

Palestine Polytechnic University



Collage of Engineering & Technology

Mechanical Engineering Department

Graduation Project

Automating of Material Handling for Furniture and Shelving System

Section at 'Taqaddom Scales Co.'

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اسم المشروع:

**Automating of Material Handling for Furniture and Shelving System Section at
'Taqaddom Scales Co.'**

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بناء على نظام كلية الهندسة والتكنولوجيا وإشراف و متابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الميكانيكية و ذلك للوفاء بمتطلبات درجة البكالوريوس ف الهندسة تخصص " ميكاترونكس "

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Abstract

This project deals with the production operations in one of the metal furniture production companies in Hebron (Taqaddom Scales Company), and a proposal for automating the handling system for one of its products (Shelving and Furniture).

A brief description of the factory is performed, and then production operations of shelving system are described in detail. A mathematical model for this product is also presented, and then the manufacturing lead time is calculated for existing plant layout in the factory.

A new layout is proposed based on automated handling system (conveyors) between workstations which is manual at this time, the required kinematical analysis is also done and the manufacturing lead time for proposed system is calculated.

A comparison between the result of the used system and the proposed one is then shown.

DEDICATION

To our fathers and grandfathers

To our mothers and grandmothers

To all brothers and sisters

To our friends and partners

To our schools and universities

To all our instructors and teachers

To all people we love

We present this honest work

ACKNOWLEDGMENTS

First, our thanks and grateful is only for god

We are indebted to many persons and establishments for their help and contributions during the preparation of this work, acknowledgment is hereby given to our university (PPU), and 'Taqaddom Scales Co.' and every one who contributes by any information or material to us in this preparation. There are individuals deserve special mention here for their help in providing reviews, ideas, and suggestions that improved text.

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LIST OF SYMBOLS AND ABBREVIATIONS

A/D	Analogue to digital converter
ASIC	Application special integrated circuits
CIM	Computer integrated manufacturing
EPROM	Electrically programmed read only memory
LP	Label printer
MLT	Manufacturing lead time
Q	Batch size
RAM	Read only memory
T_d	Delay time at workstations
T_h	Handling time
T_L	Loading time
T_{no}	Non-operation time
T_o	Operation time
T_{UL}	Unloading time
TP	Ticket printer
T_R	Ready time for every machine at a workstation

Chapter **1**

Introduction

- 1.1 Project scope (2)
- 1.2 Automation and Computer Integrated Manufacturing (CIM) (2)
- 1.3 Types of Manufacturing Companies (3)
- 1.4 Types of Productions (3)
- 1.5 Plant Layout Types (4)

1.1 Project scope

Automating of any existing manufacturing plant is very complex, and time consuming operation. Also the chosen company for study is of large and wide production types and sections.

For that, 'Metal Furniture and Shelving systems' manufacturing section is the specified part chosen for this project.

1.2 Automation and Computer Integrated Manufacturing (CIM)

Automation is concerned with the physical activities in manufacturing. Automated production systems are designed to accomplish the following with little or no human participation:

- Part processing
- Assembly operations
- material handling
- Inspection activities

By comparison, computer integrated manufacturing is concerned more with the information-processing functions that are required to support the production operations. CIM involves the use of computer systems to perform the four types of information-processing functions, which are:

- Certain business activities (e.g., marketing, and sales, order entry, etc.)
- Product design
- Manufacturing planning
- Manufacturing control

1.3 Types of manufacturing companies

The industrial companies can be classified by the following three categories [1, 3]:

1. **Basic producer:** This type of industry takes the natural resources and transforms them into the raw materials used by other industrial manufacturing firms.
2. **Converter:** The converter represents the intermediate link in the chain. The converter takes the output of the basic producer and transforms these raw materials into various industrial products and some customer items.
3. **Fabricator:** These firms fabricate and assemble final products that used by community of people and markets.

1.4 Types of productions

A one major way of classifying production activity is according to the quantity of product made [1]. In this classification, there are three types of productions

1. **Job shop production:** The features of this type are:
 - Production is of low volume
 - One kind of productions is often produced
 - The production equipments must be flexible and general purpose to allow for dealing with great variety of work
 - The workers must be relatively at high skill
2. **Batch production:** The features of this type of production are:
 - Manufacturing of medium sized lots of the same item or product at regular intervals
 - Satisfy continuous customer demand for an item

- The manufacturing equipment used is general purpose but designed for relatively higher rates of production
- The machines tools used are often combined with specially designed jigs and fixtures which increase the output rates

3. **Mass production:** This is the continuous specialized manufacture of identical product. Mass production is characterized by:

- Production is at high rates
- The equipments are completely dedicated to the manufacture of a particular product
- Very high demand rates for the product
- The skill of labor has been transferred to the machine; so the labor skill tends to be lower than in a batch production or job shop plant

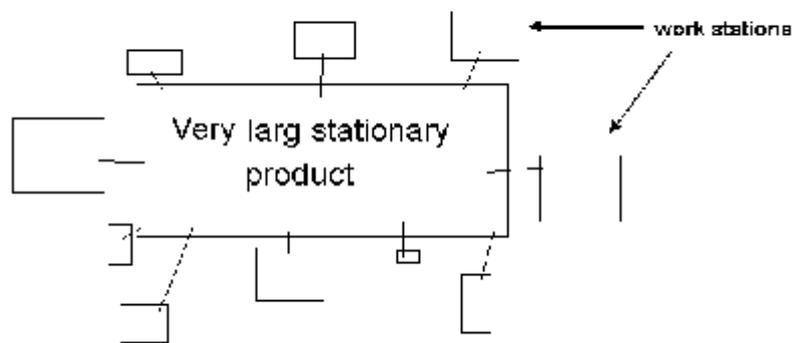
1.5 Plant layout Types

Before the layouts of the plant section introduced, it is required an overview on manufacturing plants layouts in general.

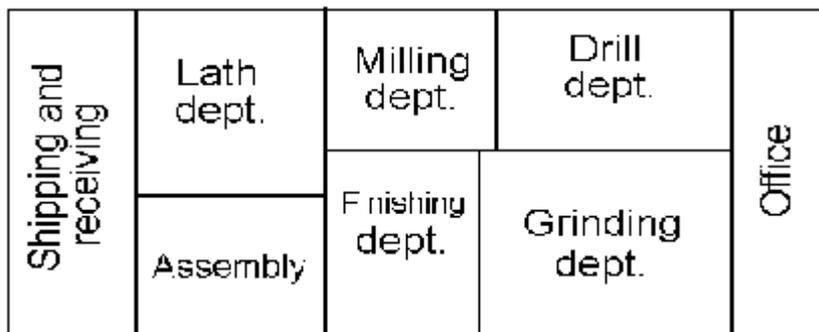
The term *plant layout* refers to the arrangement of physical facilities in a production plant. There are three principal types of plant layout associated with the traditional production Plants [1, 3]:

1. **Fixed-position** layout: the size and weight of product is large, and because of that the product remains in one fixed location, the materials and equipment used in fabrication or production is brought to it. This illustrated in example figure 1.1 (a)

2. **Process layout:** In this type the production machines are arranged into groups according to general type of manufacturing process. Fig 1.1(b)
3. **Product-flow layout:** This type of plant layouts is suitable if the plant specialized in the production of one product or one class of products in large volumes, the plant facilities should be arranged to produce the product as efficient as possible[1]. Figure 1.1 (c)



(a)



(b)

Chapter **2**

'Taqaddom Scales Company'

- 2.1 Briefing about the Company (8)
- 2.2 Company Type (8)
- 2.3 Plant Sectioning in 'Taqaddom Scales Co.' (8)
- 2.4 Sections Layouts (9)

2.1 Briefing about the Company

'Taqaddom Scales Co.' is a family company established in 1953 in Hebron and it is one of the most famous companies in the country. It was the first firm for manufacturing mechanical scales and balances.

In 1970s, the company started producing metal furniture and shelving systems and in 1984, this company introduced the production of electronic scales and balances throughout the Middle East.

All of the company's metal products are Epoxy coated (electrostatic powder)

2.2 Company Type

This company produces many metal products by forming, shaping, and joining metal sheets in the most manufacturing operation accomplished in this factory, in other words, metal sheets enter the plant to be delivered as 'goods' to customers or market, so it is a *fabricator* manufacturing plant

2.3 Plant Sectioning in 'Taqaddom Scales Co.'

The plant sections could be listed as follow:

1. **First floor:** This is the main storage section for the metal finished products (furniture and shelving systems products).
2. **Second floor:** This floor will be discussed in the next chapters in detailed study.

This section actually divided into two subsections, which are:

- Metal furniture and shelving manufacturing subsection
- Painting subsection (electrostatic powder coating) subsection

3. *Third floor:* Mechanical and electronic scales section

The following figure shows those sections organized in the factory building

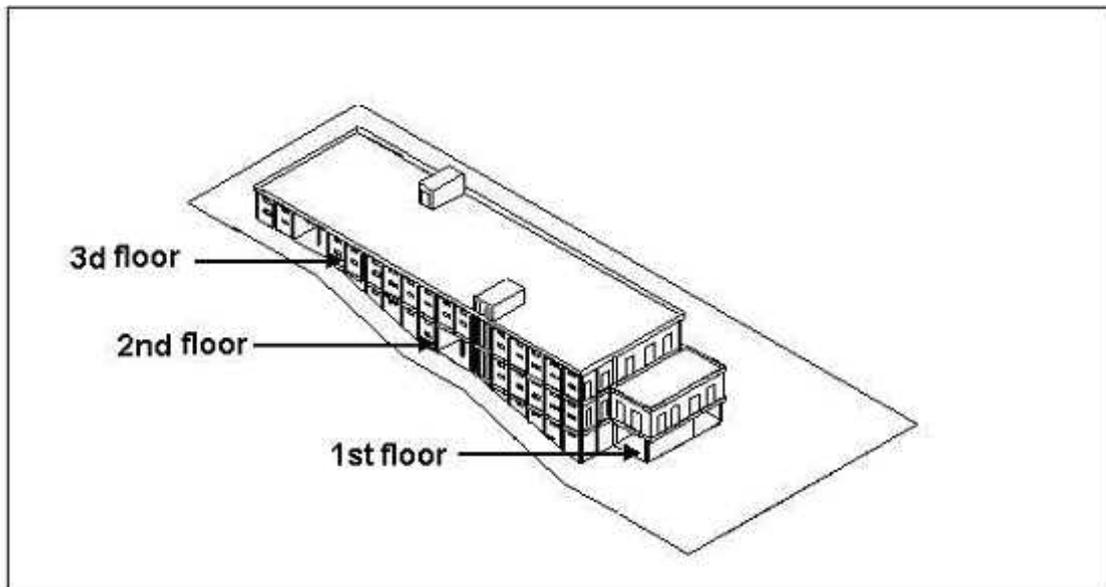


FIGURE 2.1 Factory building 3D view showing the three floors (Courtesy of Taqaddom Scales Company)

2.4 Sections Layouts

FIRST FLOOR:

Storage section of furniture and shelving finished products is located in this floor as mentioned before, but this floor actually organized into two sublevels to maximize the space used in storage.

The finished products come from the second floor (where the loading of parts done there) to this floor by an *Overhead trolley conveyor* that moves in an endless loop that configured to have turns and changes in elevation to make the access of loading and unloading stations possible. After unloading parts in this section, a distribution of those parts in the storage area done manually or by the forklift trucks.

The following figure shows the plan layout of this section

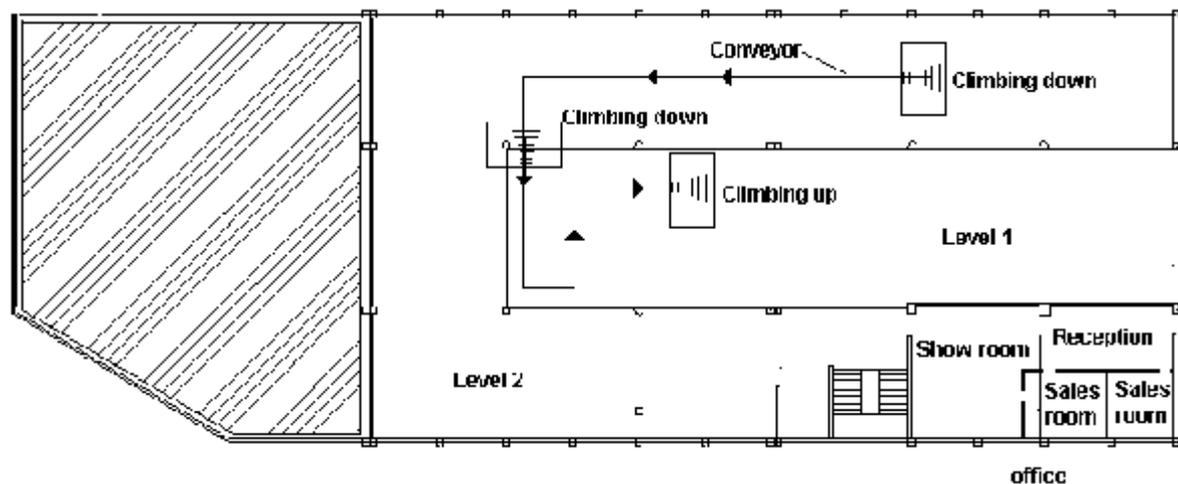


FIGURE 2.2 First floor plan layout shows the two levels and the conveyor rail path

SECOND FLOOR:

Second floor contains the manufacturing section of metal furniture and shelving systems and painting section.

The layouts in this floor appear to be a mixed of two types of layouts due to deference in production operations required. This could be presented as follow:

- Metal furniture and shelving manufacturing subsection:
Here the raw material enters in form of metal sheets to be reproduced in unfinished shelving parts, which are the raw material to the next subsection. So, the layout found in this subsection classified as *process* layout type which will be the case study in the project at hand.
- Painting subsection:
Here the unfinished metal furniture and shelving parts enters as the raw material to be passing through finishing process (electrostatic powder coating).

The output of this subsection is finished metal furniture or shelving system parts. The discreet product parts move through the finishing process phases while they are hanged up on a conveyor. So the production layout is seen to be flow line layout. Now, the finished products leave this floor to the storage section in the first floor.

The following figure (Figure 2.3) shows the second floor sectioning and the layouts for each subsection:

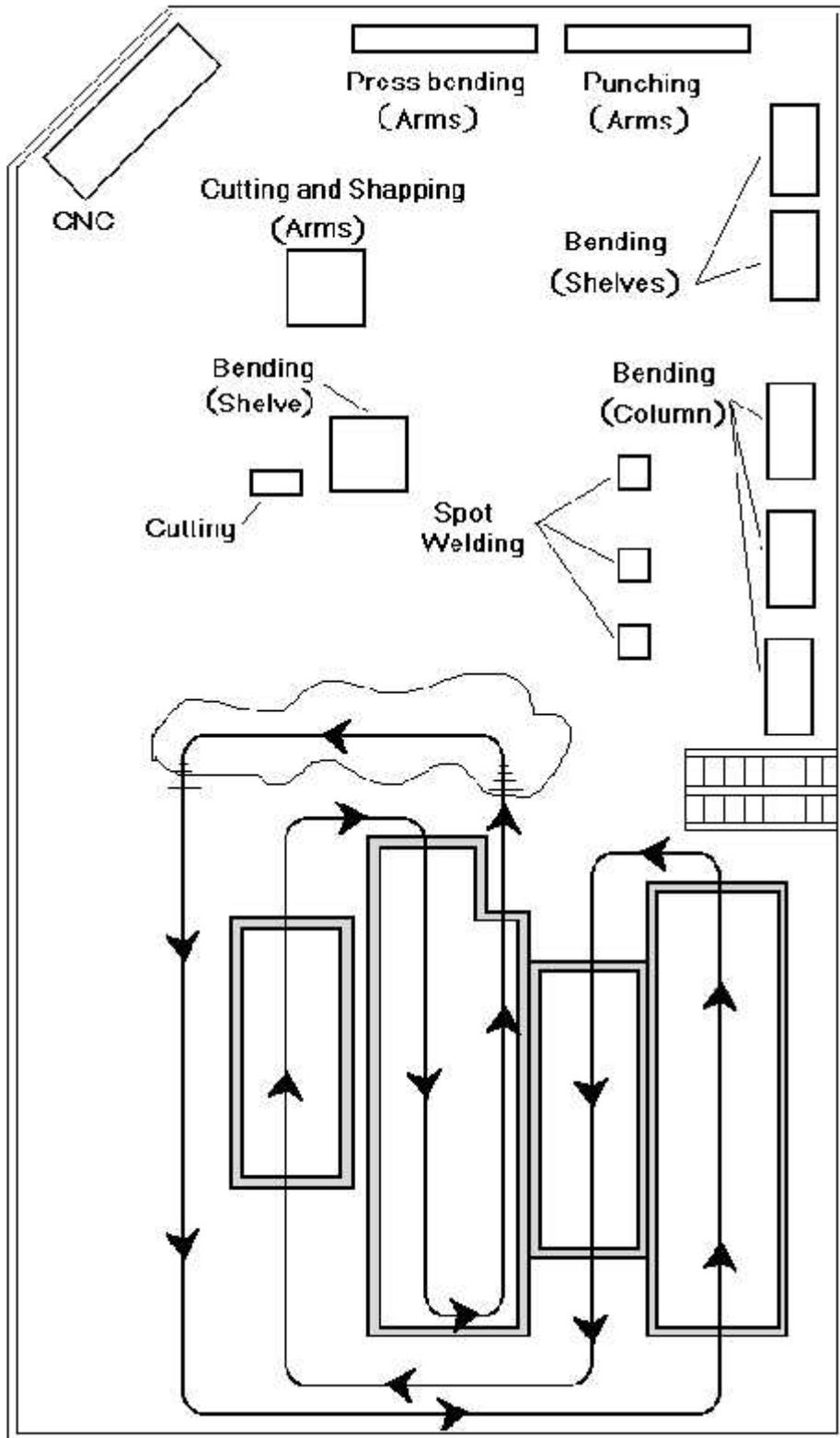


FIGURE 2.3 (Second floor sectioning layout)

In this floor the factory produces many types of metal furniture and shelving products such as:

- Pallet racks shelving (heavy-duty)
- Supermarket stands
- Library shelving system
- Dexon shelving system
- Super store shelving system
- Supermarket shelving (benkal)
- Lockers for clothes
- Office tables
- Filing cabinets
- Planfile (drawers)

THIRD FLOOR:

This floor divides into two sections, which are:

- Mechanical scales manufacturing section
- Electronic scales assembly section

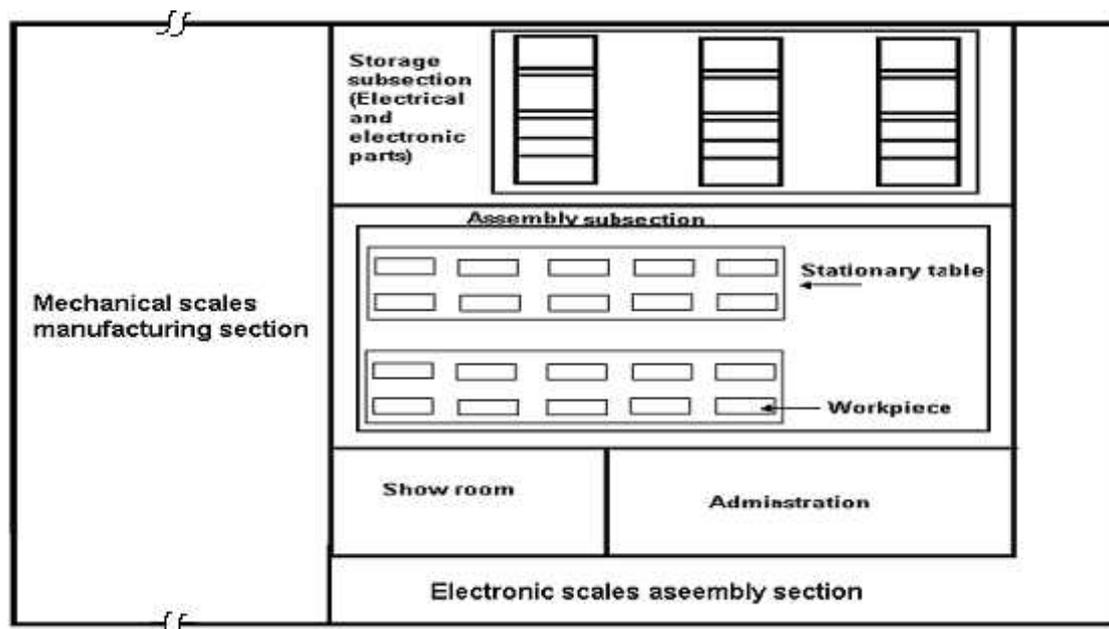


FIGURE 2.4 (Third floor layout)

The Electronic Scales Assembly Section:

This section was established in 1999, and it is located in the third floor, dedicated for producing and assembling electronic balances and scales [2].

Section contents:

The section is divided into three subsections:

1. Administration, offices, management, and show room
2. Storage subsection
3. Assembly subsection

Administration Subsection

This section is the place where the parts are orders from main suppliers are made, and the customer orders are taken, and both are transferred to the computer to do monthly plan for the assembly section.

This subsection is considered as the interface (link) between assembly section and both suppliers and customers, it is responsible for receiving the ordered items on time in order to supply the ordered scales to customers on time as well

Additionally this section is responsible for keeping stock control for many scales spare parts

Storage Subsection

This section is responsible for storing each item or part of the electronic scales in its place or on the suitable shelves, looking after preparing kits of scale's parts for the assembly section, counting items on arrival and compare it to the invoices.

These parts are different; some of them are electronic boards or integrated circuit (ICs) others are electrical parts, mechanical parts, metal parts and plastic parts.

Electronic Parts

These parts include:

a) Main Board:

These boards contain the microcontroller, Application Specific Integrated Circuit (ASIC), main memory (RAM), registers and EPROM. Which are programmed in house with special EPROM. writer by a specific program (hexadecimal file).

Microcontroller also programmed in house which represent the slave (text).

b) Analog to Digital converter (A/D) cards:

These kits interfaced with the load cell, which receive the voltage as an analog signal, and then convert it to digital in hexadecimal code and translate it to the main board.

c) Load Cell:

It is a strain gage sensor that converts the stress into a small varying in resistance, this variation produces changed in voltage and then translate it through cable to the analog to digital converter (A/D) circuit.

Load cell models differ from scale to another according to the measured weight.

d) Keyboard:

It is contain the numbers and characters used in arithmetic operations such as addition, multiplication, division, etc. The system used in these keyboards is the touch button technique (membrane-switch).

e) Printers:

There are three types LP (label), TP (ticket), and CP printer type

f) Display:

It is a very important part as it contains more than a small monitor that we take reading of the weight from it. The section has displays of modern type of FVD-type (Florescent Vacuum Display).

Electrical Parts

This part contains

a- Transformer:

Used to convert the ac voltage to an appropriate and suitable level

b- Noise Filter:

This is an important part used to remove the unwanted disturbance signals.

c- Fuse:

It adds the safety to protect the system when it is subjected to high current.

d- Cables: to connect all mentioned parts with each other.

Plastic Parts

These parts consist of the main base, bottom cover, plastic top cover, pole cover, display cover ...etc.

Metal Parts

Most of these parts are made in house like power supply holder and printers metal part.

Assembly Subsection

This is the main subsection in the electronic scales section; it contains the production line and its four large flat tables, and contains the tools and equipments needed for production and assembly processes.

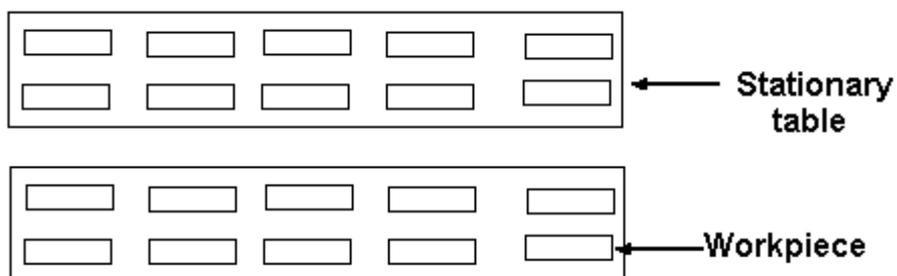


FIGURE 2.5 Assembly station layouts

Process

The process in this section is done according to the types of the scales needed by the customers and its specifications such as the ability of the scale to accept the loads without failure and if it has printer or not.

Material Handling:

All material handling in this section is done manually.

Chapter **3**

Furniture Manufacturing Operations in 2nd Floor

- 3.1 Introduction (20)
- 3.2 Sequence of Operations (20)

3.1 Introduction

In this floor many types of different furniture and shelving systems are produced, to study the manufacturing operations in this section, a specified product is chosen to be traced out through its manufacturing operation in purpose of study analysis, this product is '*Dexon Shelve*' type.

3.2 Sequence of Operations.

- The process started by brings the raw material (metal sheets 1380x880 mm.) from storage section.
- The above operation requires 2.5 minutes of time to bring it to the cutting workstation (guillotine).
- The operation time required for cutting is 7 sec.
- Then the metal sheet reformed to have a new dimension of (1360x 880 mm.).
- The removed 20mm from the length is become a scrap material.
- The sheet is now has a new dimensions, which are 1360x880 mm., then another cut by one hit is made to divide the sheet into two equal pieces at dimensions of (680x880) mm.

These operations explained in the following figure:

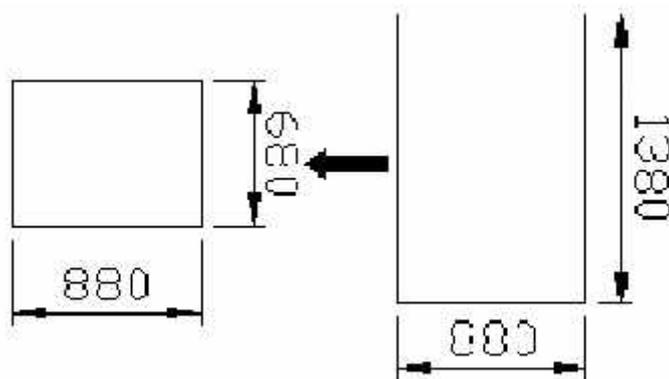


FIGURE 3.1 (The cutting process)

- The next operation is transferring the metal sheet from the cutting workstation to the punching and shaping workstation (Press) in 16 sec.
- At punching workstation, the forming of the four corners for the sheet and punching the screw holes operations are accomplished in 12 sec.

The operation explained in the following figure:

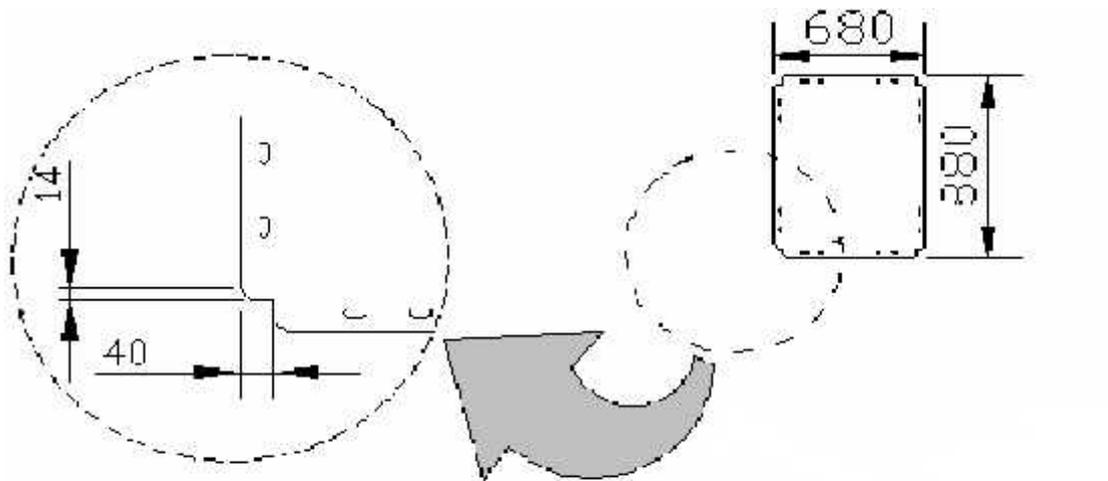


FIGURE 3.2 (Forming of the four corners and punching operations)

- After the above operations, the output from the punching workstation was transferred to bending workstation in 16 sec.
- In this station the operation time was 21 sec.

The following figure shows the output from bending workstation:

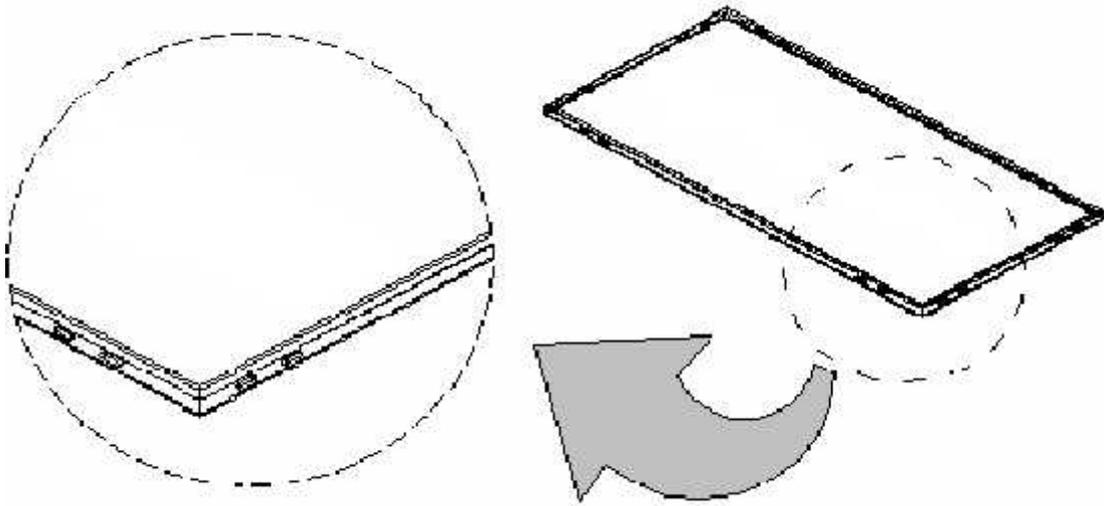


FIGURE 3.3 (The output of bending operation)

For column(Shelf reinforcement beam), the following operations were done on it:

- Transfer the raw material (metal sheets) from the storage to the cutting workstation in 2.5 min.
- Cutting: the metal sheet cut in primary dimensions (100X60 cm.) in 3 sec/unit
- Another transfer operation from cutting work station to the bending work station in 30 sec.
- Bending the metal sheet in the bending work station in 12 sec.
- A new transfer to spot welding assembly workstation in 5 sec.

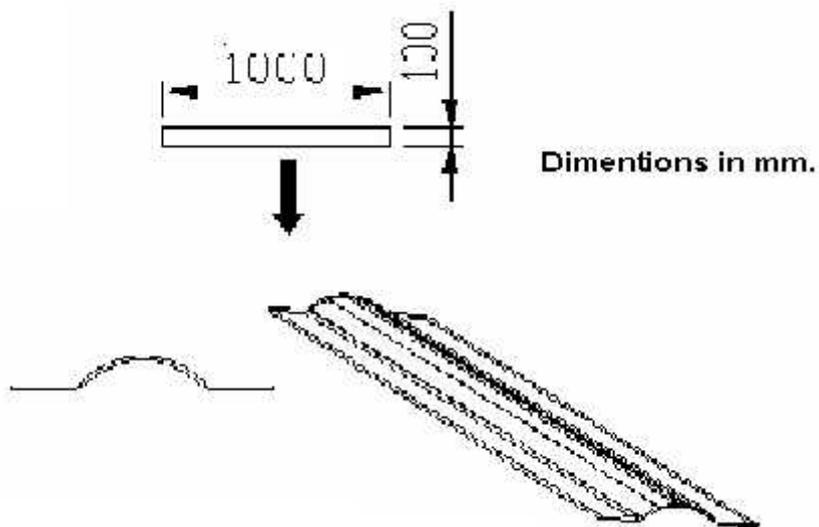


FIGURE 3.4 "Manufacturing operation of supporting column"

The shelf is completed with the assembly operation at the spot welding workstation in 50 sec.

The output is shelved with dimensions at (100X60 cm.) as in the following figure:

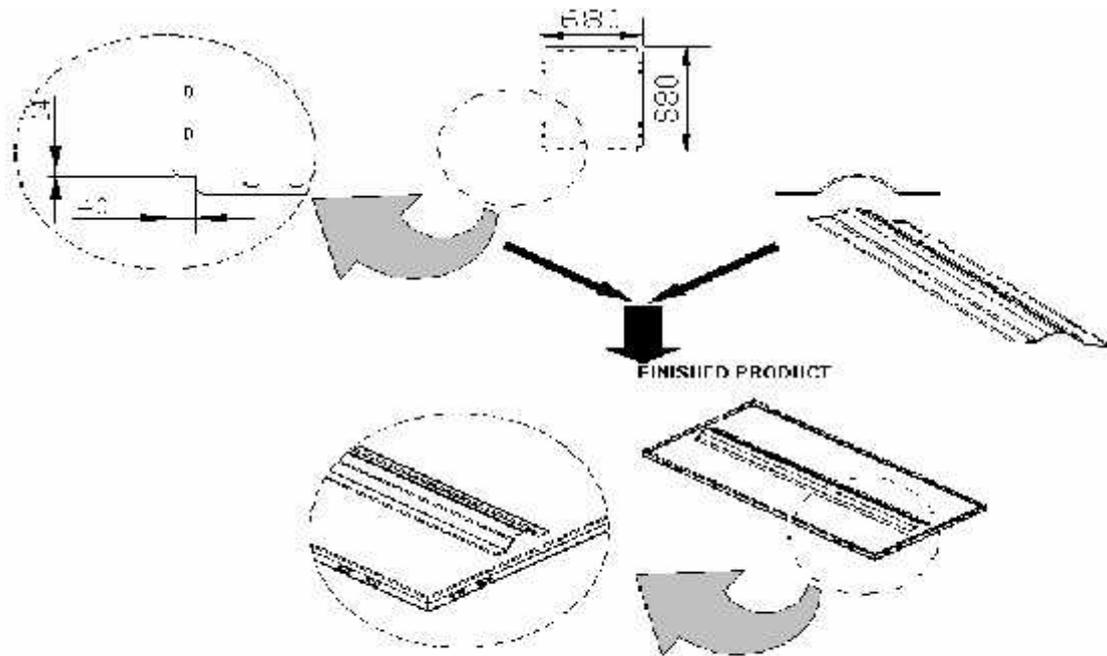


FIGURE 3.5 'Dexon' shelving system

- Now the product is unfinished surface unit need to be delivered to the painting subsection.
- The transfer of this part to be hanged up on the trolley conveyor and this requires one minute by manual transfer type (hand truck).
- In the painting section every unit of this product enters the process in discrete mode and every unit spent half a minute except the first unit that needs 2 hours because the painting work station need this time to get ready.
- Then after the finishing process is completed the product moved to the first floor for packaging and storing.

Chapter **4**

Mathematical Modeling and Analysis of Manual Operations in 2nd Floor

- 4.1 Manufacturing Lead Time (25)
- 4.2 Sequence of operations (26)
- 4.3 Measured Time (26)
- 4.4 Calculation of Manufacturing Lead Time (MLT) (28)

In the purpose of analysis for the manufacturing process operations, mathematical tools necessary to deal with this issue should be taken in a account. And so this chapter is concerns with many aspects and terms will be considered to make the decision about the proposed solution could be made.

4.1 Manufacturing Lead Time (MLT)

The time spent from the customers demand to the moment of product delivery is simply formed the manufacturing lead time which extremely influenced by the most of manufacturing phases and manipulating operations of the product [1, 3].

$$MLT = \sum_{i=1}^{n_m} (T_{sui} + QT_{oi} + T_{noi}) \quad (4.1)$$

Where:

i indicates the operation sequence in the processing; $i = 1, 2, 3, \dots, n_m$.

MLT: manufacturing lead time, T_o the time per operation at given machine Workstation, **Tno** to represent the nonoperation time associated with the same machine, n_m represent separate machines or operation through which the product must be route order to be completely processed, **Tsu** is the setup typically includes arranging the workplace and installing the tooling and fixturing required for the product, **Q** is the units of products in the batch and equal to 1 for job shop production type.

Average delay time at every machine T_d is:

$$T_d = \left(\sum_{n=0}^{Q-1} n \times T_o \right) / Q \quad (4.2)$$

Where n is the order of unit in the patch

4.2 Sequence of Operations

The operations where done on the Dexon shelve as explained in chapter three are shown in the following figure:

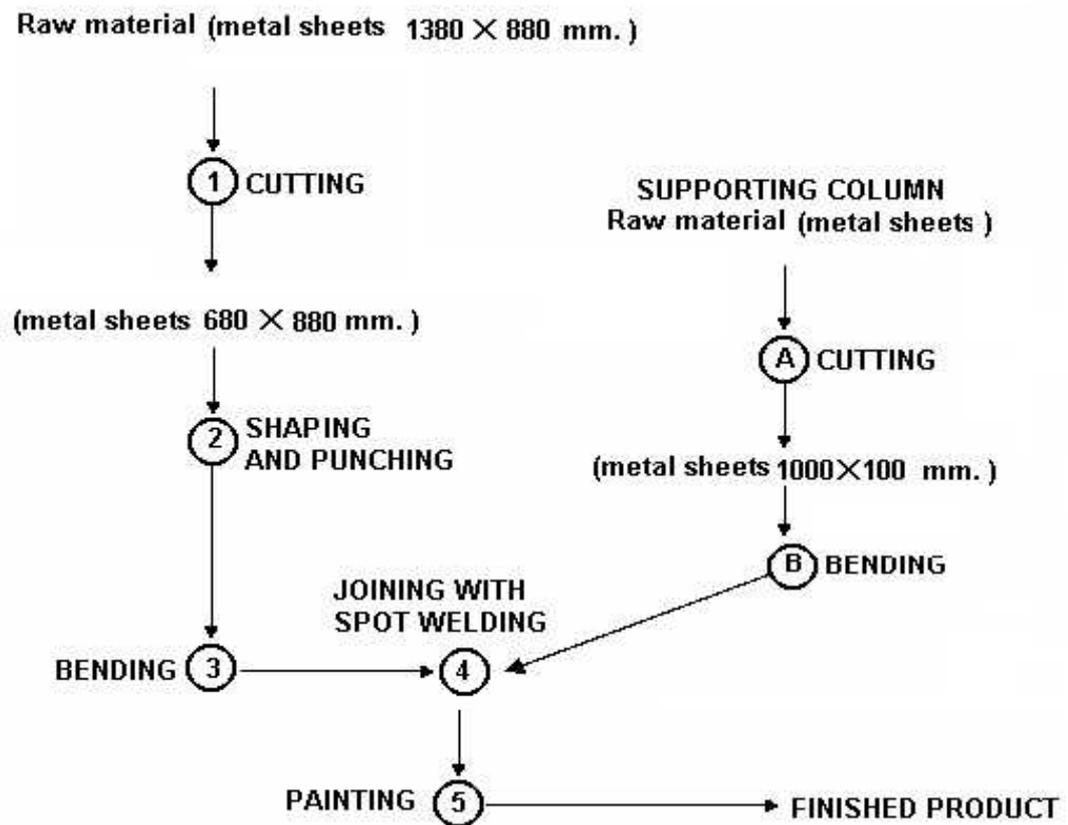


FIGURE 4.1 (Sequence of Operations on Dexon shelve System)

4.3 Measured Time

Every operation done on the product spends a period of time different from operation to another according to the type of that operation.

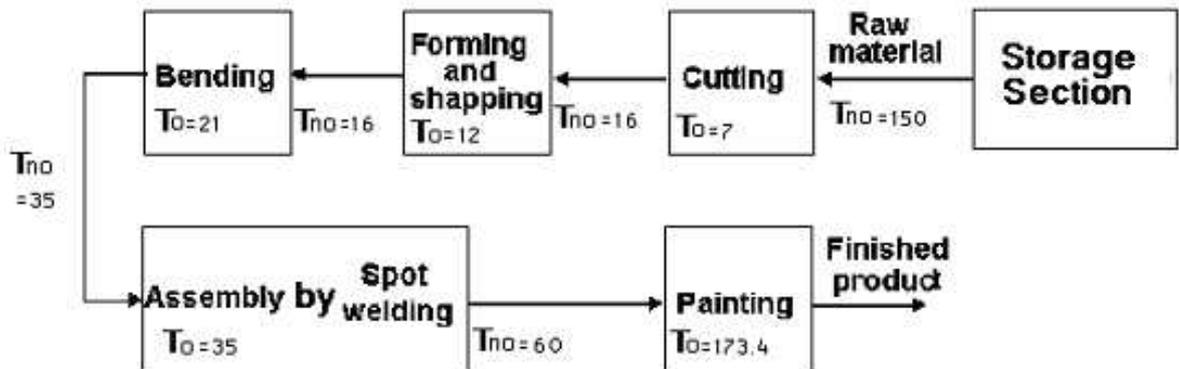
The following table shows a measured time for every individual operation accomplished on the 'Dexon shelving system':

TABLE 4.1 (Measured Time)

Type of operation	Transfer time (S)	Delay time (S)	Operation time (S)
Cutting	300	241.5	7
Shaping & punching	16	414	12
Bending for shelve	16	724.5	21
Cutting for column	300	120.75	3.5
Bending for column	30	414	12
Joining by spot welding	35	1725	50
Paining	60	887.5	132.8

The painting operation measured time seems to spend 7200 seconds, but this is not for every unit but the first one enters the painting workstation, and this is because of preparing this workstation to receive the product units. So the average time of every unit is in fact less than this measured time (132.8 S.), and this will be considered later due to calculations.

The time which was calculated for manufacturing 'Dexon shelve' and showing in the above table we will apply this time on the layout of shelving and furniture section as shown in fig 4.2 :



*All times in seconds

FIGURE 4.2 "The layout of shelving and furniture section and time calculations"

4.4 Calculation of Manufacturing Lead Time (MLT)

Table 4.2 shows the calculation for every nonoperation time T_{no} , the time per operation at given machine Workstation T_0 and the setup time for 70 units of products.

Note: the setup time is zero for all workstations in fig 4.2

TABLE 4.2 'Calculations of Manufacturing Lead Time (MLT)'

Operation	To (s)	To (h)	Th(hand) (S)	Td(delay) (s)	Tno=Td+Th (s)	Tno (h)	Q(To)+Tn (h)
Cutting	7	0.001944	300	241.5	541.5	0.150417	0.286528
Punching and shaping	12	0.003333	16	414	430	0.119444	0.352778
Bending for shelve	21	0.005833	16	724.5	740.5	0.205694	0.614028
Cutting for column	3.5	0.000972	300	120.75	420.75	0.116875	0.184931
Bending for column	12	0.003333	30	414	444	0.123333	0.356667
Joining by spot welding	50	0.013889	35	1725	1760	0.488889	1.461111
Painting	132.8	0.036889	60	887.5	947.5	0.263194	2.845417
Σ	238.3	0.066194	757	4527.25	5284.25	1.467847	6.101458

By using equation 4.1, the manufacturing lead time (MLT) for $Q=70$ will be:

$$MLT_{New} = \sum_{i=1}^{n_m} (T_{sui} + QT_o + T_{no}) = 6.101 h.$$

Note: the operation time for painting workstation shown in table 4.2 is the average time for 70 units of products in every batch.

By the same manner of calculating MLT for $Q=70$, table 4.3 shows values of MLT for different range of patch size Q :

TABLE 4.3 (Various batch sizes and the corresponding calculated MLT)

Q(units)	20	30	40	50	60	70	80	90	100	110
MLT(h)	2.7917	3.4537	4.1156	4.7776	5.4395	6.1015	6.7634	7.4253	8.0873	8.7492
Q(units)	120	130	140	150	160	170	180	190	200	
MLT(h)	9.4112	10.0731	10.7351	11.3970	12.0590	12.7209	13.3828	14.0448	14.7067	

Fig 4.3 shows the relations between multiple batch size and MLT:

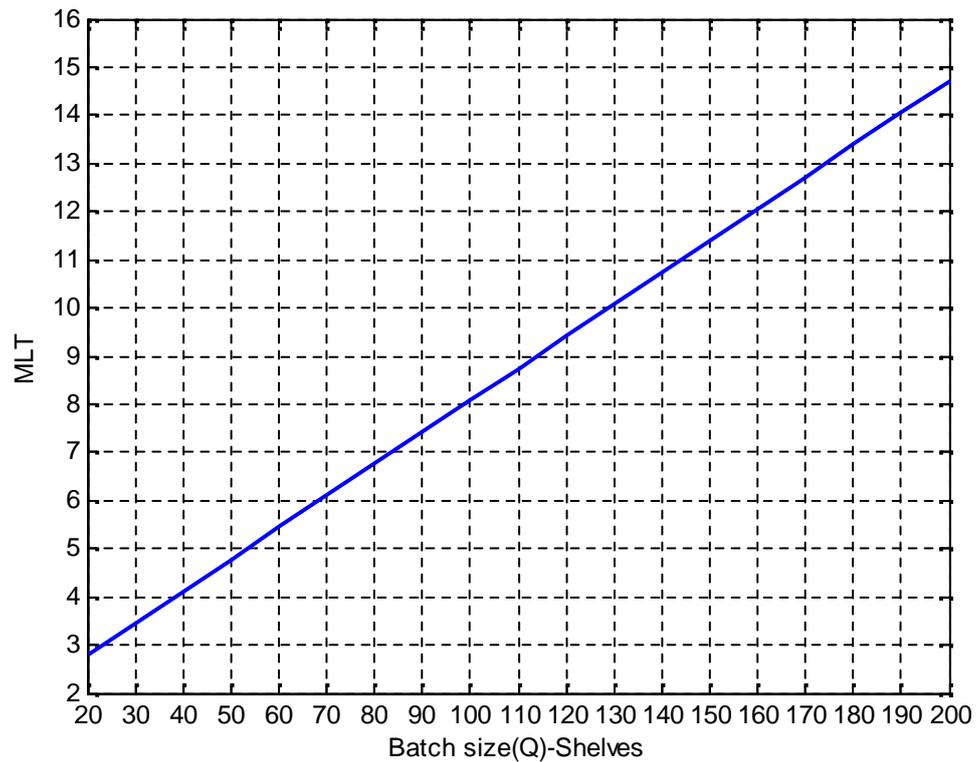


FIGURE 4.3 (Graphical representation of Q vs. MLT)

Chapter **5**

Automating of Material handling of 'Dexon shelving system' manufacturing process in 2nd Floor

- 5.1 Introduction (32)
- 5.2 Material Handling Optimization (32)
- 5.3 Rearrangement of Workstations Method (32)
 - 5.3.1 Current Layout of Workstations (33)
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 - 5.3.3 Calculation of Manufacturing Lead Lime (MLT)
For the New Layout (35)
- 5.4 Design of Material Handling System (39)
 - 5.4.1 Characteristics of Material to be moved (Dexon Shelve) (39)
 - 5.4.2 Quantity of Material to be Moved (40)
 - 5.4.3 The Stations Layout with Conveyor (40)
 - 5.4.4 Calculation of MLT for the Layout with Conveyor
System (47)

5.1 Introduction

Automating of a plant concerned basically with the improvement of material handling to reach the optimum plant layout.

The problem that is to be considered is the manual material handling in the plant so an automated material handling system is to be included in the plant layout.

After this improvement, the following could be gained:

- Reduction of manufacturing lead time(MLT)
- Reduction of non-operation time associated with the same machine ($T_{no.}$).

5.2 Material Handling Optimization

Material handling is an important, yet sometimes overlooked aspect of automation. The cost of material handling is a significant portion of the total cost of production. Estimates of handling cost run as high as two-thirds of total manufacturing cost [1, 2, 3]. This fraction varies depending on the type and quantity of production and the degree of automation in material handling function.

The optimization of material handling in this floor consists of:

- Rearrangement of workstations (modification of layout)
- Design of a suitable material handling system

5.3 Rearrangement of Workstations Method

Rearrangement of work station requires a representation of the existing layout in this section before any changes

5.3.1 Current layout of Workstations

The current layout of the Dexon shelves manufacturing section is shown in the following figure:

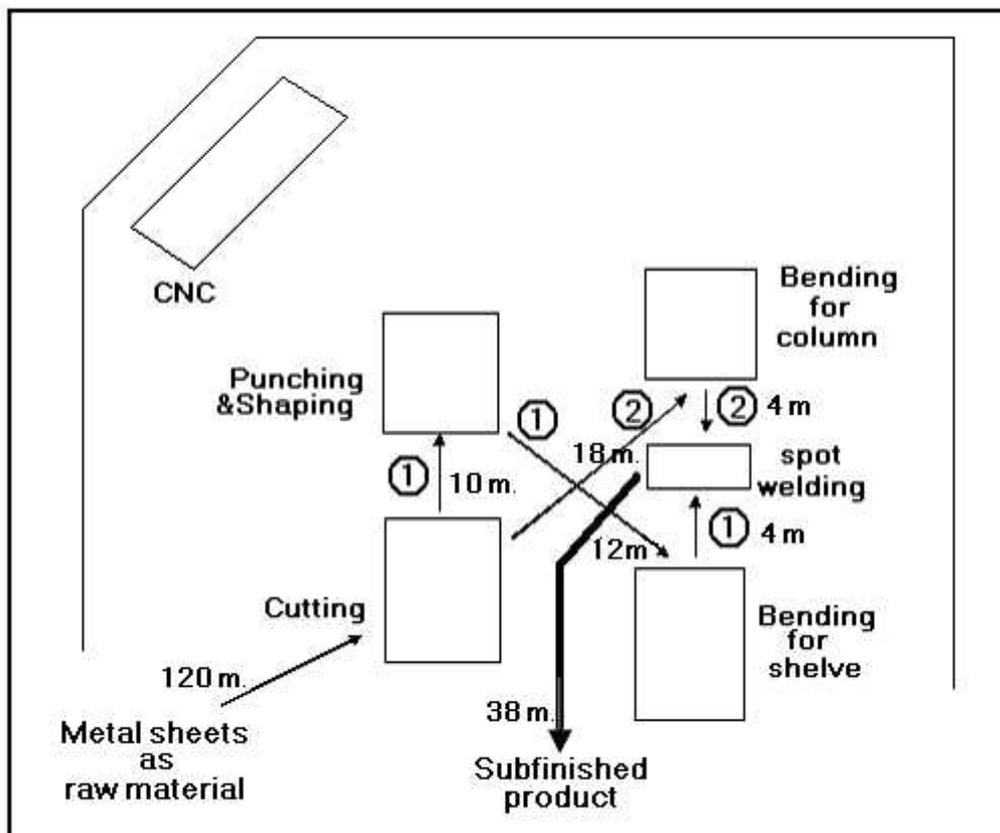


FIGURE 5.1 (Dexon shelves manufacturing section layout, arrows describes the flow direction of components between workstations, circle with number 1 indicates shelves flow, circle with number 2 indicates the column flow, and distances in meters represents the distance of material travel).

Material handling in this section is by using hand trolley between workstations and forklifts for transfer the raw material from storage section to this section.

Its clear from study these methods that the time requires to manipulates the material without any operations accomplished or simply non-operation time (Table 4.1) is occupies an effective portion of manufacturing process overall time.

5.3.2 Rearrangements of Workstations

As seen in figure 5.1 the current arrangement of the machines are very complicated and does not give the best performance of the material handling, so it needs to be rearranged to reduce the time of material traveling between workstations, and to reduce the manufacturing time(MLT) by reducing the non-operation time.

The proposed new layout is shown in figure 5.2:

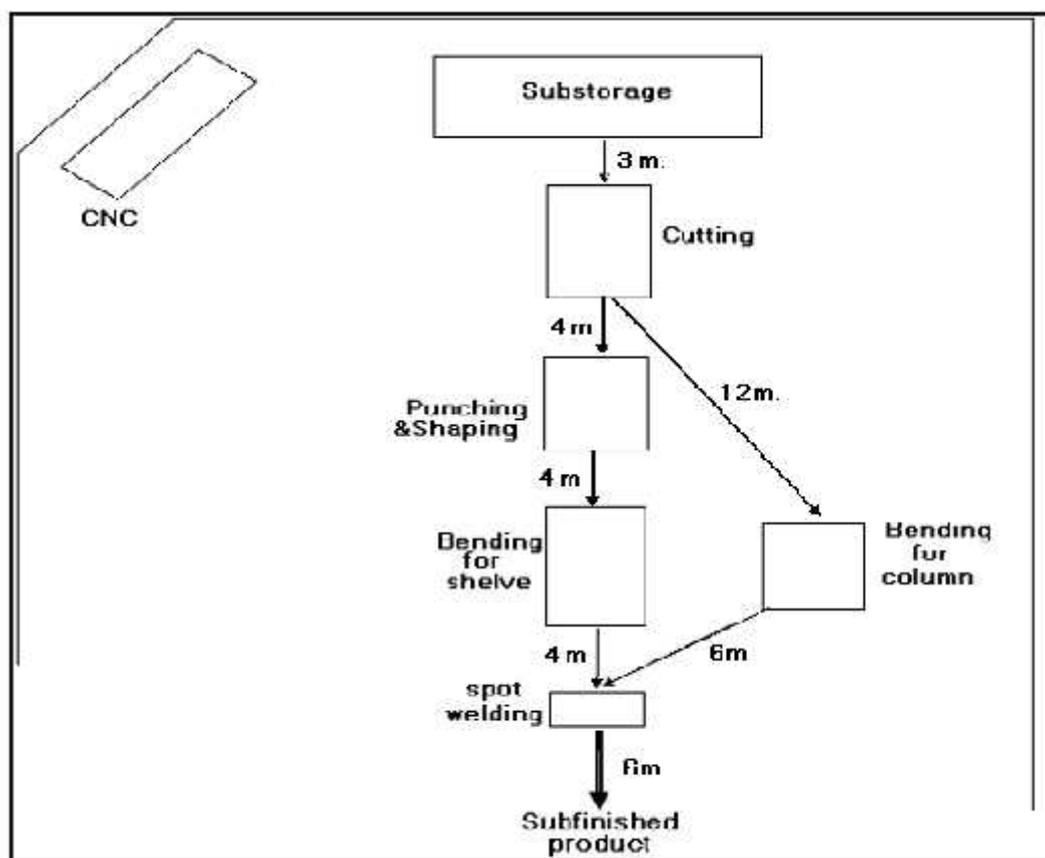


FIGURE 5.2(The new layout after rearrangement of machines)

And from figure 5.2, the new layout clearly shows the one directional flow of material between workstations and in addition to the substorage section and this gives the followings:

- Reduction of traveling time between workstations
- Prevent the moving material from repeating pass from the same point more than once.

- No path intersection is introduced
- Suitable material flow from the substorage section to the painting section
- A new suitable layout without the need of new machines or change in the plan layout of the section.

ANALYSIS OF THE NEW LAYOUT:

The following table shows the components of time consumed in the manufacturing process after modification of workstation layout:

TABLE 5.1 (Measured Time for the modified layout)

Operation	Transfer time (Tno) (S)	Delay time (S)	Operation time (To) (S)
Cutting	3	241.5	7
Punching and shaping	5	414	12
Bending for shelve	5	724.5	21
Cutting for column	3	120.75	3.5
Bending for column	11	414	12
Joining by spot welding	6	1725	50
Painting	6	887.5	7200

5.3.3 Calculation of Manufacturing Lead Time (MLT) for the New Layout

The following table shows the calculation for every non-operation time **T_{no}**, the time per operation at given machine Workstation **T_o** and the setup time for 70 units of products.

Note: the setup time is zero for all workstations in fig 4.2

TABLE 5.2 (The Calculation of Manufacturing Lead Time 'MLT' for the new layout by using rearrangement of machines)

Operation	To (s)	To (h)	Th(hand) (S)	Td(delay) (s)	Tno=Td+Th (s)	Tno (h)	Q(To)+Tn (h)
Cutting	7	0.001944	3	241.5	244.5	0.067917	0.204028
Punching and shaping	12	0.003333	5	414	419	0.116389	0.349722
Bending for shelve	21	0.005833	5	724.5	729.5	0.202639	0.610972
Cutting for column	3.5	0.000972	3	120.75	123.75	0.034375	0.102431
Bending for column	12	0.003333	11	414	425	0.118056	0.351389
Joining by spot welding	50	0.013889	6	1725	1731	0.480833	1.453056
Painting	132.8	0.036889	6.5	887.5	894	0.248333	2.830556
Σ	238.3	0.066194	39.5	4527.25	4566.75	1.268542	5.902153

By using equation 4.1, the manufacturing lead time (MLT) for $Q=70$ will be:

$$MLT_{New} = \sum_{i=1}^{n_m} (T_{sui} + QT_o + T_{no}) = 5.902 h.$$

As seen in chapter 4 the manufacturing lead time was found 6.101 h, so the reduction in manufacturing lead time is:

$$MLT_{Old} - MLT_{New}$$

$$6.101 - 5.902 = 0.2 h$$

The percentage drop in MLT is:

$$((MLT_{Old} - MLT_{New}) / MLT_{Old}) * 100\%$$

$$\left(\frac{0.2}{6.101}\right) \times 100\% = 3.2\%$$

This percentage shows that the manipulation of work stations layouts (locations) could effect the manufacturing lead time MLT, but in relatively small effect.

By the same manner of calculating MLT for the new layout, again it could represent a various batch size and their corresponding calculated MLT as shown in table 5.3:

TABLE 5.3 (Various batch sizes and the corresponding calculated MLT for the new modified layout by the rearrangement method)

Q(units)	20	30	40	50	60	70	80	90	100	110
MLT(h)	2.5924	3.2544	3.9163	4.5783	5.2402	5.9022	6.5641	7.2260	7.8880	8.5499
Q(units)	120	130	140	150	160	170	180	190	200	
MLT(h)	9.2119	9.8738	10.5358	11.1977	11.8597	12.5216	13.1835	13.8455	14.5074	

Fig 5.3 shows the relations between multiple batch size and MLT represented graphically for the new modified layout by the rearrangement method:

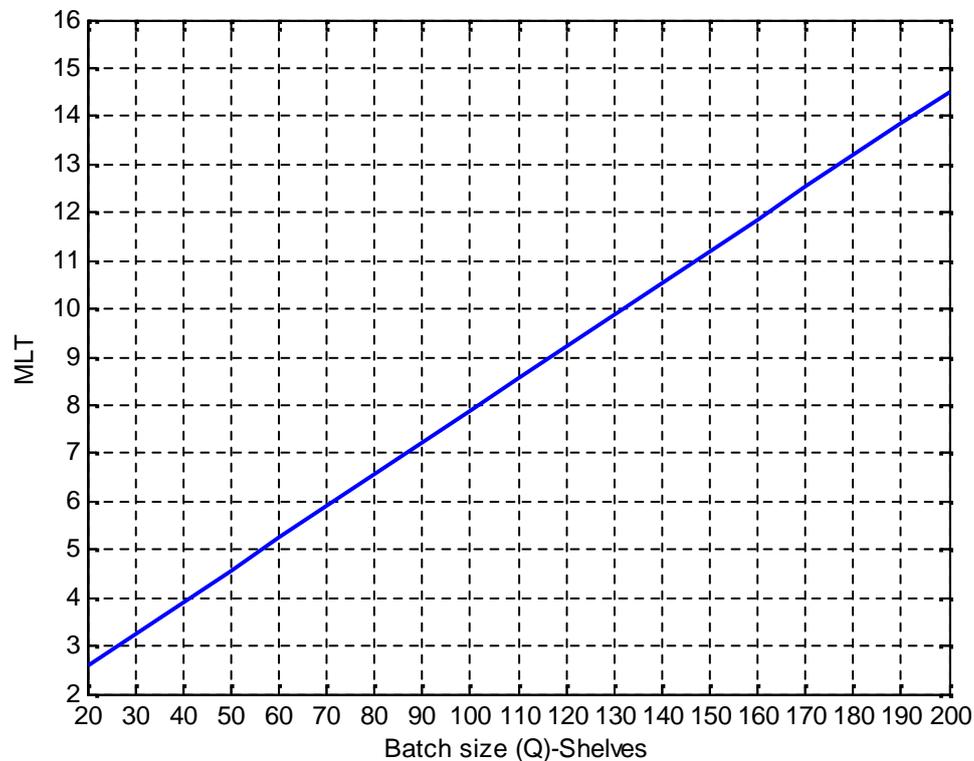


FIGURE 5.3 (Graphical representation of Q vs. MLT)

By comparison, it could be seen the small change in MLT due to the rearrangement method, this shown in fig 5.4:

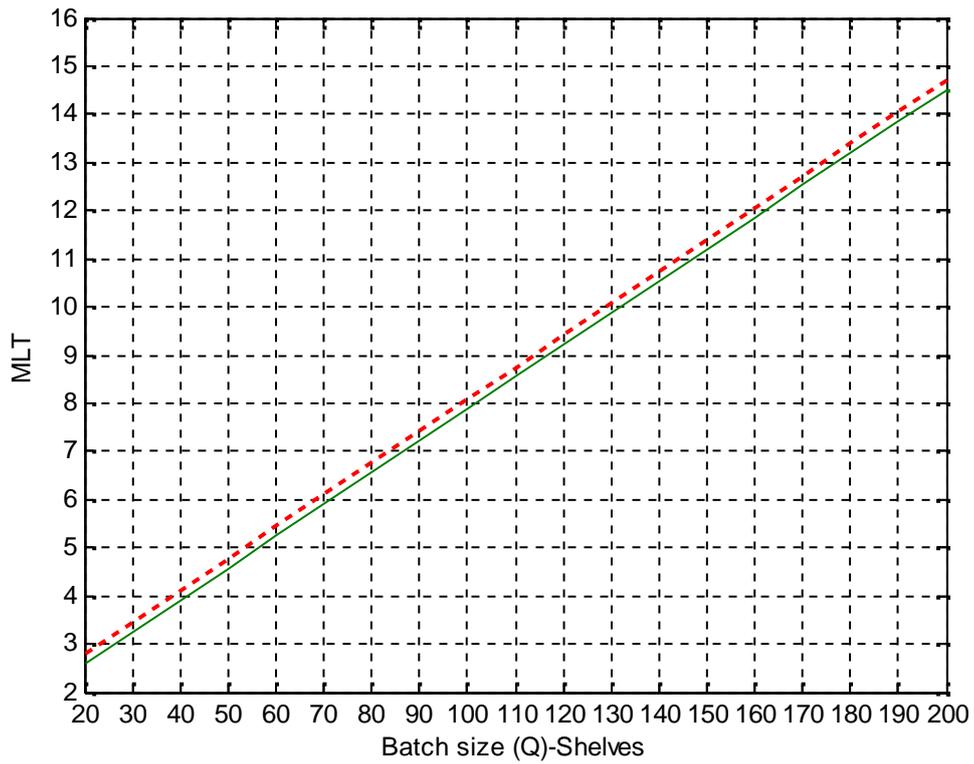


FIGURE 5.4 (the small difference between MLT calculated for various batch sizes for both layouts before and after modification by rearrangement method as a comparison. Dotted line for original current layout).

5.4 Design of Material Handling System

The design of material handling system related to the improving of manufacturing process is now by introducing of *conveyor system* design.

The planning for material handling system passes through a sequence of phases with the considering of many considerations necessary to be taken in accounts, which are:

- Characteristic of martial to be moved
- The quantity of material to be moved
- The rate of flow required
- The scheduling of the moves (Timing of the material movement)
- Distance of material traveling from location to another
- Location of load stations(where the material must be picked up)
- Location of unload stations(where the material must be delivered)

5.4.1 Characteristics of Material to be Moved (Dexon shelve)

The following table shows the characteristics of the material in the shelve system manufacturing section:

TABLE 5.4 Characteristic of Material

<i>Category</i>	<i>Measure or description</i>
Physical form	Solid
Size	100X60X2.6=15600 cm ³
Weight	2.5 kg
Shape	Long and flat
Safety risk	Corrosive
Condition	Hot

5.4.2 Quantity of Material to be moved

The quantity of material here is the batch size in units which could be changed due to company standards or plans and it should be handled by the material handling system design.

5.4.3 The Stations layout with Conveyor

A new proposed design to improve material handling in the section of 'Dexon Shelving System' manufacturing section in the 2nd floor is to include in its main layout a conveyor system to transfer workpieces between the different workstations

A full detailed procedure for design and analysis of this conveyor system and the effect on the manufacturing lead time is now to be introduced.

Fig 5.5 shows the general new layout include a single direction conveyor system to handle the transfer process between workstations, the conveyor divided into two paths to spread between the shelve units and the columns while moving towards the following workstations for each part, where V_c defines conveyor velocity (m/min) and L_d defines distance of travel for units between any workstation and the other following one.

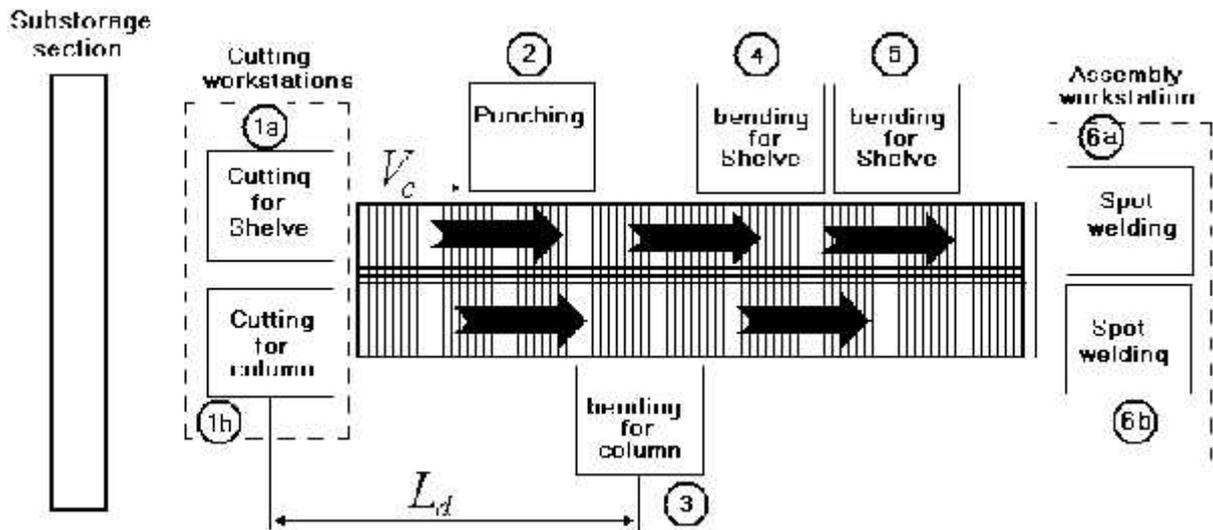


FIGURE 5.5 (The single direction conveyor between workstations)

Now, the next step is to configure the layout due to:

- Operation time at every workstation (T_o)
- The time of loading (T_L) and unloading (T_{UL}) at every workstation
- And all those times forms the overall time (T_R) required to put the workpiece on the conveyor again to pass to the next workstation
- Time of transfer T_t () between every workstation the next other which by the separation distances between workstations pairs (L_d) could be estimated by choosing a suitable velocity of conveyor (V_C).

Depending on table 5.1 and figure 5.5, table 5.5 shows the measured and expected times at every workstation, which are necessary for the analysis of the design at hand:

TABLE 5.5 Ready time at every workstation (average loading and unloading time is 1 sec.)

Workstation #	T_o (S)	T_L (S)	T_{UL} (S)	$T_R = T_L + T_{UL} + T_o$ (S)
1a	7	1	1	9
1b	3.5	1	1	5.5
2	12	1	1	14
3	12	1	1	14
4	21	1	1	23
5	21	1	1	23
6	25	1	1	27

Now, by the expected ready time (T_R) for every workstation and the next workstation, it could be determine the time required for the unit to moves (transferred) between those workstation pairs.

Figure 5.6 explains the estimated and required transfer time for each unit between every workstation pairs by equation 5.1.

$$T_t = T_{R2} - T_{R1} \quad (5.1)$$

Where: T_{R1} is the ready time of the first workstation in the pair and

T_{R2} is the ready time of the second workstation in the pair

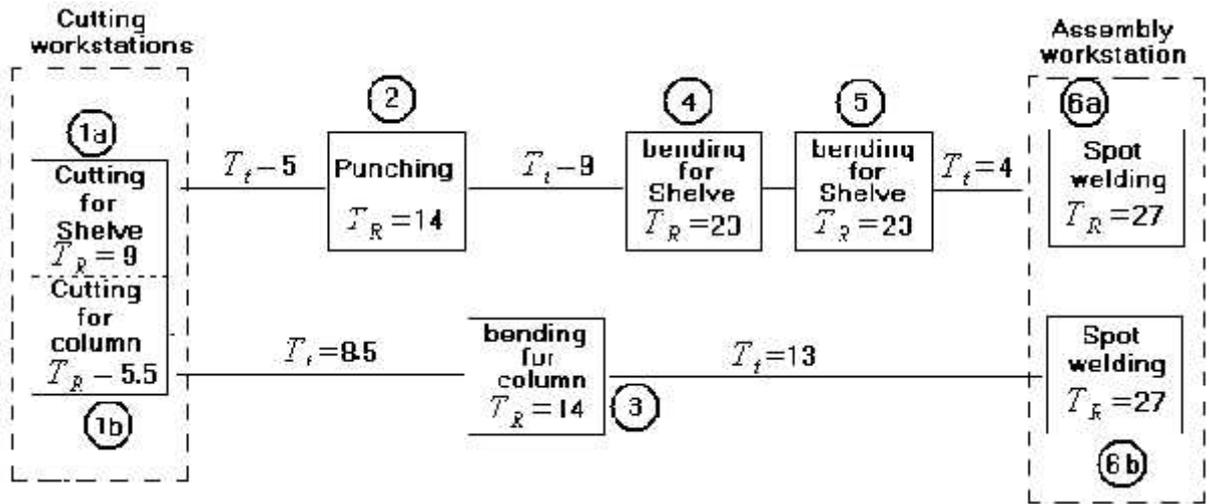


FIGURE 5.6 (ready time for every work station and transfer time required)

As seen in figure 5.5 the cutting workstation is alternating cutting once for the shelving and another for the columns in the same cutting machine, and to prevent blocking or line flow jamming a two bending machines are used, and for the same problem and in a purpose of inspection and test, a buffer storage could be used at the spot welding workstation.

In the buffer storage there are an inspection and test done on unfinished product on it which are the sheet of shelfe and the supporting column, then after the inspection and test if any unfinished product is not under the specification will reject it if it is under will accept it and transfer it to spot welding workstation.

At this point, the speed of conveyor could be chosen and then the distances between workstations could be calculated. The distance of travel between workstations is equals to the speed of conveyor multiplied by the necessary transfer time between every workstation pair, or as it explained in the following equation:

$$L_d = V_c \times T_t \tag{5.2}$$

By taking the speed of conveyor to be 25 m/min, the distances between workstations calculated with using equation 5.2:

SHELVING PATH:

The distance L_d between cutting for shelving workstation (1a) and punching workstation (2):

$$L_d = 25 * 5 / 60 = 2.08 \text{ m}.$$

Distance L_d between punching workstation (2) and bending workstation (3&4):

$$L_d = 25 * 9 / 60 = 3.75 \text{ m}.$$

Distance L_d bending workstation (4&5) and spot welding buffer storage (6):

$$L_d = 25 * 4 / 60 = 1.66 \text{ m}.$$

The total necessary length of the shelve parts traveling distance which forms the length of conveyor is:

$$\text{Total length of shelving conveyor} = 2.08 + 3.75 + 1.66 = 7.5 \text{ m}.$$

COLOUMN (REINFORCEMENT BEAM) PATH:

The distance L_d between cutting for columns workstation (1b) and bending workstation (3):

$$L_d = 25 * 8.5 / 60 = 3.54 \text{ m}.$$

Distance L_d bending for columns workstation (3) and spot welding buffer storage (6):

$$L_d = 25 * 13 / 60 = 5.41 \text{ m.}$$

The total necessary length of the columns parts traveling distance which forms the length of conveyor is:

$$\text{Total length of columns conveyor} = 5.41 + 3.54 = 8.95 \text{ m.}$$

As noticed from calculating path length for both the shelving path and column path, there is a difference in length, and thus the shortest path is to be modified to make the implementation of each path by a single conveyor possible.

The modification generally involves increasing the distance between workstation (5) and workstation (6), the modification generally involves increasing the distance between workstation (5) and workstation (6) rather than changing any distance between any other workstation pair, because:

Difference in distances between both paths is:

$$\text{Differences} = 8.95 - 7.5 = 1.45 \text{ m.}$$

The new transfer time between workstations (5) and (6) is:

$$T_{t(new)} = \left(\frac{1.45}{25} \times 60 \right) + 4 = 7.5 \text{ sec.}$$

This difference is to be added easily because of the possibility of using buffer workstation.

So the new distance between (5) and (6) is:

$$L_d = 25 \times 7.5 / 60 = 3.125 \text{ m.}$$

TABLE 5.6 (The distances and transfer time between workstations pairs)

Shelve path	Workstation pair	(1a)&2	2&(4,5)	(4,5)&6
	Distance (m)	2.08	3.75	3.12
	Transfer time (S)	5	9	7.5
Column path	Workstation pair	(1b)&3	3&6	
	Distance (m)	8.5	13	
	Transfer time (S)	3.54	5.41	

After getting the distances and the transfer time between the workstations, the new layout could be introduced as shown in fig 5.6:

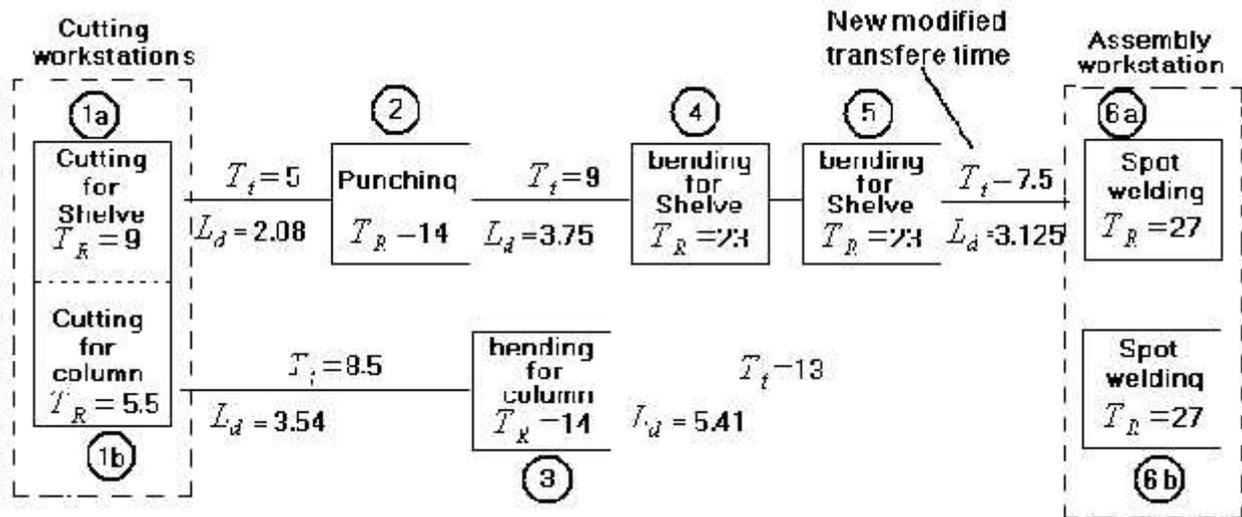


FIGURE 5.7 (The new layout of the shelving manufacturing section after modification with new design of conveyor system)

Figure 5.8 shows the conveyor system and the distribution of workstations:

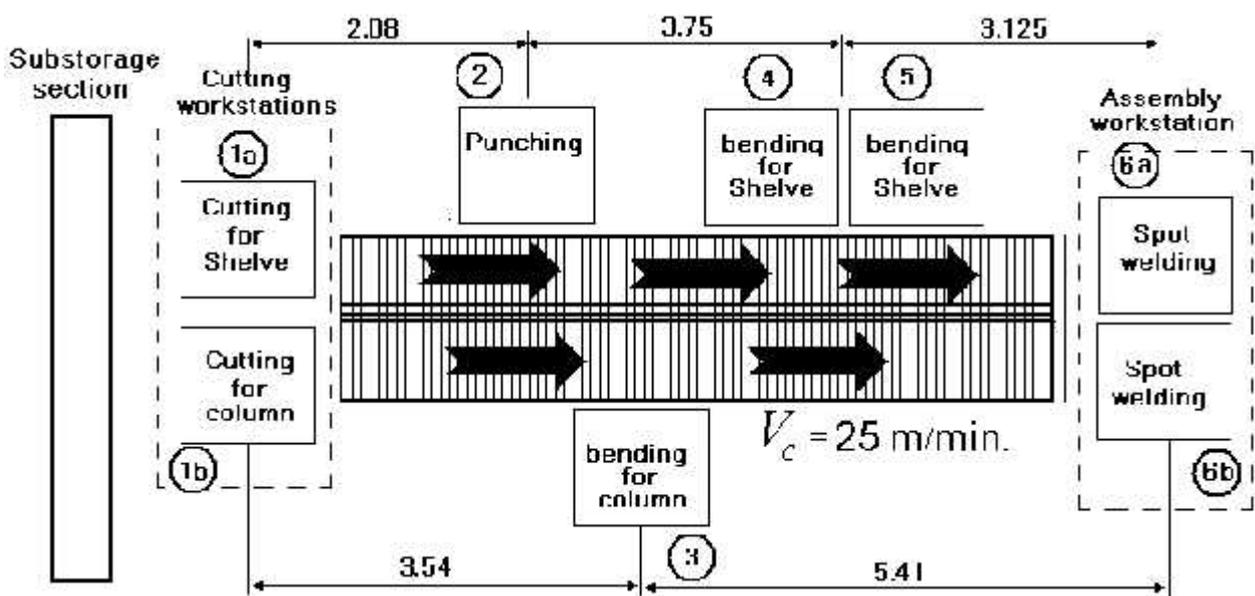


FIGURE 5.8(The distribution of workstations around the conveyor system)

5.4.4 Calculation of MLT for Layout with Conveyor System

Table 5.7 shows calculations for every non-operation time T_{no} , the time per operation at given machine Workstation T_o and the setup time for 70 units of products, as mentioned in the previous chapters the setup time for every machine is zero.

By using equation (4.1), the calculation of MLT needs the calculation of:

- Operation time: the actual machining time associated with every workstation
- Non-operational time: this include handling time and different delays at every workstation
- Setup time for machines and tools

Non-operation time involves more than a component, the following relation explains this:

$$T_{no} = T_h + T_d \quad (5.3)$$

$$T_h = T_t + T_L + T_U \quad (5.4)$$

Where:

T_t : is the transfer time between workstation pairs

T_L : is the loading time at workstation,(time required to pick part from conveyor)

T_U : is the unloading time at workstation,(time required to pick part from conveyor)

T_h : is the handling time

T_d : is the delay time associated with workstation

TABLE5.7 (Calculation of T_h and T_{no} at workstations with the new layout and conveyor system introduced)

Operation	T_o (S)	T_L (S)	T_{UL} (S)	T_t (S)	T_d (S)	T_h (S)	T_{no} (S)
Cutting for shelve	7	1	1	0	0	2	2
Punching and shaping	12	1	1	5	0	7	7
Bending for shelve	21	1	1	9	0	11	11
Cutting for column	3.5	1	1	0	0	2	2
Bending for column	12	1	1	8.5	0	10.5	10.5
Joining by spot welding	50	1	1	13	5	15	20
Painting	132.8	1	1	6	887.5	8	895.5
Σ	213.3	7	7	41.5	892.5	55.5	948

Here again it is recommended to remember that painting operation include a delay time rises because of packaging parts to prepare them to enter the operation. And the delay time appears at joining workstation (6), this because buffering parts at the buffer storage.

Table 5.8 shows the calculation of manufacturing lead time.

TABLE 5.8 (Calculation of manufacturing lead time for 70 product of batch in using conveyor system)

Operation	T_o (S)	T_o (h)	T_{no} (S)	T_{no} (h)	$(Q \times T_o) + T_{no}$ (h)
Cutting for shelve	7	0.001944	2	0.000556	0.136667
Punching and shaping	12	0.003333	7	0.001944	0.235278
Bending for shelve	21	0.005833	11	0.003056	0.411389
Cutting for column	3.5	0.000972	2	0.000556	0.068611
Bending for column	12	0.003333	10.5	0.002917	0.23625
Joining by spot welding	50	0.013889	20	0.005556	0.977778
Painting	132.8	0.036889	895.5	0.24875	2.830972
Σ	213.3	0.066194	948	0.263333	4.896944

As shown in table the manufacturing lead time become:

$$MLT_{New} = \sum_{i=1}^{n_m} (T_{sui} + QT_o + T_{no}) = 4.89 h.$$

By comparison, MLT calculated for the current layout of factory and MLT calculated for the new layout with conveyor system, there is a clear and noticed difference in time required to deliver a patch from this section (manufacturing of metal 'Dexon Shelving System') and this forms a gained benefit by introducing a conveyor system in the layout at hand.

At this point, it is good to show this gained useful and feasible change as follow:

$$MLT_{New} - MLT_{Old}$$

$$6.101 - 4.89 = 1.211 \text{ h}$$

The percentage drop in MLT is:

$$\left(\frac{1.211}{6.101}\right) \times 100\% = 19.85\%$$

This percentage of drop in MLT is the maximum drop obtained from taking the different methods in order to optimize material handling.

Now continuing to find MLT for various batch sizes as done before for the previous discussed methods.

TABLE 5.9 (Various batch sizes and the corresponding calculated MLT for layout with conveyor system)

Q(units)	20	30	40	50	60	70	80	90	100	110
MLT(h)	1.5872	2.2492	2.9111	3.5731	4.2350	4.8969	5.5589	6.2208	6.8828	7.5447
Q(units)	120	130	140	150	160	170	180	190	200	
MLT(h)	8.2067	8.8686	9.5306	10.1925	10.8544	11.5164	12.1783	12.8403	13.5022	

Fig 5.9 shows the relations between multiple batch size and MLT:

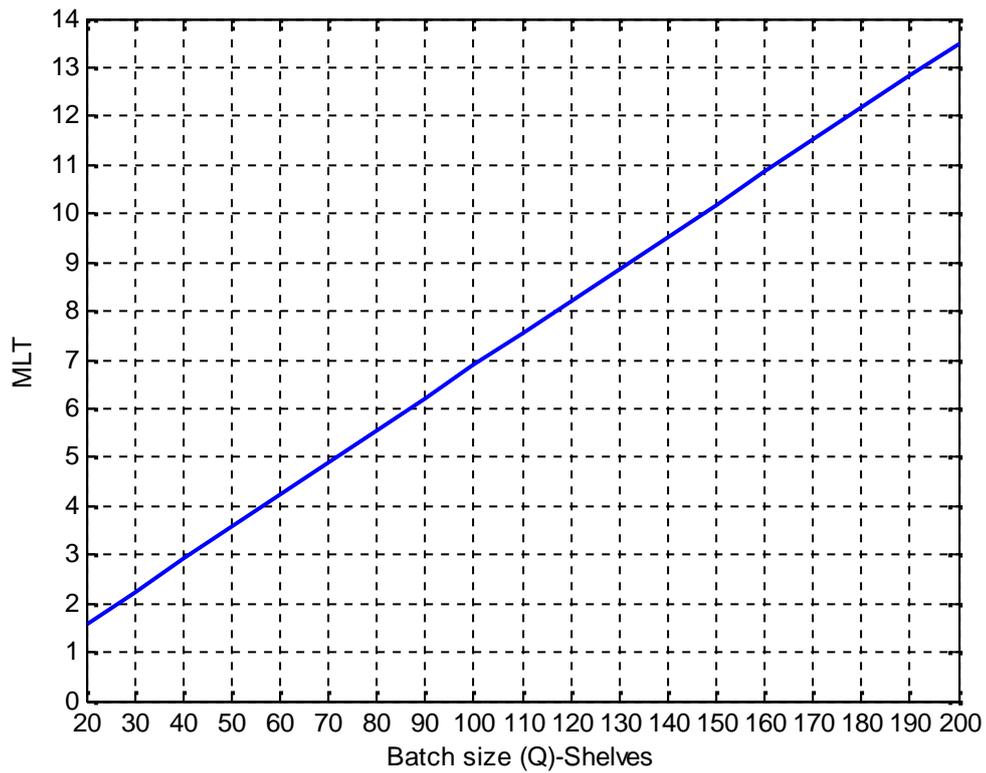


FIGURE 5.9 (Graphical representation of Q vs. MLT after conveyor system included)

By comparison, it could be seen more acceptable change from the value of MLT due to the rearrangement method and to the value of MLT due to introduced conveyor system in layout, this clearly shown in fig 5.10:

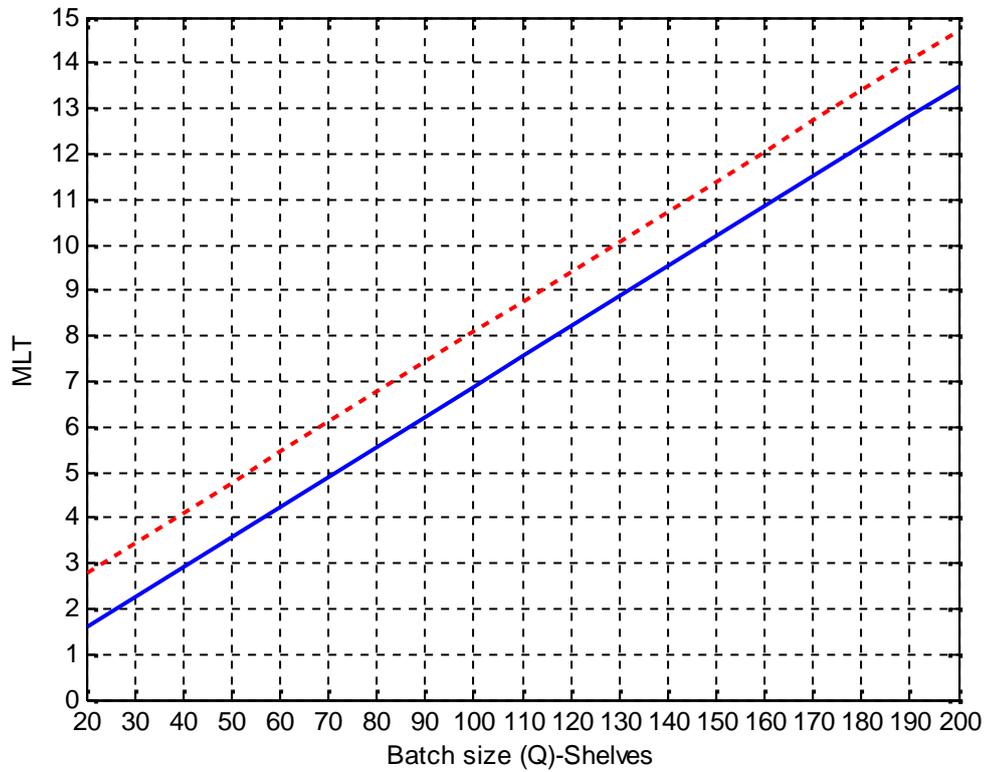


FIGURE 5.10 (Comparing calculated MLT for both original layout and the new layout with conveyor system. Dotted line represents MLT for the original layout.)

As shown in figure 5.9 the deviation is increase with comparison between the original layout and the new layout with conveyor system but as shown in figure 5.4 The deviation was small.

Chapter **6**

Briefing Review about Economical Considerations

- 6.1 introduction (54)
- 6.2 Roller Conveyor (54)
- 6.3 Roller Conveyor Cost (56)

6.1 Introduction

Any proposed plan or project for improving a plant or -specifically industrial plants-, the economical factors is to have a major influence that make any decision makers to compromise their choices when they taking any proposed plane or project.

A profit or the return that would be gained from taking the decision of accepting the proposed plan has to make the implementation of the plan feasible and reasonable to pay for.

In this chapter a different versions of Roller conveyors is included as a short view on the models prices and versions that could introduce the answers about cost or the feasibility of choice if this project is discussed by the company at some how.

6.2 Roller Conveyor

Roller conveyors have many specifications that characterize every version or model and define their cost. The followings are from these specifications:

- Length of conveyor: By variation the conveyor length the physical components required to build and run it effectively is varies too, and thus variation of cost proportionally.
- Width of conveyor: This influence the choice of conveyor according to cost of drivers, power, and suitable size to facilitates moving of handled or moved parts.

- Height or elevation level and moving path: Horizontal or oblique or elevation variation, straight or curved, path turns, all these specifications defines the complexity of design and so defines the general cost
- General size of conveyor: The space available restrict the choice of conveyor physical specifications
- Speed of conveyor : This defines the type and size of driving unit and so affect the general cost of installing the conveyor
- degree or level of automation: Single direction or reversible motion, tuned or constant speed,



FIGURE 6.1(Various models of Roller conveyor)

TABLE 6.1(An example of a conveyor specifications and its cost)

19SR (24 in. OAW, 12 in. Rlr Ctrs, 5 ft. Long)	
	Quantity in Basket: <i>none</i> Code: 19SR-21-12-5L Price: \$59.94 Shipping Weight: 72.00 pounds

6.3 Roller Conveyor Cost

Some versions and models of roller conveyors are listed in table 6.1 with their corresponding prices in markets

TABLE 6.2 (Price list for Model: 138VP BELT DRIVEN ROLL)

Roll width	Price (5'0" length)	per foot adder
10"	\$1,817.00	\$78.00
16"	\$1,964.00	\$83.00
22"	\$2,044.00	\$89.



FIGURE 6.2 (MODEL 138VP BELT DRIVEN LIVE ROLL)

TABLE 6.3(Price list for Model: 196VP BELT DRIVEN ROLLER)

Roll width	Price (5'0" length)	per foot adder
15"	\$2,429.00	\$87.00
21"	\$2,519.00	\$99.00
27"	\$2,632.00	\$107.00
39"	\$2,829.00	\$136.00



FIGURE 6.3 (MODEL 196VP BELT DRIVEN ROLLER)

TABLE 6.4(Price list for Model:)

Roll width	Price (6'0" length)	per foot adder
15"	\$2,631.00	\$117.00
21"	\$2,716.00	\$129.00
27"	\$2,802.00	\$141.00
39"	\$3,010.00	\$167.00



FIGURE 6.4 (MODEL 196ZPA BELT DRIVEN ROLL ZERO PRESSURE)

Chapter **7**

Results and Discussions

- 7.1 Results and Discussions (59)
- 7.2 Conclusions (60)
- 7.3 Recommendations (61)
- 7.4 To Future Studies (61)

7.1 Results and Discussion

For the original layout and the two proposed new layouts, table 7.1 explained the differences between them.

TABLE 7.1 (Comparison between MLT for various materials handling system)

Figure 7.1 compares between the three layouts with the corresponding calculated manufacturing lead time MLT for various batch sizes

The Used Layout	The original layout (manual handling)	The new layout with rearranged workstations	The new layout using conveyor system
MLT (h)	6.101	5.902	4.89

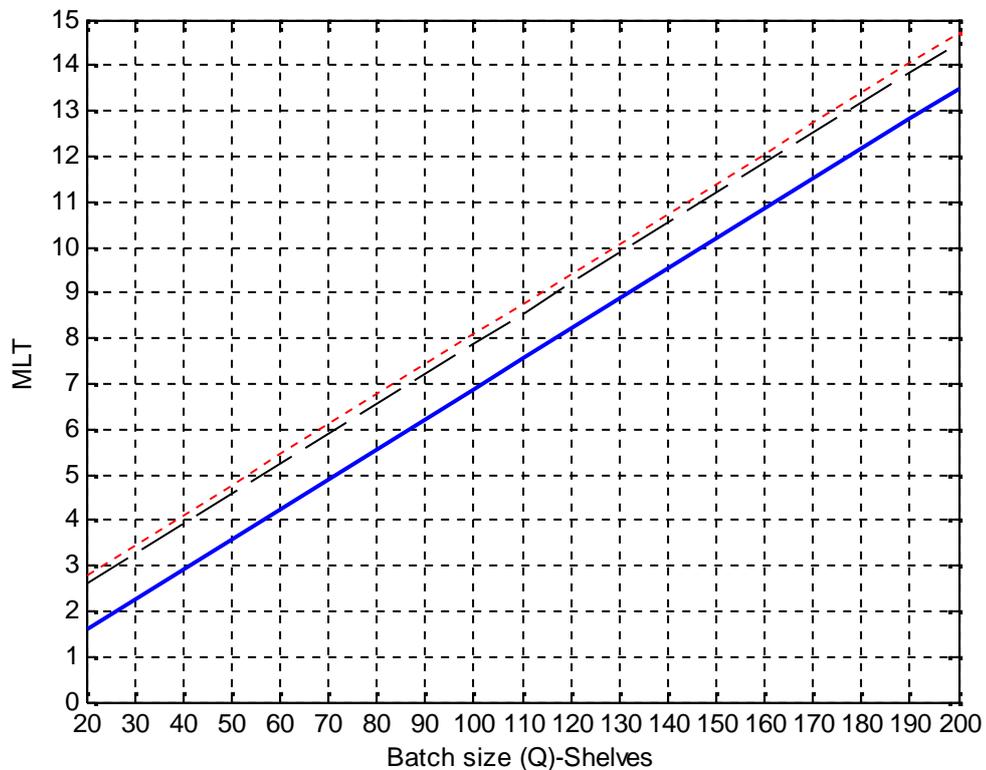


FIGURE 7.1 (manufacturing lead time MLT for various batch size (Q) for original layout with the *dotted* line, new rearranged layout with the *dashed* line and for the new layout with conveyor system with the *solid* line)

7.2 Conclusions

All investigations in this research come with important facts, which are:

- Optimization of material handling is very effective to improve manufacturing process
- Methods used to optimize material handling different in the form and the effect on manufacturing process
- The best way that clearly changes to the best, that is, the way facilitates the elimination of non-operational time associated with the different manufacturing operations rather than the way of change in the sequence of operations.
- Rearrangement of workstations (layout modification) could serve to reduce non-operational time, but in very small reduction due to delays that could not be reduced by this way efficiently.
- Improving material handling by using conveyor system, assists effectively in elimination of delays, and thus effectively reduction of the non-operational time.
- Reduction of manufacturing lead time comes with more profits to any manufacturing plant if one or more components of manufacturing process is improved (like improving material handling taking by this project)

7.3 Recommendations

To come with more effective results and benefits in future for society, many recommendations comes up at the end of the project text towards:

- *Local industrial plants*: to improve manufacturing processes by implementing of suitable automation strategies in their plants
- *Students of engineering and IT*: to integrate this project search by the possible modern means and approaches in order to improve the local and national industry, the physical activities improved by means of engineering. Information processing, management and control in the plant by computer and IT modern means.

7.4 To Future studies

This project is concerned with material handling in a specific section in a local industrial plant and as a proposed solutions or plans, but this is not enough to improve the entire manufacturing process. So from this point, any further study or researches must take other sections and departments under study to come with complete automating plan for the company, and of course with the economical consideration taken in a account.

$$+T_{noi}) = 5.55$$

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