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ABSTRACT

The study of factory layout design is a complicated task because there is no standardized or unified way to solve the layout problems of location planning and the use of modern management methods for production represents the necessary step for a successful industrial project. Choice of an optimal production way represented the best selection of necessary machines for production, best planning and locating of workstations. The success of this step requires the determination of a set of information such as (machine size, operation planning type, layout type, department necessary space etc.). The objectives of this research is to study the variables and requirements that are needed in the factory planning then achieving the optimum work elements, in order to obtain least possible transmission distance and lowest handling cost of materials or any other standard approved to evaluate the identification of work elements and allow workers, materials or customers to move within the work space more easily and effectively. Also determine the best technological methods to use in production factories through optimal distribution of various production departments, minimum distance possible through which the material is allowed move, the least possible paths of required materials between operations, optimal utilization of available land area, reduce the congestion points and accumulation in the workstations. A case study at the General Company of Leather in Baghdad, Iraq was used to show the application of the methodology developed through the present work, focusing on studying and evaluating the planning at the current layout, requirements and variables of the planning process at number 7 factory for manufacturing men's shoes and studying the possibility of developing it. Scientific and mathematical methods were applied to assist in decision-making. Microsoft Visual Basic C++ 6.0 has been used in the current planning problem to achieve the best possible decision at a minimum possible time, effort as well as accuracy of distances and clarity of results. The design and current situation of the factory plant has been evaluated on the basis of the total distance standard. The total distance between the machines used to produce each part of the men's shoe operations by raw material and semi-finished material on its way to reach a

complete manufacturer of complete product is 286.9 meters. The new design for the factory departments was reached through the proposed optimization method resulting in that total transit distance decreased to 196.9 meters. Thus reducing the transported distance by 68.63% in the new design also the total distance of the sewing division was reduced by 50.276% from 181 m to 91. The cost was reduced, productivity and profit was increased.

Keywords: Factory Layout Design, Layout Optimization, Men's Shoes Industry, Path Movements of Parts and Materials, Transportation Distance.

Introduction

One of the most important factors considered in designing manufacturing facilities lies in determining an effective layout. A general definition of plant layout problem is to find the best arrangement of physical facilities to provide an efficient operation. Layout affects the cost of material handling, time and throughput and hence affects the overall productivity and efficiency of the plant. Developing a manufacturing layout is an important step in designing manufacturing facilities due to the impact of the layout on material handling cost and time, and consequently affects the overall productivity of the shop floor. Poor layout would result in having more parts spending longer time moving from one machine to another, and thus results in increasing material handling costs (Hassan, 1995).

In general the manufacturing plant layout is a systematic arrangement of facilities which are essential for production of goods or delivery of services (Hari Prasad et al., 2014). The type of layout most suitable to any organization is a function of the operations the organization performs. The operations function in any organization can be either intermittent or continuous (Adams and Ebert, 1992). Intermittent operations deal with made-to-order products, low product volume, general purpose equipment, labor intensive operations, interrupted product flow, frequent schedule changes and large product mix. Continuous operations on the other hand deal with standardized products made to store inventory, high product volume, special purpose equipment, capital intensive operations, continuous product flow and small product mix. A process layout is most appropriate operations (Adams and Ebert, 1992).

The layout for a process consists of grouping like process together and placing individual process departments relative to one another based on workflow between departments (Tompkins and White, 1996). The layout of manufacturing facilities used to be classified as job shop, flow shop and fixed layout (Hassan, 1995). The right layout for an organization improves productivity, the quality of the product or service, and the delivery rates. The layout decision is very important strategically for any organization to stay competitive in the present era (Yang, 1994).

Plant Layout is the physical arrangement of equipment and facilities within a plant. The Plant Layout can be indicated on a floor plan showing the distances between different features of the plant. Optimizing the layout of a plant can improve productivity, safety and quality of products. Unnecessary efforts of materials handling can be avoided when the plant layout is optimized through: 1. Distances which material has to move 2. Distances equipment has to move 3. Distances operators have to move 4. Types of handling equipment needed (Kadane and Bhatwadekar, 2011).

A manufacturing system consists of workstations or departments, as well as resources like personnel, material and machinery which must be arranged to form a well-ordered system to maximize benefits. However, it is not an easy task to design best possible layout in order to achieve the desired goal of productivity and profitability, while at the same time ensure safety and satisfaction of workers (González-Cruz and Gómez-Senent Martínez, 2011).

The planning of events in the fields of production plays an important role in facilitating the production processes by drawing a clear picture of the paths movement for (parts, semi-finished materials, finished products), also workers between different productions activities with minimum distance as possible.

The layout should be designed such that the manufacturing process can be carried out in an efficient way. This can be attained by arranging machines, material, and work areas so that material moves smoothly, eliminating all delays possible, planning the flow in such a manner that work passing can be easily identified (Farah and Binti, 2007).

A good layout keeps costs low and reduces unnecessary material handling while maintaining the product flow through the facility. Improving the layout also increases the machine utilization that enhances the machining capacity of the shop floor (Dhawan et al., 2014).

In this work, a case study has been adopted at the Iraqi Company for Leather Industries which is engaged in making of shoes of all types and different leather products. The company produces of variety of shoes according to customer requirement. As the customer's demand is high, the firm has to increase productivity, where it has characterized by a traditional style in different levels of production system.

Problem Conception

Designing of facility is concerned with the relocation of the workstations in an optimum sequence so that the completion of the product takes less time during movement; the unused spaces in the plant are utilized so as to reduce the material handling cost.

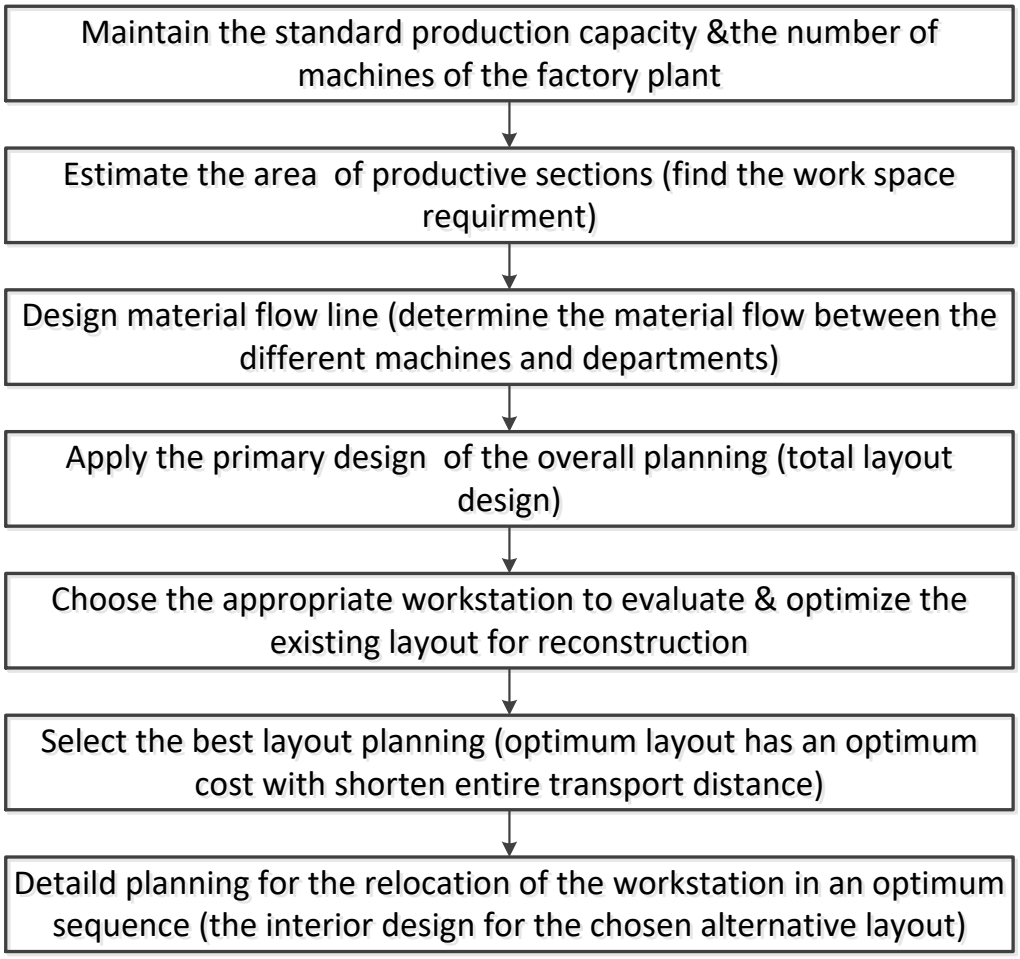
The facility layout problem is concerned with obtaining the most efficient arrangement of individual workstation with unequal area requirements within a defined facility area. The objective of facility layout problem is to minimize the material handling costs inside a facility which is subjected to two sets of constraints: (1) workstation and floor area requirements and (2) workstation location restrictions.

The present factory layout under consideration is studied in detail which unutilized the areas. The facility design should be such that it accounts for all the production.

Facility Layout Design Steps

The main steps that are used in designing process of facility layout for a plant can be illustrated in Figure 1 below:

Figure 1. *Steps for Layout Design and Evaluation*



Choosing the optimum facility layout planning can be in one of the following ways:

1. Economic Assessment: On the basis of a chosen alternative, is less expensive, that is the best planning that gives the cost of production less per unit, through reducing the area of transport or the cost of transport between workstations in the production line.
2. Compare of Material Handling Cost: Alternatives are compared on the basis of calculating the cost of material handling between workstations, and it is possible to adopt a general and simplified equation. As the best planning will give the least cost to the total handling of materials, which means the transfer of materials between sections to a minimum distance (Krajewski et al., 2013).

The present layout is analyzed and searched for areas where the workstations can be relocated or placed so that the material handling cost is reduced and then the new layout design is generated, which are evaluated by C++ programing

language. The layout evaluation plays an important role in the process of designing an effective facility layout.

Mathematical Methods and Algorithms Used to Design the Facility Layout

Algorithms and mathematical methods adopted in the design of the work layout lead to the lowest number of serial steps that are used to find a solution that represents the best design of the work site (Mayer, 1975).

It is necessary to use scientific and mathematical methods to help decision making in this field. Many mathematical models are used to contribute to finding the best ranking of the workplace assets, considering that there is no algorithm, mathematical method or simulation model are used to ensure access to the best design of the workplace, but provide approximate solutions.

Simulation models are an important tool in decision-making, depending on the use of computers as one of the most important and widely used methods. It is used to obtain the best location for work site with least possible time and highest clarity, where it enters the field of design and expansion of work sites, calculation of the machine capacity and the handling cost within the workplace (Zeydon and Golec, 2004).

Basic Criteria for Evaluating Current Location of Workstations

There are two basic criteria on which the current design and determination of the plant have been assessed:

1. Standard Material Handling Cost: The value is found using formula (1):

$$CT = \sum_{i=1}^{N} \sum_{j=i+1}^{N} \text{Fij Cij } Dij \quad (1)$$

Where, CT: Total Transfer Cost, N: total number of workstations, Fij: Transfer Rate From workstation i to workstation j in time unit, Cij: Cost of Transfer from i To j , Dij: Distance from i to j positions (from centroid).

2. The total distance criterion: represents the total transportation distance of materials between different machines according to the general steps to produce different parts. The value of this standard is obtained for each batch of production. The total distance can be calculated using formula (2) as follows:

$$Dt = \sum_{i=1}^{N} \sum_{j=1}^{N} Dij \quad (2)$$

If the distance between departments are Euclidean (between the two centroids of the (workstation), dij is calculated using Equation (3).

$$Dij = \sqrt{(\mathrm{Xi} - \mathrm{Xj})^2 + (\mathrm{Yi} - \mathrm{Yj})^2} \quad (3)$$

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

The value of the traveled total distance is determined by formula (4)

$$DT = \sum_{i=1}^{5} Dti \quad (4)$$

Description of the Production Line of Modern Men's Shoes Manufacturing

The research has been applied in an Iraqi production company for leather industries. It is one of the oldest industries in Iraq, which characterized by a traditional style of production, in terms of administration and management, organizing contracts with suppliers and customers, the flow of production line, planning and control at both levels of processes and inventories.

This work depends on study and analysis of the reality of current work status, then classifying activities and operations. The work sites have been studied in detail so as to evaluate design of the current site of work stations as a case study. One of the most important reasons for choosing this factory to study is the importance of the company, high quality of its products, continuation of production and demand for its products despite the unusual circumstances in Iraq.

The factory was established by the Valeso Company it specializes in the production of men's shoes in different sizes and shapes according to customers demand and according to market changes. Traditional machines have been employed in the production using manual and mechanical work and of relatively high design capacity of 250 000 pairs per year. The work of one batch (5/30 hours/day). The production is characterized by being batch production and work with one shift at 6 hours for 208 working days per year, in order to reach the production volume of (25000) pairs per year in case of continuous demand for the product.

The plant has three production and service divisions:

1. Design Division: consisting of 9 work stations.
2. Sewing Division: number of machines in this division is 18 machines, arranged in two parallel lines, and contains an electric transfer line but it is unemployed at present time. This division consists of a group of production stages that carry production in lines and according to required machines for operations.

3. Fixing and packing Division: consisting of 23 machines, arranged as U-form shape. It contains a belt used for handling and transforming products.

Study Current Layout of the Factory

There are various layouts designs for plant like product layout, group layout and fixed layout. In the present case it is product layout that is redesigned to obtain the reduced material handling cost without altering the manufacturing process.

The factory has been designed and positioned work departments in the form of specialized production sections (layout design based on the process) to cover the diversity of production. The work site within each section is continuous so as to meet the required large production volume at the shortest possible time (layout design based on the product).

The general design of the work site is currently a hybrid design as shown in Figure 2, which shows the centers and sections of the work within the plant with distances. Table 1 represents all activities that are performed in the actual status of the production flow line.

Figure 2. *Present Factory Layout with Distances*

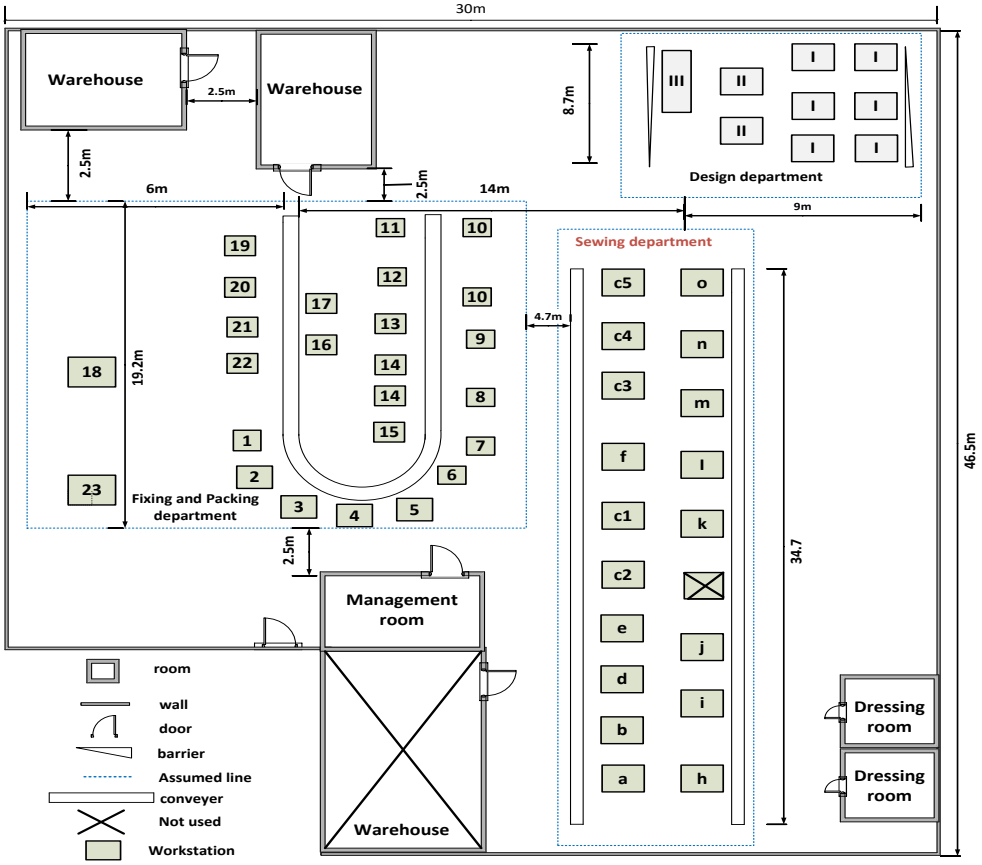


Table 1. *The Actual Status Activities Achieve on the Production Line of Men's Shoe Industry*

Activity no.	Description
.1	Receipt and transport raw material from warehouse to weaning facility
.2	Design department
.3	Prepare filling material
.4	Sorting leather
.5	Cutting filling material
.6	Designing leather
.7	Packaging weaning leather and filling material in packs
.8	Inspection WIP
.9	Transport packs to warehouse Storing WIP
.10	Receipt and transport WIP from warehouse to sewing facility
.11	Sewing department
.12	Marking all the parts of weaning leather
.13	Gluing parts
.14	Sewing parts (leather and filling material)
.15	make holes for the cord
.16	Fixing two valves at side face of shoes
.17	Cleaning face of shoes
.18	inspection WIP
.19	Packaging in sack
.20	Transport sack to warehouse
.21	Storing WIP at warehouse
.22	Receipt and transport WIP from warehouse to fixing and packing facility
.23	Fixing and Packing department
.24	Fix and glue the base of shoe on its die
.25	heating face of shoes
.26	Drew face of shoes
.27	Cut excesses
.28	Grinding and gluing
.29	Gluing the sole
.30	Fixing the sole
.31	Pluck out die
.32	Sewing sole
.33	Inspection finished shoes
.34	Packing finished shoes
.35	Transport box to warehouse

The plant consists of three main workstations (design, sewing, fixing and packing), which are situated within an area of 46.5×30 meters.

The design division includes six face cutting machines and two faceting machines (Lewis) used in the first stage of manufacturing and then moved to the sewing section to complete production processes. Finally, to fixing and packing department to complete production.

The machines are arranged in these sections so as to occupy as little as possible space. In the sewing division there are two parallel lines for materials flow in accordance with operations to be performed as shown in Figure 3.

The sewing division contains eighteen machines with fourteen different types (there are frequent machines to balance the production process). Table 2 shows dimensions of sewing department machines.

Figure 3. *Layout of Sewing Machines Workstation*

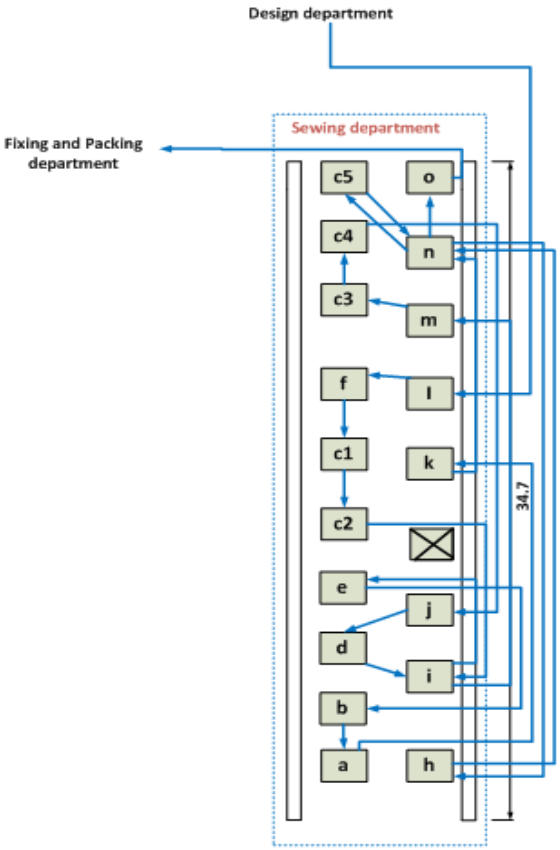


Table 2. *The Dimensions of Sewing Machines*

a		b		d		e		c2		c1		f		c3		c4	
x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
0.25	0.2	0.25	3.96	0.25	7.72	0.25	11.5	0.25	15.3	0.25	19.1	0.25	22.9	0.25	26.7	0.25	30.5
h		i		j		k		l		m		n		o		c5	
x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
2.25	0.2	2.25	4.521	2.25	8.84	2.25	17.5	2.25	21.8	2.25	26.1	2.25	30.4	2.25	34.7	0.25	34.3

Evaluation of Current Layout Design of Workstations

The current design and determination of the plant is evaluated on the basis of the total distance standard and represents the total distance between the different machines according to the general steps of producing the different parts as shown in Table 3.

Table 3. *Estimated Distance between the Workstations of the Current Layout Design*

Machine no.	distance(meter)
design division	
I	**19**
Ii	**3.7**
Iii	**4.8**
swing division	
L	**21**
F	**2.1**
c1	**2.6**
c2	**2.6**
I	**9.5**
M	**17.9**
c3	**1.6**
c4	**2.6**
J	**18.4**
D	**2.1**
I	**3.7**
E	**6.8**
B	**6.3**
A	**2.1**
K	**14.7**
N	**10.5**
c5	**4.2**
N	**4.2**
H	**24.2**
N	**24.2**
O	**2.1**
fixing and packing	
1	**1**
2	**1**
3	**1.5**
4	**2**
5	**3**
6	**1**
7	**2**
8	**2**
9	**2**
10	**3**
11	**2**
12	**1.5**
13	**1.5**
14	**1**
15	**1**
16	**10**
Total distance = 286.9	

Thus, the value of the total distance between the machines used for the production of each part of the men's boot, which is made from raw material and semi-finished material, is:

Total distance traveled for all parts within the manufacturing process = 286.9 meters

Optimization of the Current Layout

The current location of the work stations in the factory has been studied. The possibility of improving the design of the work site, selecting the best possible alternative, using a specialized computer program and obtaining accurate results for distances is studied. Due to the evolution of modern industry features and the tremendous advances in computing capabilities, a range of specialized software has emerged to identify a better design for the workplace more quickly and accurately and ensuring its optimization.

The task of designing a work layout in most cases is complex depending on large amount of data as it needs to be formulated and studied in time-consuming, if done manually. The advantage of the accuracy of computer work as well as easy to control the data (Jo and Gero, 1998). The need to generate good alternatives to design the work layout that is analyzed according to the requirements of the production process, and to avoid wasting time studying inefficient alternatives (Ahmad et al., 2004).

So designers use computers to work faster and more accurate There are several programs for planning processes where programming languages can be used with Microsoft Visual Basic C ++ 6.0 programming language has been used in the current planning problem to get the best decision possible in the least time and effort as well as accuracy and clarity. Also, to examine possibility of improving the design and positioning of the factory of men's shoes. In general, the study will include sewing machines. As the machines of the fixing and packing division will be considered as fixed location, for the reason of high cost of changing the positioning of machines as it is a continuous production line.

The problem is the improvement of the arrangement of the eighteen workstations in the sewing section in a rectangle space (34.75, 3). It includes a width of 1.5 meters between the machines of the two parallel lines of the section, in order to study the possibility of reducing the total distance of the material taking into consideration that the machines of both lines cannot be replaced by other line machines because the floor under the machines of the left line (sewing machines) is suitable for this type of machines for installation and absorption of vibrations.

Figures 4 and 5 illustrated the input and output c++ screen respectively.

Figure 4. *The Program Input Screen for the Problem Studied*

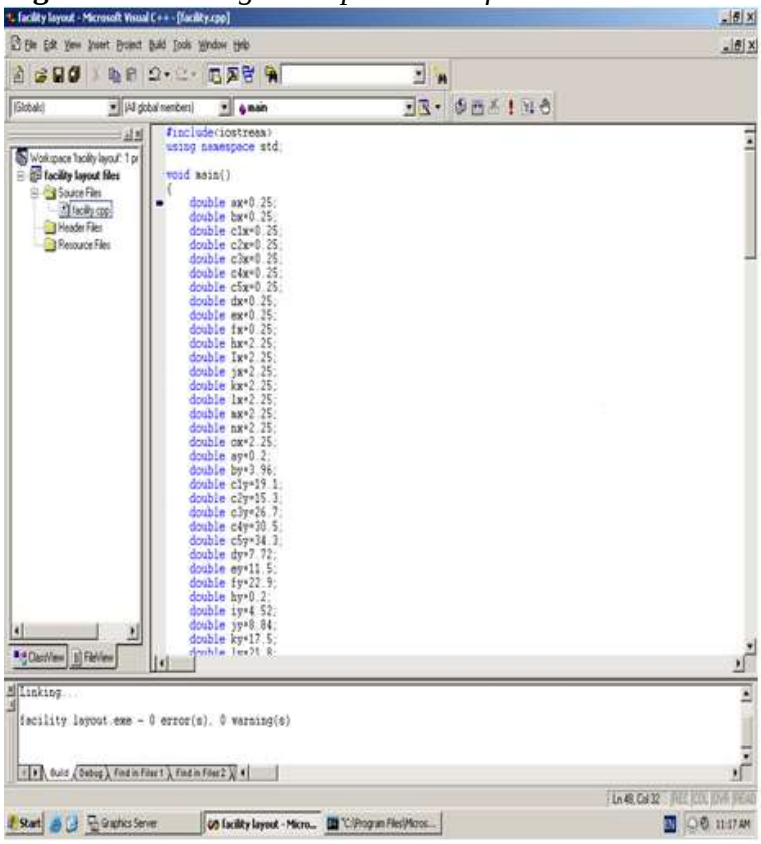
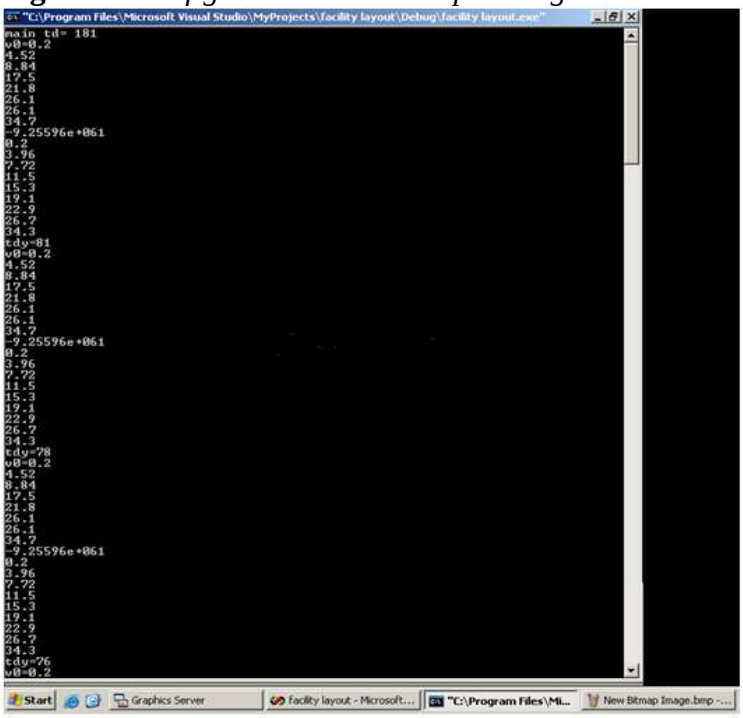


Figure 5. *Configurable Screen Output Program*



Current and Proposed Layout Design of the Factory

The current and proposed design and definition of work locations in the sewing division of the men's shoes factory developed with the flow of materials between the various machines are shown in Figures 6 and 7, respectively.

Figure 6. *The Current Design, Determination and Flow of Work Locations in the Section of Separation, Sewing and Drawing*

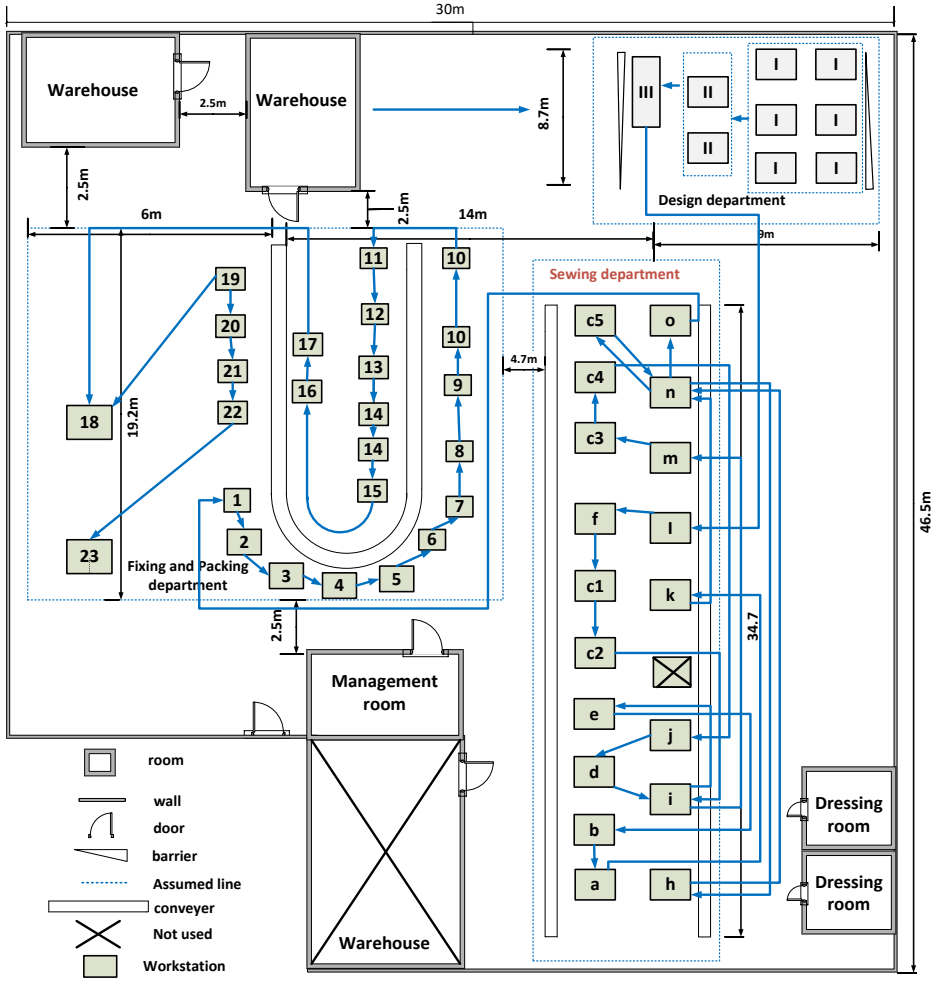
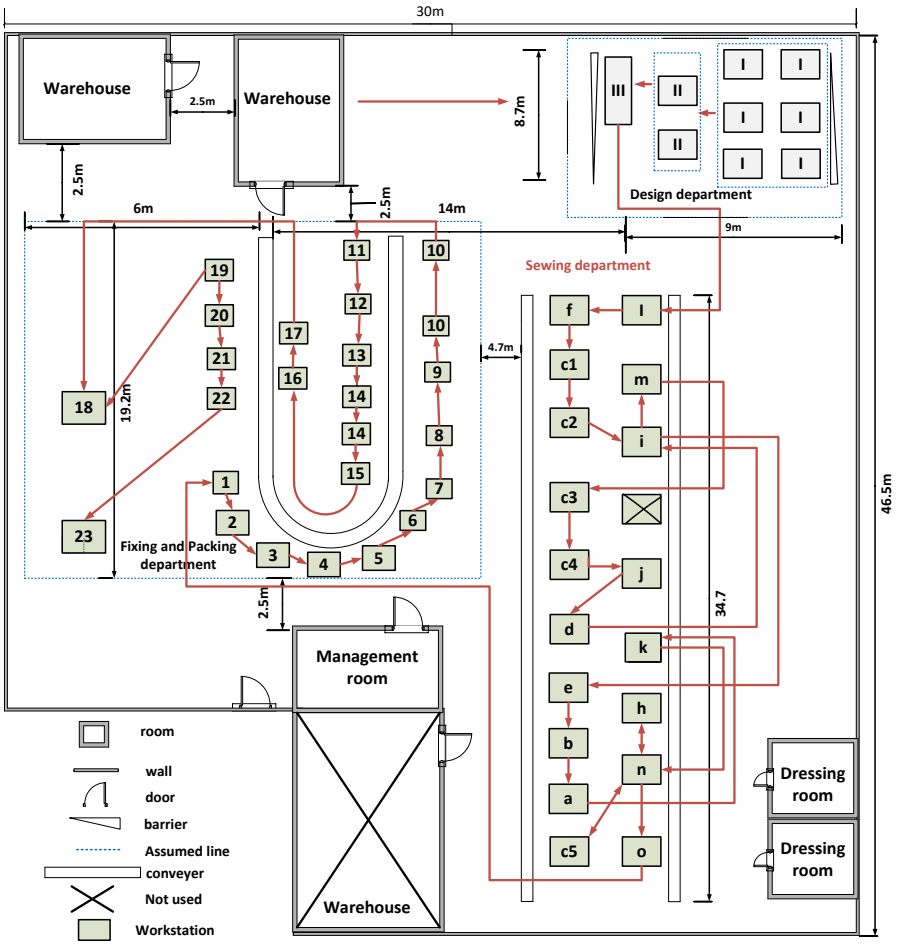


Figure 7. *Illustration of the Proposed Design after Changing the Location of Sewing Machines*



The total distances between different machines of each part according to the proposed layout design are illustrated in table 4.

Table 4. *The New Distance between the Workstations of the Proposed Design*

Machine no.	New distance(meter)	Machine no.	New distance(meter)
I	15	**1**	43.7
II	3	**2**	1
III	3	**3**	1.5
L	15.7	**4**	2
F	2	**5**	3
c1	3.8	**6**	1
c2	3.8	**7**	2
I	2.3	**8**	2
M	4.3	**9**	2
c3	9	**10**	3

c4	3.8	**11**	2
J	4	**12**	1.5
D	4	**13**	1.5
I	11.5	**14**	1
E	15.3	**15**	1
B	3.8	**16**	10
A	3.8	**17**	2.5
K	9.2	**18**	17
N	8.6	**19**	8
c5	4.3	**20**	1
N	4.3	**21**	1
H	4.3	**22**	1
N	4.3	**23**	10
O	4.3		
Total distance = 196.9			
The total distance of the product in the sewing division before modification=181			
The total distance of the product in the sewing division after modification=181			

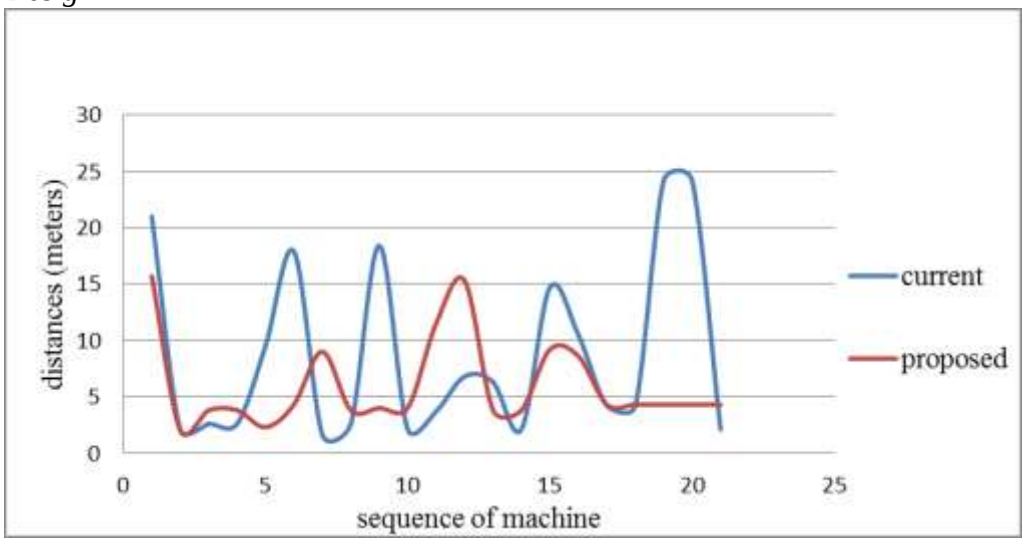
Comparison of the Results between the Current and Proposed Layout Design

Through the proposed optimized results and comparing them with current site data it can be seen:

1. Clear regulation of material flow in the sewing division and direct flow of materials, which reduces the production process time.
2. From comparing the results of the distances of current and proposed design, it is observed that the total distance of the sewing division was reduced by 50.276% from 181 m to 91 m and the total distance of the factory by 68.63% from 286.9 m to 196.9 m.

Figure 8 shows the difference in the route distances of the sewing division for the current and proposed design.

Figure 8. *The Difference in Distances between the Current and Proposed Design*



Conclusions

1. The transmission distance of the units produced in the current layout design of the factory is 286.9 meters.
2. The adoption of scientific foundations for design and determination of work layouts, and installation of technological paths for the basis of the allocation was reached in new design of the work layout in the factory, which has a total transit distance of (196.9) meters, thus we were able to reduce the transport distance by (68.63%) less than the current value of the design.
3. Improving the quality level in finished products, these results from reducing the damage and returns of the product. The quality level of the new machines added, which shortens the number of operations, is much better due to its technological progress.
4. The possibility of making materials flow more uniform by arranging the entry and exit of materials and reducing reaction movements and access to large areas for future expansions.

Recommendations

Recommendations for the future research are:

1. It is necessary to study the layout design and location of work sites and monitor it continuously, especially after making any change in the production process or production line.
2. Following the improved design of the plant's work site to achieve a more orderly flow of materials, reduce total transport distance and

material handling cost, thereby reducing the cost and time of the production process and obtaining safer work site design for the worker and product.

3. Do not leave spaces for the purpose of accumulating materials and products under implementation between work stages.
4. Adopting a criterion that is less than a total area used in assessing and determining the design of work sites.
5. Reducing the overall paths of the movement of materials between the stages of work and reduction in the area of land and output through:

    i. Reducing the number of machines per division as a result of the selection of machines with a higher capacity.
    ii. The use of machines with high productivity with multiple functions and this leads to:

        - Reducing manpower to operate machines.
        - Reduce the cost of maintenance and result from reducing the total number of machines

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