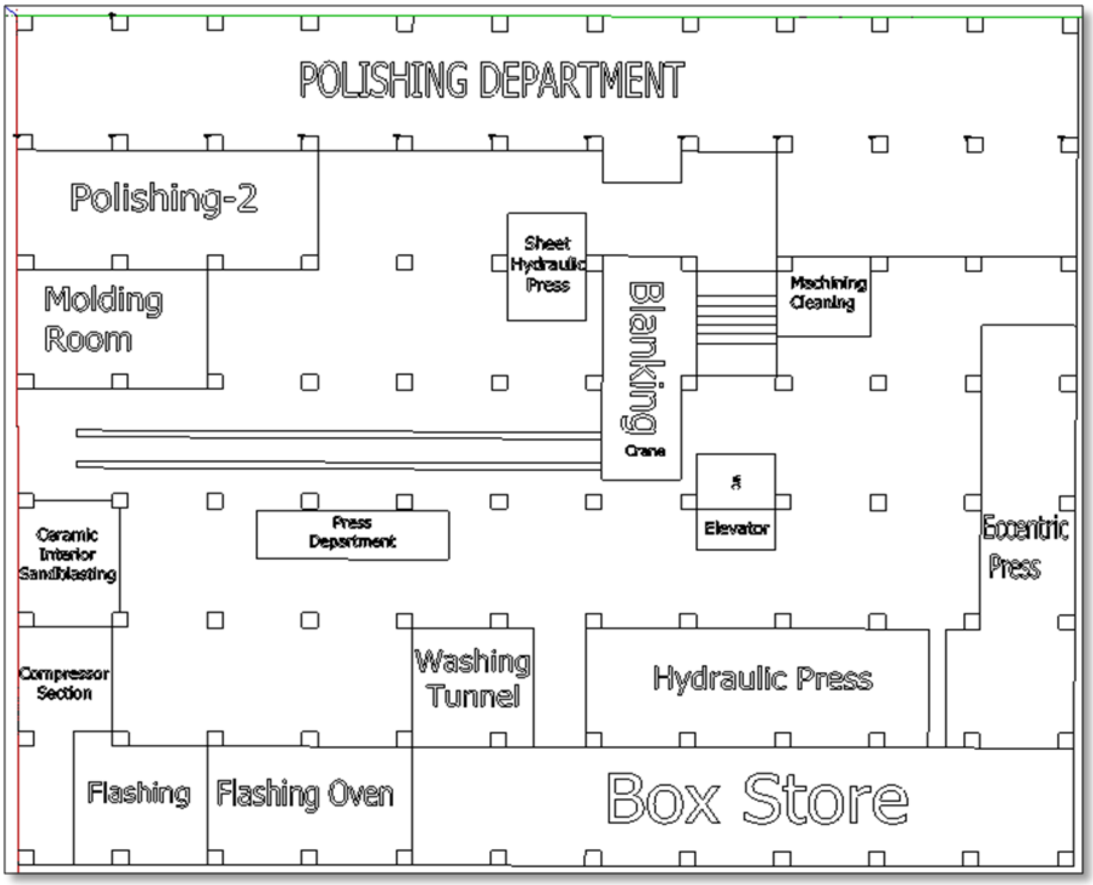


Figure 5.1 Production Floor 2163 m^2

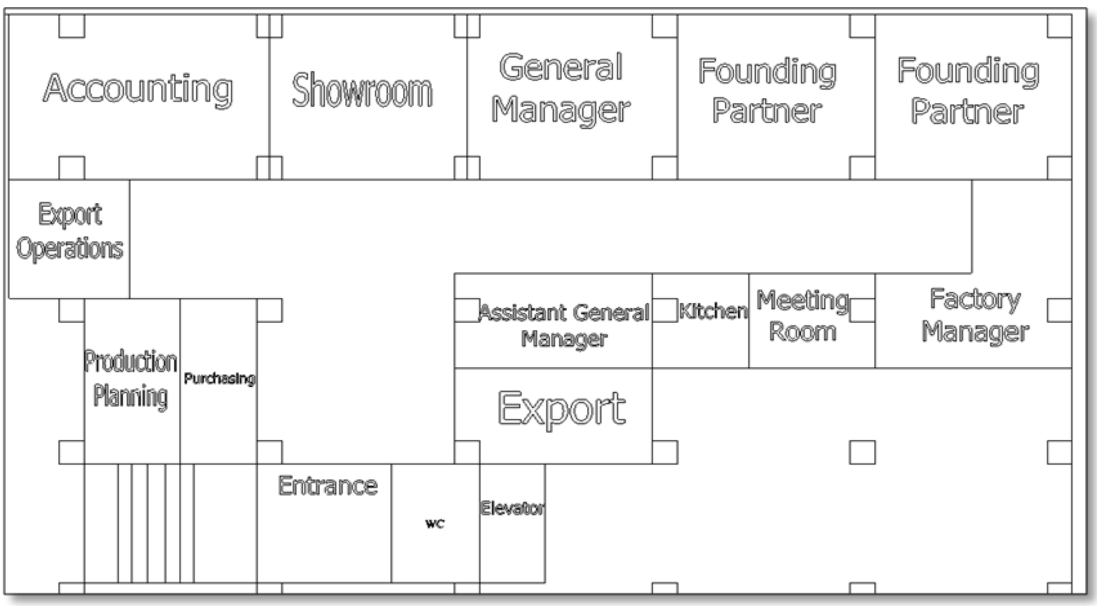


Figure 5.2 Management Floor 399 m^2

5.2.2 Information about the Departments

I) Management Floor

The management section is located on the fourth floor of the building. A portion of the floor is used. Used space is 399 m^2. There are 13 departments. Currently, information flow is more with departments close each other. In the existing plan, departments that have high intensive information flow with each other are located as close to each other as possible.

Table 5.1 Departments of Management Floor

1	Founder
2	Founding Partner
3	General Manager
4	Showroom
5	Accounting
6	Export Operations
7	Production Planning
8	Purchase
9	Assistant General Manager
10	Export
11	Kitchen
12	Meeting Room
13	Factory Manager

II) Production Floor

The production floor is the lowest floor of the building. The area is 2163 m^2. The currently available are based on layout and the most intense production process, which is positioned close to each other. The type of layout is process layout.

Production is carried out in four different product groups. These are pot, pressure cooker, samovar, and ceramic series. It has the capacity to produce 10,000 units in total.

Every product group has a different route in the production line. All product groups start on the lowest floor, then flow patterns differ on route. In this floor, the major part of the product is created. Then, they move to other floors by lift. For packaging, production is continued in the other floors.

Manufacturing occurs based on coming order. The production planning department makes a time line and determines material requirements by bill of materials. Orders usually come from abroad. Incoming orders change the time line of the production flow pattern. The flow chart is shown below:

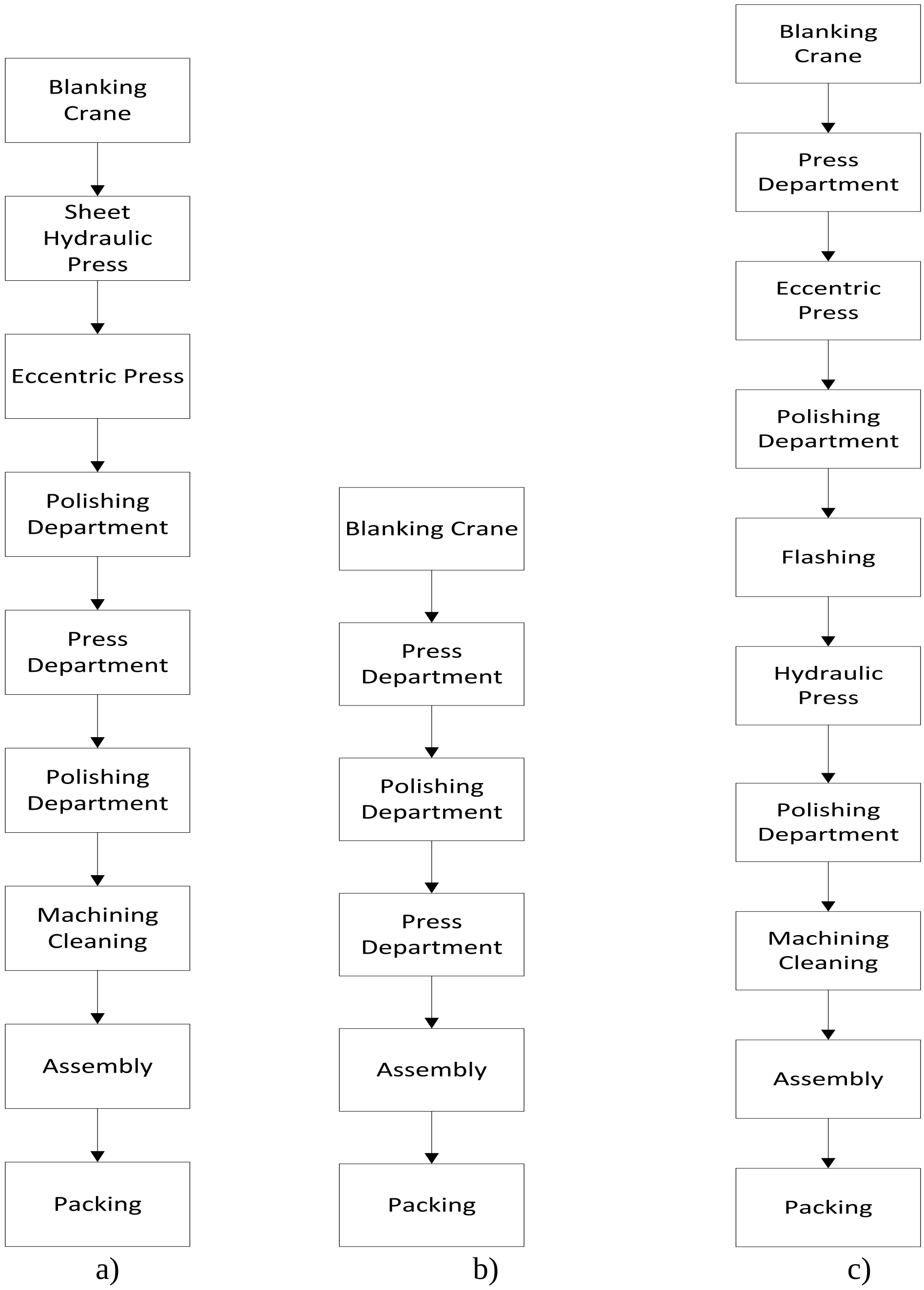


Figure 5.3 a) Flow Chart of Pot, b) Flow Chart of Samovar, c) Flow Chart of Pressure Cooker

Based on product groups, the capacity of departments are given in the below tables:

Table 5.2 Daily Capacities of Departments for Pot.

Flow of POT	Daily Capacity
Blanking and Crane	11000
Sheet Hydraulic Press	1850
Eccentric Press	11100
Polishing Department	1700
Press Department	10000
Polishing Department	10000
Machining Cleaning	550
Assembly	5200

Table 5.3 Daily Capacities of Departments for Samovar.

Flow of Samovar	Daily Capacity
Blanking and Crane	11000
Press Department	3750
Polishing Department	7050
Press Department	1800
Assembly	15250

Table 5.4 Daily Capacities of Departments for Pressure Cooker.

Flow of PRESSURE COOKER	Daily Capacity
Blanking and Crane	11000
Press Department	1850
Eccentric Press	8800
Polishing Department	5900
Flashing	4000
Hydraulic Press	5300
Polishing Department	5050
Machining Cleaning	1100
Assembly	10150

We also required some information about the order quantities of the facility. It is based on the steel group. The data is coming from the amount of orders in 2014. The unit of the price is in body pieces.

Table 5.5 Order Quantities of Pot.

Order Quantities of 2014 of POT			
MONTHS	**Domestic Market**	**Foreign Market**	**TOTAL**
January	4500	2500	7000
February	2040	11400	13440
March	3960	17580	21540
April	5688	4277	9965
May	4567	20000	24567
June	6583	1805	8388
July	4800	9515	14315
August	4579	13315	17894
September	6500	8140	14640
October	4020	13300	17320
November	4000	27800	31800
December	3789	18480	22269
TOTAL	55026	148112	203138

Table 5.6 Order Quantities of Samovar.

Order Quantities of 2014 of SEMOVAR			
MONTHS	**Domestic Market**	**Foreign Market**	**TOTAL**
January	2184		2184
February	3750		3750
May	2490	1300	3790
October		6430	6430
November		4990	4990
December		9430	9430
TOTAL	8424	22150	30574

Table 5.7 Order Quantities of Pressure Cooker.

Order Quantities of 2014 of POT			
MONTHS	**Domestic Market**	**Foreign Market**	**TOTAL**
January	4300	500	4800
February	302	8536	8838
March	7973	3500	11473
April	4909		4909
May	3492	3500	6992
June	1200		1200
July	7800	1991	9791
August	3583	2300	5883
September	5047	3500	8547
October	5500	12078	17578
November	4500		4500
December	564	3000	3564
TOTAL	49170	38905	88075

5.2.3 Data Collection

We required some data to apply the programs. Generally we used the activity relationships data, areas of departments, and rectilinear distance between departments. Activity relationships data is classified into two groups. Qualitative measure may range departments by looking at the closeness for flow. Quantitative measurements include pieces per hour, moves per day (or week like that). I studied quantitative data for the production floor and the qualitative data is for the management floor.

Real data is not used directly in the program. In order to use real data for Mcraft and SFLA, we have rearranged the data. Also, the places out of the determined department area are included into particular departments to get an optimum result. Besides, the fractional numbers have been rounded up or down.

1) Management Floor Data

Management floor data is as follows. On this floor we have 13 departments.

Table 5.8 Properties of Management Floor.

	Real	Rounded
Number of Departments	13	
Facility Width (Horizontal)	32,29	32
Facility Length(Vertical)	12,38	12
Total Area	399,7502	384

Table 5.9 contains real area, used area in program and x-y centroid of department. This information is used with both Mcraft and SFLA programs.

Table 5.9 Real Data of Management Floor.

	Departments	*Real Area*	*Area*	*x*	*y*
D 1	**Company Partner-1**	30,75	40	39,6528	47,625
D 2	**Company Partner-2**	30,37	40	33,6528	47,625
D 3	**General Manager**	31,78	42	27,516	47,625
D 4	**Showroom**	30,38	40	21,375	47,625
D 5	**Accounting**	39,86	50	14,4229	47,625
D 6	**Export Operations**	13,8	23	12,3019	43,125
D 7	**Production Planning**	14,7193	24	12,7351	39,5093
D 8	**Purchase**	10,2041	19	16,4909	39,5595
D 9	**Asst General Manager**	9,1623	18	28,645	39,5595
D 10	**Export**	10,5608	19	25,7126	39,4895
D 11	**Kitchen**	9,8621	19	31,6082	39,4845
D 12	**Meeting Room**	11,8343	21	34,8473	39,497
D 13	**Factory Manager**	19,7231	29	39,6751	39,522
	Corridor	127			

Table 5.10 Flow matrix chart; this chart occurs on daily information flow.

			TO												
		Departments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
FROM	**1**	**Company Partner-1**	0	50	90	10	10	0	5	0	0	0	0	10	90
	2	**Company Partner-2**	10	0	10	10	10	0	0	0	0	0	0	10	90
	3	**General Manager**	60	50	0	10	10	10	10	0	10	20	0	10	80
	4	**Showroom**	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	**Accounting**	40	80	90	0	0	0	20	60	60	20	30	10	30
	6	**Export Operations**	60	60	60	0	40	0	90	70	20	90	30	10	50
	7	**Production Planning**	40	20	60	10	40	50	0	80	50	40	20	10	90
	8	**Purchase**	40	40	60	0	70	20	80	0	20	10	10	10	90
	9	**Asst. General Manager**	20	40	90	10	30	60	60	50	0	80	10	10	70
	10	**Export**	60	60	80	10	60	50	20	20	60	0	10	10	70
	11	**Kitchen**	40	40	40	40	40	40	40	40	40	40	0	40	40
	12	**Meeting Room**	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	**Factory Manager**	60	60	80	10	40	60	90	30	50	50	0	10	0

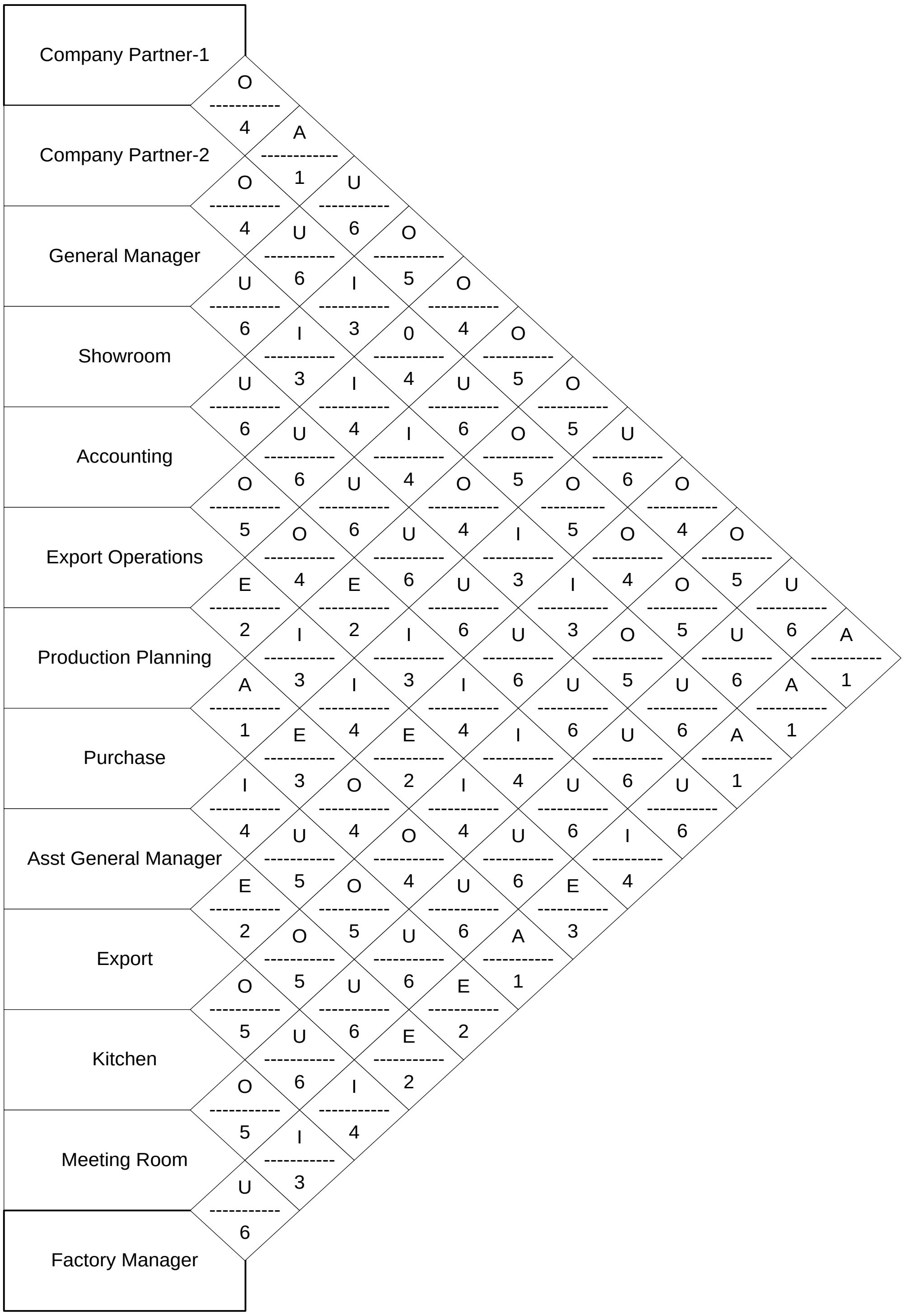


Figure 5.4 Relationship Chart of Management Floor.

2) Production Floor Data

The production floor has 15 departments. Toilet, stairs, elevator, and aisle areas are added to the department in direct proportion to area. All decimal numbers are rounded.

Table 5.11 Properties of Production Floor.

	Real	Rounded
Number of Departments	15	
Facility Width (Horizontal)	50,25	50
Facility Length(Vertical)	42,75	44
Total Area	2148,188	2200

Table 5.12 Real Data of Production Floor.

	Departments	**Real Area**	**Area**	**X**	**y**
1	**Blanking+Crane**	46,8407	82	17,3972	29,8201
2	**Sheet Hydraulic Press**	20,16	32	12,5776	25,13
3	**Flashing**	39,09	69	39,5908	5,7451
4	**Flashing Oven**	58,5	100	39,6731	13,8732
5	**Washing Tunnel**	34,56	60	33,7646	21,6619
6	**Hydraulic Press**	95,61	170	33,6882	35,1792
7	**Eccentric Press**	102,61	181	26,7292	47,689
8	**Polishing Department**	406,91	737	4,542	28,5146
9	**Press Department**	22,51	40	26,0825	15,9119
10	**Polishing-2**	83,25	151	9,6791	7,125
11	**Molding Room**	52,88	94	15,6941	4,5399
12	**Ceramic Interior Sandblasting**	29,81	54	27,5254	2,464
13	**Box Store**	185,06	335	39,6941	34,4601
14	**Compressor Section**	40,22	70	35,8505	1,8894
15	**Machining Cleaning**	17,43	25	14,0527	38,3105
	Wc	10,46			
	Elevator	7,49			
	Stairs	19,12			
	Column	54,32			
	Aisle	819,83			
	TOTAL	2146,6607	2200		

Four product groups are available on the production floor. Three of them are steel and the other is aluminum. In this study, the steel groups are taken into consideration. The reason behind this decision is that the most proceeded group is the steel group.

In order to generate a flow chart of the production floor, all items produced from steel are collected under one specific class to obtain simplification. The items produced from steel are pot, samovar, and pressure cooker and these items are accumulated inside the pot class.

After having an interview with the production manager, the flow from one department to another shows changeability in terms of product type and the amount of product. For this reason, all product types are gathered under one class to generate the flow chart. The quantities are collected based on carried pallet per day. The volume of one pot is matched with one samovar and pressure cooker in order to use one unit during calculations. By this way, the amount of pots transformed from one department to another department is evaluated.

Table 5.13 Flow Chart of Production Floor.

	Department	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Blanking + Crane	0	700													
2	Sheet Hydraulic Press		0			750										
3	Flashing			0	200	250	400									
4	Flashing Oven			400	0					250						
5	Washing Tunnel				250	0		200		550						
6	Hydraulic Press						0		400							
7	Eccentric Press				200			0	250	50						50
8	Polishing Department								0	450						400
9	Press Department				200			250	300	0	50		250			250
10	Polishing-2							50			0					
11	Molding Room											0				
12	Ceramic Interior Sandblasting												0			
13	Box Store													0		
14	Compressor Section														0	
15	Machining Cleaning															0

5.3 APPLICATION WITH MCRAFT

All data were used as described above. The Mcraft program was performed on both the management and manufacturing floors.

1) Management Floor Mcraft Solution

Firstly enter the data, and the initial cost is calculated by the program. Select new cost by pressing the 'random layout' button, look at the calculated cost and select the optimum cost then start the optimization by pressing the 'solve' button.

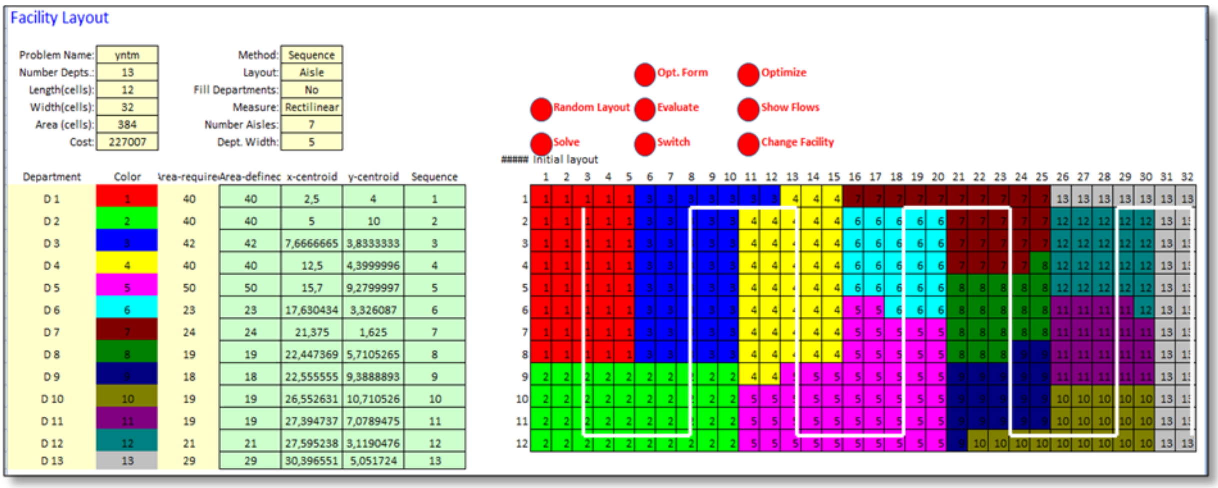


Figure 5.5 Excel Screenshot of Mcraft for Initial cost and Layout.

As a result, get this cost when making the random, and then reach the final cost with calculating 5 iterations. The table shows the costs step by step.

Table 5.14 The Result of Management Floor calculated using Mcraft.

	All department Variable
Initial cost	227007
Random 1	222185
Random 2	222232
Random 3	220954
# of iterations	5
Final cost	214418,75

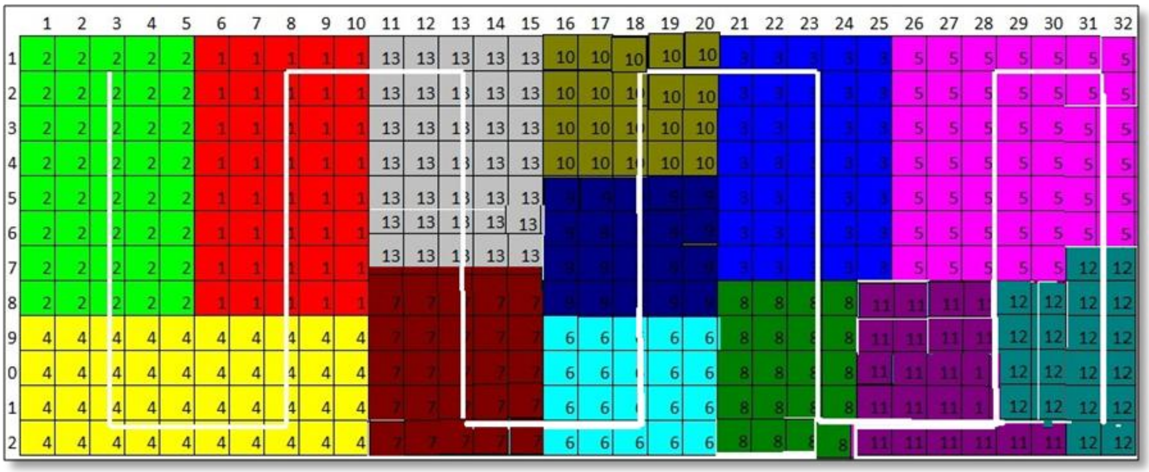


Figure 5.6 Iteration table and optimum cost, Organized Final Layout of Mcraft
Z= 214418.

2) Production Floor Mcraft Solution

As a result, get this cost when making the random, and then reach the final cost by calculating 6 iterations. The table shows the costs step by step.

Table 5.15 The Result of Production Floor calculated using Mcraft.

	All Department Variable
Initial cost	86220
Random 1	93915
Random 2	86359
Random 3	75083
# of iterations	7
Final cost	49338*2=98676

Init. Cost	75082,8125

Iterations: 7

Index	Init. Seq.
1	13
2	6
3	11
4	9
5	5
6	2
7	14
8	1
9	8
10	3
11	12
12	7
13	10
14	4
15	15

Iter.	Type	Action	Cost
1	Switcl	15 and 13	65447
2	Switcl	7 and 1	59441
3	Switcl	3 and 12	54882
4	Switcl	3 and 5	51982
5	Switcl	15 and 4	50282
6	Switcl	14 and 8	49829
7	Switcl	8 and 10	49338

Figure 5.7 Steps of improving the initial layout.

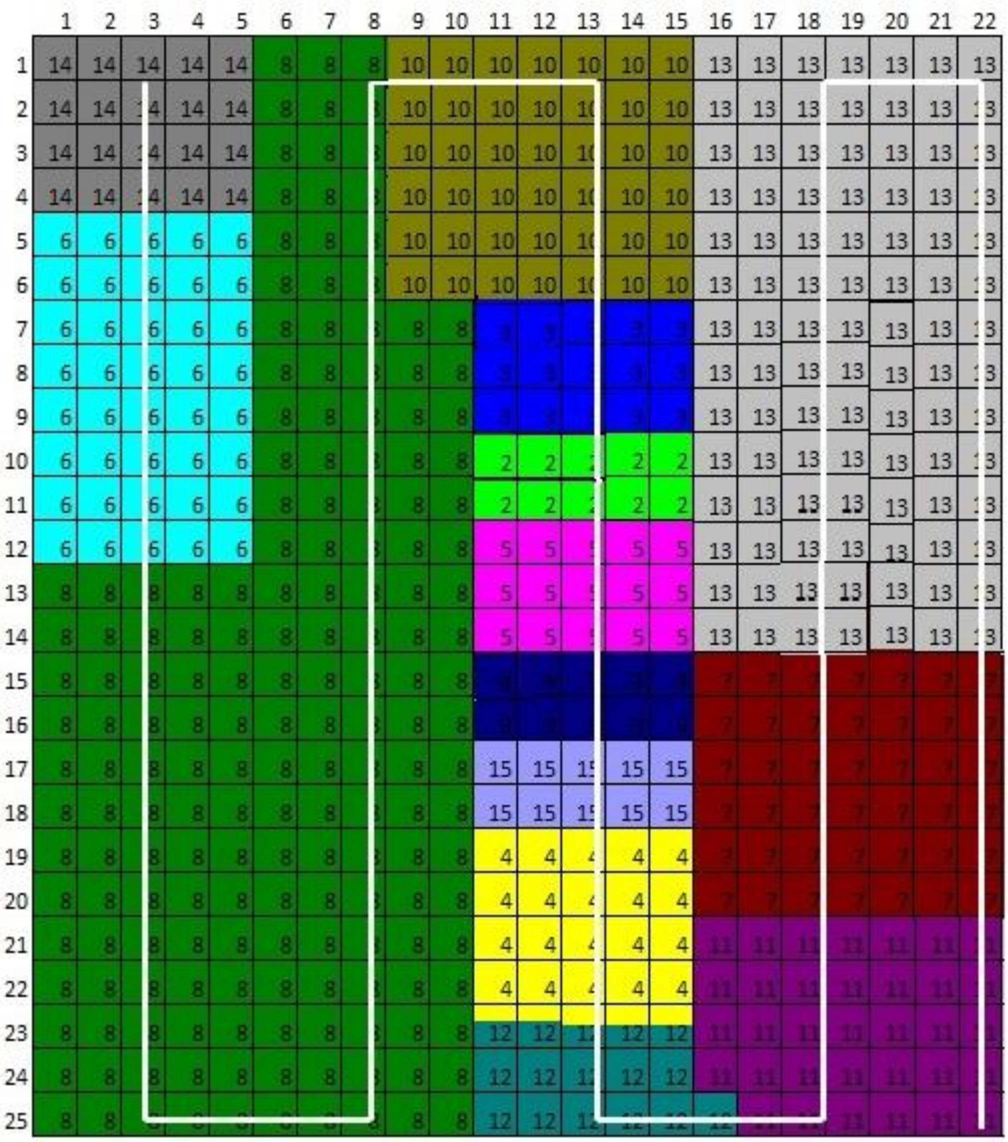


Figure 5.8 Mcraft Iterations Screenshot, Organized Final Layout of Mcraft
Z= 49338*2=98676.

5.4 APPLICATION WITH SFLA

1) Management Floor SFLA Solution

Firstly we enter data like below. In SFLA data is entered like Mcraft. The macro program calculates.

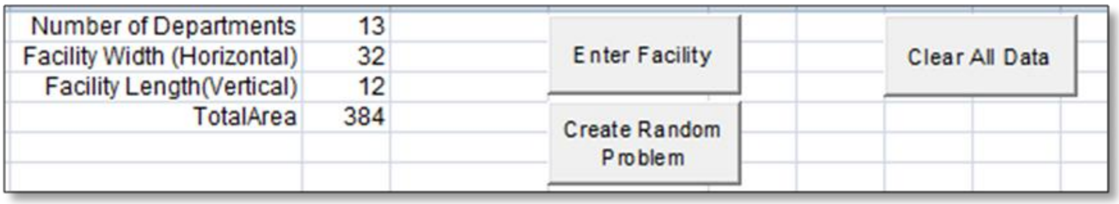


Figure 5.9 Screenshot of SFLA when Data Entering.

First clear all data, then enter the below data to the program. Also, the user can create random problem data.

Table 5.16 Entered Management Floor Data.

Dept Name	Dept C(	Area	X Coordinates	Y Coordinates	Order
Dept 1	A	40	39,6528	47,625	1
Dept 2	B	40	33,6528	47,625	2
Dept 3	C	42	27,516	47,625	3
Dept 4	D	40	21,375	47,625	4
Dept 5	E	50	14,4229	47,625	5
Dept 6	F	23	12,3019	43,125	6
Dept 7	G	24	12,7351	39,5093	7
Dept 8	H	19	16,4909	39,5595	8
Dept 9	I	18	28,645	39,5595	9
Dept 10	J	19	25,7126	39,4895	10
Dept 11	K	19	31,6082	39,4845	11
Dept 12	L	21	34,8473	39,497	12
Dept 13	M	29	39,6751	39,522	13

I entered the area, x-y coordinates. Order part is automatically coming.

Table 5.17 Flow Matrix of Management Floor.

Flow Matrix	Dept 1	Dept 2	Dept 3	Dept 4	Dept 5	Dept 6	Dept 7	Dept 8	Dept 9	Dept 10	Dept 11	Dept 12	Dept 13
Dept 1	0	50	90	10	10	0	5	0	0	0	0	10	90
Dept 2	10	0	10	10	10	0	0	0	0	0	0	10	90
Dept 3	60	50	0	10	10	10	10	0	10	20	0	10	80
Dept 4	0	0	0	0	0	0	0	0	0	0	0	0	0
Dept 5	40	80	90	0	0	0	20	60	60	20	30	10	30
Dept 6	60	60	60	0	40	0	90	70	20	90	30	10	50
Dept 7	40	20	60	10	40	50	0	80	50	40	20	10	90
Dept 8	40	40	60	0	70	20	80	0	20	10	10	10	90
Dept 9	20	40	90	10	30	60	60	50	0	80	10	10	70
Dept 10	60	60	80	10	60	50	20	20	60	0	10	10	70
Dept 11	40	40	40	40	40	40	40	40	40	40	0	40	40
Dept 12	0	0	0	0	0	0	0	0	0	0	0	0	0
Dept 13	60	60	80	10	40	60	90	30	50	50	0	10	0

I entered the flow matrix chart by collecting from the company.

Table 5.18 Example Formula for Excel Macro.

Distance Matrix	Dept 1	Dept 2	Dept 3	Dept 4	Dept 5	Dept 6	Dept 7	Dept 8	Dept 9	Dept 10	Dept 11	Dept 12	Dept 13
Dept 1	0	6	12,1368	18,2778	25,23	31,85	35,03	31,23	19,07	22,076	16,185	12,934	8,1253
Dept 2	6	[illegible]	6,1368	12,2778	19,23	25,85	29,03	25,23	13,07	16,076	10,185	9,3225	14,125
Dept 3	12,1368	6,137	0	6,141	13,09	19,71	22,9	19,09	9,195	9,9389	12,233	15,459	20,262
Dept 4	18,2778	12,28	6,141	0	6,952	13,57	16,76	12,95	15,34	12,473	18,374	21,6	26,403
Dept 5	25,2299	19,23	13,0931	6,9521	0	6,621	9,804	10,13	22,29	19,425	25,326	28,552	33,355
Dept 6	31,8509	25,85	19,7141	13,5731	6,621	0	4,049	7,755	19,91	17,046	22,947	26,173	30,976
Dept 7	35,0334	29,03	22,8966	16,7556	9,804	4,049	0	3,806	15,96	12,997	18,898	22,125	26,953
Dept 8	31,2274	25,23	19,0906	12,9496	10,13	7,755	3,806	0	12,15	9,2917	15,192	18,419	23,222
Dept 9	19,073	13,07	9,1945	15,3355	22,29	19,91	15,96	12,15	0	3,0024	3,0382	6,2648	11,068
Dept 10	22,075	16,08	9,9389	12,4731	19,43	17,05	13	9,292	3,002	0	5,9006	9,1422	13,995
Dept 11	16,1851	10,19	12,2327	18,3737	25,33	22,95	18,9	15,19	3,038	5,9006	0	3,2516	8,1044
Dept 12	12,9335	9,323	15,4593	21,6003	28,55	26,17	22,12	18,42	6,265	9,1422	3,2516	0	4,8528
Dept 13	8,1253	14,1	20,2621	26,4031	33,36	30,98	26,95	23,22	11,07	13,995	8,1044	4,8528	0

=MUTLAK(D12-D10)+ MUTLAK(E12-E10)

This formula is rectilinear distance metric in table 5.18. It is calculated in the program using the above macro code. Original formulas are written in the previous chapter. For calculating suggested block size, macro formulas are defined in Figure 5.10.

For width:

=YUVARLA(KAREKÖK(B3/TAVANAYUVARLA(KAREKÖK(B2);1)^2*B4/B5);0)

For length:

=YUVARLA(KAREKÖK(B3/TAVANAYUVARLA(KAREKÖK(B2);1)^2*B5/B4);0)

163	164	165	166	167	168	169	176	177	184	185	192	193	200	201	208	209	216	217	218	219	220	221	222
162	161	160	159	158	157	170	175	178	183	186	191	194	199	202	207	210	215	228	227	226	225	224	223
151	152	153	154	155	156	171	174	179	182	187	190	195	198	203	206	211	214	229	230	231	232	233	234
150	149	148	147	146	145	172	173	180	181	188	189	196	197	204	205	212	213	240	239	238	237	236	235
139	140	141	142	143	144	1	8	9	16	17	24	25	26	27	28	29	30	241	242	243	244	245	246
138	137	136	135	134	133	2	7	10	15	18	23	36	35	34	33	32	31	252	251	250	249	248	247
127	128	129	130	131	132	3	6	11	14	19	22	37	38	39	40	41	42	253	254	255	256	257	258
126	125	124	123	122	121	4	5	12	13	20	21	48	47	46	45	44	43	264	263	262	261	260	259
115	116	117	118	119	120	93	92	85	84	77	76	49	50	51	52	53	54	265	266	267	268	269	270
114	113	112	111	110	109	94	91	86	83	78	75	60	59	58	57	56	55	276	275	274	273	272	271
103	104	105	106	107	108	95	90	87	82	79	74	61	62	63	64	65	66	277	278	279	280	281	282
102	101	100	99	98	97	96	89	88	81	80	73	72	71	70	69	68	67	288	287	286	285	284	283
381	380	373	372	365	364	357	356	349	348	341	340	333	332	325	324	317	316	289	290	291	292	293	294
382	379	374	371	366	363	358	355	350	347	342	339	334	331	326	323	318	315	300	299	298	297	296	295
383	378	375	370	367	362	359	354	351	346	343	338	335	330	327	322	319	314	301	302	303	304	305	306
384	377	376	369	368	361	360	353	352	345	344	337	336	329	328	321	320	313	312	311	310	309	308	307

Figure 5.10 SFLA Example with Number.

Firstly, SFLA programs use all this data and form the spiral space filling curve. Suggested block width is 8, length is 3. But I entered block dimensions as6x4. Objective function cost is 64466,4. This cost is the initial cost.

It gives layout in both letters and numbers as shown Figure 5.10 and 5.11.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	F	F	F	F	F	F	F
2	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E	E	F	F	F	F	F	F	F
3	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E	E	F	F	F	F	F	F	F
4	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E	E	F	G	G	G	G	G	F
5	D	D	D	D	D	D	A	A	A	A	A	A	A	A	A	A	A	A	G	G	G	G	G	G
6	D	D	D	D	D	D	A	A	A	A	A	A	A	A	A	A	A	A	G	G	G	G	G	G
7	D	D	D	D	D	D	A	A	A	A	A	A	A	A	A	A	B	B	G	G	G	G	G	G
8	D	D	D	D	C	C	A	A	A	A	A	A	B	B	B	B	B	B	H	H	H	H	H	G
9	C	C	C	C	C	C	C	C	C	C	B	B	B	B	B	B	B	B	H	H	H	H	H	H
10	C	C	C	C	C	C	C	C	C	C	B	B	B	B	B	B	B	B	H	H	H	H	H	H
11	C	C	C	C	C	C	C	C	C	C	B	B	B	B	B	B	B	B	H	H	I	I	I	I
12	C	C	C	C	C	C	C	C	C	C	B	B	B	B	B	B	B	B	I	I	I	I	I	I
13	M	M	M	M	M	M	M	M	L	L	L	L	K	K	K	K	K	K	I	I	I	I	I	I
14	M	M	M	M	M	M	M	L	L	L	L	L	K	K	K	K	K	J	J	J	J	J	I	I
15	M	M	M	M	M	M	M	L	L	L	L	L	L	K	K	K	K	J	J	J	J	J	J	J
16	M	M	M	M	M	M	M	L	L	L	L	L	L	K	K	K	K	J	J	J	J	J	J	J

Figure 5.11 SFLA Example with Letters.

The improvement section shows the initial layout with color and coordinates firstly, as shown in Figure 5.12 and 5.13.

Index	1	2	3	4	5	6	7	8	9	10	11	12	13
Department	F	M	H	K	I	J	G	C	B	A	E	L	D
X -Center	9,4	15	16	10	4,8	3,4	3,5	7,2	18	22	20	13	5,5
Y -Center	6,6	6,8	11	11	11	8,9	5,3	2,2	2,3	6,7	14	14	15
Cost													
55555,98													

Figure 5.12 Coordinates of Initial Layout.

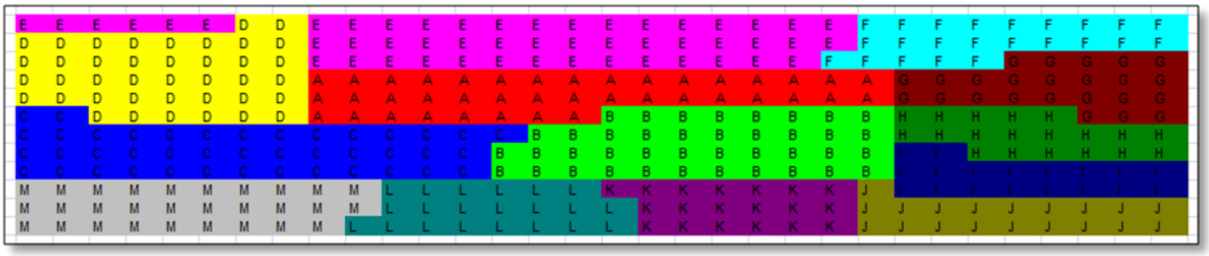


Figure 5.13 Initial Layout of SFLA.

For the path department algorithms, the final cost is strongly related with the initial layout that the algorithm started with. SFLA optionally uses two kinds of initial layout generation. The first one is randomly generating, and the second one is enhanced initial layout algorithms. For enhanced initial algorithms, the initial layout is selected not randomly by looking at the cost.

When making the random sequences layout, select the minimum objective function result (cost), then run the pairwise improvement.

Index	1	2	3	4	5	6	7	8	9	10	11	12	13
Department	A	B	C	D	E	F	G	H	I	J	K	L	M
X -Center	12	15	5,5	3,4	11	21	22	21	22	21	15	10	4,1
Y -Center	6,3	10	10	4,9	2,3	2,2	5,7	9,3	12	15	14	15	14
Cost													
64466,44													

Figure 5.14 The coordinates of Random Layout-1.

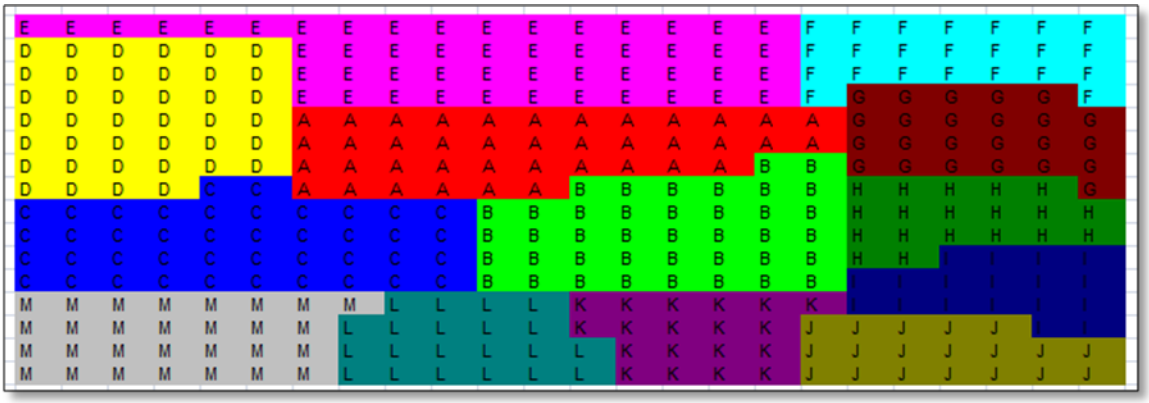


Figure 5.15 Random Layout-1 Z=64466, 44.

Index	1	2	3	4	5	6	7	8	9	10	11	12	13
Department	M	K	C	J	I	G	H	E	L	B	D	A	F
X -Center	14	21	18	5,7	4,7	4,8	4,8	18	29	28	27	15	4,3
Y -Center	4,8	5,3	8	8,4	6,8	4,1	1,6	1,9	2,3	6,1	11	11	11
Cost													
55948,75													

Figure 5.16 X-Y Coordinates and Cost Random Layout-2.

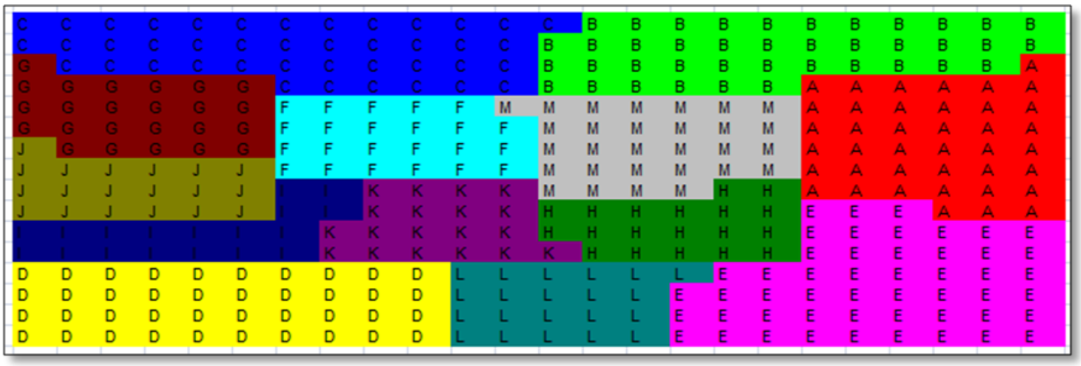


Figure 5.17 Random layout-2, Z= 55948, 75.

	Cost														
Initial Layout	55555,98		F	M	H	K	I	J	G	C	B	A	E	L	D
Iter 1	53969,25	Switch 11 and 13	F	M	H	K	I	J	G	C	B	A	D	L	E
Iter 2	52728,51	Switch 3 and 6	F	M	J	K	I	H	G	C	B	A	D	L	E
Iter 3	51814,73	Switch 3 and 4	F	M	K	J	I	H	G	C	B	A	D	L	E
Iter 4	51001,4	Switch 9 and 10	F	M	K	J	I	H	G	C	A	B	D	L	E
Iter 5	50894,95	Switch 1 and 2	M	F	K	J	I	H	G	C	A	B	D	L	E
Iter 6		No Further Improvement													

Figure 5.18 All iterations of the improvements.

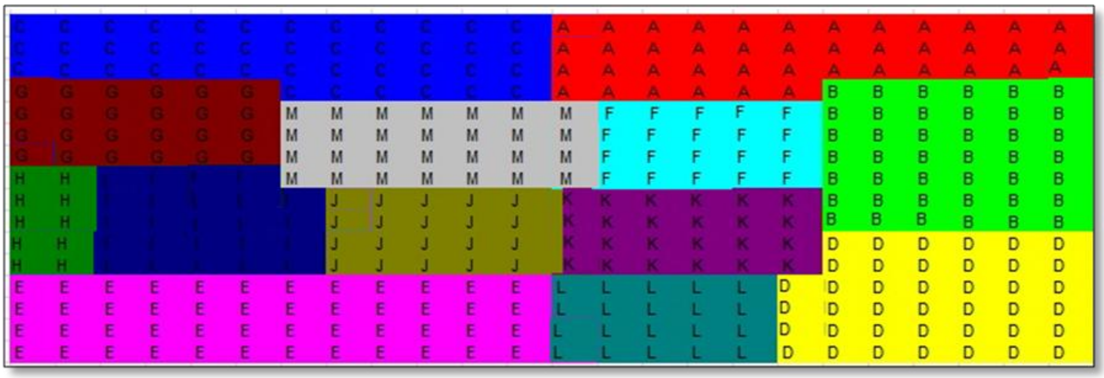


Figure 5.19 Organized Optimum Management Layout, Z= 50894, 95.

2) Production Floor SFLA Solution

In the management layout section, all steps of the SFLA are explained. So, in this part, I will explain only result-based.

Firstly enter the facility data (areas, coordinates, facility width and length, total area, flow matrix), then run the program.

The initial cost is 156170. The program used block width 13, and length 11. But I entered the 10 x 11 dimensions. When I looked at the improvement layout, my entered dimensions layout was more feasible than the suggested block dimensions.

When made enhancement initial layout, the cost was calculated as 15548. I selected the improvement layout, and then ran the pairwise improvement. The program makes eight iterations for minimizing the cost. The final cost is 86230. At the end of these steps I reached the optimum final layout in Figure 5.20.

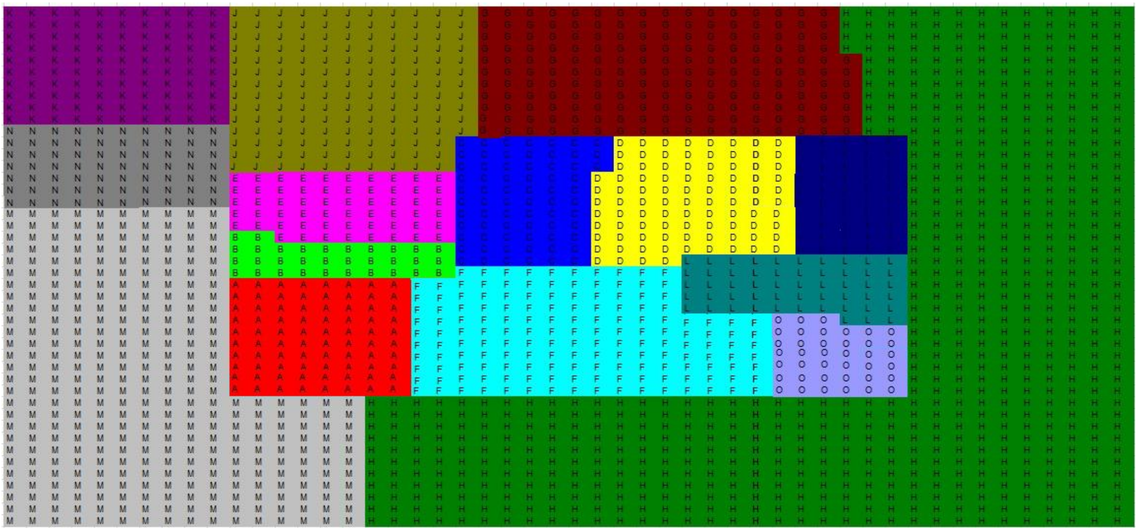


Figure 5.20 Organized Optimum Program Layout Z= 133210,57.

5.5 COMPARISON AND ASSESSMENT OF RESULT

As a result, for management floor costs comparison shows that Mcraft has the lowest cost in finding the optimum layout. The results of the two algorithms and existing layout costs are shown in Table 5.19.

Table 5.19 Management Floor Solution.

Cost	Value
Existing Cost	73660
SFLA Cost	50895
Mcraft Cost	42883

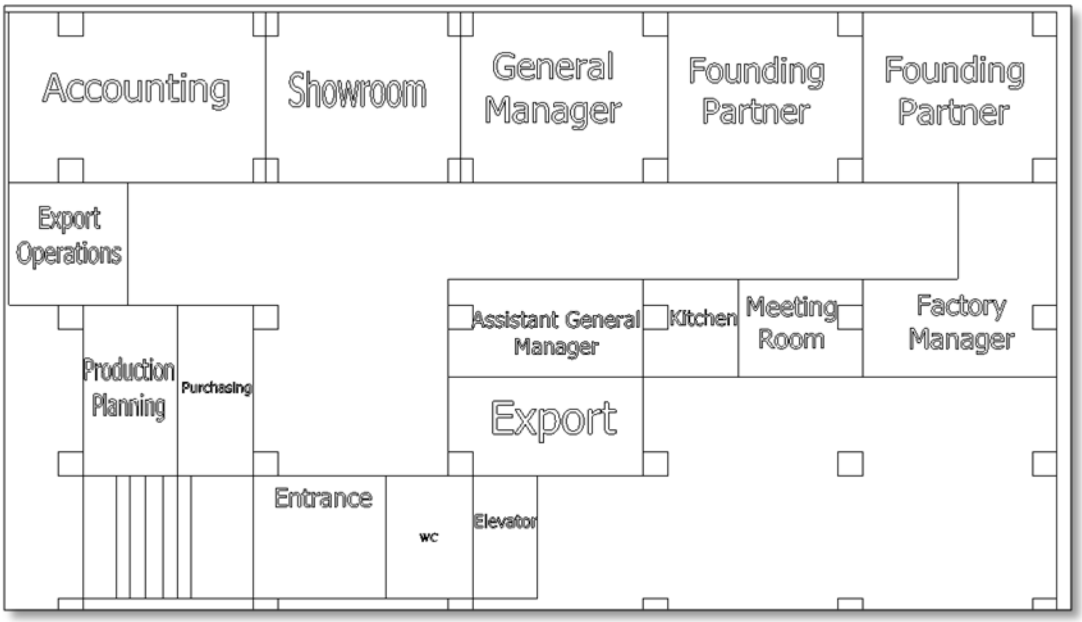


Figure 5.21 Existing layout Z=73660.

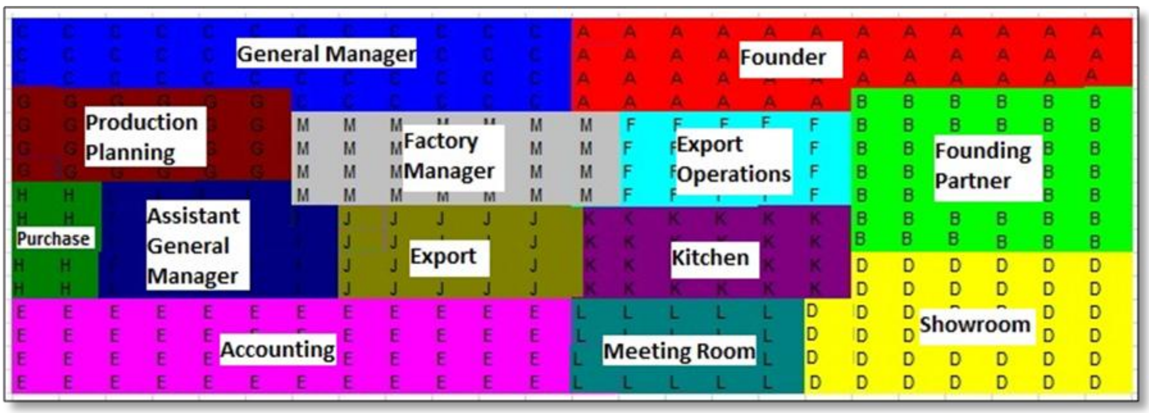


Figure 5.22 Organized Layout of Management Floor by SFLA Z= 50895.

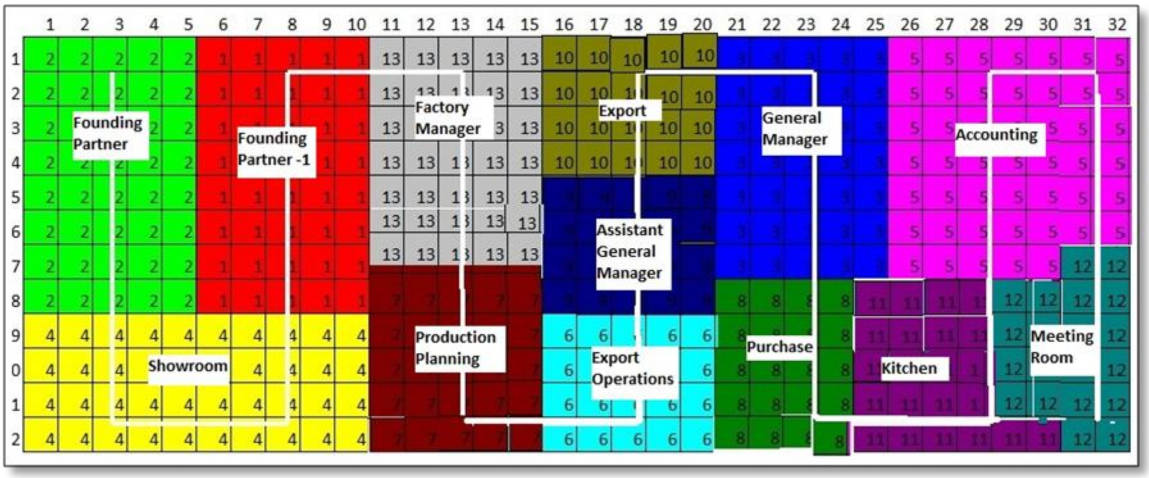


Figure 5.23 Organized Layout of Management Floor by McraftZ= 21441,8 *2=42883,7.

As a result, for production floor costs, comparison shows that SFLA has the lowest cost for finding the optimum layout. The results of the two algorithms and existing layout costs are shown in Table 5.20.

Table 5.20 Production Floor Solution.

Cost	Value
Existing Cost	168749
SFLA Cost	86230
Mcraft Cost	98676

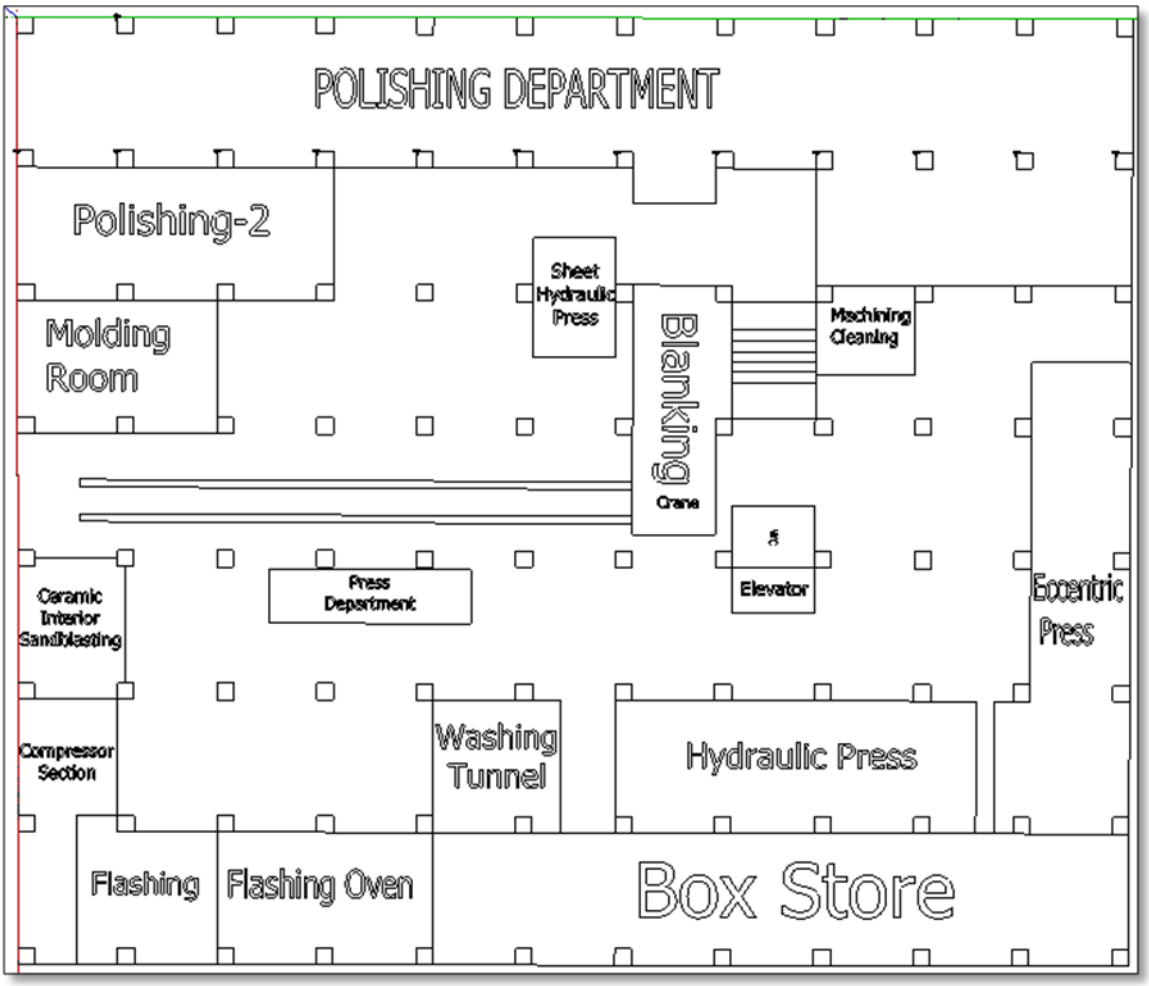


Figure 5.24 Existing layout Z= 168749.

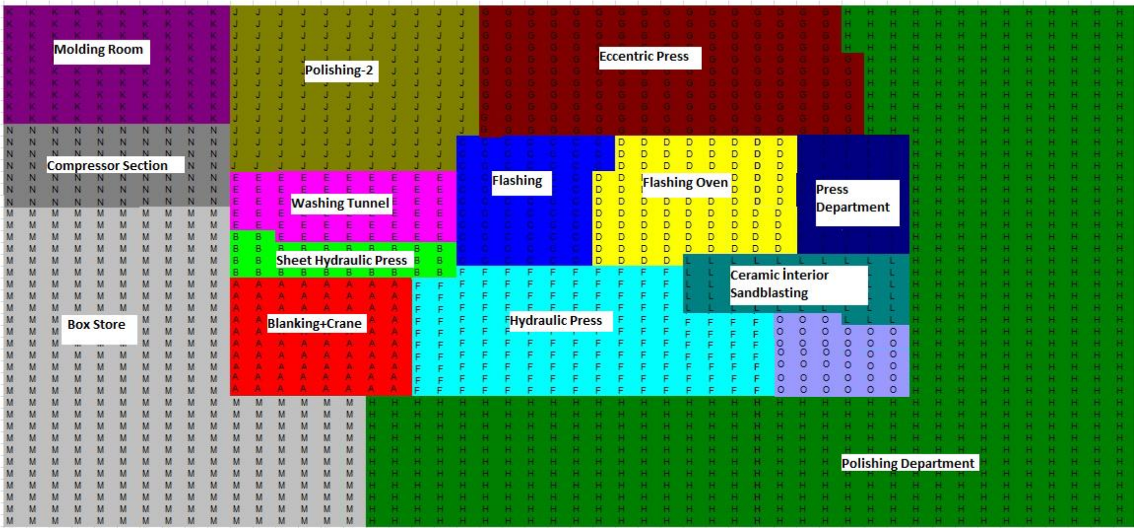


Figure 5.25 Organized Layout of Production Floor by SFLA Z= 86230.

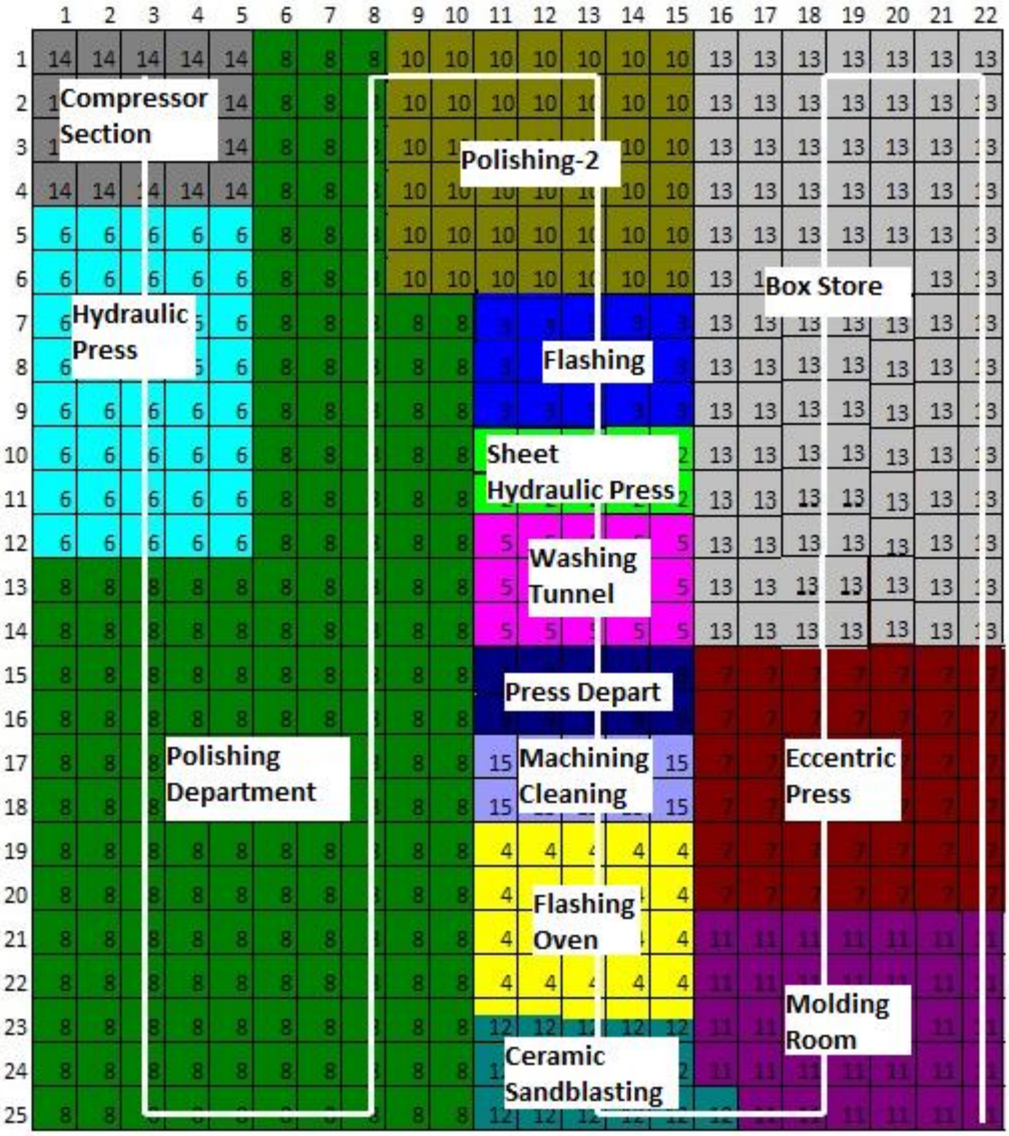


Figure 5.26 Organized Layout of Production Floor by Mcraft Z= 49338*2=98676.

CHAPTER 6

RESULT AND CONCLUSION

6.1 GENERAL FINDINGS

In this study, the literature about the facility layout algorithms is examined from the past to today. This concept is one of the major problems in the production system. Until the present, the facility layout design problem has been worked on by many researchers. Because of the complexity of the problem, the researchers find algorithms to find the good and optimum solution for FLP. Numerous types of algorithms have been developed. Constraints of optimal solution algorithms, heuristic and metaheuristic algorithms to solve the problems of facility layout design have been developed. Heuristic algorithms are "Construction" and "Improvement" classified as algorithms. Most algorithms are improved as a computer-aided facility layout algorithm.

Mcraft and SFLA are two heuristic algorithms which are developed for FLP. These algorithms use discrete representation type and blocks to find the optimum layout. In SFLA, the most used department is put at the center of the plant area and the most related departments are assigned around it. The possible material handling situations are considered when the new model is designed.

Application results in this study show that the performance of the algorithms depends on the initial data. Any software system for a manufacturing or service industry can be improved using facility design algorithms. But the most important thing is how accurate the available data is. If there are deficiencies in data entry as required by the software program, the results will not be well-suited to real-life situations.

In this study, the actual data is obtained from a company. Two floor designs are investigated, which are the management floor and the production floor. The existing layout is modified in order to implement the algorithms. We tried to keep equal conditions to make comparisons. Toilets, elevators, stairs, columns and aisles are added to departments based on the right proportion of the area. Fixed points are not added to the algorithms. Mcraft can apply the fixed point but the solution is not optimum. When the fix point is entered, the program changes the position of the department. The fixed point did not suit the SFLA logic. So do not make any improvement for SFLA codes. Therefore, common and fixed points are added to the departments.

Mcraft solution (cost) is multiplied by 2 because at the beginning of the program some of the data was scaled. The program scaled the entered data to a certain extent. In this study, the program took half of the data. So, the result was multiplied by 2.

The existing layout distance objective function is calculated by hand. Mcraft and SFLA objective function cost are calculated automatically. So the result table occurred.

Different floors have different results. For the management floor, the Mcraft cost is the lowest. For the production floor, the SFLA algorithm gave the lowest result. When the layout is examined, a better usage of the layout alternative is Mcraft for management floor. And for the production floor, SFLA gives the better layout solution.

Performances of the algorithms are changes based on the actual data. These factors are bandwidth and plant length to width ratio. As a result, SFLA is the new alternative algorithm to facility layout design. It works as efficiently as Mcraft. It is the improved version of CRAFT. In previous studies, SFLA is a new algorithm but cannot be used in real life despite giving good solutions. This study is different from previous ones because of the actual data being used. So, SFLA has been tested in both literature data and actual data.

6.2 RECOMMENDATIONS FOR FURTHER WORK

The studies and literature surveyed show the methods used found the best layout for the facility. But a new layout should suit the function of the facility in true life. In other words, an optimum solution can be feasible for facility layout.

Qualitative and quantitative factors that affect the facility layout can be taken into account. In this respect; the following advice can be regarded as future research directions:

- Which factors affect which algorithms.
- Fixed point enhancement can be considered.
- Other production factors such as batch sizes, processing time, operation cost, material cost, inventory cost can be considered.
- Ergonomic factor can be added to designing procedure.
- Discrete representation type layout can be combined with metaheuristic approaches.

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