# Facilities Slides With Notes

( 2nd Semester 2023/2024 )
Notes are written by Nada Ababneh

# Chapter 1

# Introduction

# Facilities Planning Defined

- *Facilities planning* is a complex and broad subject that cuts across several specialized disciplines. (civil, electrical, industrial, mechanical, etc)
- *A facility* could be:
  - new factory
  - new hospital
  - School
  - Bank
  - Store
  - existing warehouse
  - assembly department
  - office
  - baggage department of an airport.
  - Etc.

Facility Planning*
هي جزء من ال
Facility management

# Facility Management:

- Coordinating the physical workplace with the people and work of the organization integrating the principles of business administration, architecture, and the behavioral sciences.

- Facility management encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes and technology.

# Facility Planning:

سهل التغيير و التعديل

Strategic Facility planning

(هنا مكلف جداً التغيير)

- the tactical day-to-day issues and not the more macro topics addressed in SFP. It solves problems related to specifics, such as where individuals sit or the type of equipment required accommodating a specific situation.

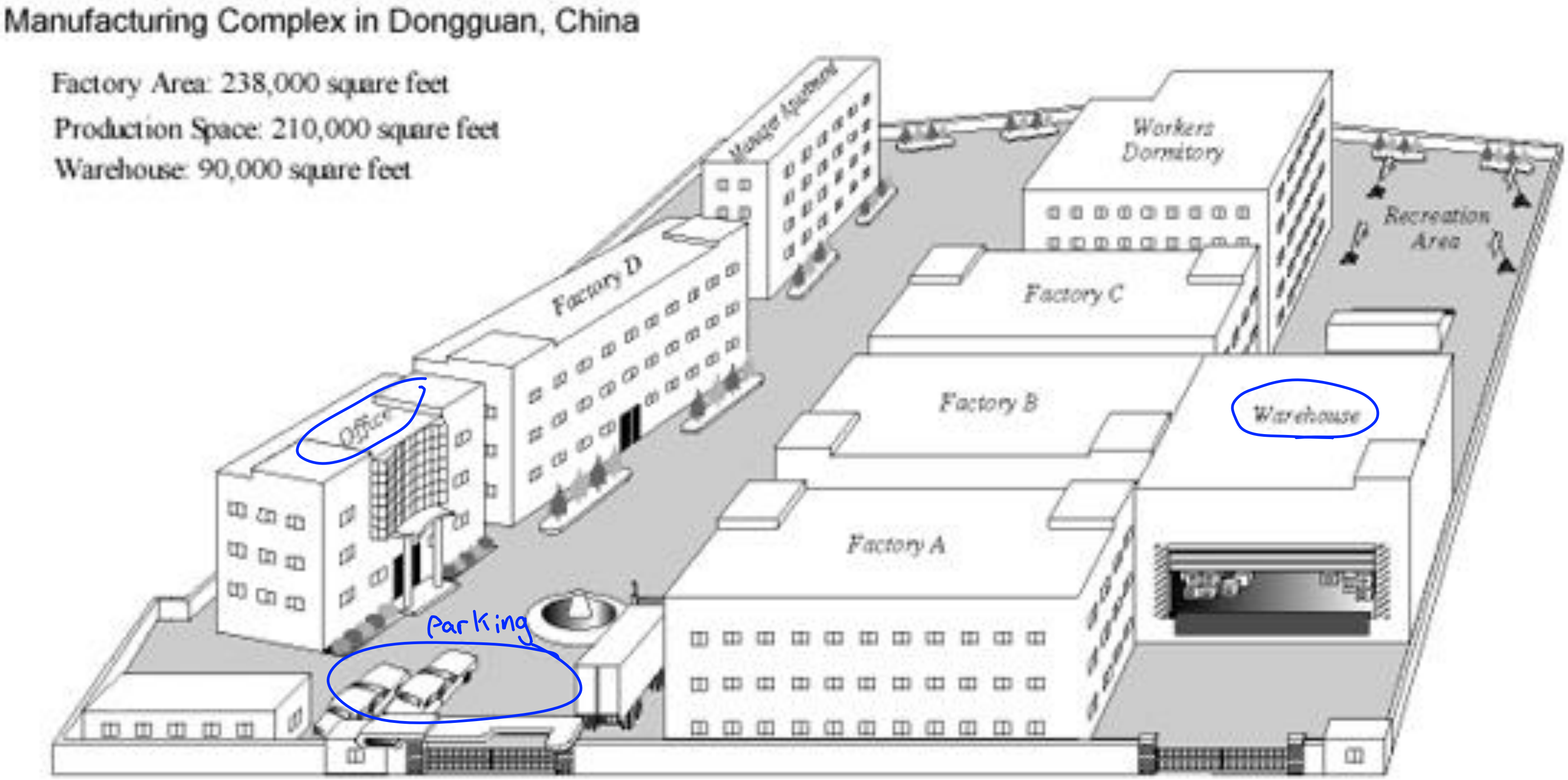
# Strategic facility Planning :

Changing a Desicion is very expensive

- A long-term process that can lead to better, more proactive delivery of services from a facility management organization to its stakeholders.

استباقي

أصحاب المصلحة



Manufacturing Complex in Dongguan, China

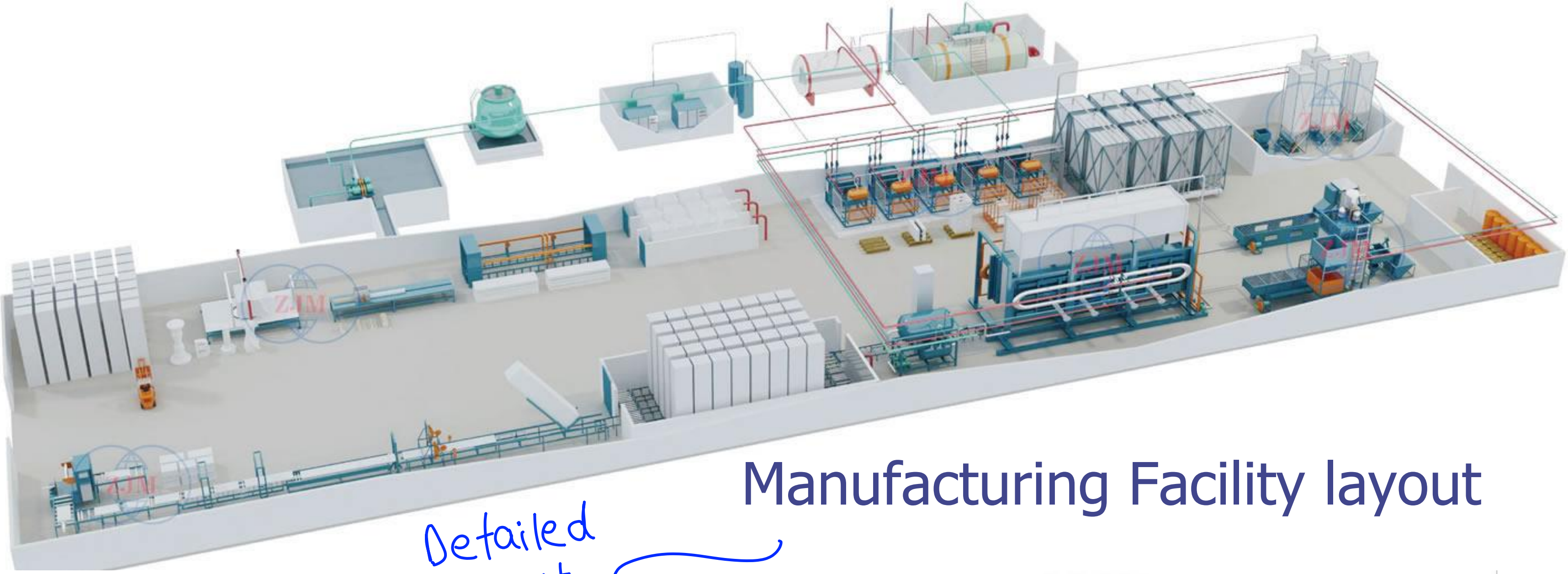
Factory Area: 238,000 square feet

Production Space: 210,000 square feet

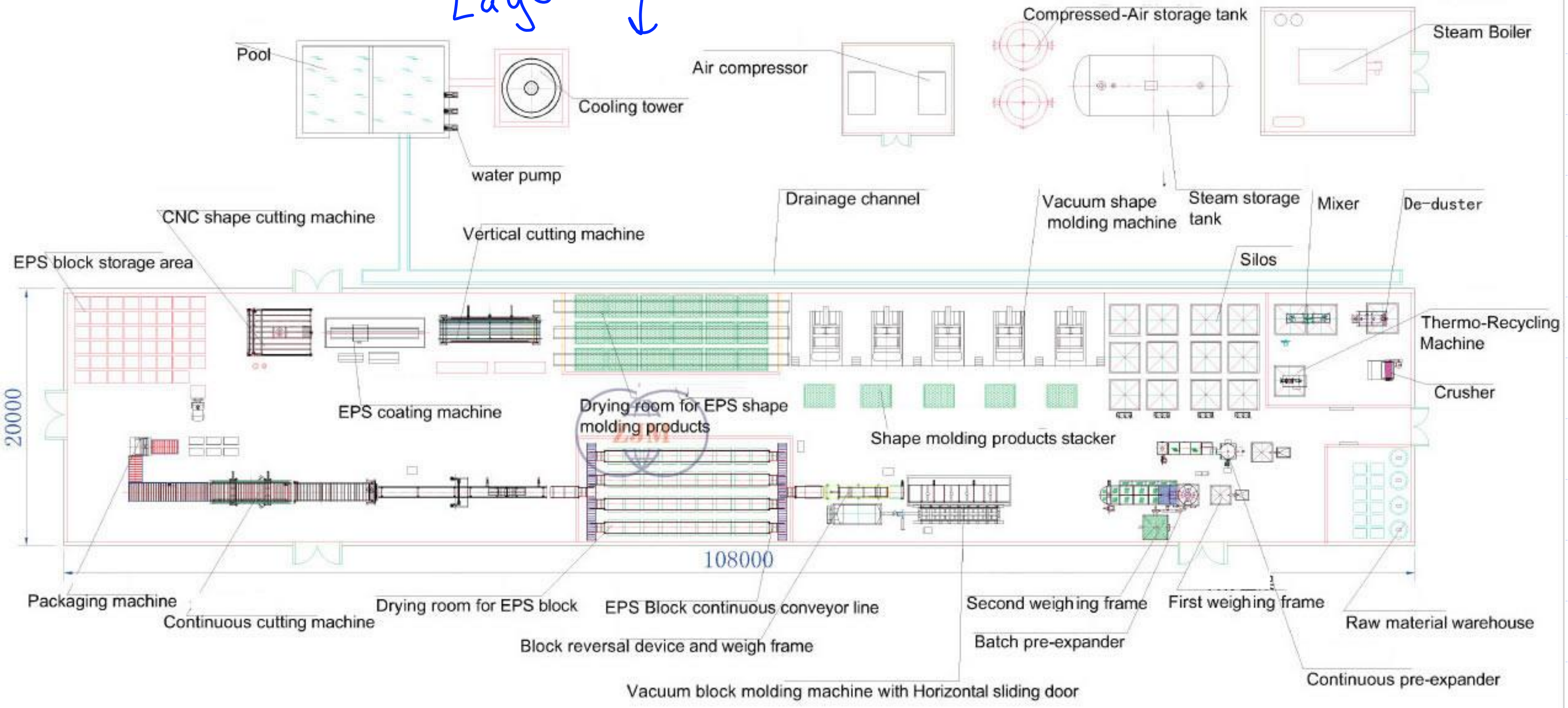
Warehouse: 90,000 square feet

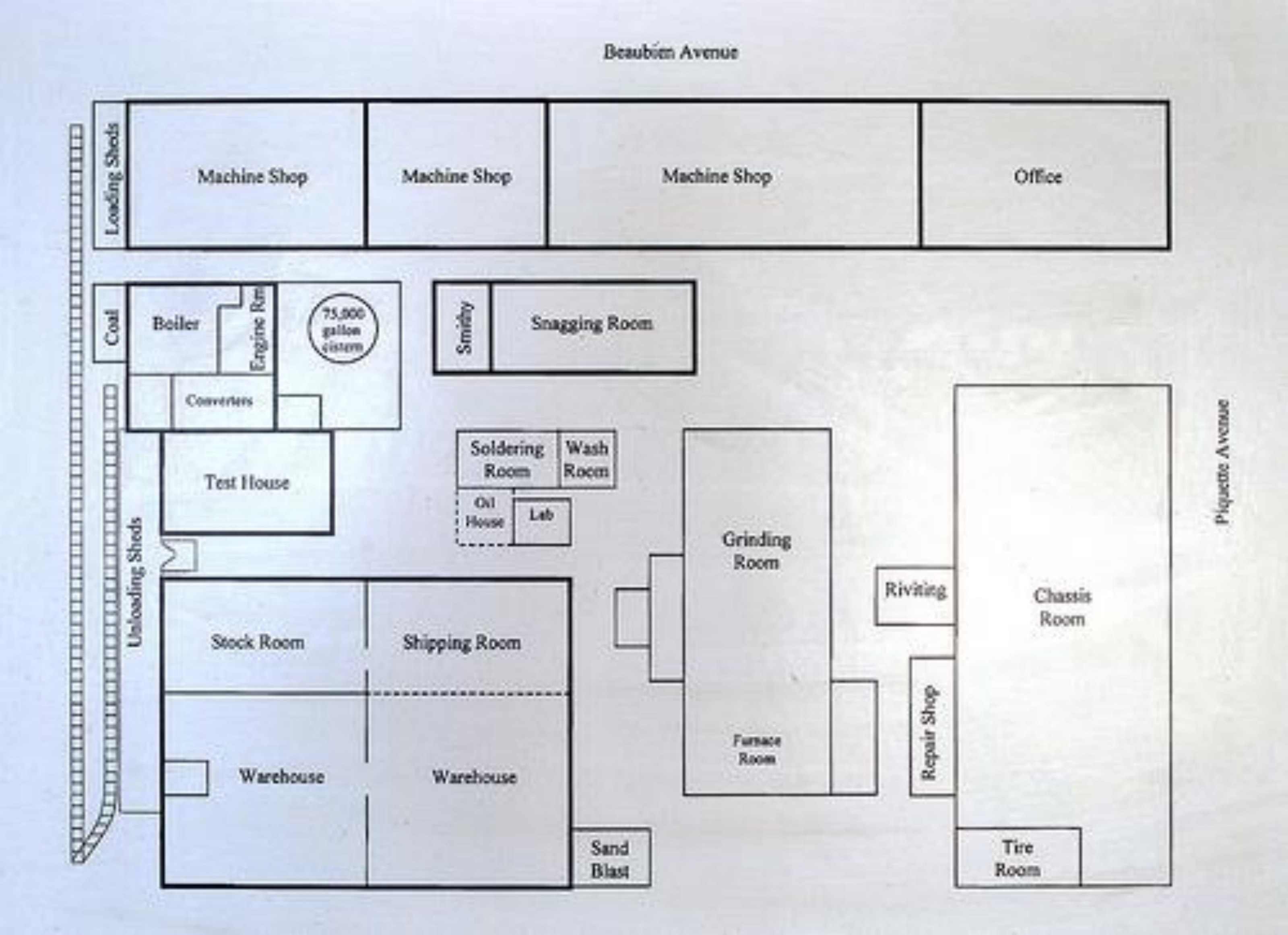
# Manufacturing Complex

# Manufacturing Facility layout

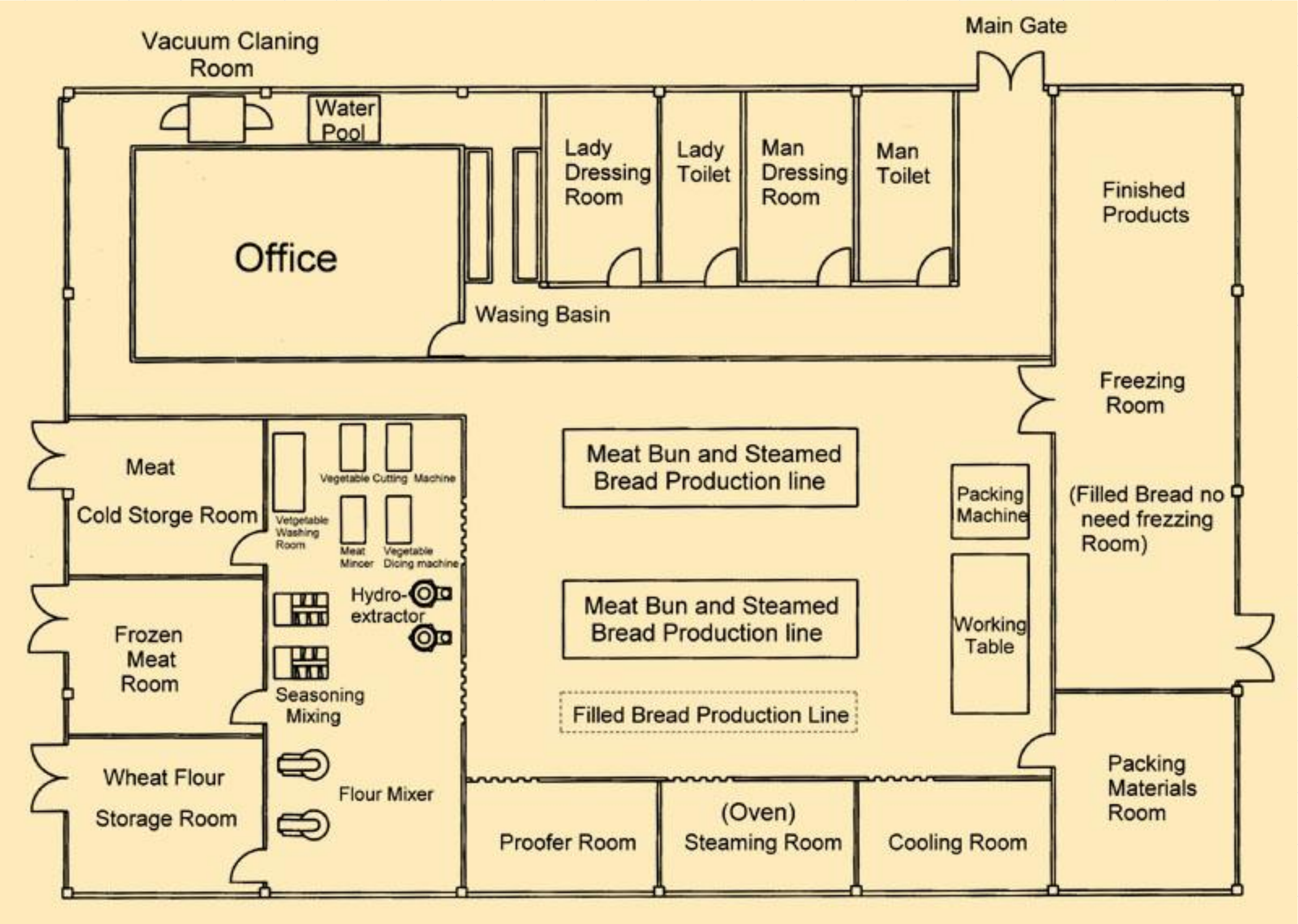


Detailed Layout



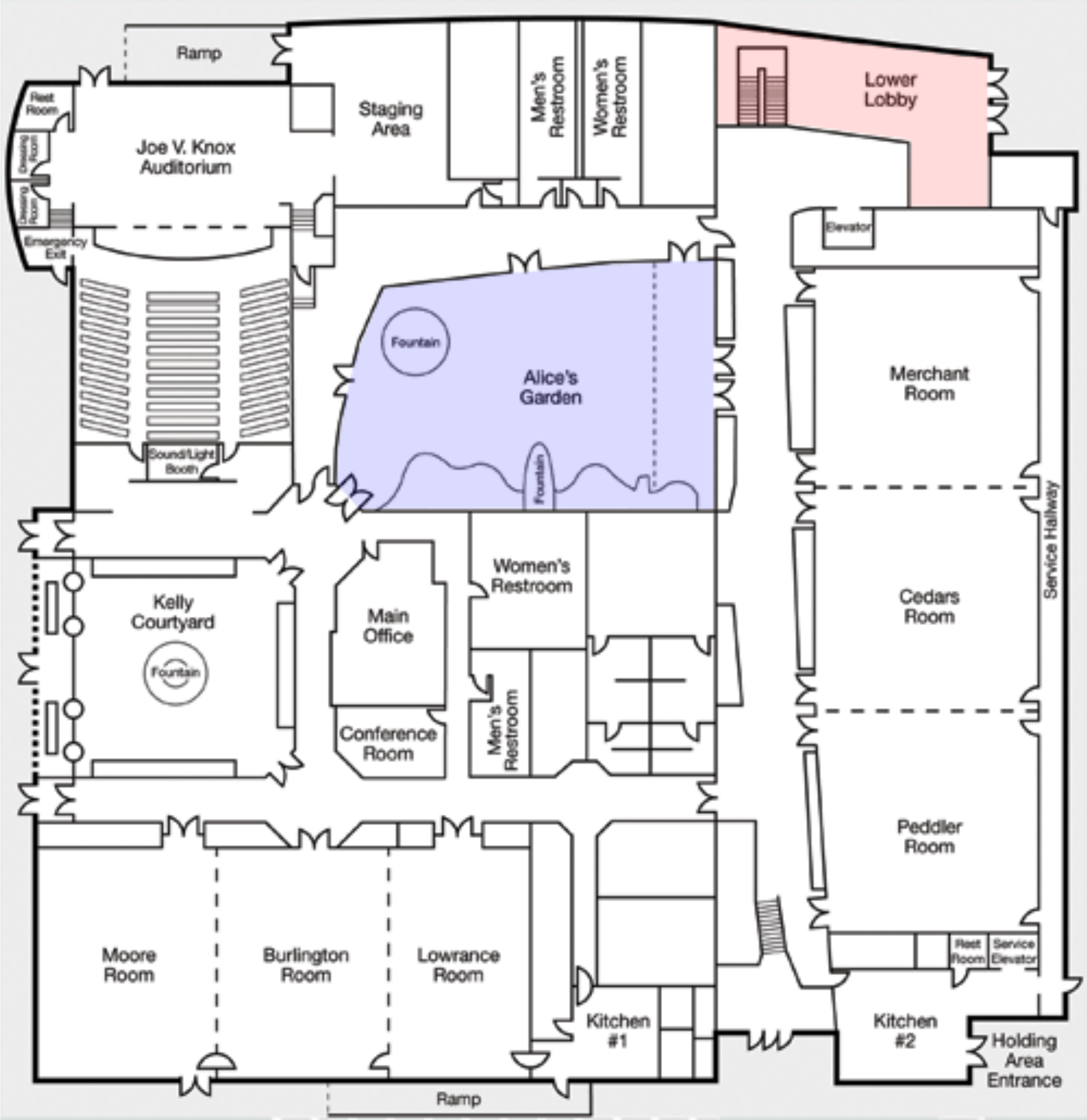


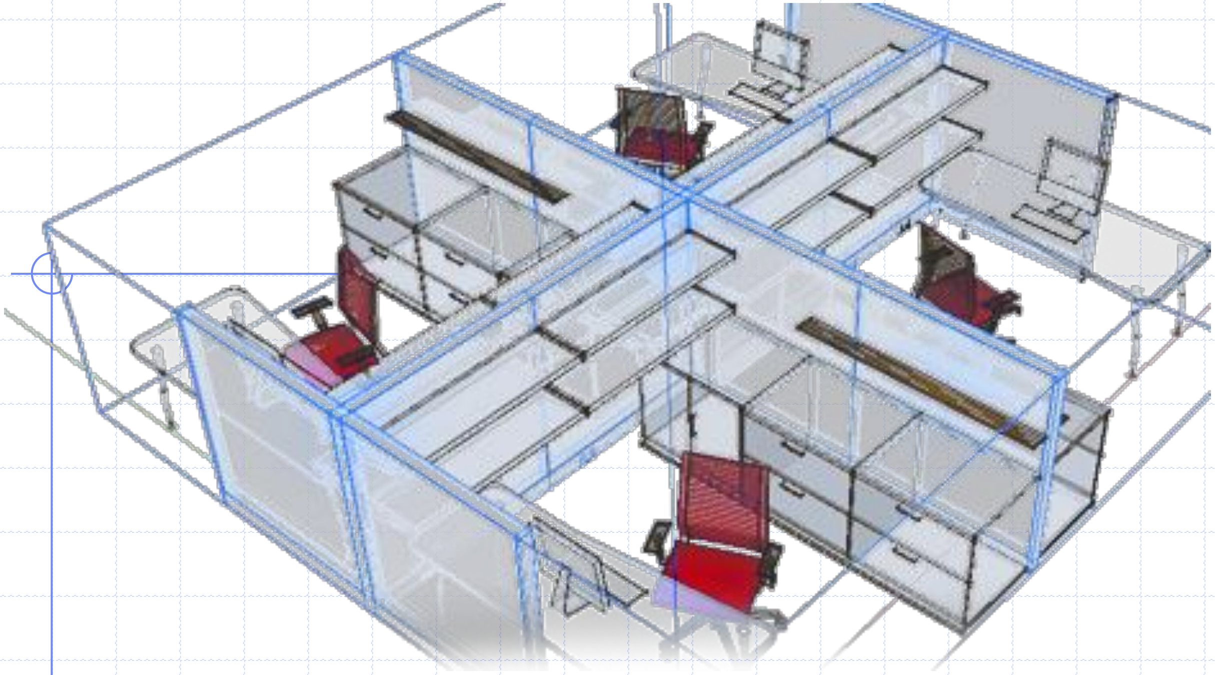
Manufacturing Facility layout



# Manufacturing Facility layout (Food industry)

# Cultural Center layout





Office Layout

Parking Layout

in chapter (4)

# Facilities Planning Defined (contd.)

← نهتم بال Fixed
Assets

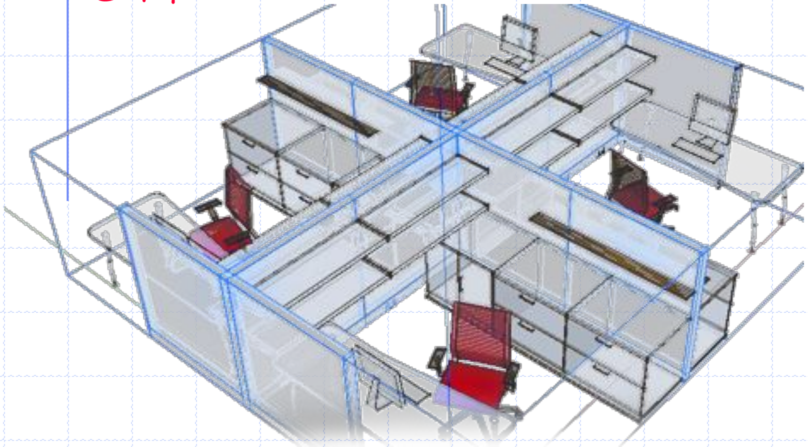
ال Management
تشمل ال planning

- *Facilities planning* determines how an activity's tangible fixed assets best support achieving the activity's objective.

- Examples:
  - Manufacturing facility: how the manufacturing facility best support production
  - Airport: how the airport facility supports the passenger-airport interface
  - Hospital: how the hospital facility supports providing medical care to patients

# Fixed Tangible Assets

offices



Tools

Material Handling Equipment

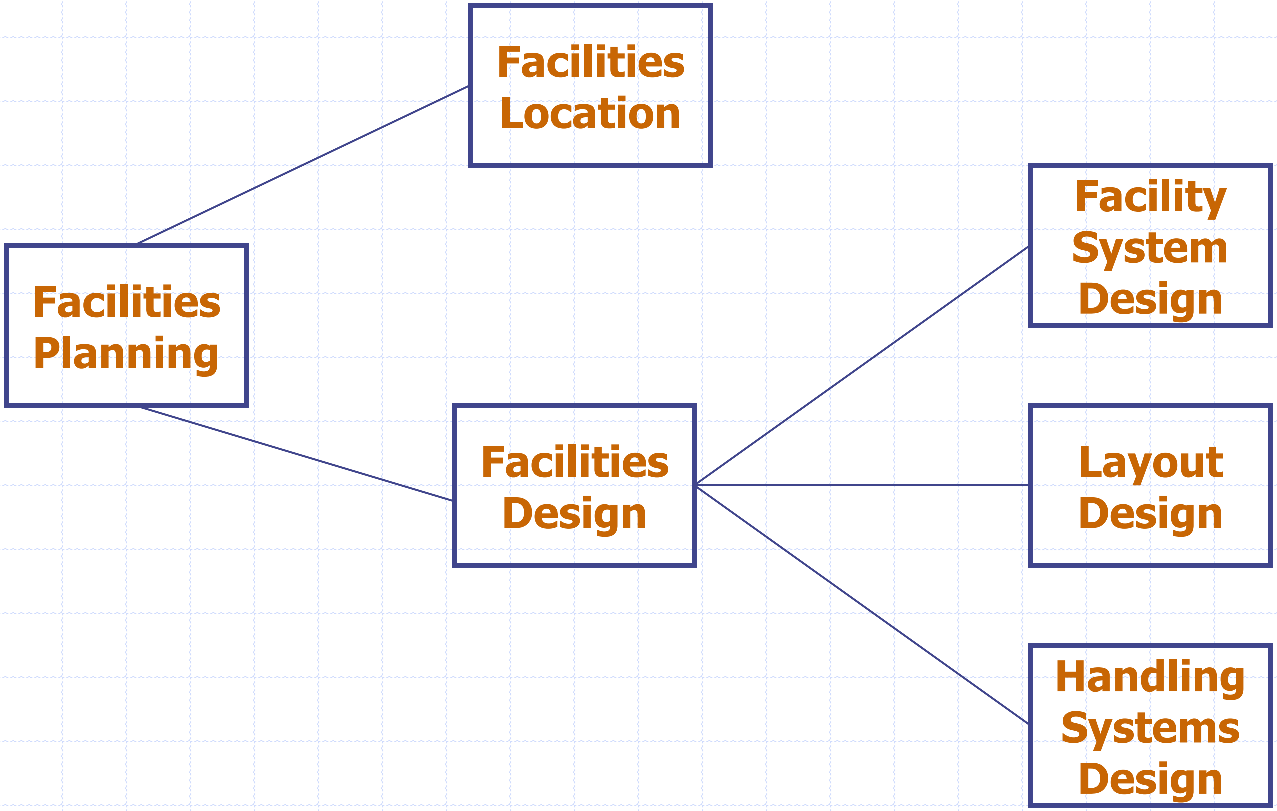
# Facilities Planning Hierarchy

is a combination between
→ Location
→ Design

- Facilities planning:
  - Facilities location
  - Facilities design
    - Facilities systems design
    - Layout design
    - Handling systems design

- Facilities planning combines the efforts to determine location of a facility and design of it

# Facilities Planning Hierarchy (contd.)



Facilities Planning

Facilities Location

Facilities Design

Facility System Design

Layout Design

Handling Systems Design

# Facilities Planning Hierarchy (contd.)

- Facilities design: consists of the facility systems, the layout, and the handling system
  - Facility system – structural systems, the atmospheric systems, the enclosure system, the lighting/electrical/communication systems, the life safety system and the sanitation system.
  - Layout – consists of all equipment, machinery, and furnishings within the building envelope.
  - Handling system – consists of the mechanisms needed to satisfy the required facility interactions.

    Material handling is very important to the facility design activity. The choice of material handling equipment will greatly effect the appropriateness of the facility design.

very important in Facility planning

# Facilities Planning Hierarchy (contd.)

- Which comes first, *the material handling system* or the *facility layout*?

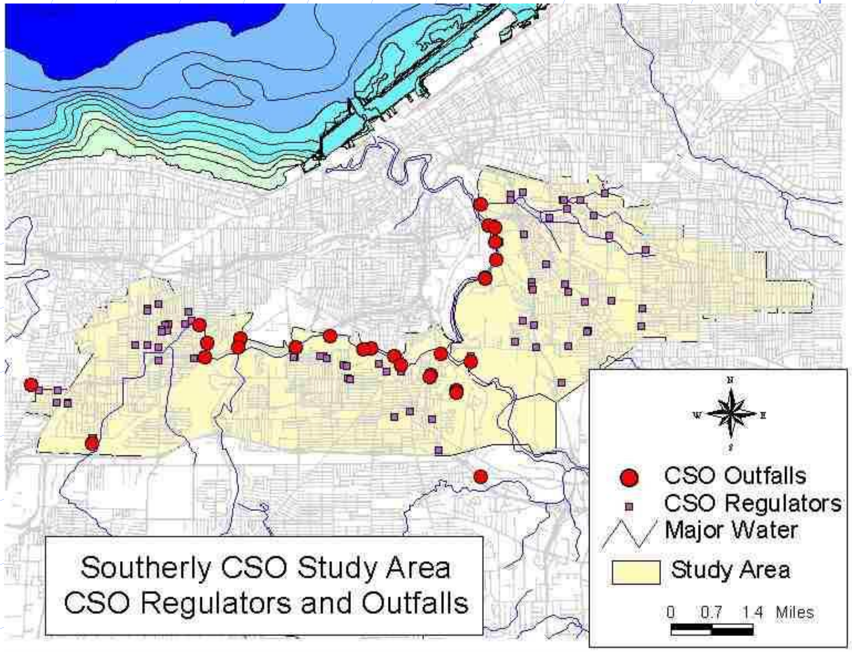
- BOTH! The layout and the handling system should be designed simultaneously

# Facilities Planning Hierarchy (contd.)

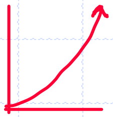
Facilities location: placement with respect to customer, suppliers, and other facilities with which it interfaces.

Influences of Plant location:

- Proximity to raw material
- Markets
- Transportation systems
- Economic development programs (financial incentives)
- Environmental consideration
- Climate
- President’s home town
- Etc.



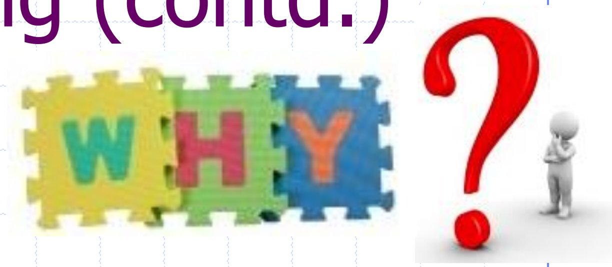
# Significant of Facilities Planning



1. The size of investment in new facilities each year.
   - 8% of gross national product (GNP) in USA has been spent annually on new facilities.

2. Economic considerations
   - One of the most effective methods for increasing plant productivity and reducing cost is to reduce or eliminate all activities that are unnecessary or wasteful.
   - A facilities design should accomplish this goal in terms of material handling, personnel and equipment utilization, reduced inventories, and increased quality.

# Significant of Facilities Planning (contd.)



3. Employee health and safety
    - Occupational Safety and Health Act: redesign facilities to consider health and safety and to eliminate possible hazardous conditions
4. Energy conservation
    - Energy has become an important and expensive raw material
5. Community considerations:
    - Fire protection, security, air pollution, noise, and the ADA (Americans with Disabilities Act) of 1989 نراعي احتياجات +
الhandicapped

# Objectives of Facilities Planning

- Improve customer satisfaction by being easy to do business with, conforming to customer promises, and responding to customer needs.
- Increase return on assets (ROA) by maximizing inventory turns, minimizing obsolete inventory, maximizing employee participation, and maximizing continuous improvement.

it tells us how much efficient is the facility

- Maximize speed for quick customer response.
- Reduced costs and grow the supply chain profitability

# Objectives of Facilities Planning (contd.)

- Integrate the supply chain through partnership and communication.
- Support the organization’s vision through improved material handling, material control, and good housekeeping.
- Effectively utilize people, equipment, space, and energy.
- Maximize return on investment (ROI) on all capital expenditures

يكون ال Layout سهل نغيره

- Be adaptable and promote ease of maintenance.
- Provide for employee safety and job satisfaction.

# Main Features of Successful Facilities Plan

- Flexibility:
  - Flexible facilities are able to handle a variety of requirements without being altered
- Modularity:
  - Modular facilities include systems that cooperate efficiently over a wide range of operating rates
- Upgradeability
  - Upgraded facilities easily incorporate advances in equipment systems and technology

Technology
متطورة

# Main Features of Successful Facilities Plan (contd.)

القدرة على التكيف

- **Adaptability:**
  - Considering the
    - Calendar
    - Cycles →
    - Peaks

- **Selective operability**
  - Understanding how each facility segment operates
  - Allows contingency plans to be put in place

ممكن تكون علاقة
off و علاقة on

# Facilities Planning Process

★ [illegible]

- Must start at the beginning of the project
- Even though facilities planning is not an exact science, it can be approached in an organized, systematic way.
- Types and Sources of Manufacturing Facilities Design Projects
    - New facility -
    - New product -
    - Design changes - of the product
    - Cost reduction - better layout for better productivity and cost reduction (Lean Thinking)

# Facilities Planning Process

By applying the engineering design approach, a systematic approach can be developed

1. Define the problem
   - Define (or redefine) the objective of the facility (products and productivity levels)
   - Specify the primary and support activities to be performed in accomplishing the objective

2. Analyze the problem
   - Determine the interrelationships among all activities

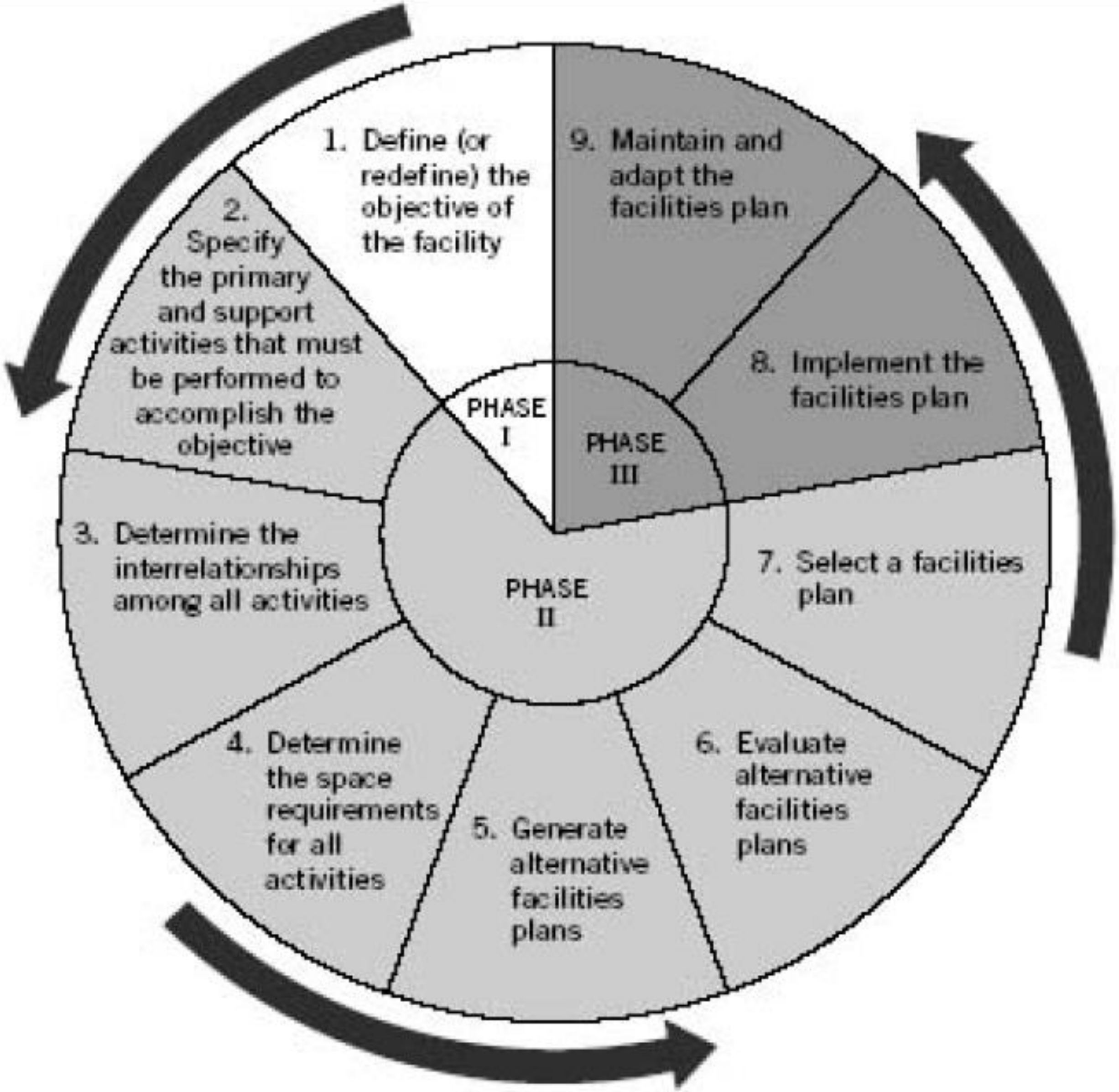
3. Determine the space requirements for all activities
   - Generate alternative facilities plans

# Facilities planning process

4. Evaluate the alternatives
    - Evaluate alternative facilities plans on the basis of accepted criteria.
5. Select the preferred design
    - Select a facilities plan
6. Implement the design
    - Implement the facilities plan
    - Maintain and adapt the facilities plan
    - Redefine the objective of the facility

على الترتيب

# Facilities Planning Process



1. Define (or redefine) the objective of the facility

2. Specify the primary and support activities that must be performed to accomplish the objective

3. Determine the interrelationships among all activities

4. Determine the space requirements for all activities

5. Generate alternative facilities plans

6. Evaluate alternative facilities plans

7. Select a facilities plan

8. Implement the facilities plan

9. Maintain and adapt the facilities plan

PHASE I

PHASE II

PHASE III

# Lean Thinking and Lean Manufacturing

- *Lean manufacturing* - a concept by which all people work together to eliminate waste
  - Overproduction
  - Waiting
  - Transportation
  - over Processing
  - Inventory → لأنه بندفع Holding cost
  - Motion
  - Rework the part may be → Defect → يمكن اصلاحه
    → Defective → لا يمكن اصلاحه
  - Poor people utilization

# The 7 Wastes

**MUDA** is the Japanese word for WASTE.

Seek it out and get rid!

An 8th waste is the wasted potential of people

1. **Overproduction**: To produce sooner, faster or in greater quantities than customer demand.
2. **Inventory**: Raw material, work in progress or finished goods which is not having value added to it.
3. **Waiting**: People or parts that wait for a work cycle to be completed.
4. **Motion**: Unnecessary movement of people, parts or machines within a process.
5. **Transportation**: Unnecessary movement of people or parts between processes.
6. **Rework**: Non right first time. Repetition or correction of a process.
7. **Over Processing**: Processing beyond the standard required by the customer.

# The Seven Types of Wastes

| The Waste | Definition |
|---|---|
| **Over Production** | Producing more than needed or Producing faster than needed (need storage place, can be damaged, lost, no sale) |
| **Over processing** | Effort Which Adds No Value to a Product or Service. (Customers not welling to pay for these efforts) |
| **Inventory** | Any Supply in Excess. (money tied up in inventory, holding costs, may damage or lost) |
| **Waiting** | Idle Time, including man wait time and machine wait time. |
| ★ **Motion** | Any Movement of People Which Does Not Contribute Added Value to the Product or Service. |
| ★ **Transportation** | Any Material Movement That Does Not Directly Support a Lean Manufacturing System, or achieve direct value. (a risk of damaged, lost, delayed, Also need assets to move such as equipments and/or workers ). |
| **Rework** | Repair of a Product or Service To Fulfill Customer requirements (rework costs, rescheduling production) |

# Other Types of Wastes

| The Waste | Definition |
|---|---|
| **Breakdown** | Poor maintenance |
| **Lake of skill** | Unskilled workers |
| **Unsafe work** | Causes lost work hours |
| **Poor information** | Poor Information system, poor communication |
| **Loss of Material** | If expensive |
| **Unused Capacity** | (unused spaces, unused machines) |
| | |

# Strategic Facilities Planning

كل اجزاء الشركة تساهم فيها

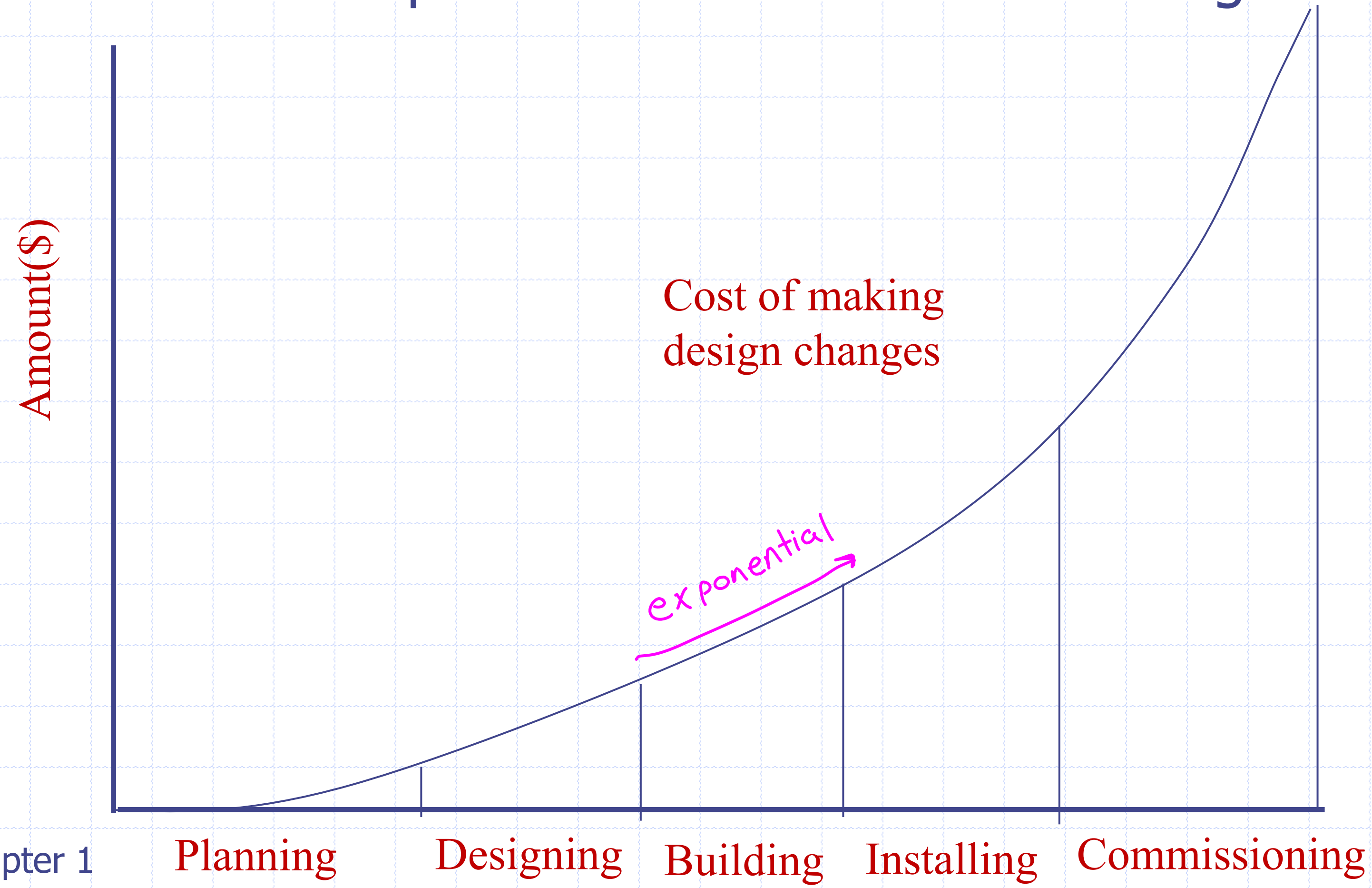
- Facilities planning is a strategic process
  - Must be an integrated part of overall corporate strategy
  - Every element of the organization must support the objectives of the firm.

- Previously, strategies was restricted to marketing and finance without clear understanding of the impact on manufacturing or on support functions such as material handling, information system, facilities, etc.

# Cost of design changes during a project

أَساسيّ

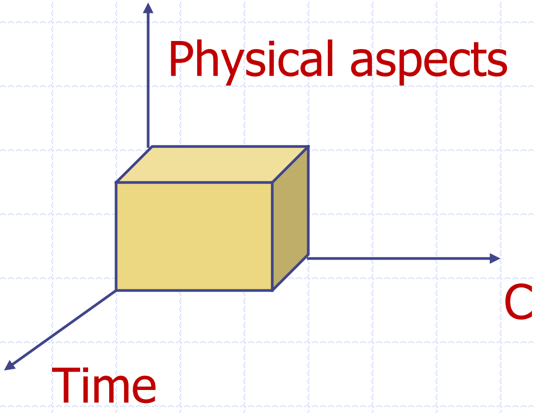
- Planning is a vital process
- Where in the process should we make changes?



# Developing Facilities Planning Strategies

- The facilities planning process can be improved in three potential dimensions:
  - Physical aspects: building, equipment, and people
  - Control: material control, space control, productivity measures
  - Time: for planning (sufficient lead time is needed to do it right)

- The objective is to improve on these three levels



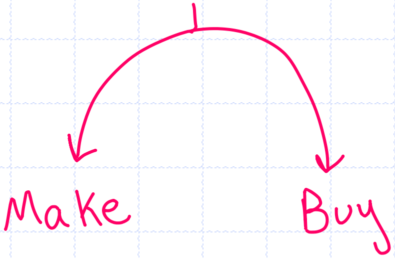
# Developing Facilities Planning Strategies

- Facilities planning should also be well defined as to how each function fits, interacts and integrate
- Customer satisfaction
- Team work: everyone involved
- Should not accept information delays (true partnership)

كل Part من الشركة يجب أن يقوم
بعمله ontime

- Facilities planner should be proactive, and participate in the decision making that create the needs.
- Continuous improvement

# Sources Of Information For Manufacturing Facilities Design



Make Buy

- Product and process design
- Marketing
- Management policy

- Product design
  - blueprints
  - bill of material (part list)
    - indented BOM
    - buyouts/fabricate
  - assembly drawings
    - Part and assembly drawings are especially helpful in visualization of how parts will fit together
  - model shop samples (prototypes)
- Relationship between FD and product design is important

# Sources Of Information For Manufacturing Facilities Design

- Marketing
  - Volume, how many can we sell?
  - Seasonality, summer or winter product
  - Selling price
  - Replacement parts, older products

# Sources Of Information For Manufacturing Facilities Design

- Management policy - refers to the upper-level employees
  - inventory policy (Just in Time, Kanban, WIP)
  - lean thinking
  - investment policy (ROI)
  - startup schedule
  - make or buy decision
  - feasibility studies (what product or process proposal is the most profitable for the company

# Chapter 2

# Chapter 2

# Product, Process, and Schedule Design

عملية مستمرة

# Facilities Planning Process

Facilities Planning Process for manufacturing and assembly facilities can be listed as follows:

- Define the product to be manufactured or assembled
- Specify the required manufactured or assembled
- Determine the interrelationships among all activities
- Determine the space requirement for all activities
- Generate alternative facilities plan
- Evaluate the alternative facilities plan
- Select the preferred facilities plan
- Implement the facilities plan
- Maintain and adopt the facilities plan
- Update the products to be manufactured or redefine the objectives of the facility

# Introduction

- Before we start developing alternative facility plans, we should have answers for the following questions:

1. What is to be produced?
2. How are the products to be produced?
3. When are the products to be produced?

هل هو لوقت محدد مثلاً في رمضان فقط ........

4. How much of each product will be produced?
5. For how long will the product be produced?
6. Where will the products be produced?

Answer for the first 5 Questions can be obtained from:
**•Product design**
**•Process design**
**•Schedule design**

Answer for the last question might be obtained from **facility location** determination or it may answered by **schedule design** when the production is to be allocated among several existing factories

# Introduction (Contd.)

operating or occurring at the same time

- Organisations create teams (concurrent engineering team) with:
  - Product planner
  - Process planner
  - Schedule planner (production planner)
  - Facility design planner
  - Personnel from marketing , purchasing and accounting

Why?

To address the design process in an integrated or concurrent way

# Introduction (Contd.)

- **Product designers** focus on the end product is to be in terms of its dimensions, material composition, and perhaps packaging.
- **Process planner** determines how the product will be produced.
- **Production planner** specify the production quantities and schedules the production equipment.
- *Facility planner* is dependent on timely *and* accurate input from product, process and schedule designers.

# Introduction (Contd.)

- This team approach reduces the design cycle time, improve the design process, and minimising the engineering changes.

- Implementing this integrated approach have reported significant improvement in cost, quality, productivity, sales, customer satisfaction, delivery time, inventories, space and handling requirements, and facilities utilisation.

# Introduction (contd.)

- The success of a firm is dependent on having an efficient production system. Hence, it is essential that product designers, process selections, production schedules, and facilities plans to be mutually supportive.

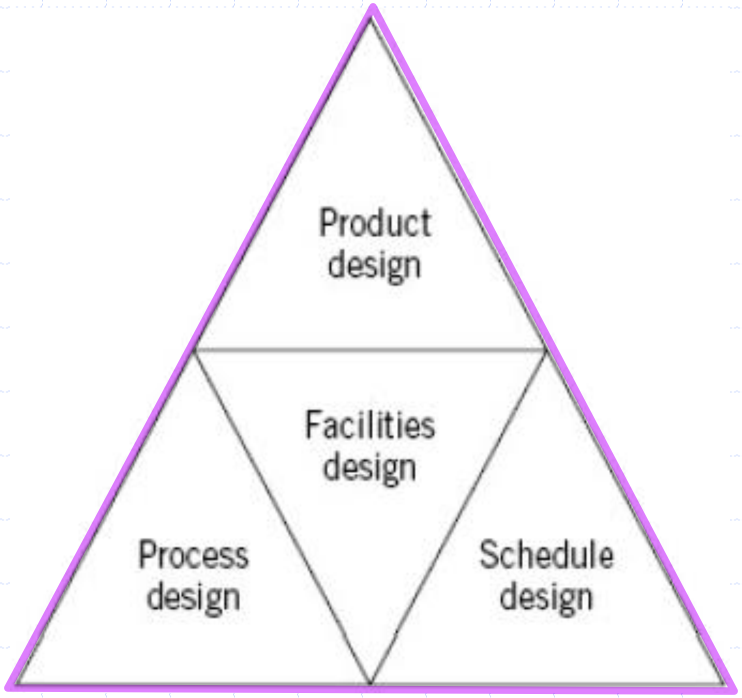


Fig 2.1: The need for close coordination among the four groups

# Product Design

- **Product design**
- **Process design**
- **Schedule design**

1. Determination of a product to be produced
2. Detailed design of the product

## 1. Product Determination

- Product Determination made by upper level management and based on input from:
  - Marketing
  - Manufacturing
  - Finance
  - Etc.

- **Product design**
- **Process design**
- **Schedule design**

# 1. Product Determination (contd.)

- If changes are likely in facility mission and products:

  A high degree of flexibility and a very general space. سعر اكبر

- If a high degree of confidence about facility mission and products:

  The facility design should optimize the production of those products

under the Risk of changing the ... . so I choose more space

ال Design يتأثر بال customer requirements

- **Product design**
- **Process design**
- **Schedule design**

# 2. Detailed Design

- The detailed design of the product is influenced by aesthetics, function, materials and manufacturing considerations.
- The product must meet the needs of the customer.
- This challenge can be accomplished by:

*Quality Function Deployment (QFD)* - Translation of the customers' desires into product design, and subsequently into parts characteristics, process plans and production requirements.

وضع المعايير

- *Benchmarking*

يعني احاول اعمل satisfy customer requirement عشان اعرف انافس الشركات الاخرى

يمكن خطط

- **Product design**
- **Process design**
- **Schedule design**

# 2. Detailed Design (contd.)

- Finally, detailed designs take place:
  - CAD designs
  - Prototypes
  - Assembly designs
  - 2D drawings and dimension determinations
- All these can be observed easily in most of the commercial CAD programs (AutoCAD, ProE, CATIA etc)

- **Product design**
- **Process design**
- **Schedule design**

# 2. Detailed Design– Documentation

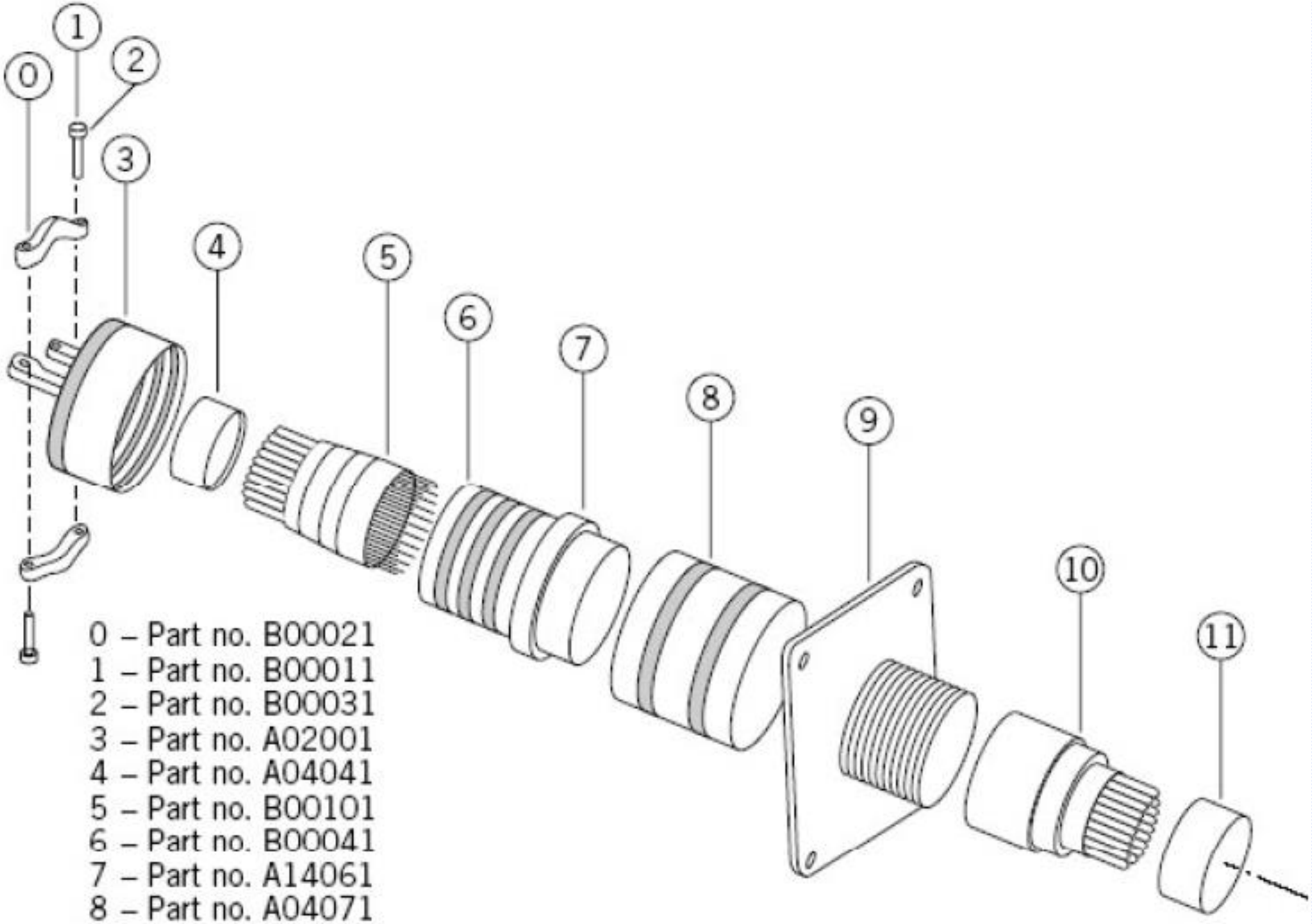
- Once the product design is completed, usually following documents are provided for the facilities planning process as inputs:

يعني ما فيها ابعاد

without dimensions

  - ***Exploded assembly drawing*** – omits specifications and dimensions, useful in designing the layout and handling system
  - ***Exploded parts photographs*** – allow the planner to visualize how the product is assembled, provide a reference for part numbers, and promote cleaner communication during oral presentation
  - ***Component part drawing*** – provide part specification and dimensions in sufficient details to allow part fabrication

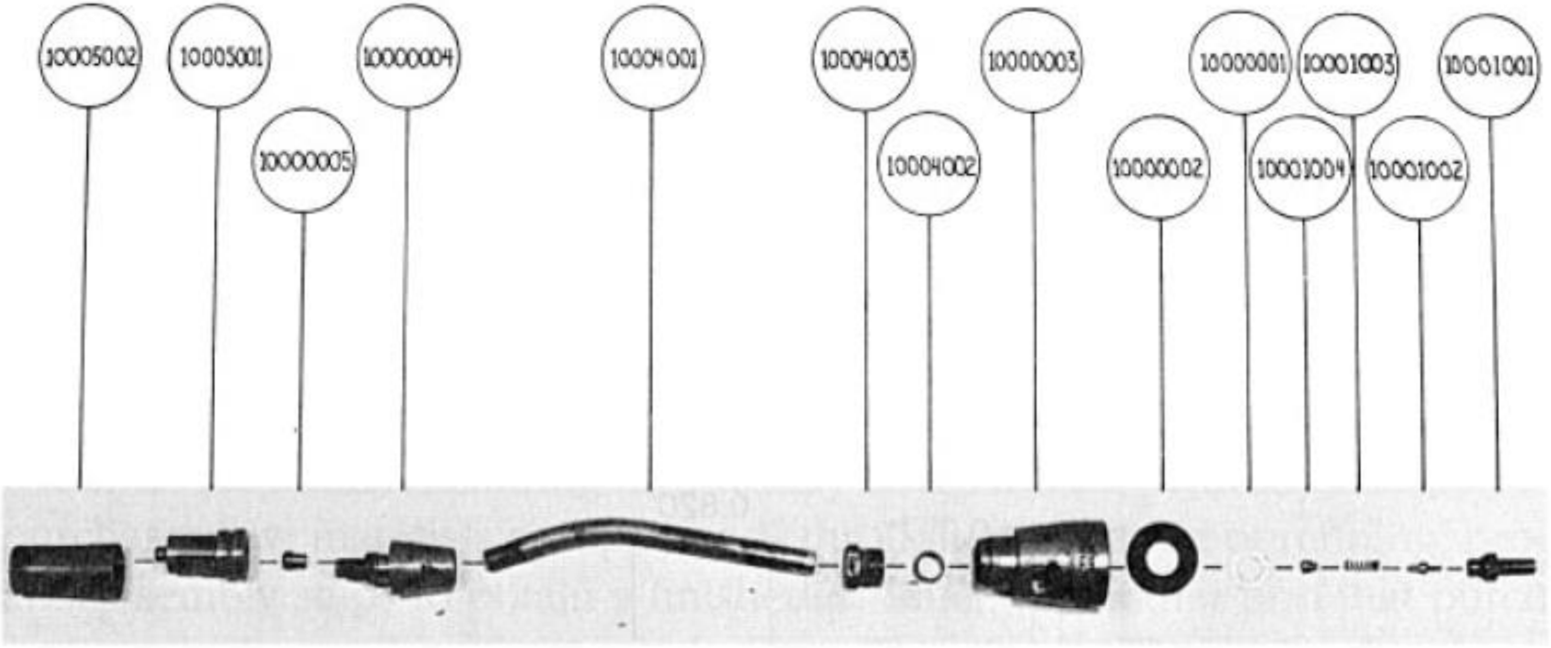
كاف



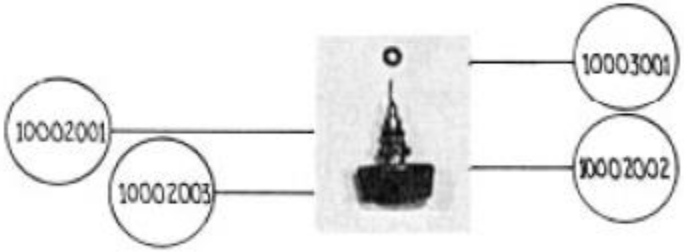
0 – Part no. B00021
1 – Part no. B00011
2 – Part no. B00031
3 – Part no. A02001
4 – Part no. A04041
5 – Part no. B00101
6 – Part no. B00041
7 – Part no. A14061
8 – Part no. A04071
9 – Part no. A24051
10 – Part no. B00111
11 – Part no. A04091

# Exploded assembly drawing

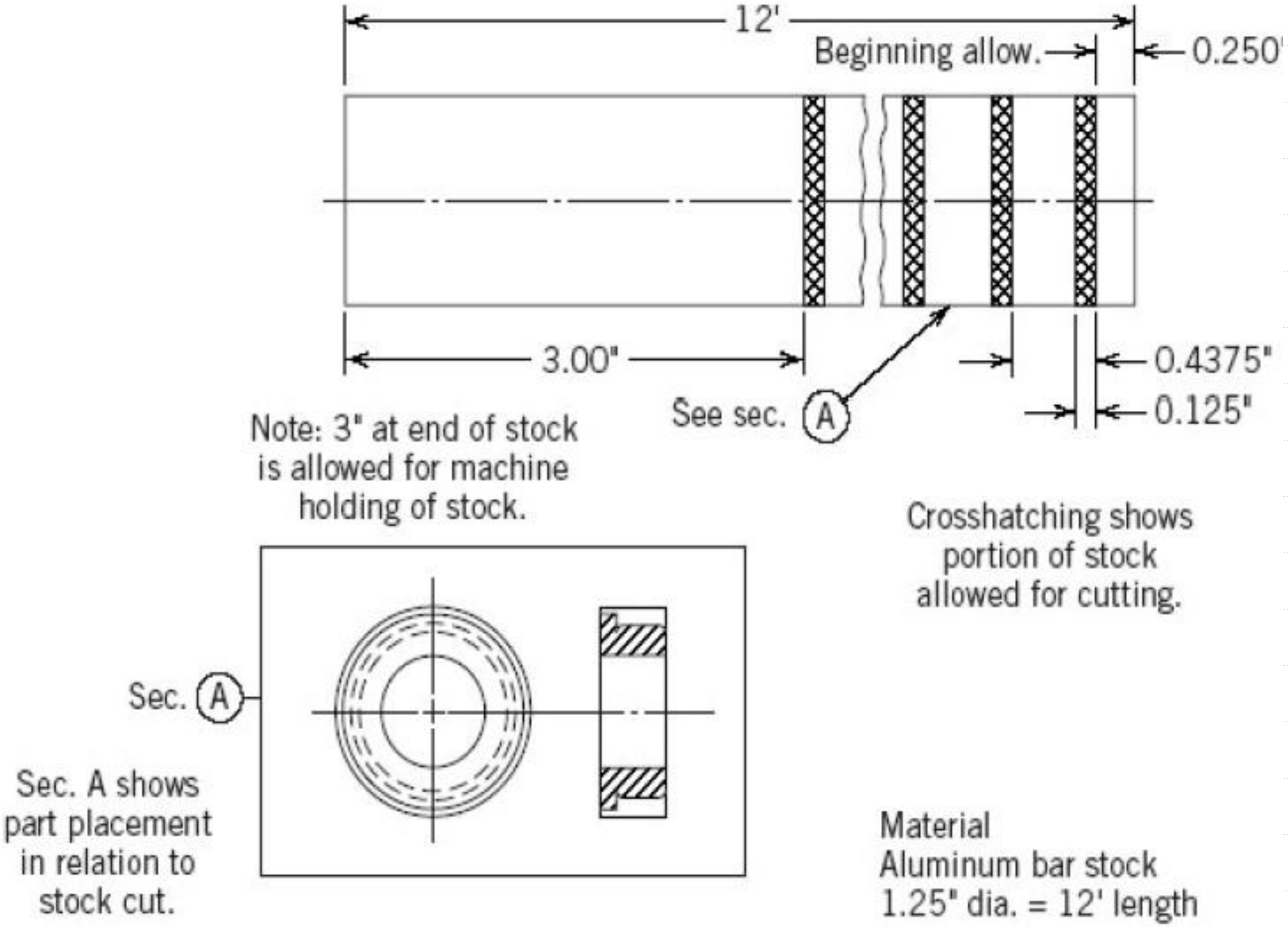
It doesn't include details (Just the part number)



| | |
|---|---|
| Drawing No. | 4482 |
| Drawing Type | Exploded Assembly |
| Prepared By | Frazelle |
| Checked By | Dew |
| Date | 3-14-91 |
| Company | Uncan-Arnell, Inc. |



Exploded parts photograph



Note: 3" at end of stock is allowed for machine holding of stock.

Crosshatching shows portion of stock allowed for cutting.

Sec. A shows part placement in relation to stock cut.

Material
Aluminum bar stock
1.25" dia. = 12' length

Component part drawing

2

# Process Design

في كتير مصانع بتكون فقط للAssembly

- **Product design**
- **Process design**
- **Schedule design**

- Determination of ***how*** the product is to be produced:

  (in the facility itself)

  - Which part of the products should be made in-house?
  - Which equipment will be used? (for the parts which will be made in-house)
  - Who should do the processing?
  - How long will it take to perform the operation?

اكتر factor بيؤثر على

- Production methods are the most fundamental factor affecting the physical layout

ترتيب ال process

- **Product design**
- **Process design**
- **Schedule design**

# Process Design (contd.)

- Within the process design process, we need to consider following issues:

**1. Process identification**
2. Process selection
3. Process sequencing

*1. Process identification*

- Make-or-buy analysis
- Parts identification

*2. Process selection*

- How the product will be made (operations, equipment, raw material, etc.)

*3. Process sequencing*

- How components are put together

# Process Design:
## 1. Process identification

**1. Process identification**
2. Process selection
3. Process sequencing

- ***Make-or-buy decisions:***
  - Determining the scope of the facility (determining the processes that are to be included within the facility)
  - How are the make-or-buy decisions made?
    - Can the item be purchased? If NO: MAKE
    - Can we make the item? If NO: BUY
    - Is it cheaper for us to make than to buy? If NO: BUY
    - Is the capital available so that we can make it? If NO: BUY, IF Yes: MAKE
- Make-or-buy decisions are managerial decisions requiring input from finance, industrial engineering, marketing, process engineering, purchasing, human resources, etc.

★ figure 2 in the book is important

بنسأل هاي الأسئلة على كل جزء بالاشي

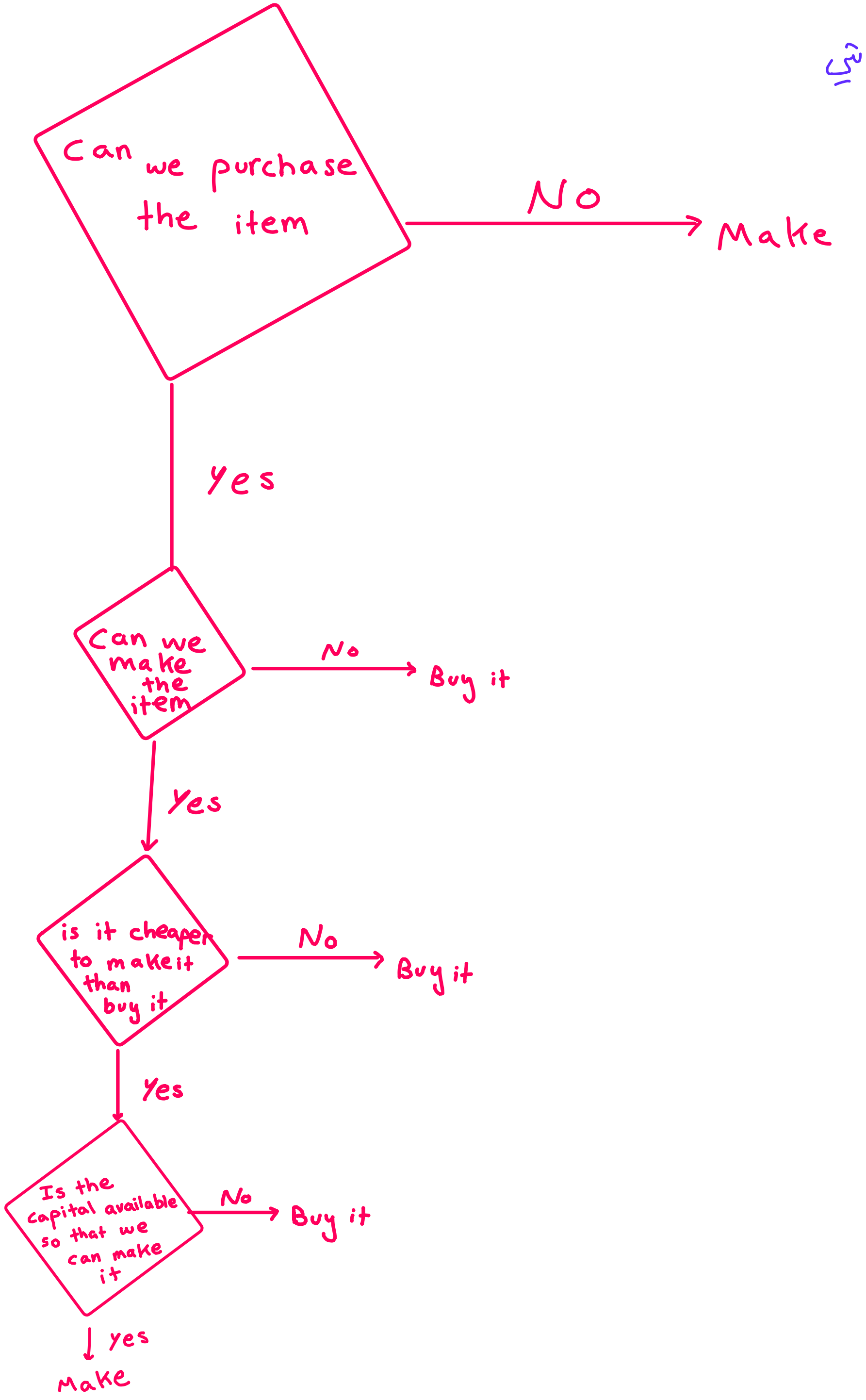


Figure (2.6) in the book

# Process Design:
## 1. Process identification (contd.)

**1. Process identification**
2. Process selection
3. Process sequencing

- Advantages of outsourcing:
  - Minimize your capital investment
  - Free machines or equipments
  - Hazards/ problems
  - Concentrate on Core competence

(تحت رحمة ال supplier)
ال supplier يتحكم بال quality و كلشي
و الحل الوحيد اصير اعمل الاشياء بالمصنع تبعي

- Advantages of in-sourcing:
  - To retain control over the design, quality, reliability and delivery schedules.
  - To avoid increase in supplier price

# Process Design:
## 1. Process identification (contd.)

**1. Process identification**
2. Process selection
3. Process sequencing

- After the make or buy decisions have been made, the list of items to be made and the items to be purchased.
- The listing often takes the form of a parts list or a bill of materials (BOM). A parts list includes at least the following

make or buy

1. Part number
2. Part name
3. Number of parts per product
4. Drawing (drawing number)
5. Material
6. Size (Dimensions)
7. Make or buy

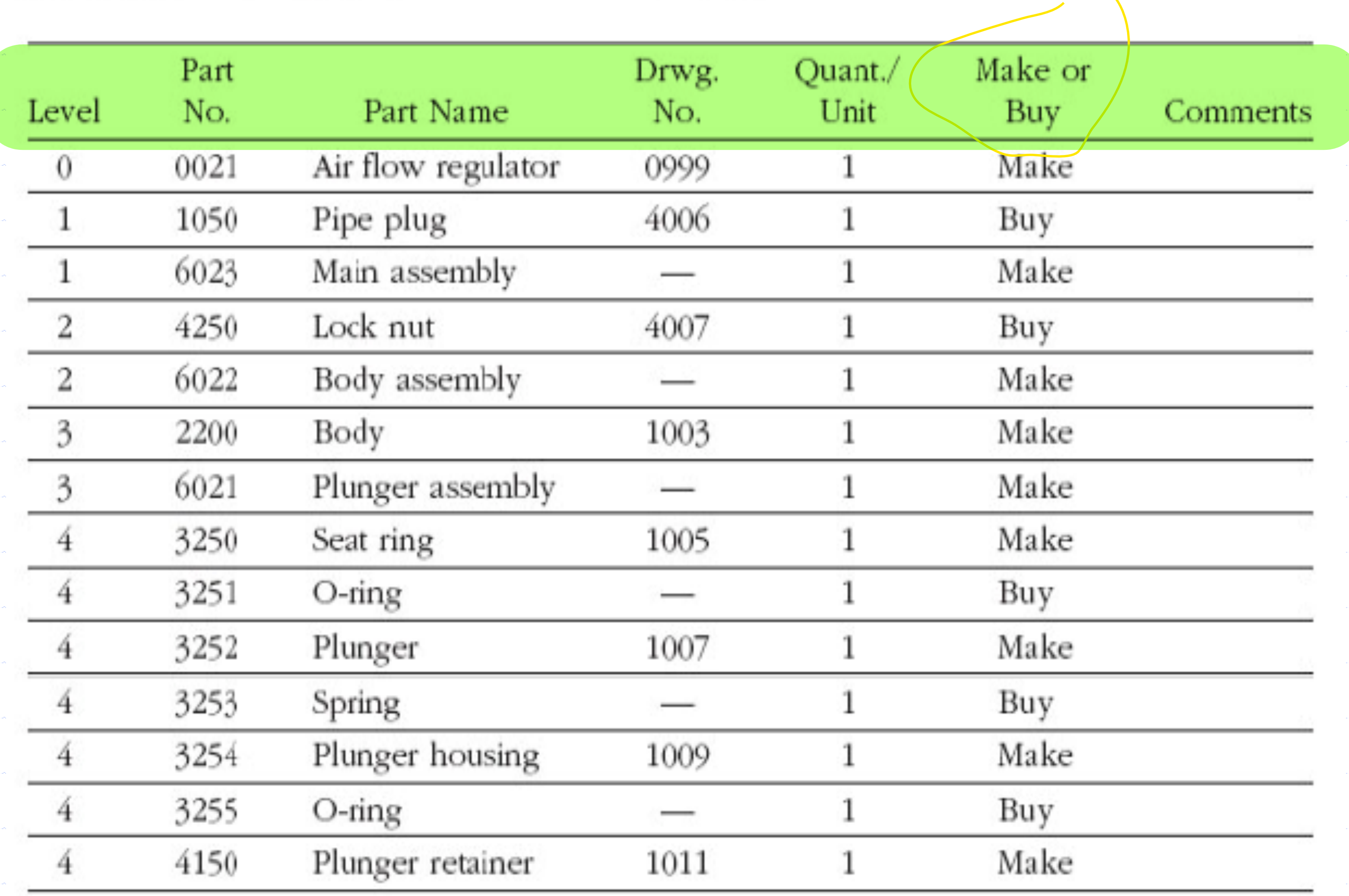
# Bill of Material (BOM) for an **Air flow regulator**

one per product

**BILL OF MATERIALS** → Table → Tree

→ for the whole product

Company T. W., Inc. Prepared by J. A.
Product Air Flow Regulator Date



| Level | Part No. | Part Name | Drwg. No. | Quant./ Unit | Make or Buy | Comments |
|---|---|---|---|---|---|---|
| 0 | 0021 | Air flow regulator | 0999 | 1 | Make | |
| 1 | 1050 | Pipe plug | 4006 | 1 | Buy | |
| 1 | 6023 | Main assembly | — | 1 | Make | |
| 2 | 4250 | Lock nut | 4007 | 1 | Buy | |
| 2 | 6022 | Body assembly | — | 1 | Make | |
| 3 | 2200 | Body | 1003 | 1 | Make | |
| 3 | 6021 | Plunger assembly | — | 1 | Make | |
| 4 | 3250 | Seat ring | 1005 | 1 | Make | |
| 4 | 3251 | O-ring | — | 1 | Buy | |
| 4 | 3252 | Plunger | 1007 | 1 | Make | |
| 4 | 3253 | Spring | — | 1 | Buy | |
| 4 | 3254 | Plunger housing | 1009 | 1 | Make | |
| 4 | 3255 | O-ring | — | 1 | Buy | |
| 4 | 4150 | Plunger retainer | 1011 | 1 | Make | |

**Figure 2.8** Bill of materials for an air flow regulator.

الـ Tree اوضح من الـ Table

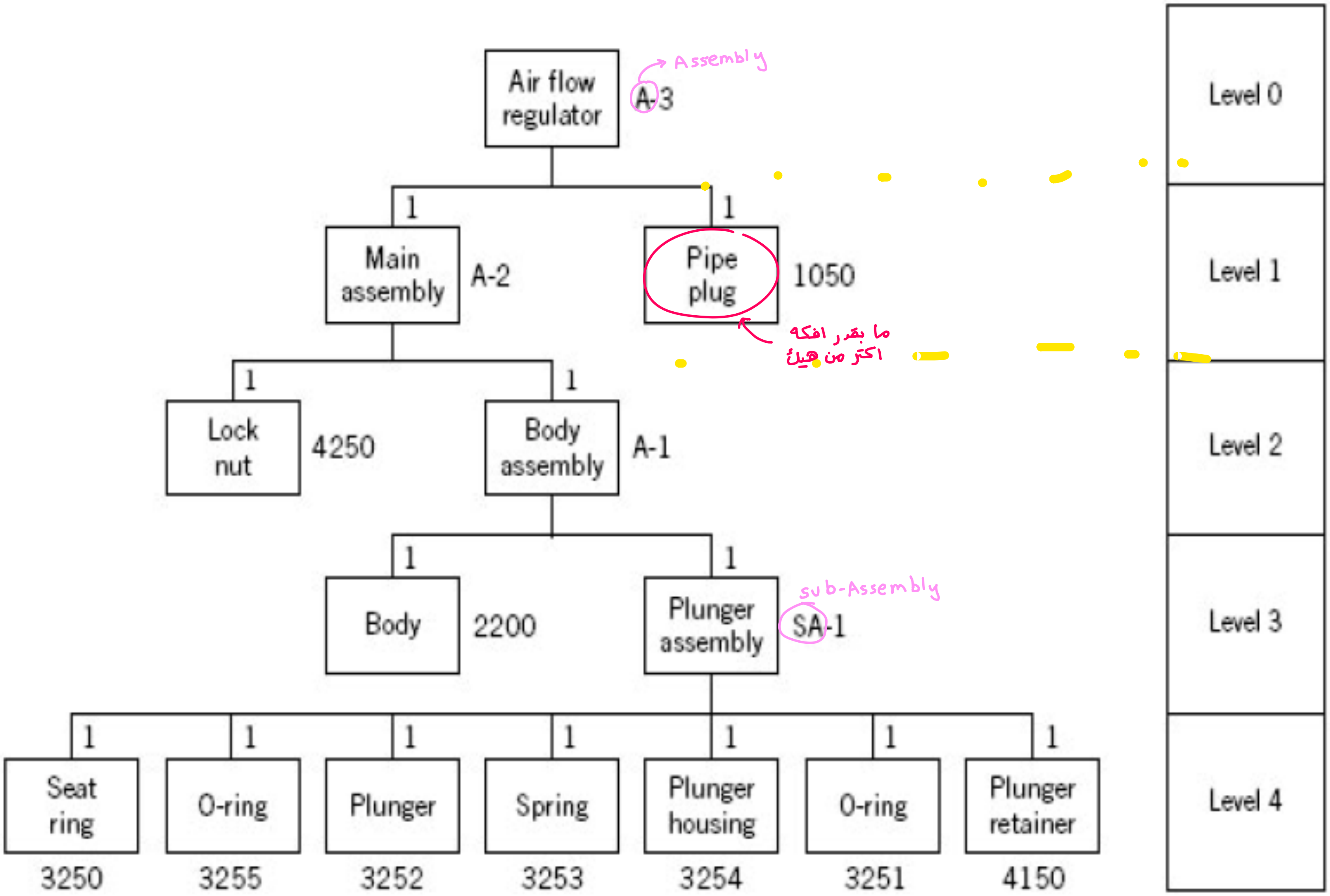


Figure 2.9 Bill of materials for an air flow regulator.

# Process Design:
# 2. Process selection

(تحديد ال Process المناسبة
لكل Part)

1. Process identification
**2. Process selection**
3. Process sequencing

- After determining "in house" parts decisions are needed as to: ***how the products will be made***

- Such decisions are based on:
  - previous experiences
  - related requirements
  - available equipment
  - production rates
  - future expectations. (for example Forecasting)

# Process Design:
# 2. Process selection (contd.)

| 1. Process identification |
|---|
| **2. Process selection** |
| 3. Process sequencing |

## Process selection steps:

1. Define the elemental operations
2. Identify alternative processes for each operation
   - Manual vs. automated
3. Analyze the alternative processes
   - Consider equipment utilization
4. Evaluate the processes
   - Economics
   - Flexibility
   - Reliability
   - Maintainability
   - Safety
5. Select the process

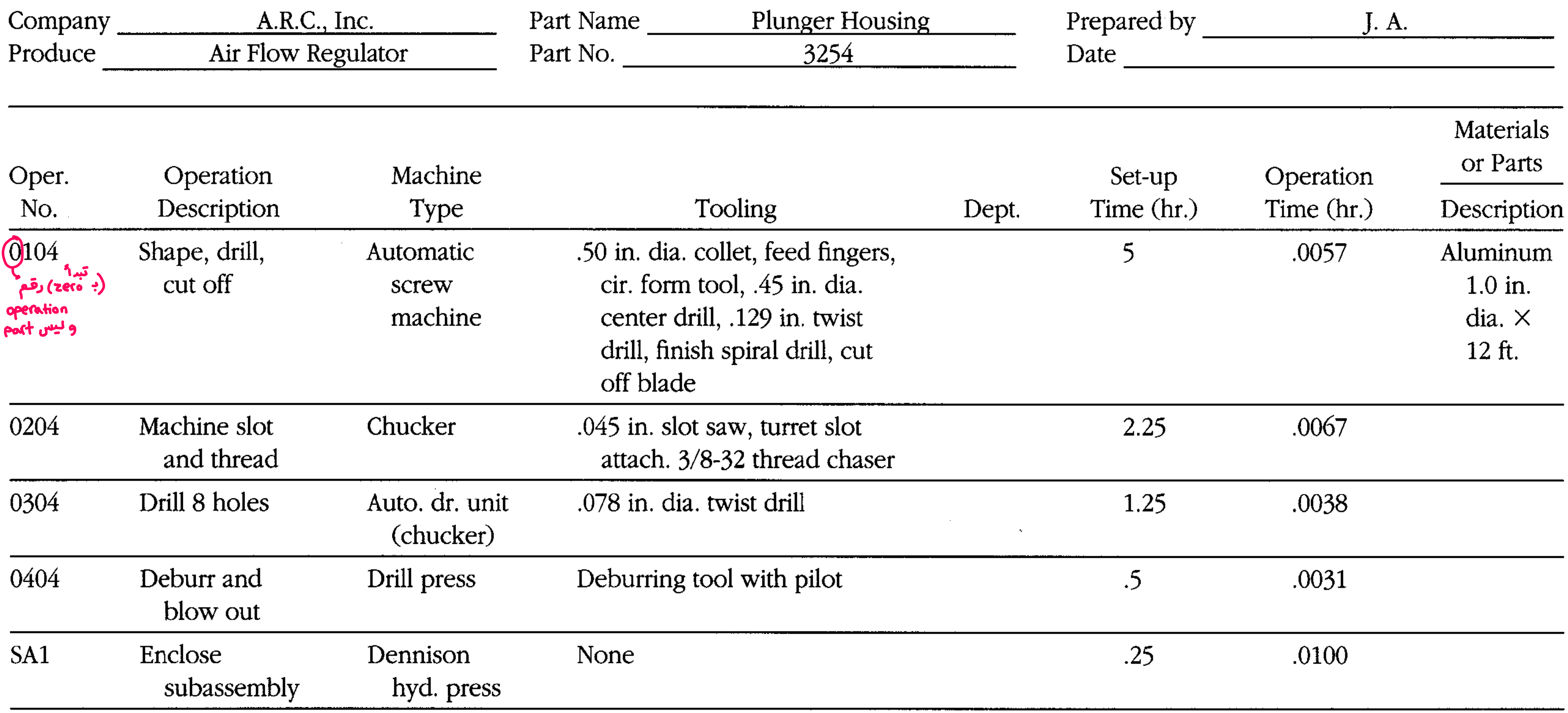
# Process Design:
# 2. Process selection (contd.)

1. Process identification
**2. Process selection**
3. Process sequencing

- Process identification can be done manually or with a computer.
- With a computer it is referred to as *Computer Aided Process Planning* (CAPP).
- Two general CAPP:
  - **Variant**: call up standard plans and modify
  - **Generative**: create a new plan from scratch (do not use existing plans).
- **Outputs** are processes, equipment, and raw materials required for the in-house production of products, also called a **route sheet**.

# Route sheet

per name



Company A.R.C., Inc.
Produce Air Flow Regulator
Part Name Plunger Housing
Part No. 3254
Prepared by J. A.
Date

| Oper. No. | Operation Description | Machine Type | Tooling | Dept. | Set-up Time (hr.) | Operation Time (hr.) | Materials or Parts Description |
|---|---|---|---|---|---|---|---|
| 0104 | Shape, drill, cut off | Automatic screw machine | .50 in. dia. collet, feed fingers, cir. form tool, .45 in. dia. center drill, .129 in. twist drill, finish spiral drill, cut off blade |  | 5 | .0057 | Aluminum 1.0 in. dia. × 12 ft. |
| 0204 | Machine slot and thread | Chucker | .045 in. slot saw, turret slot attach. 3/8-32 thread chaser |  | 2.25 | .0067 |  |
| 0304 | Drill 8 holes | Auto. dr. unit (chucker) | .078 in. dia. twist drill |  | 1.25 | .0038 |  |
| 0404 | Deburr and blow out | Drill press | Deburring tool with pilot |  | .5 | .0031 |  |
| SA1 | Enclose subassembly | Dennison hyd. press | None |  | .25 | .0100 |  |

تبدأ
رقم (zero :ب)
operation
و ليس part

**Figure 3.11** Route sheet for one component of the air flow regulator.

# Rout sheet Data Requirements

| **Data** | **Production Example** |
|---|---|
| Component name and number | Plunger housing – **3254** |
| Operation description and number | Shape, drill, and cut off – **0104** |
| Equipment requirements | Automatic screw machine and appropriate tooling |
| Unit times (Per components) | Set-up time: 5 hrs.<br>Operating time: 0.0057 hrs |
| Raw material requirement | 1 in. diameter X 12 ft aluminum bar per 80 components |

# Process Design:
## ~~2~~3. Process sequencing

1. Process identification
2. Process selection
3. **Process sequencing**

- The method of assembling the product.

- ***Assembly chart***
  - shows how the components are combined

- ***Operation process chart***
  - Gives an overview of the flow within the facility
  - A combination of route sheets and assembly charts

مشكلته
الوحيدة انه ما بيعطيني
ال Dependency
و لهذا سوف نحتاج
Precedence diagram

- ***Precedence diagram***
  - establishes precedence relationships

# Process Design:
# 2. Process sequencing

1. Process identification
2. Process selection
3. **Process sequencing**

- *Assembly chart:*
- *Assembly chart* shows the sequence of operations in putting the product together.
- The easiest method of constructing an assembly chart is to begin with the completed product and trace the product disassembly back to its basic components.
- See figure 2.11

# Assembly chart

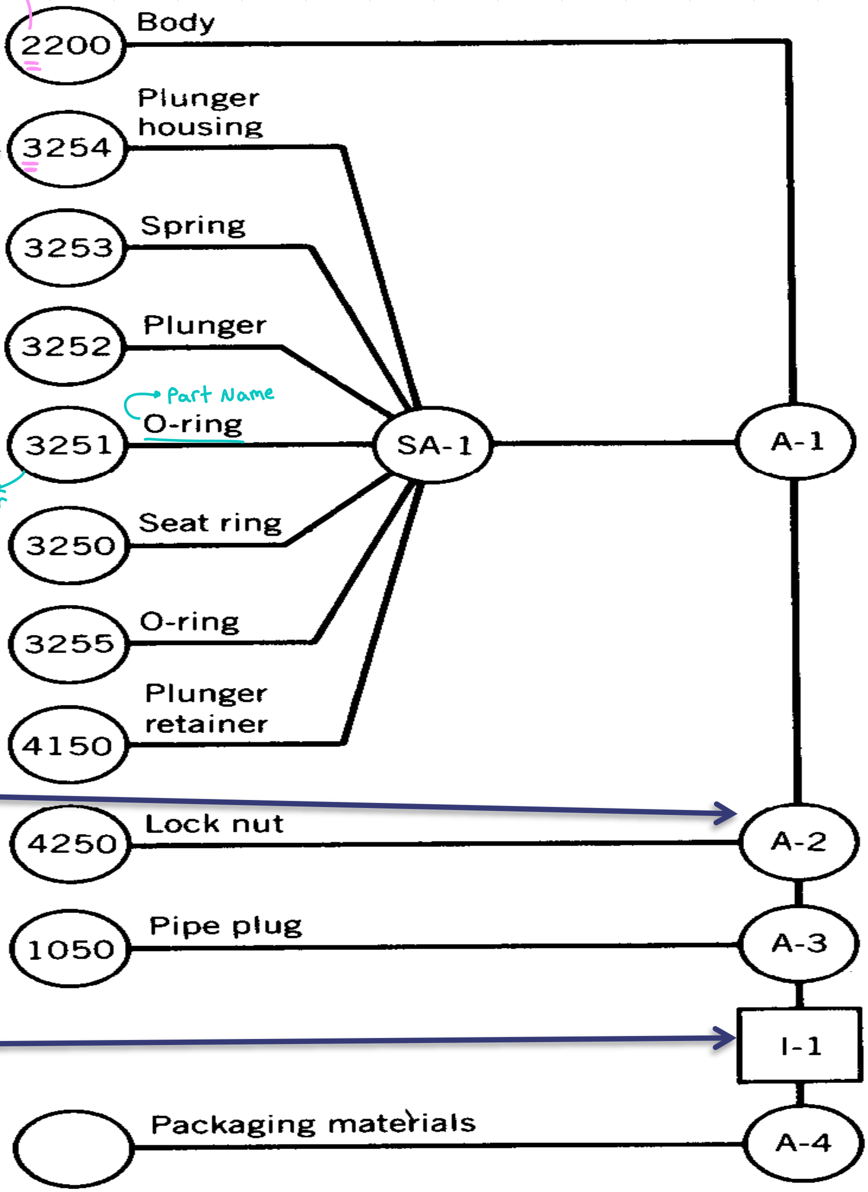
اذاً هذه الارقام تمثل
Part Number

(I need information from the Route Sheet)

This was identified in route sheet already

Assemblies

Inspection



Assembley 2

square
inspection

**Figure 3.12** Assembly chart for an air flow regulator.

# Process Design:
# 2. Process sequencing

1. Process identification
2. Process selection
3. **Process sequencing**

②

- *Operation process chart:*

Assembly sheet is for the component

عبارة عن → Route sheet and → Assembley chart

- Although route sheets provide information on production methods and assembly charts indicate how components are combined, neither provides an overall understanding of the flow within the facility.

- This is accomplished with the **operation process chart**.

- See figure 2.12

# Operation process chart

هنا استفدنا من ال

Assembley chart

Routh sheet

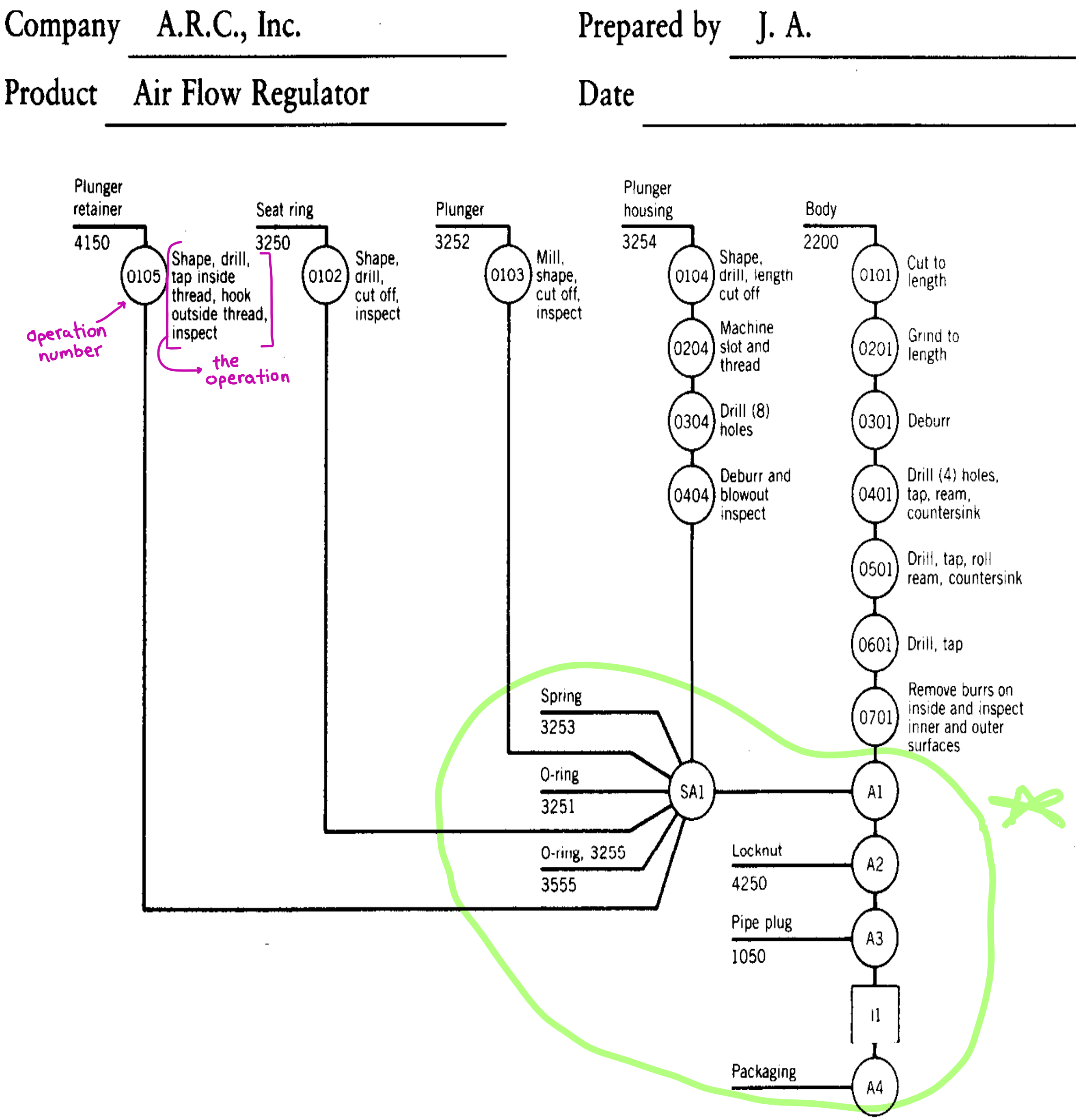


Figure 3.13 Operation process chart for the air flow regulator.

# Process Design:
# 2. Process sequencing

1. Process identification
2. Process selection
3. **Process sequencing**

③ - ***Precedence diagram:*** طريقة ثانية لعرض ال output

- A second viewpoint (from graph and network theory) is to interpret the charts as network representations, or more accurately, tree representations of a production process.

- A variation of the network viewpoint is to treat the assembly chart and the operations process chart as special cases of a more general graphical model, the **precedence diagram**.

# Precedence Diagram

- In the operation process charts, it is not clear if two machining operations have any dependency

- Observe the part#3254 Operations 0204 and 0304 can be done **at the same time**
- Yet, the operation 0104 should be completed **before both 0204 and 0304**

- We cannot observe this information in operation process charts

الترتيب تبعهم
لا يعني .... مدري

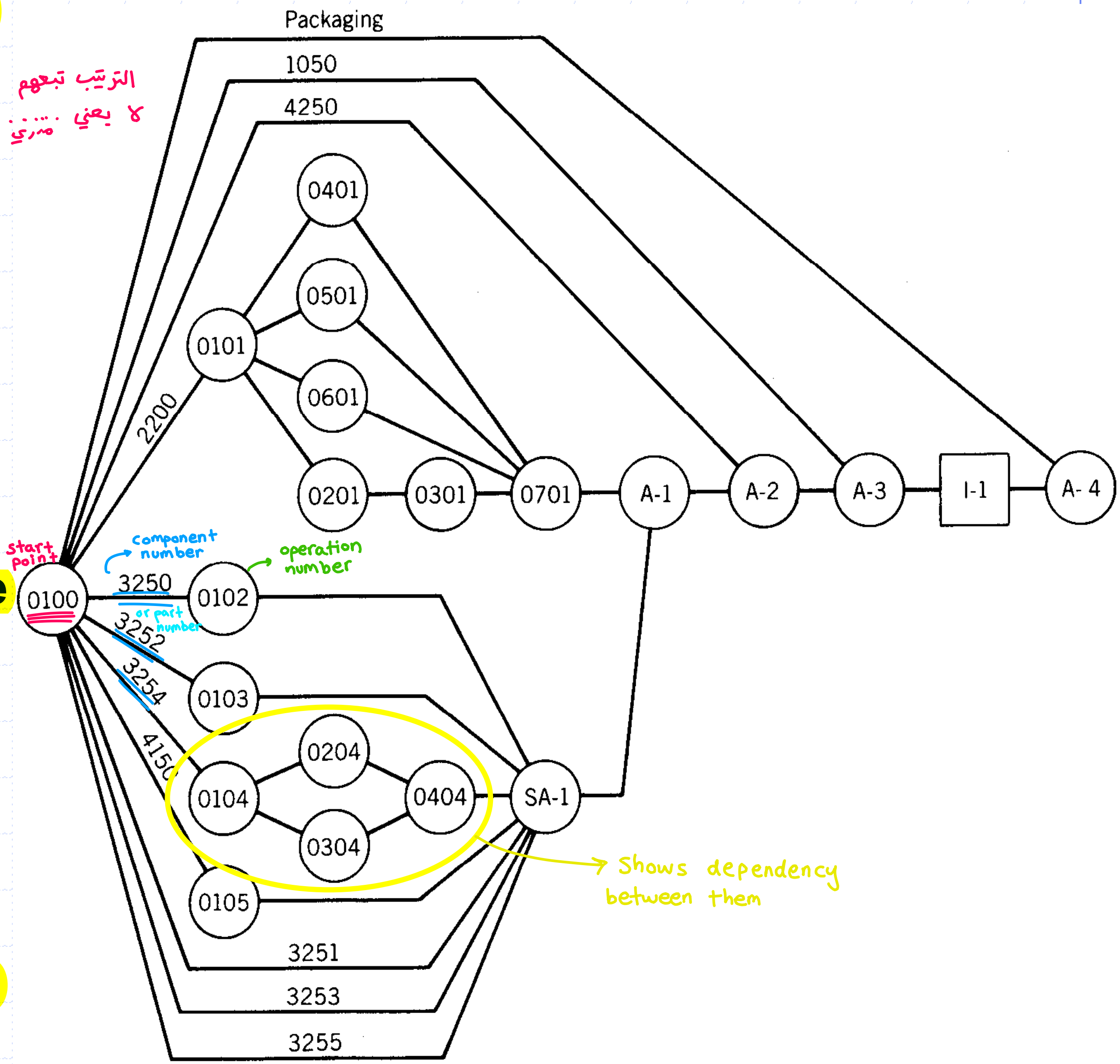


Figure 3.14 Precedence diagram for the air flow regulator.

# Schedule Design

Rejection
Allowance
slides
are important

- **Product design**
- **Process design**
- **Schedule design**

- Schedule design decisions provide answers to questions involving:
  - how much to produce?
  - when to produce?
  - How long will the products be produced?
- *Production quantity* decisions are referred to as lot size decisions
- Determining *when* to produce is referred to as production scheduling.

جدولة الانتاج

# Schedule Design (contd.)

- **Product design**
- **Process design**
- **Schedule design**

- We design facilities for major <u>parts</u> and <u>operations</u>
- What do we need to know to start designing our facilities:
  - Number of products to be produced
  - Number of machines required
  - Number of employees required
  - Sequence of operations
  - Relationships between departments

scheduale ال
designer
يحددها

in chapter
(3)

# Impact of Schedule Design

- **Product design**
- **Process design**
- **Schedule design**

1. Machine selection
2. Number of machines
3. Number of shifts
4. Number of employees
5. Space requirements
6. Storage equipment
7. Material handling equipment
8. Personnel requirements
9. Storage policies
10. Unit load design
11. Building size, and so on.

# Schedule Design *(Marketing)*

- **Product design**
- **Process design**
- **Schedule design**

- Marketing department provides a research function that analyzes what the world's consumer wants. Some of the information that marketing provides is:
  - Production volume, how many can we sell?
  - Seasonality, summer or winter product
  - Trends
- Note the Pareto effect that often 85% of the production volume comes from 15% of the product. So focus on the high volume products but don't completely ignore the low volume ones.

# Schedule Design *(Marketing)*

- **Product design**
- **Process design**
- **Schedule design**

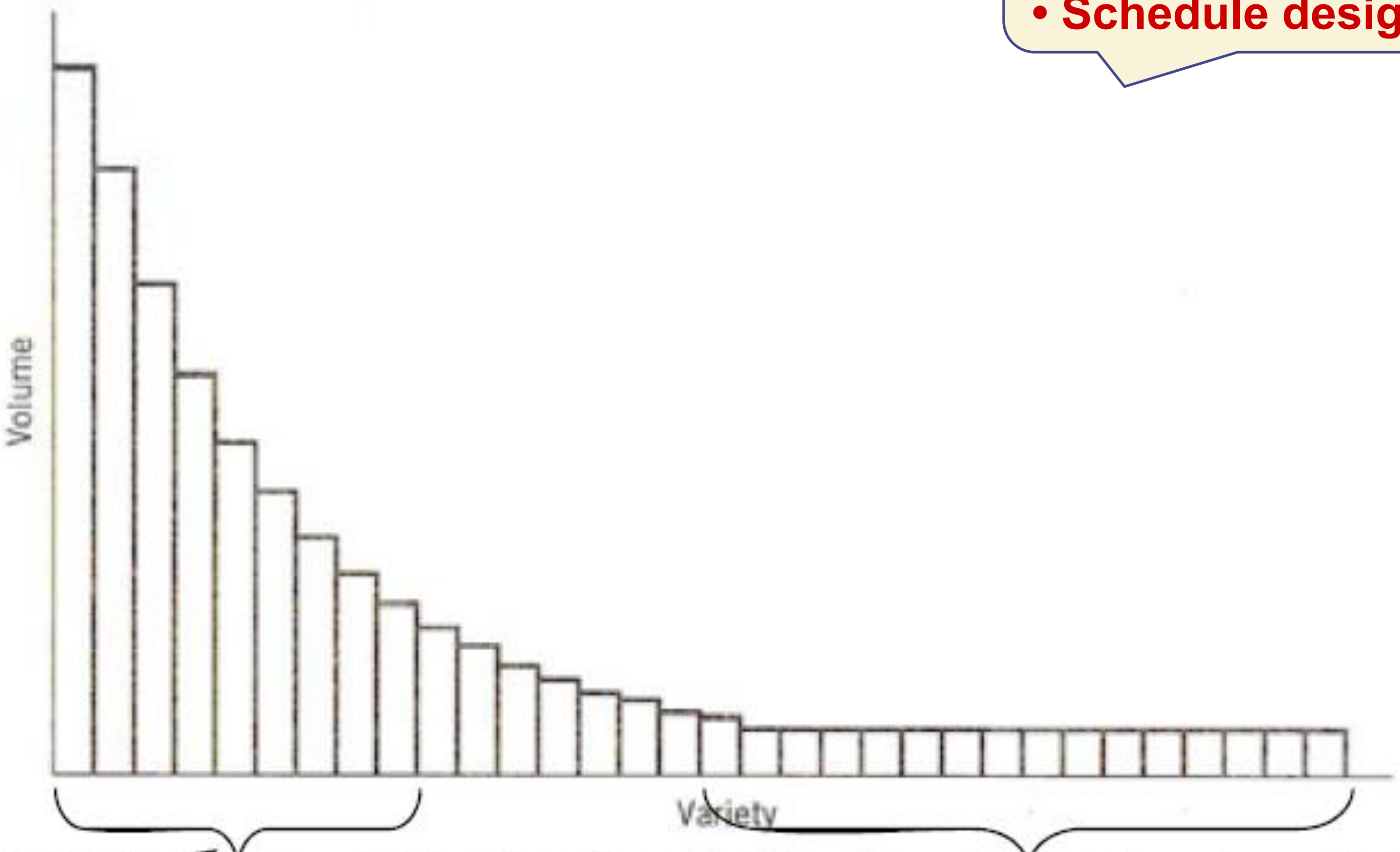


Figure 2.15 Volume-variety chart for a facility where Pareto's law is applicable.

More general items produced everyday: *Mass production area*

Items that are produced (may be) by special orders etc.: *Job shop area*

# Schedule Design *(Marketing)*

- **Product design**
- **Process design**
- **Schedule design**

- Valuable information that should be obtained from marketing and used by a facilities planner. See table 2.4 (on next slide)
  - Who are the consumers?
  - Where are the consumers?
  - Why will the consumer purchase the product?
  - Where will the consumer purchase the product?
  - What is the trend in product change?

# Schedule Design
# (*Process Requirements*)

- **Product design**
- **Process design**
- **Schedule design**

◆ Process design determines the specific equipment types required to produce the product. Schedule design determines the number of each equipment type.

◆ Specification of process requirements typically occurs in 3 phases.

1. Qty of components to be produced including scrap
2. Equipment requirements for each operation
3. Combine the operation requirements

# Quantity Determination :-

- 1st Method → **Scrap estimation :-** Determination of the quantity to be manufactured including scrap for each component/part
  - for High volum production
  - the estimation of scrap as constant percent or average
  - cheap product
- 2nd Method → **Rejection Allowance :-** Determination the number of additional units to allow, when number of units to produce are very few and rejection randomly occurs
  - for Low volume production
  - the cost of scrap is very high
  - the rejection randomly occurs

# Schedule Design (*Process Requirements)*
## *Scrap estimate*

- Scarp is the material waste generated in the manufacturing process due to geometric or quality considerations.

- The amount of scrap depends on how tight the tolerance is, automated process or not, (quality ↑), (certified ↑ suppliers,) and the grade of material.

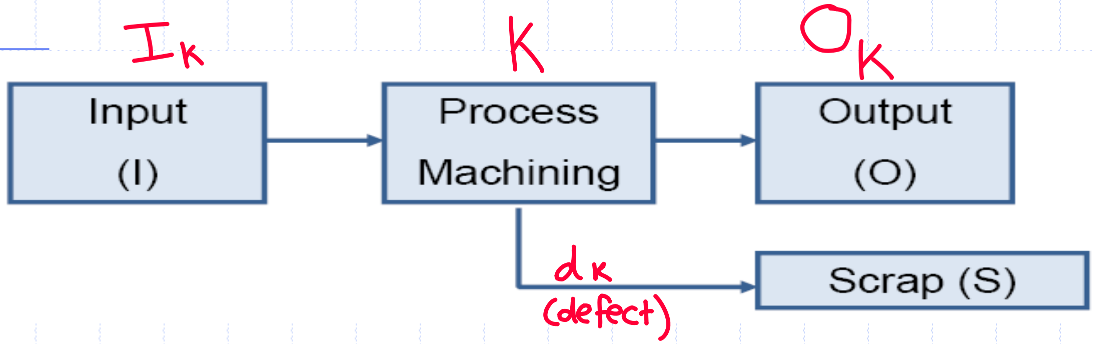
  scrap ↓ scrap ↓

- *Scrape estimates*: how many units of the product we need to make.

for example
5% defect rate

علاقة طردية
tight of tolerance ↑
scrap ↑

# Schedule Design (*Process Requirements*)
## *Scrap estimate (contd.)*



$d_k$ =percentage of scrap made at operation *k*
$O_k$ =desired output of non-defective items from operation *k*
$I_k$ =the production input to operation *k*

$I_k= O_k+\boxed{d_k I_k}$ → defect (ممكن اصلاحه عن طريق الRework)

OR

$O_k = I_k (1-d_k)$

اما ال Defective
لا يمكن اصلاحه

Round up

Not Round down

$I_k= O_k/1- d_k$

# Schedule Design (*Process Requirements)*

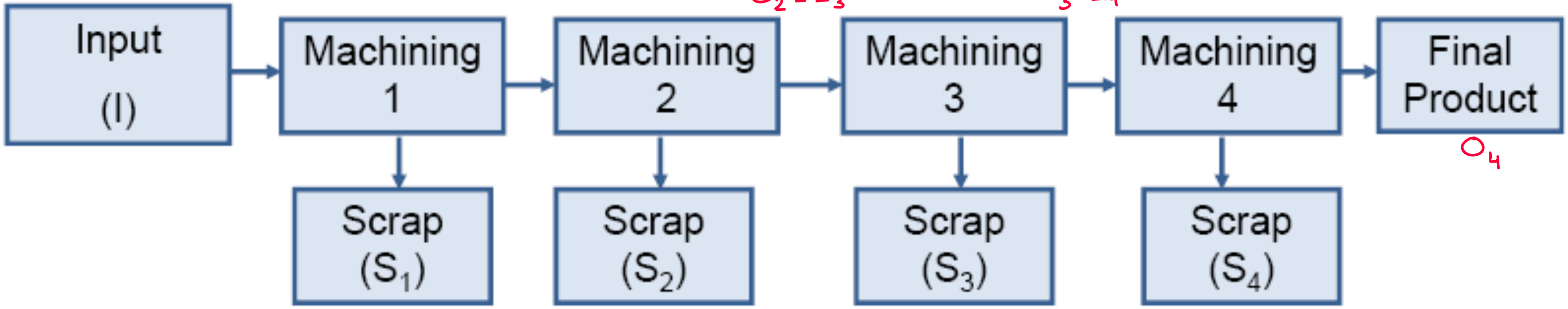
## *Scrap estimate (contd.)*

Actual case in Real Life

input = 3.2 → ~~3~~ 4 (Round up)

output → $O_2 = I_3$ ← input

$O_3 = I_4$



Input (I)

Machining 1

Machining 2

Machining 3

Machining 4

Final Product

$O_4$

Scrap ($S_1$)

Scrap ($S_2$)

Scrap ($S_3$)

Scrap ($S_4$)

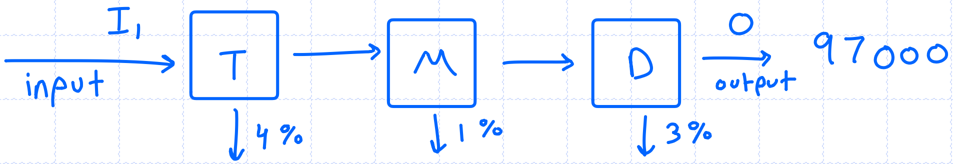
The expected number of units to start production for a part with n operations is:

$$I_1=O_n/ (1-d_1)(1-d_2)\ldots(1-d_n)$$

# Schedule Design (*Process Requirements)*

## *Scrap estimate (contd.)*

- Example:
  - Market estimate of 97,000 components
  - 3 operations: turning, milling and drilling
  - Scrap estimates: d1=0.04, d2=0.01 and d3=0.03
  - Input to the production?
  - Production quantity scheduled for each operation?



$$Input = \frac{FinalOutput\ (O_3)}{(1-d_1)(1-d_2)(1-d_3)}$$

$$I_3 = \frac{O_3}{1-d_3} \longrightarrow = \frac{97000}{0.97} = 100000 \text{ unit}$$

$$\overset{(I_1)}{Input} = \frac{97{,}000}{(1-0.04)(1-0.01)(1-0.03)} = \underline{105{,}219}$$

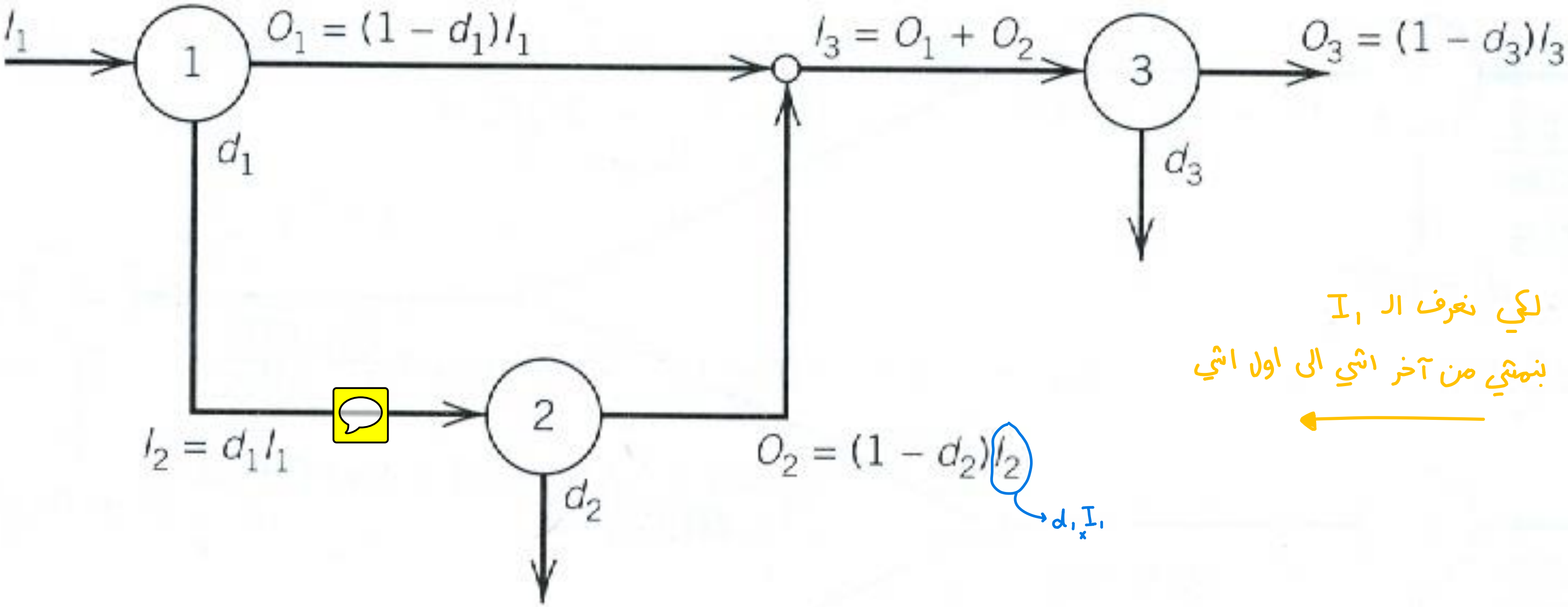
$$I_2 = \frac{O_2}{1-d_2} = \frac{100000}{0.99} = 101010.1$$

$$= 101011 \text{ unit}$$

(Round ~~down~~ up)

# Schedule Design (*Process Requirements)*

## *Scrap estimate with Rework*



لكي نعرف ال $I_1$
بنمشي من آخر اشي الى اول اشي

$$Input = \frac{FinalOutput}{(1-d_3)[(1-d_1)+d_1(1-d_2)]}$$

- We assume 100 % inspection at each operation, including the rework operation

2.16

76

part one

$O_3$

$$I_3 = \frac{O_3}{1-d_3} = \frac{5000}{1-.1}$$

$I_3 = 5555.5$

Round up

$\approx 5556$

$I_3 = O_2 + O_4 = 5556$

$O_2 = (1-d_2)\, I_2$

$O_4 = (1-d_4) . d_2 . d$

# Schedule Design (*Process Requirements)*
## *Equipment fraction*

- Total required processing time for equipment divided by the time available per machine.
- Required processing time

  =Standard time per unit * Number of units
- Equation $$F = \frac{SQ}{EHR}$$

F = number of machines required per shift

S = standard time per unit produced (obtained from route sheet)

Q = number of units to be produced per shift

E = actual performance, expressed as percent of standard time

H = amount of time available per machine

R = reliability of machine, expresses as percent of up time

percent of time Machine is actually productive

Machine Fraction :- the ~~quality~~ or number of machine Required to perform an operation

$$= \frac{\text{Total time Required to perform operation}}{\text{Total time available per machine}}$$

# Schedule Design (*Process Requirements)* *Equipment fraction (contd.)*

Q = 200

بما انه ما جاب سيرة ال defects اذاً

S

- A machined part has a standard machinery time of 2.8 min per part on a milling machine. During an 8-hr shift 200 unites are to be produced. Of the 8 hours available for the production, the milling machine will be operational 80% of the time. During the time the machine is operational, parts are produced at a rate equal to 95% of the standard rate.

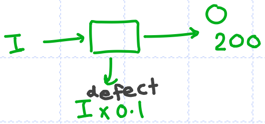
Q

R

لو كمل وحكى انه ال defect rate هو 0.1

Q = 200

- S=2.8 min, Q=200 units, H=480min, E=0.95 and R=0.8
- **How many milling machines are required**?



$I \times 0.1 + \underline{200} = I$

which is without any defect

$$F = \frac{SQ}{EHR} = \frac{2.8(200)}{0.95(480)(0.80)} = 1.535$$

?.

*

Round up (to satisfy the customer needs)

مو متأكدة

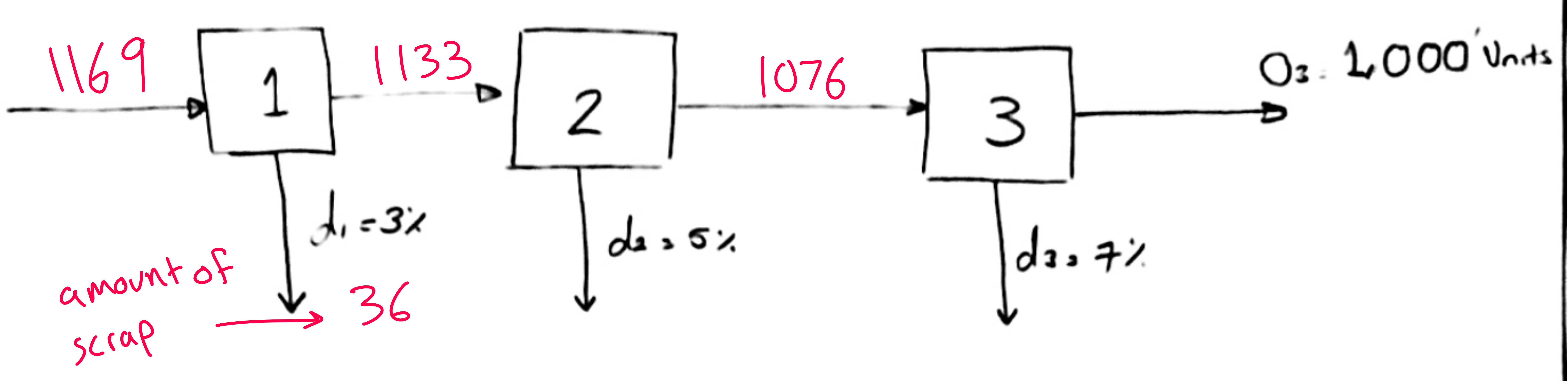
- We need 1.535 machines per shift.

# Schedule Design (*Process Requirements)*
## *Equipment fraction*

F can also be affected by:

- Number of shifts
- Set-up times
- Degree of flexibility- small lots or large lots
- Layout type-process or product
- Total productive maintenance

$\boxed{2.13}$



Cost of scrap at process 1 = \$5 / Unit

Cost of scrap at process 2 = \$10 / Unit

Cost of scrap at process 3 = \$15 / Unit

$$I_3 = \frac{1,000}{1-d_3} = \frac{1,000}{0.93} = 1,075.269 \xrightarrow{\text{Round up}} 1,076 \text{ Units}$$

$$I_2 = \frac{1,076}{1-d_2} = \frac{1,076}{0.95} = \overset{\times\, 1132.63}{\underline{1,131.58}} \Rightarrow 1,132 \text{ Units}$$

$$I_1 = \frac{1,132}{1-d_1} = \frac{1,132}{0.97} = 1,167.01 \Rightarrow \underline{\underline{1,168}} \text{ Units}$$

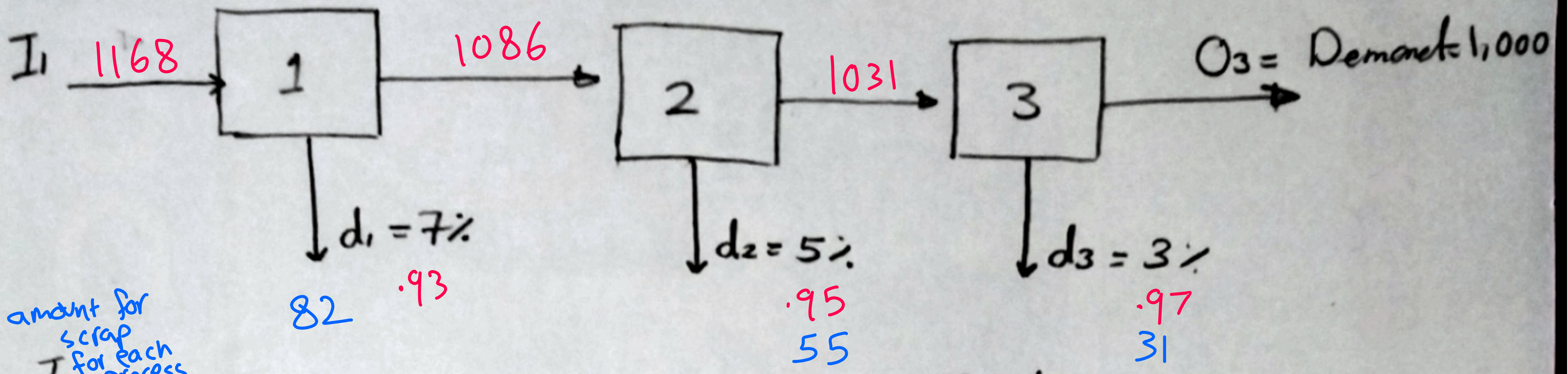
Amount of scrap and its cost

| Process | # of scrap | Cost of scrap |
|---|---|---|
| 1 | $I_1 - O_1 \overset{(I_2)}{=} 1,168 - 1,132 = 36$ | 36 × 5 = \$180 |
| 2 | $I_2 - O_2 \overset{(I_3)}{=} d_2 I_2 = 1,132 - 1,076 = 56$ | 56 × 10 = \$ 560 |
| 3 | $I_3 - O_3 = d_3 I_3 = 1,076 - 1000 = 76$ | 76 × 15 = \$ 1,140 |

total Cost = \$1880

2.13

If scrap rates are reversed then:



amount for scrap for each process

$$I_3 = \frac{1,000}{1-d_3} = \frac{1,000}{0.97} = 1,030.93 \xrightarrow{\text{Round up}} 1,031$$ ✓

$$I_2 = \frac{1,031}{1-d_2} = \frac{1,031}{0.95} = 1,085.26 \xrightarrow{\text{Round up}} 1,086$$ ✓

$$I_1 = \frac{1,086}{1-d_1} = \frac{1,086}{0.93} = 1,167.74 \longrightarrow 1,168$$ ✓

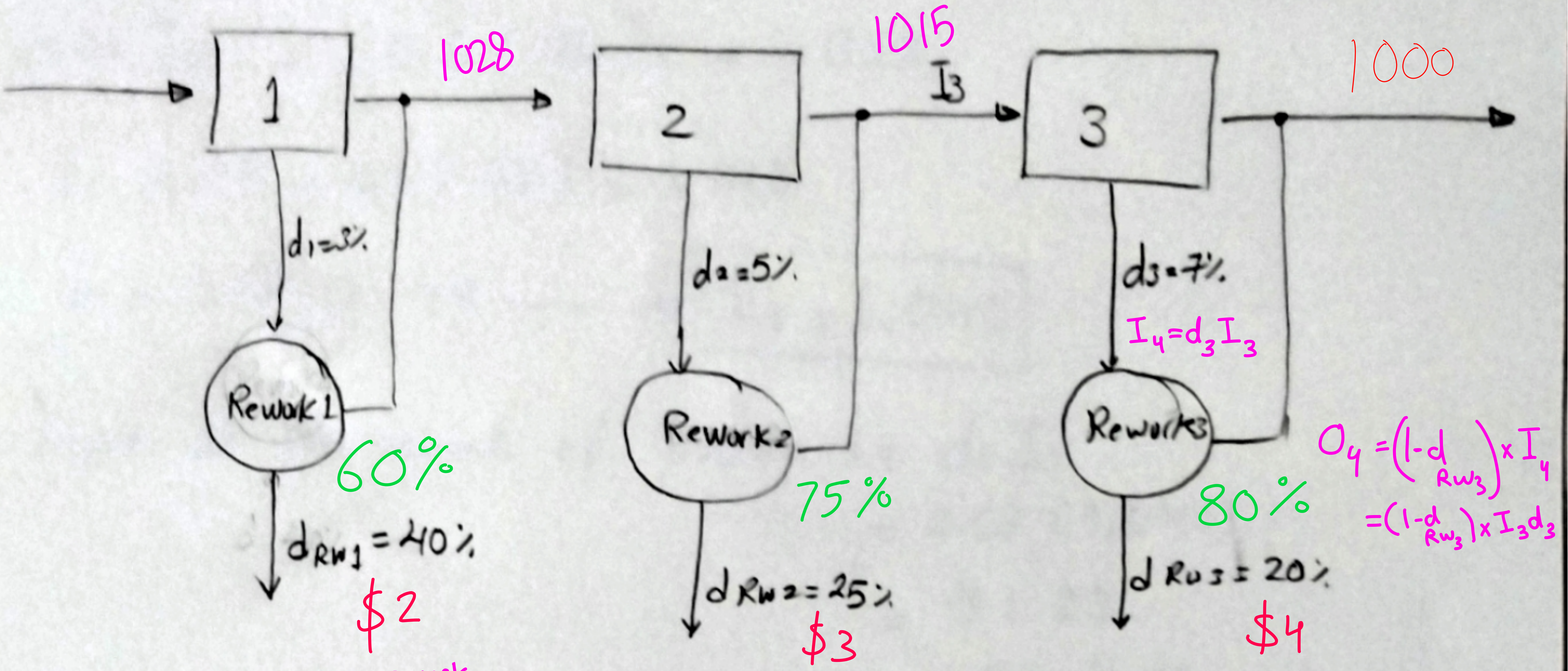
Scrap value and cost for the new System.

| Process | # of Scrap | Cost of Scrap |
|---|---|---|
| 1 | $I_1 - \overset{\sim(I_2)}{O_1} = d_1 I_1 = 1,168 - 1,086 = 82$ | 82 × 5 = \$410 |
| 2 | $I_2 - O_2 = d_2 I_2 = 1,086 - 1,031 = 55$ | 55 × 10 = \$550 |
| 3 | $I_3 - O_3 = d_3 I_3 = 1,031 - 1,000 = 31$ | 31 × 15 = \$465 |
| | Total Scrap cost | = \$1,425 ✓ |

* The System with reversed scrap rates has Lower scrap cost So it would be preferred.

## 2.14

Rework % = 1 - Defect%



$$(1-d_3)I_3+\overset{\text{rework}}{(1-d_{RW3})}d_3I_3 = 1{,}000$$

$$0.93\,I_3+(0.8)(.07)I_3 = 1{,}000$$

$$I_3\cdot((0.93+0.8(.07))) = 1{,}000 \Rightarrow 0.986\,I_3 = 1{,}000$$

$$I_3 = 1{,}014.199$$

Round up $\Rightarrow$ $\boxed{I_3 = 1{,}015}$

Input to rework of process 3 = $d_3I_3 = 0.07(1{,}015)$

$= 71.05 \Rightarrow 72$ Units

$$(1-d_2)I_2+(1-d_{RW2})d_2I_2 = 1{,}015$$

$$0.95I_2+(0.75)(.05)I_2 = 1{,}015$$

$$I_2(0.95+.75(.05)) = 1{,}015$$

$$0.9875\,I_2 = 1{,}015 \Rightarrow I_2 = 1{,}027.85 \Rightarrow \boxed{I_2 = 1{,}028 \text{ Units}}$$

Input to rework of process 2 = $d_2I_2 = 0.05\,(1{,}028)$

$= 51.4 \Rightarrow$ 52 Units

## $\boxed{2.14}$

$$(1-d_1)I_1 + (1-d_{RW1})d_1 I_1 = 1,028$$

$$0.97\, I_1 + 0.6\,(.03)\, I_1 = 1,028$$

$$I_1\,(0.97 + 0.6\,(.03)) = 1,028$$

$$I_1 = 1,040.49 \rightsquigarrow \boxed{I_1 = 1,041}$$

Input to the rework of process $1 = d_1 I_1$

$= 0.03\,(1,041)$

$= 31.23$

$\underline{\underline{32 \text{ Units}}}$

So the total cost of reworked parts =

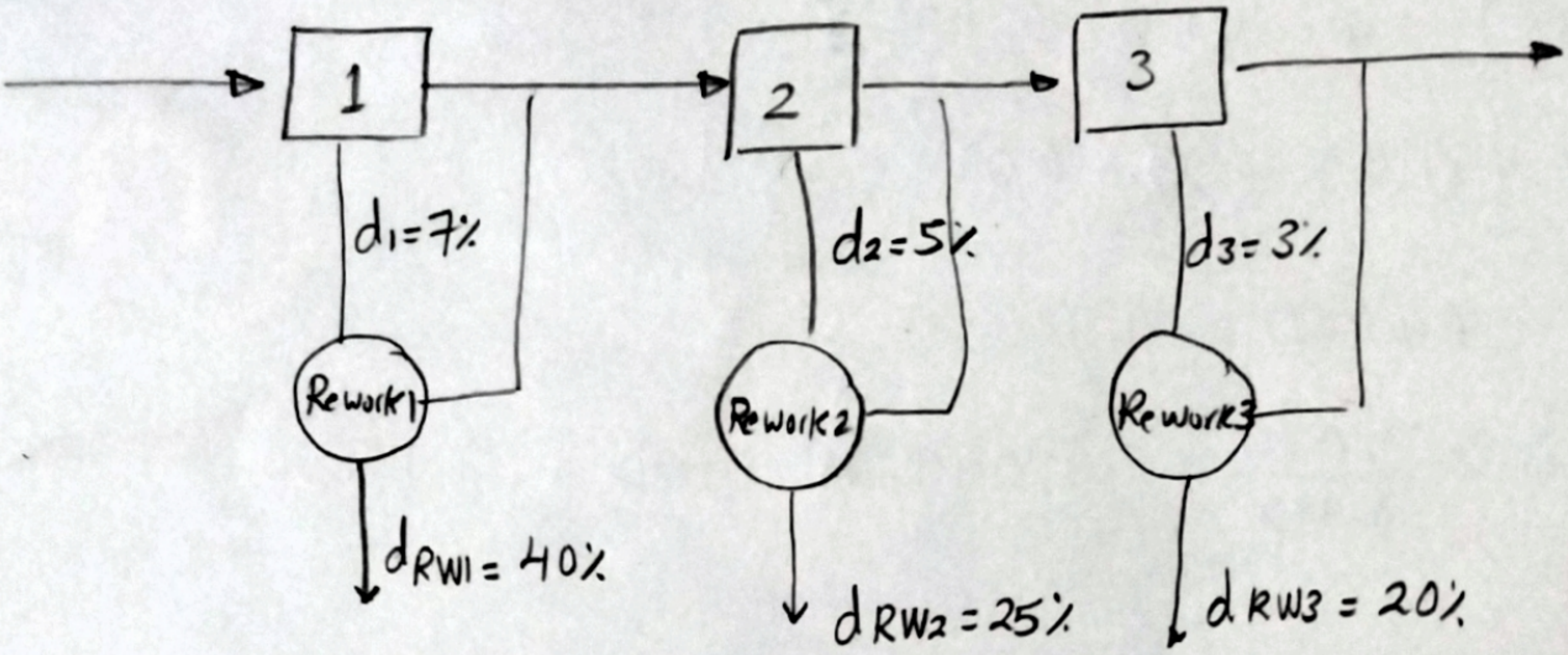
$$\underline{32 \times 2} + 52 \times 3 + 72 \times 4 =$$

$$64 + 156 + 288 = 508$$

$$\longrightarrow$$

2.14

For the system with reversed scrap rates.



$(1-\cancel{d_3})I_3 + (1-\cancel{d_{RW3}})d_3 I_3 = 1{,}000$

$0.97\, I_3 + (0.8)\,(.03) I_3 = 1{,}000 \Rightarrow I_3\,(.97 + 0.8\,(.03)) = 1{,}000$

$I_3 = 1{,}006.04$

$\boxed{I_3 = 1{,}007}$

Input to rework of process 3 $= d_3 I_3 = 0.03\,(1{,}007) = \underline{\underline{30.21}}$

$= 31$ parts

$(1-\cancel{d_2})\, I_2 + (1 - d_{RW2})\, d_2 I_2 = 1{,}007$

$0.95\, I_2 + (0.75)\,(.05)\, I_2 = 1{,}007$

$I_2\,(0.95 + (.75)(0.05)) = 1{,}007$

$I_2\,(0.9875) = 1{,}007$

$I_2 = -1{,}019.75 \Rightarrow I_2 = 1{,}020$

input to the rework of process 2 $= d_2 I_2$

$= 0.05\,(1{,}020)$

$= 51$ parts

2.14

$$(1-d_1)I_1 + (1-d_{RW1})\,d_1 I_1 = 1{,}020$$

$$0.93\,I_1 + (0.6)(0.07)\,I_1 = 1{,}020$$

$$I_1\,(0.93 + 0.6\,(0.07)) = 1{,}020$$

$$I_1\,(0.972) = 1{,}020$$

$$I_1 = \frac{1{,}020}{0.972} = 1{,}049.38 \Rightarrow I_1 = 1{,}050$$

input to rework of process 1 $= d_1 I_1 = 0.07\,(1{,}050)$
$= 73.5$
$= 74$ Units

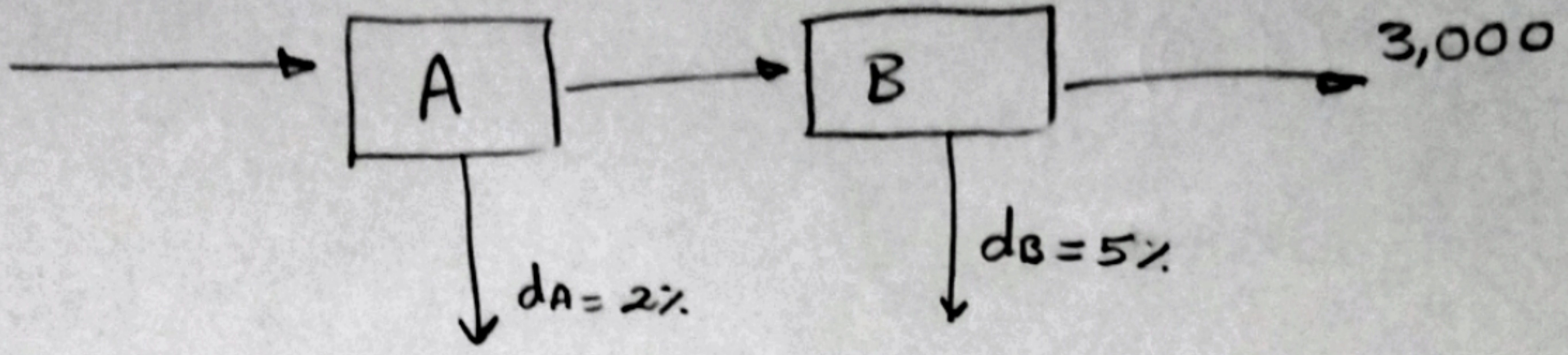
The total cost of reworked parts for the reversed system =

$$\underline{74\,(2)} + 51\,(3) + 31\,(4) =$$
$$148 + 153 + 124 = 425$$

Based on the total rework cost, the reversed system is preferred.

$\boxed{2.15}$

| | | |
|---|---|---|
| $S_A = 3$ min | $E_A = 0.95$ | $R_A = 0.95$ |
| $S_B = 5$ min | $E_B = 0.95$ | $R_B = 0.90$ |



$$I_B = \frac{3{,}000}{1-d_B} = \frac{3{,}000}{0.95} = 3{,}157.895 \Rightarrow \boxed{I_B = 3{,}158}$$

$$I_A = \frac{3{,}158}{1-d_A} = \frac{3{,}158}{0.98} = 3{,}222.45 \Rightarrow \boxed{I_A = 3{,}223}$$

$$H_{\cancel{A}\,B} = \frac{5\ \cancel{\text{day}}}{\text{week}} \times \frac{18\ \cancel{\text{hr}}}{\cancel{\text{day}}} \times \frac{60\ \text{min}}{\cancel{\text{hr}}} - \underbrace{\boxed{\overbrace{\left(\frac{3{,}158}{500}\right)}^{\#\text{ of PM}} \times 30}}_{\text{time for PM}} =$$

$$= 5{,}400 - 189.48$$

$$\boxed{H_B = 5{,}210.52}\ \text{min/week}$$

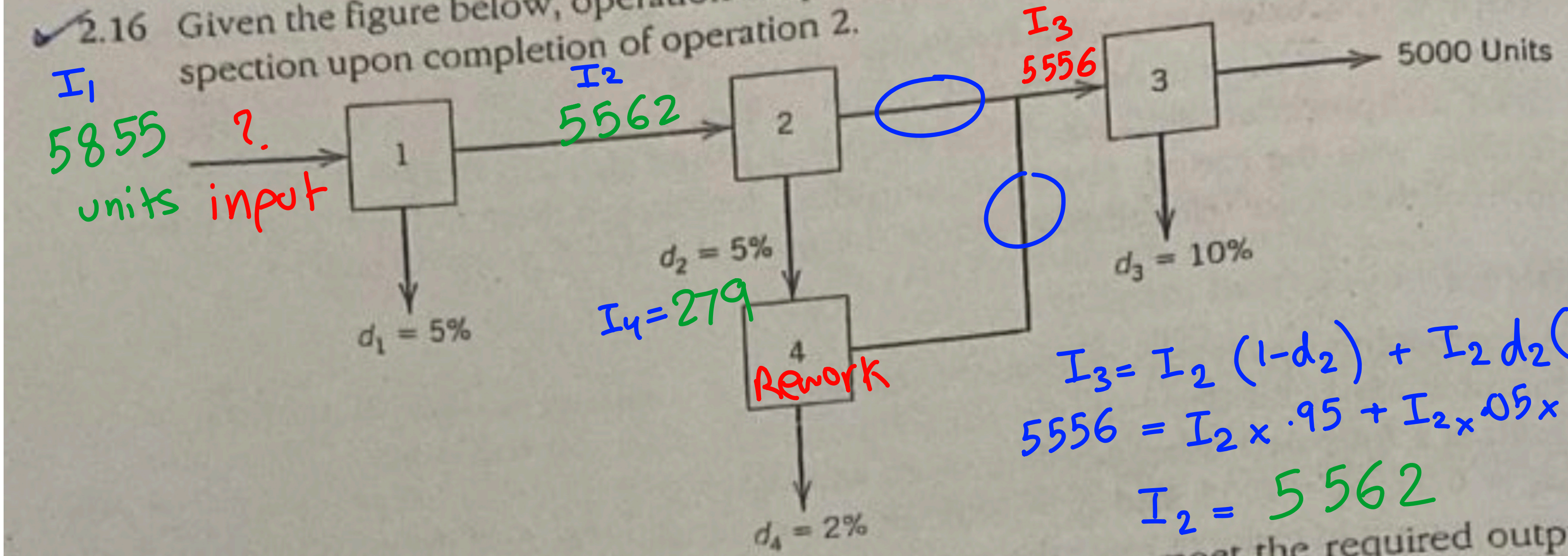
$$H_A = 5{,}400 - 193.38 = 5{,}206.62$$

$$F_A = \frac{S_A\ Q_A}{E_A\ H\ R_A} = \frac{3\ (3{,}223)}{0.95\ (5{,}206.62)\ (0.95)} = \underline{\underline{2.058}}$$

$$F_B = \frac{S_B\ Q_B}{E_B\ H\ R_B} = \frac{5\ (3{,}158)}{0.95 \times 5{,}210.52 \times 0.9} = 3.5443$$

$$F = 5.59 \approx 6\ \text{machines}$$

✓2.16 Given the figure below, operation 4 represents a rework operation on parts that fail inspection upon completion of operation 2.



$$I_3 = I_2(1-d_2) + I_2 d_2 (1-d_4)$$

$$5556 = I_2 \times .95 + I_2 \times .05 \times .98$$

$$I_2 = 5562$$

How many units must the process start with in order to meet the required output of 5000 units?

Problem 2.16 and the information in the table below, how

(round up to nearest integer)?

# Management Tools

# Management Tools

- Once we have the product, process, and scheduling information we need to organize the information and generate and evaluate layout, material handling, and storage alternatives.
- In this process it may be helpful to apply the following seven management tools to facilities planning and design: (read in text book)

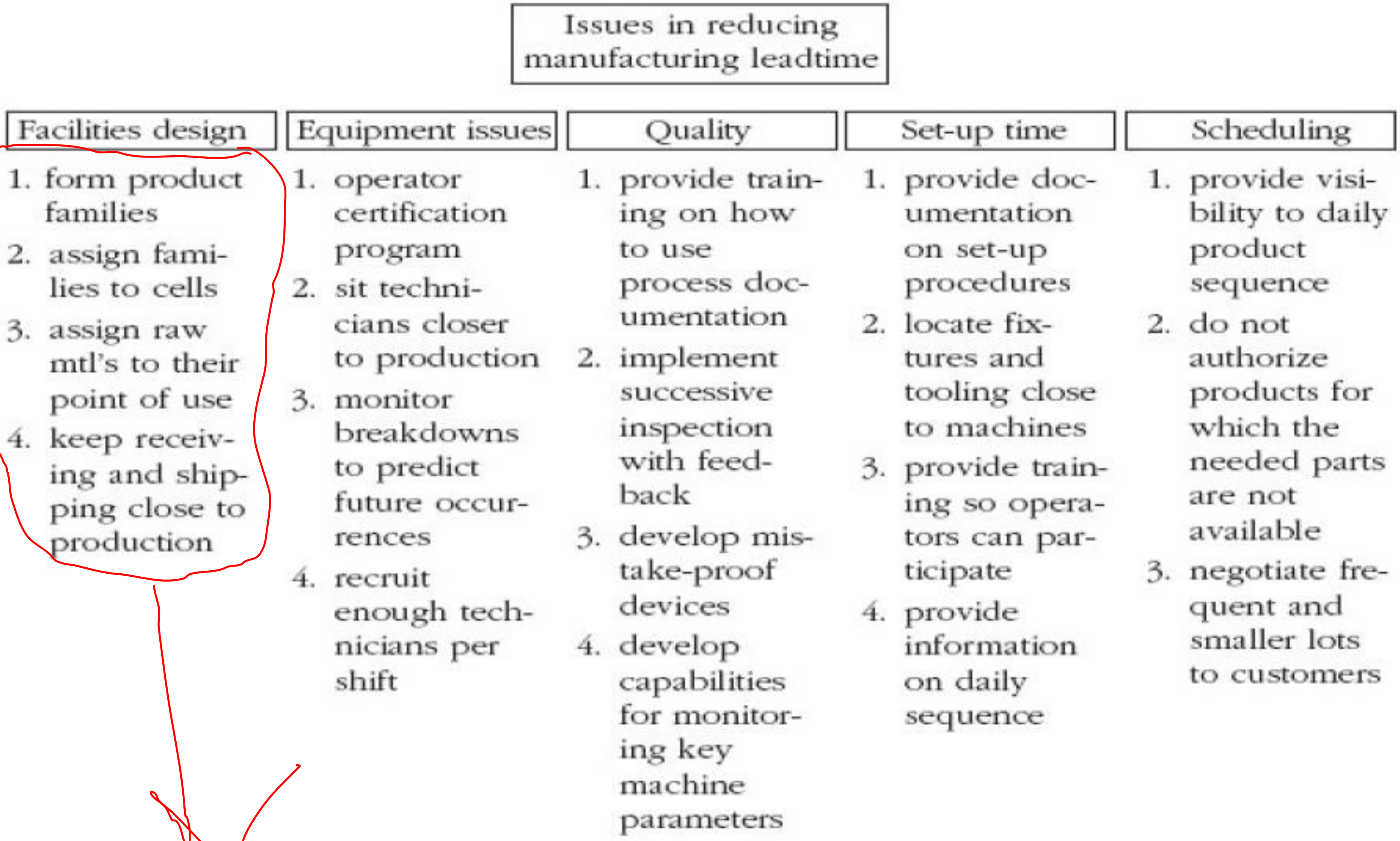
# Management Tools

1. Affinity diagram
    - Brainstorm ideas
    - Gather the ideas into general headings or topics
2. Interrelationship diagraph
    - Show the relationships between headings
    - Directed arcs
    - Help to show the order of doing things
3. Tree diagram
    - Gives more detail about the various activites that need to be done

# Management Tools

4. Matrix diagram
    - Can show who is responsible for doing what task
5. Contingency diagram
    - Plan for unfamiliar tasks
6. Activity network diagram
    - Basically a Gantt chart or PERT CPM type information
    - Who does what, when.
7. Prioritization matrix
    - Evaluate design alternatives

# Affinity diagram



Issues in reducing manufacturing leadtime

| Facilities design | Equipment issues | Quality | Set-up time | Scheduling |
|---|---|---|---|---|
| 1. form product families | 1. operator certification program | 1. provide training on how to use process documentation | 1. provide documentation on set-up procedures | 1. provide visibility to daily product sequence |
| 2. assign families to cells | 2. sit technicians closer to production | 2. implement successive inspection with feedback | 2. locate fixtures and tooling close to machines | 2. do not authorize products for which the needed parts are not available |
| 3. assign raw mtl's to their point of use | 3. monitor breakdowns to predict future occurrences | 3. develop mistake-proof devices | 3. provide training so operators can participate | 3. negotiate frequent and smaller lots to customers |
| 4. keep receiving and shipping close to production | 4. recruit enough technicians per shift | 4. develop capabilities for monitoring key machine parameters | 4. provide information on daily sequence | |

Figure 2.19 Affinity diagram example for reducing manufacturing leadtime.

# Interrelationship diagraph

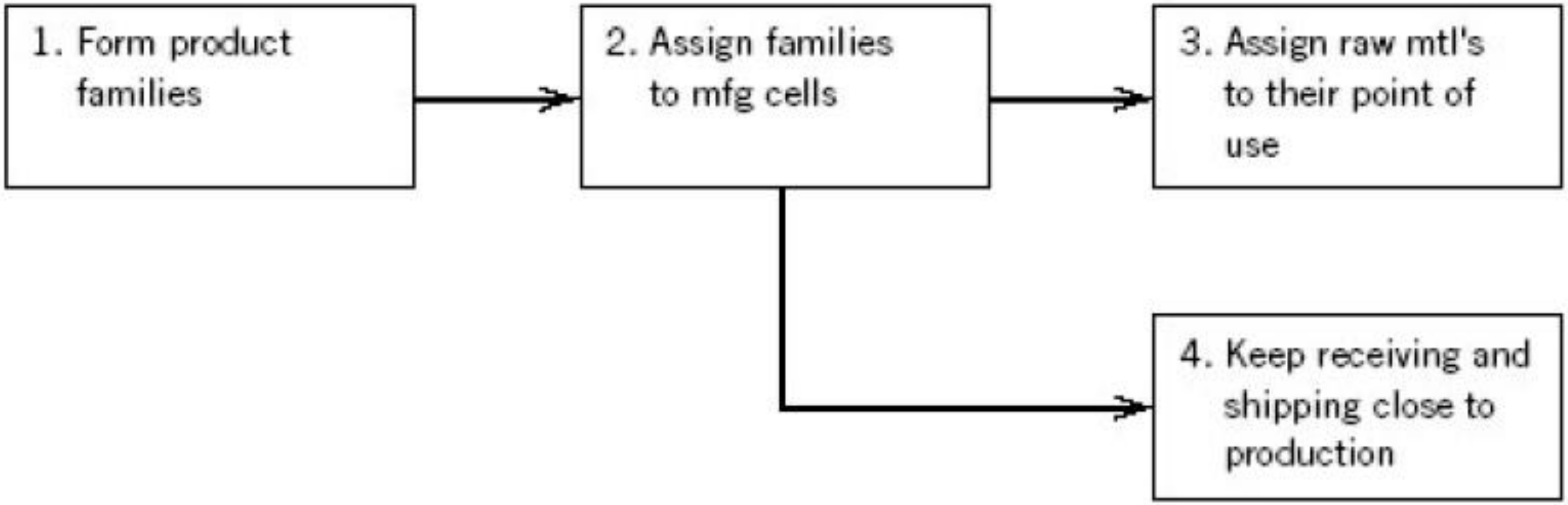

1. Form product families
2. Assign families to mfg cells
3. Assign raw mtl's to their point of use
4. Keep receiving and shipping close to production

Figure 2.20 Interrelationship digraph for facilities design.

# Tree Diagram

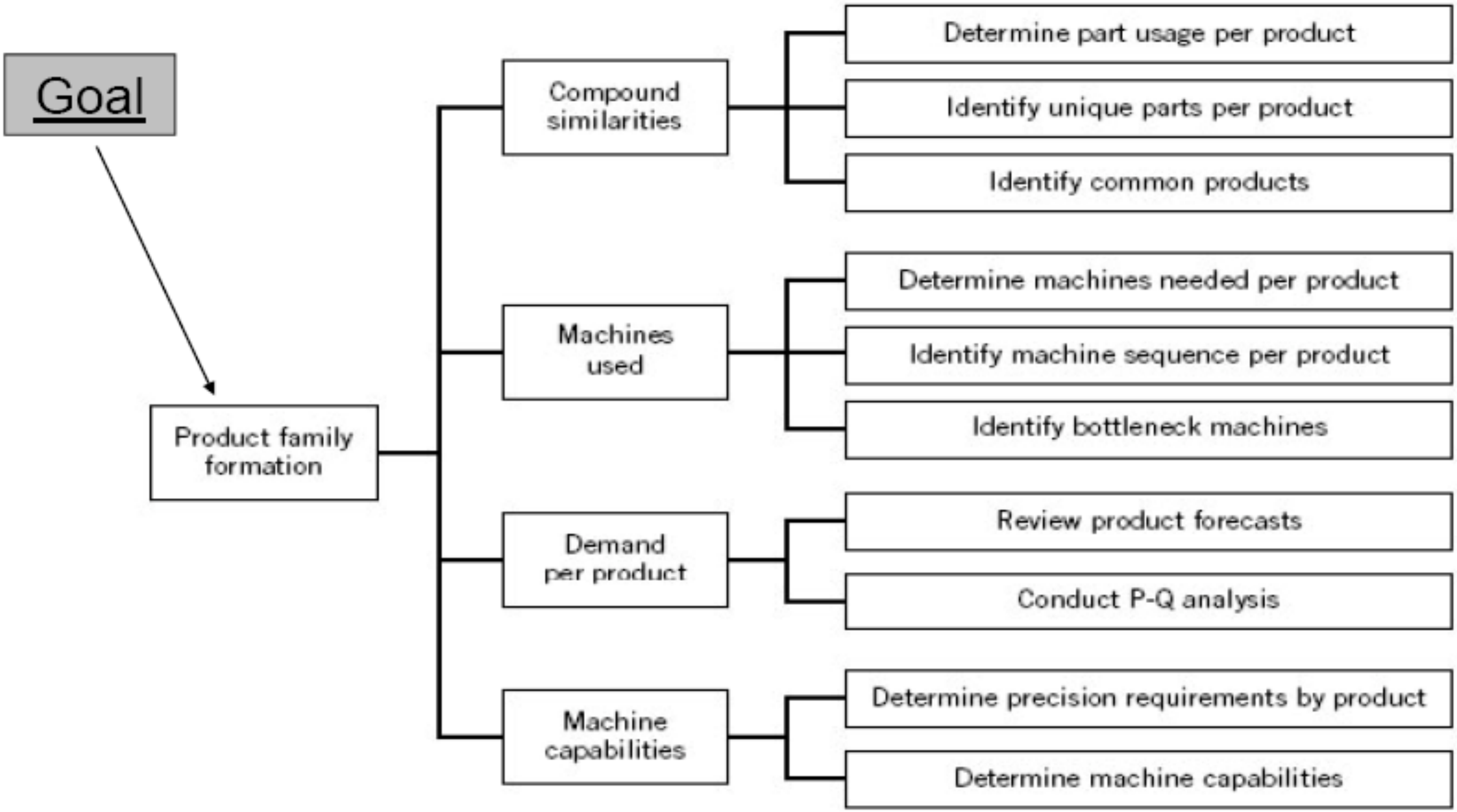

Goal
Product family formation
Compound similarities
Machines used
Demand per product
Machine capabilities
Determine part usage per product
Identify unique parts per product
Identify common products
Determine machines needed per product
Identify machine sequence per product
Identify bottleneck machines
Review product forecasts
Conduct P-Q analysis
Determine precision requirements by product
Determine machine capabilities

Figure 2.21 Tree diagram for the formation of product families.

# Matrix diagram

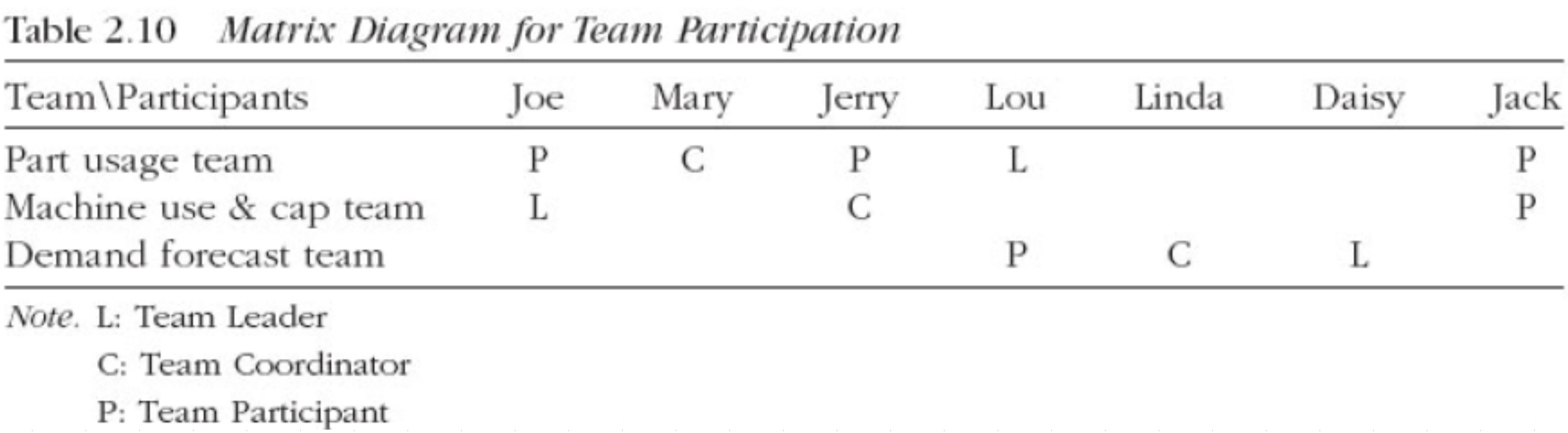
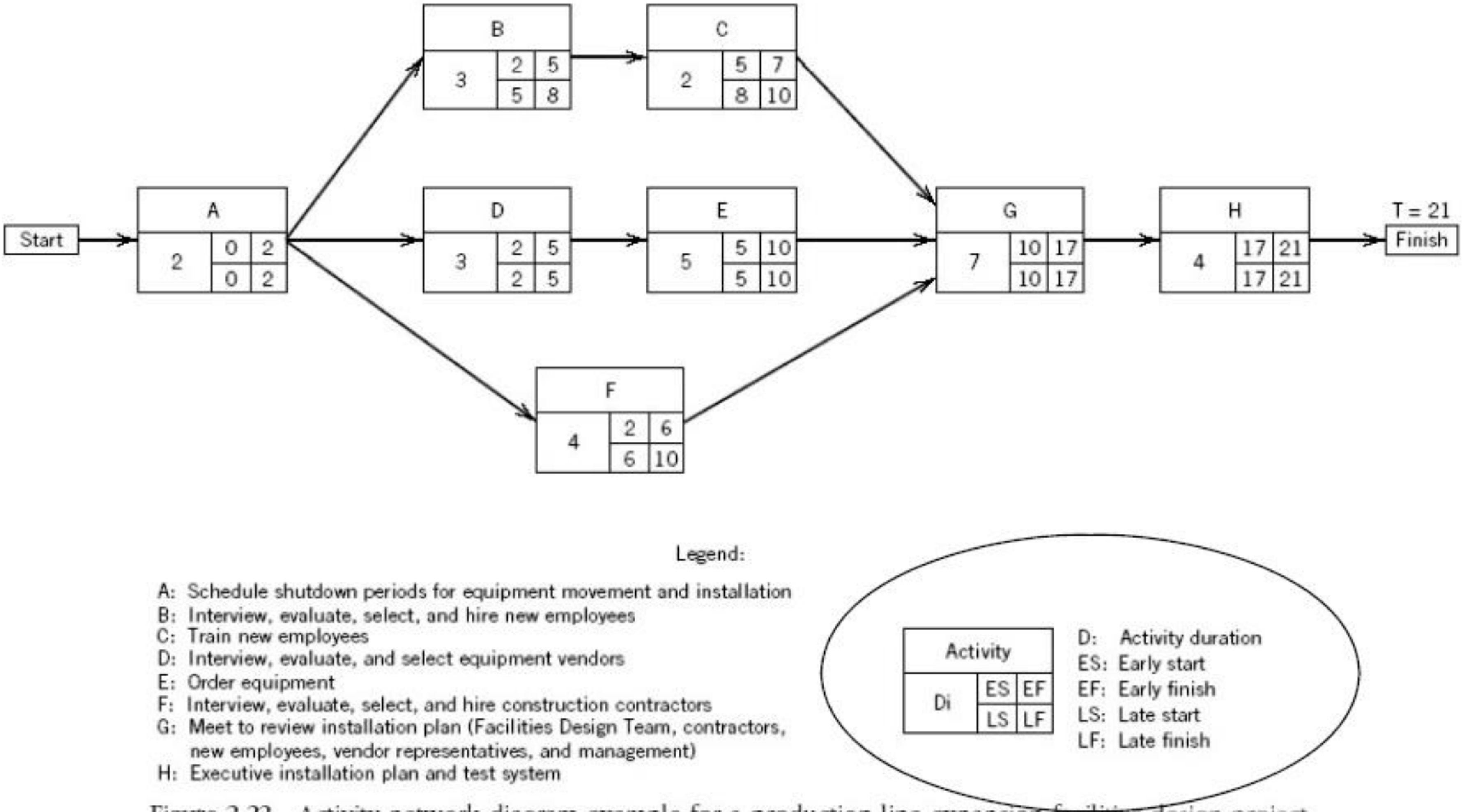


Table 2.10 *Matrix Diagram for Team Participation*

| Team\Participants | Joe | Mary | Jerry | Lou | Linda | Daisy | Jack |
|---|---|---|---|---|---|---|---|
| Part usage team | P | C | P | L | | | P |
| Machine use & cap team | L | | C | | | | P |
| Demand forecast team | | | | P | C | L | |

*Note.* L: Team Leader
C: Team Coordinator
P: Team Participant

# Activity network diagram



Legend:

A: Schedule shutdown periods for equipment movement and installation
B: Interview, evaluate, select, and hire new employees
C: Train new employees
D: Interview, evaluate, and select equipment vendors
E: Order equipment
F: Interview, evaluate, select, and hire construction contractors
G: Meet to review installation plan (Facilities Design Team, contractors, new employees, vendor representatives, and management)
H: Executive installation plan and test system

Figure 2.22 Activity network diagram example for a production line expansion facilities design project.

# Prioritization matrix

| *Criteria used to evaluate facilities design alternatives* | |
|---|---|
| A. Total distance traveled | B Manufacturing floor visibility |
| C. Overall aesthetics of the layout | D. Ease of adding future business |
| E. Use of current equipment | F. Investment in new equipment |
| G. Space requirements | H. People requirement |
| I. Impact on WIP levels | J. Human factor risk |
| K. Estimated cost of alternatives | |

| *Weights used in comparison of criteria* | |
|---|---|
| 1= Equally important | |
| 5 = Significantly more important | 1/5 = significantly less important |
| 10 = extremely important | 1/10 = extremely less important |

# Prioritization matrix

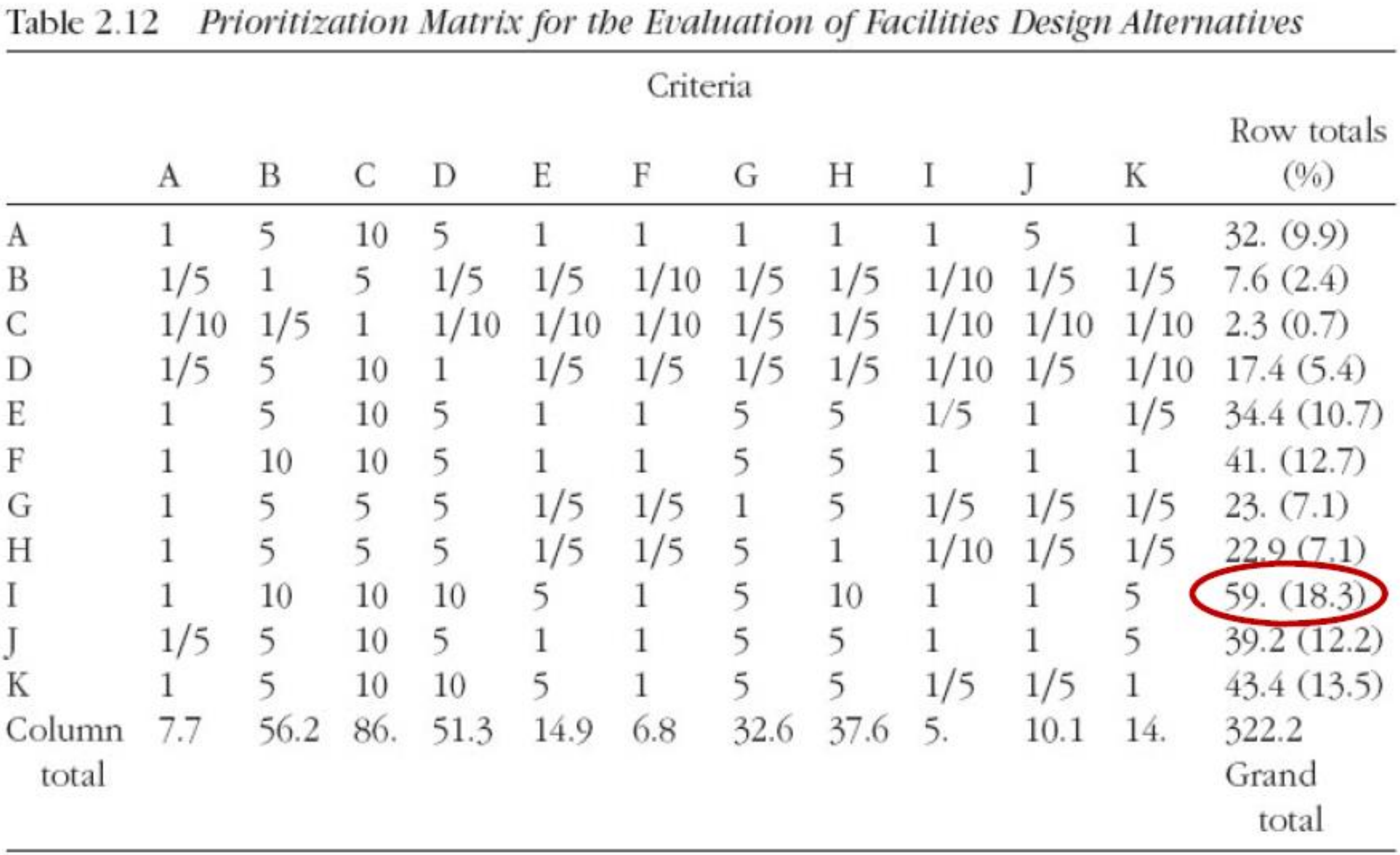


Table 2.12 *Prioritization Matrix for the Evaluation of Facilities Design Alternatives*

| | Criteria | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | Row totals (%) |
| A | 1 | 5 | 10 | 5 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 32. (9.9) |
| B | 1/5 | 1 | 5 | 1/5 | 1/5 | 1/10 | 1/5 | 1/5 | 1/10 | 1/5 | 1/5 | 7.6 (2.4) |
| C | 1/10 | 1/5 | 1 | 1/10 | 1/10 | 1/10 | 1/5 | 1/5 | 1/10 | 1/10 | 1/10 | 2.3 (0.7) |
| D | 1/5 | 5 | 10 | 1 | 1/5 | 1/5 | 1/5 | 1/5 | 1/10 | 1/5 | 1/10 | 17.4 (5.4) |
| E | 1 | 5 | 10 | 5 | 1 | 1 | 5 | 5 | 1/5 | 1 | 1/5 | 34.4 (10.7) |
| F | 1 | 10 | 10 | 5 | 1 | 1 | 5 | 5 | 1 | 1 | 1 | 41. (12.7) |
| G | 1 | 5 | 5 | 5 | 1/5 | 1/5 | 1 | 5 | 1/5 | 1/5 | 1/5 | 23. (7.1) |
| H | 1 | 5 | 5 | 5 | 1/5 | 1/5 | 5 | 1 | 1/10 | 1/5 | 1/5 | 22.9 (7.1) |
| I | 1 | 10 | 10 | 10 | 5 | 1 | 5 | 10 | 1 | 1 | 5 | 59. (18.3) |
| J | 1/5 | 5 | 10 | 5 | 1 | 1 | 5 | 5 | 1 | 1 | 5 | 39.2 (12.2) |
| K | 1 | 5 | 10 | 10 | 5 | 1 | 5 | 5 | 1/5 | 1/5 | 1 | 43.4 (13.5) |
| Column total | 7.7 | 56.2 | 86. | 51.3 | 14.9 | 6.8 | 32.6 | 37.6 | 5. | 10.1 | 14. | 322.2 Grand total |

# Prioritization matrix

Layout alternatives

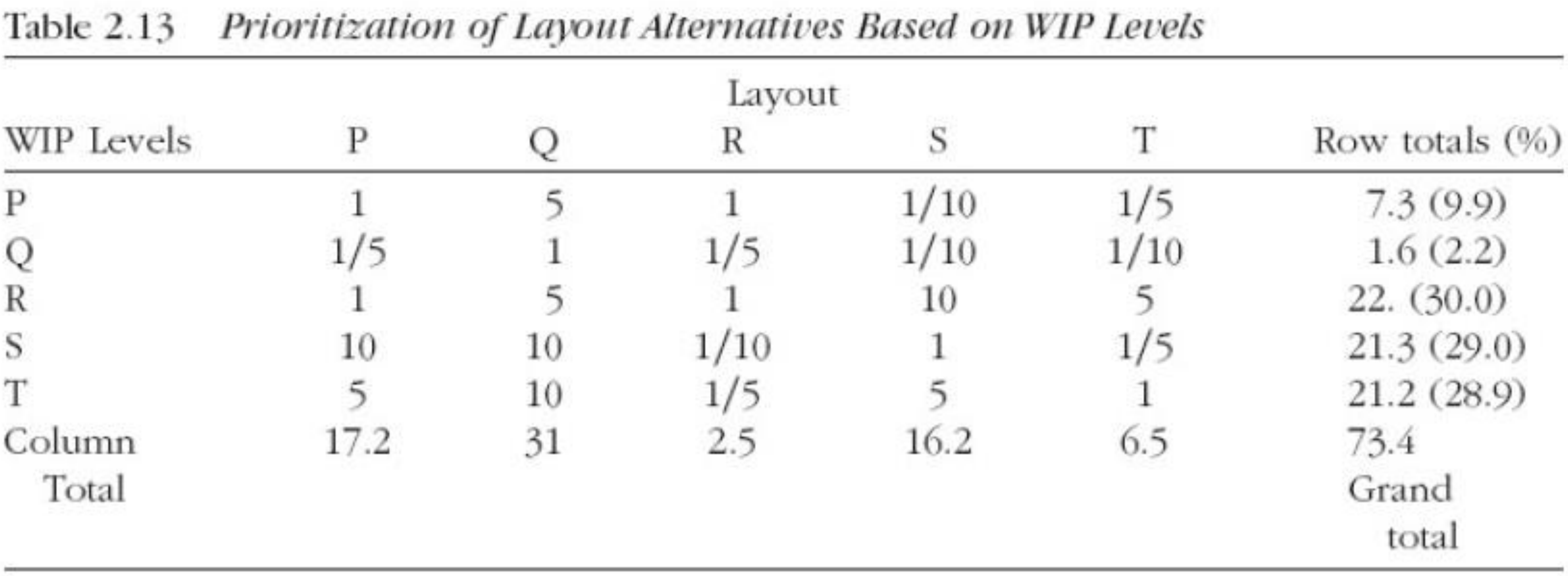


Table 2.13 *Prioritization of Layout Alternatives Based on WIP Levels*

| | Layout | | | | | |
|---|---|---|---|---|---|---|
| WIP Levels | P | Q | R | S | T | Row totals (%) |
| P | 1 | 5 | 1 | 1/10 | 1/5 | 7.3 (9.9) |
| Q | 1/5 | 1 | 1/5 | 1/10 | 1/10 | 1.6 (2.2) |
| R | 1 | 5 | 1 | 10 | 5 | 22. (30.0) |
| S | 10 | 10 | 1/10 | 1 | 1/5 | 21.3 (29.0) |
| T | 5 | 10 | 1/5 | 5 | 1 | 21.2 (28.9) |
| Column Total | 17.2 | 31 | 2.5 | 16.2 | 6.5 | 73.4 Grand total |

# Facilities Planning

## Reject Allowance

# Process requirements – Quantity determination

- *Scrap Estimates*
  - Determination of the quantity to be manufactured for each component
    - For ***high volume*** production
    - The estimation of scrap depend on **constant percent of scrap**

- *Reject Allowance Problem*
  - Determination the number of additional units to allow when the number of items to produce are very few and rejects randomly occur
    - For ***low volume*** production
    - The cost of scrap is very high

# Reject allowance problem

يوجد مشكلة كبيرة والتي هي Randomness

20 → 15 x P(x)
→ 5

Q > X

output
- *x*: Number of good units
- *p(x)*: Probability of producing exactly *x* good units

Input
- *Q*: Quantity of production
- *C(Q, x)*: Cost of producing *Q* units, with *x* good units
- *R(Q, x)*: Revenue from producing *Q* units, with *x* good units
- *P(Q, x)*: Profit from producing *Q* units, with *x* good units *P(Q, x)* = *R(Q, x)* - *C(Q, x)*

input
- *E[P(Q)]*: ***Expected profit*** when *Q* units are produced

$$\text{Profit} = \underset{\text{Revenue}}{R} - \underset{\text{cost}}{C}$$

Maximum
(optimal)

$$E[P(Q)] = \sum_{x=0}^{Q} P(Q,x)p(x)$$

أعلى قيمة
لـ x هي Q →

$$E[P(Q)] = \sum_{x=0}^{Q} [R(Q,x) - C(Q,x)]p(x)$$

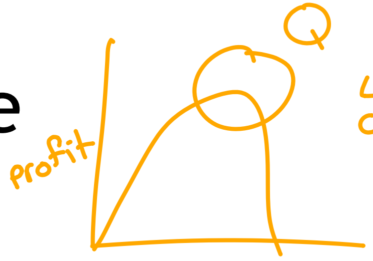
How do we actually decide Q?

The goal is having exactly **x** units of good items.

Q , X → discrete
variables

# Reject allowance problem

- To maximize expected profit, *Q* can be determined by enumerating over various values of *Q*
- For most cost and revenue formulations the equation is a concave function
- ***X*** and ***Q*** are discrete variables, therefore ***p(X)*** is a discrete probability function
- If ***b*** is the number of defects then probability of each number of defects may be different: P(***b***=1), P(***b***=2) etc.



معنى concave

$P(x=1) \neq P(x=2) \neq P(x=3) \ldots$

Probability of having one good unit

هذا السؤال في الكتاب

# Reject Allowance Problem - Problem 1

سبائك

4 castings needed, **no less no more**

Price=$30,000/ casting

Cost=$15,000/ casting

The probability of casting being good is 90%

- How many castings to produce?
- Probability of losing money?

P → profit

p → probability

$p(\text{success}) = 0.9$

or

(good units)

the customer will accept neither few nor more than 4 casting

$R$ if $x<4$ $= 0\$$

$$\underset{\text{Revenue}}{R} = \begin{cases} 0 & \text{for } x < 4 \\ 30000 * \underset{\nwarrow Q}{4} = 120000\$ & \text{for } 4 \le x \le Q \end{cases}$$

الأسئلة فهم و ليست حفظ
لأن كل سؤال يختلف عن الثاني

$$\underset{\text{Cost}}{C} = \$15000 * Q$$

$$\underset{\text{Profit}}{P} = \begin{cases} -\$15\,000 * Q & \text{for } x < 4 \\ \$30000 * 4 - \$15\,000Q = \$(120000 - 15000Q) & \text{for } 4 \le x \le Q \end{cases}$$

$$E[P(Q)] = \sum_{x=0}^{3} (-\$15\,000 * Q)p(x) + \sum_{x=4}^{Q} (120000 - 15000Q)p(x)$$

$$\Sigma\,(\text{Profit} * \text{Probability})$$

# Probabilities

- For each Q, the probability associated with each x is different!

- The historical probabilities may be available
- You may need to calculate the values of probability mass function:

$$p(x) = \binom{\overset{Q}{N}}{x} \underset{0.9}{p}^{x} (1-p)^{(\overset{Q}{N}-x)}$$

binomial

success or failure

  - Example: Probability of producing only $\underset{x}{2}$ good items when an order size is $\overset{Q}{10}$ and when the probability of producing a good item is p = 95%

$$P(2) = \binom{10}{2} 0.95^{2} * (1-0.95)^{(10-2)}$$

P(10, 2)
we read it
probability of 10 and 2 of them are good

# Reject Allowance Problem - Problem 1

## Probability mass function: (p=90%)

x → متعلقة بال customer order

Q x

$P(4,0) = \binom{4}{0}(0.9)^0(.1)^4$

| Casting Production | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Good Castings | Probabilities | | | | |
| 0 | 0.0001 | 0.00001 | 0.000001 | 0.0000001 | 0.00000001 |
| 1 | 0.0036 | 0.00045 | 0.000054 | 0.0000063 | 7.2E-07 |
| 2 | 0.0486 | 0.0081 | 0.001215 | 0.0001701 | 0.00002268 |
| 3 | 0.2916 | 0.0729 | 0.01458 | 0.0025515 | 0.00040824 |
| 4 | 0.6561 | 0.32805 | 0.098415 | 0.0229635 | 0.0045927 |
| 5 | 0 | 0.59049 | 0.354294 | 0.1240029 | 0.03306744 |
| 6 | 0 | 0 | 0.531441 | 0.3720087 | 0.14880348 |
| 7 | 0 | 0 | 0 | 0.4782969 | 0.38263752 |
| 8 | 0 | 0 | 0 | 0 | 0.43046721 |
| Total Probability | 1 | 1 | 1 | 1 | 1 |

* بهمني وين ال interval يتغير

(مثلاً هنا عند ال (3))

$$p(x) = \binom{N}{x} p^x (1-p)^{(N-x)}$$

$P(5,0) = \binom{5}{0}(0.9)^0(0.1)^5 = 0.0001$

$P(4,1) = \binom{4}{1}(.9)^1(.1)^3$

$P(4,0) = \binom{4}{0}(0.9)^0(0.1)^4 = 0.0001$

# of good units needed

Q

| | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|
| 0 | | | | | | |
| 1 | | | | | | |
| 2 | | | | | | |
| ⋮ | | | | | | |
| Q | | | | | | |

# Reject Allowance Problem - Problem 1

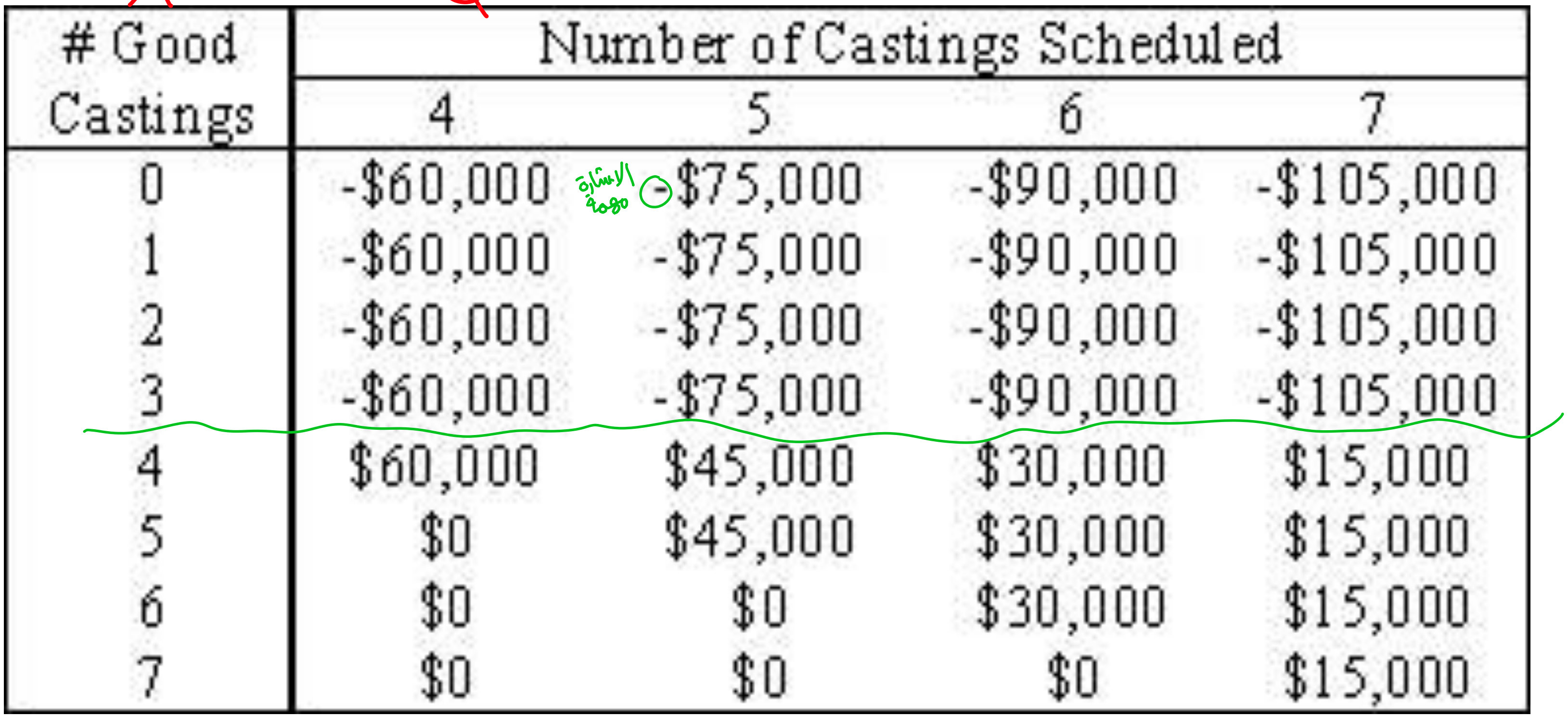
Calculation of net income for combinations of x and Q

$$P(Q,x) = \begin{cases} -15000*Q & x < 4 \\ \$120000 - 15000*Q & 4 <= x <= Q \end{cases}$$

Profit

X

Q



| # Good Castings | Number of Castings Scheduled | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| 0 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 1 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 2 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 3 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 4 | $60,000 | $45,000 | $30,000 | $15,000 |
| 5 | $0 | $45,000 | $30,000 | $15,000 |
| 6 | $0 | $0 | $30,000 | $15,000 |
| 7 | $0 | $0 | $0 | $15,000 |

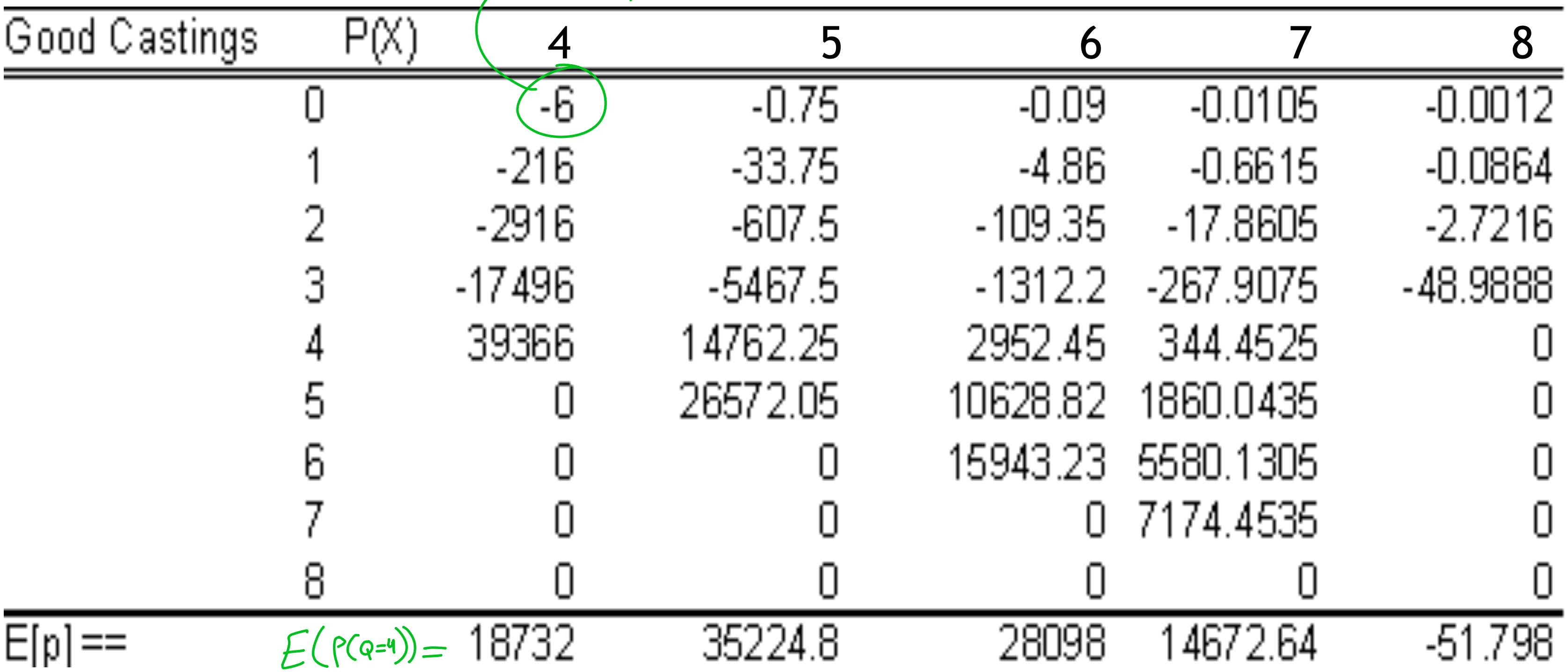
الاشارة مهمة

# Reject Allowance Problem - Problem 1

Calculation of expected profits for Q = 4,5,6,7 and 8

$$E\left[P(Q)\right]=\sum_{x=0}^{Q}P(Q,x)\,p(x)$$

p(x) P(Q,x) ناتج



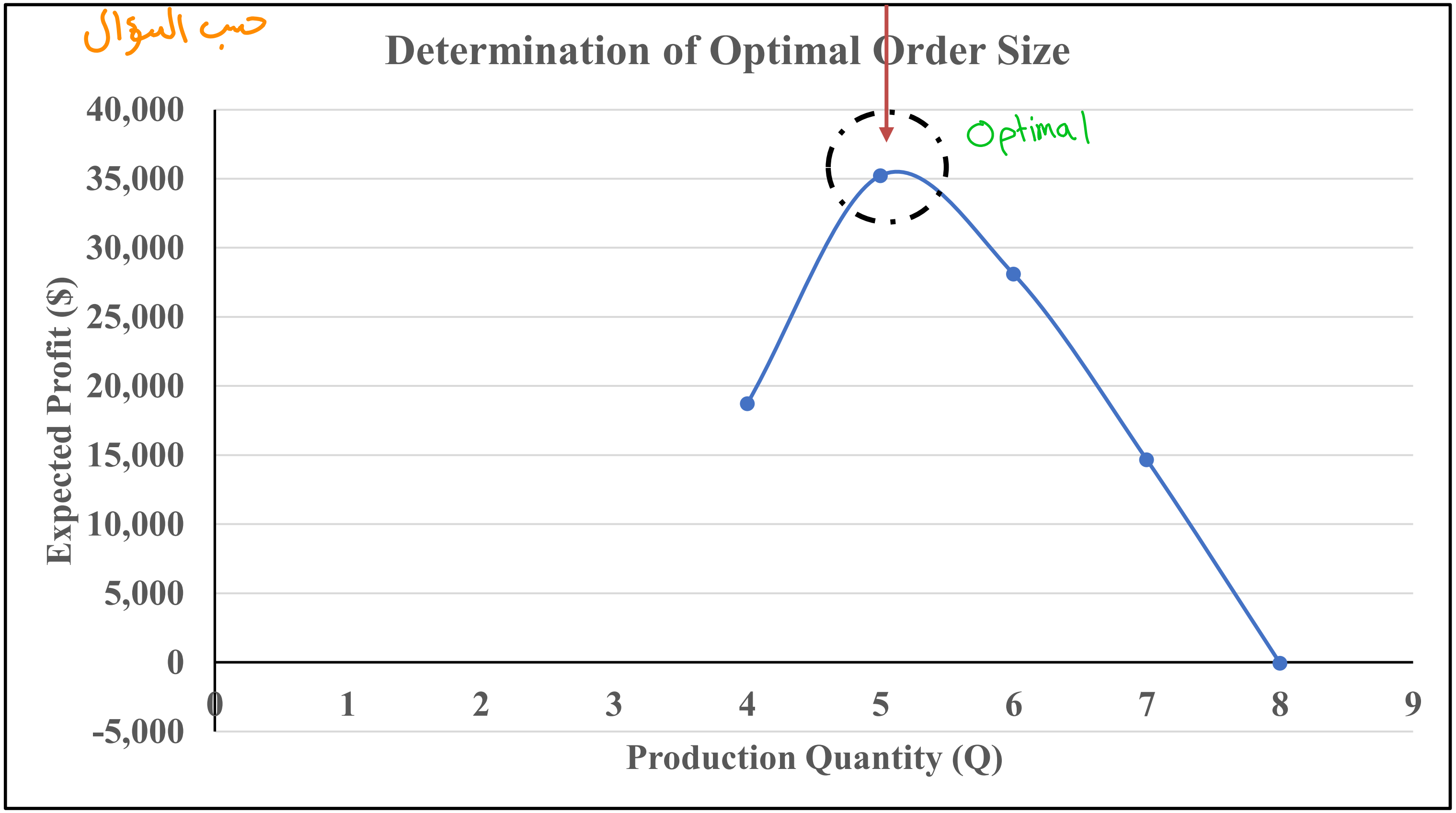
| Good Castings | P(X) | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|
| 0 | | -6 | -0.75 | -0.09 | -0.0105 | -0.0012 |
| 1 | | -216 | -33.75 | -4.86 | -0.6615 | -0.0864 |
| 2 | | -2916 | -607.5 | -109.35 | -17.8605 | -2.7216 |
| 3 | | -17496 | -5467.5 | -1312.2 | -267.9075 | -48.9888 |
| 4 | | 39366 | 14762.25 | 2952.45 | 344.4525 | 0 |
| 5 | | 0 | 26572.05 | 10628.82 | 1860.0435 | 0 |
| 6 | | 0 | 0 | 15943.23 | 5580.1305 | 0 |
| 7 | | 0 | 0 | 0 | 7174.4535 | 0 |
| 8 | | 0 | 0 | 0 | 0 | 0 |
| E[p]== | $E(P(Q=4))=$ | 18732 | 35224.8 | 28098 | 14672.64 | -51.798 |

expected
profit when Q=4

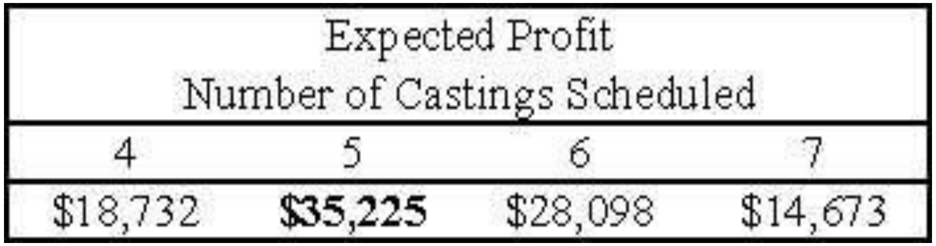
# Reject Allowance Problem - Problem 1

في هذا الدرس المعادلات ممكن تتغير

حسب السؤال



Optimal



Expected Profit

Number of Castings Scheduled

| 4 | 5 | 6 | 7 |
|---|---|---|---|
| $18,732 | **$35,225** | $28,098 | $14,673 |

# Reject Allowance Problem - Problem 1

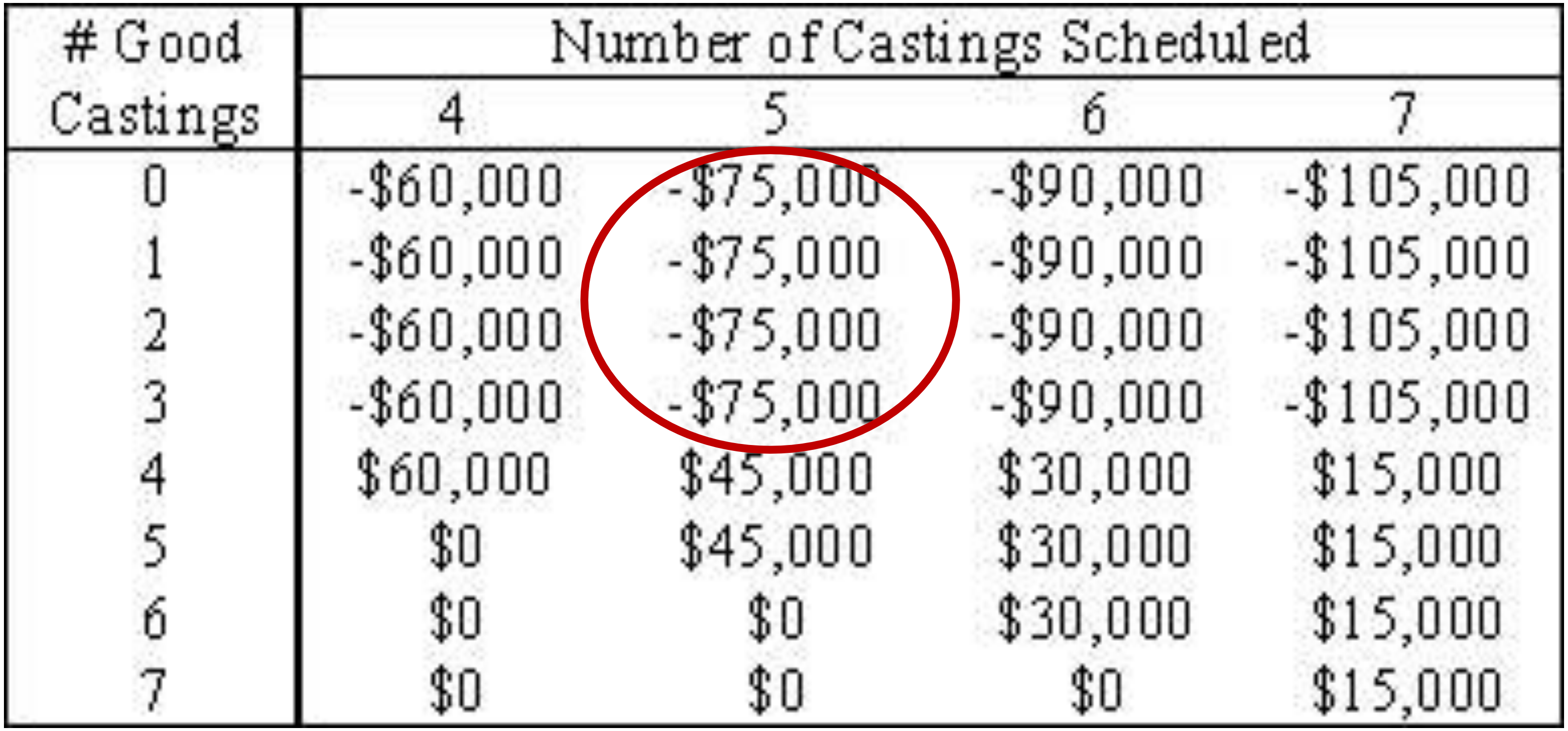
- Probability of losing money (if Q=5)?

- The probability of losing money on the transaction is the probability of the net income being negative when *Q* equals 5.

# Reject Allowance Problem - Problem 1

Calculation of net income for combinations of x and Q

profit

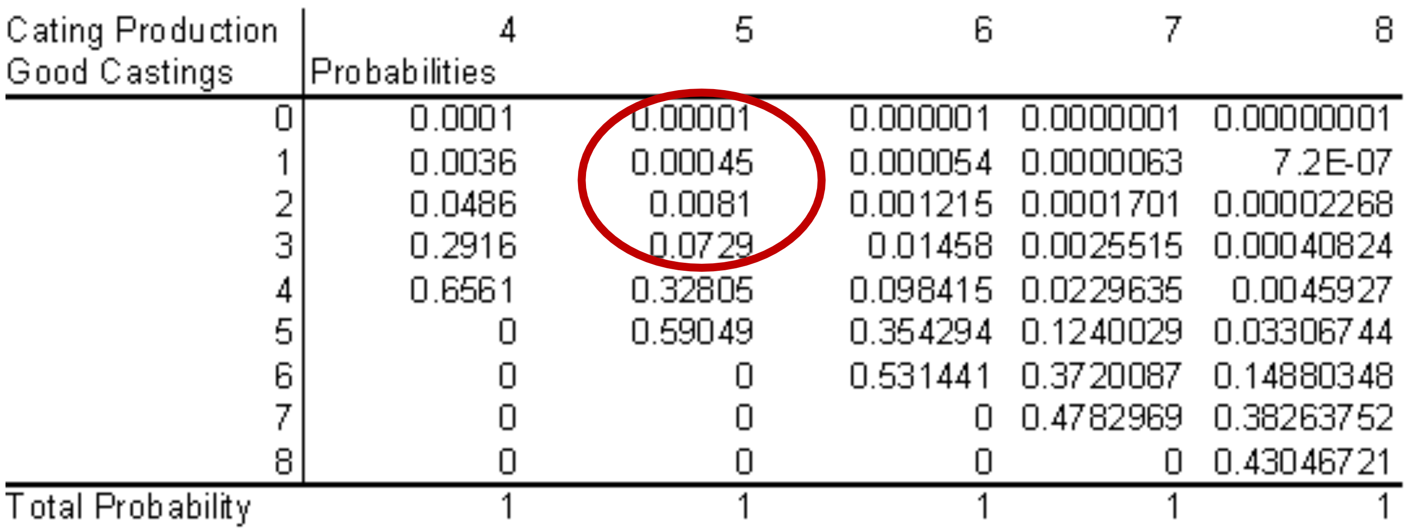


| # Good Castings | Number of Castings Scheduled | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| 0 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 1 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 2 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 3 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 4 | $60,000 | $45,000 | $30,000 | $15,000 |
| 5 | $0 | $45,000 | $30,000 | $15,000 |
| 6 | $0 | $0 | $30,000 | $15,000 |
| 7 | $0 | $0 | $0 | $15,000 |

A negative net cash flow occurs if less than 4 good castings are produced.

# Reject Allowance Problem - Problem 1

- The probability of losing money on the transaction is the probability of the net income being negative when *Q* equals 5.
- A negative net cash flow occurs if less than 4 good castings are produced.



| Cating Production | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Good Castings | Probabilities | | | | |
| 0 | 0.0001 | 0.00001 | 0.000001 | 0.0000001 | 0.00000001 |
| 1 | 0.0036 | 0.00045 | 0.000054 | 0.0000063 | 7.2E-07 |
| 2 | 0.0486 | 0.0081 | 0.001215 | 0.0001701 | 0.00002268 |
| 3 | 0.2916 | 0.0729 | 0.01458 | 0.0025515 | 0.00040824 |
| 4 | 0.6561 | 0.32805 | 0.098415 | 0.0229635 | 0.0045927 |
| 5 | 0 | 0.59049 | 0.354294 | 0.1240029 | 0.03306744 |
| 6 | 0 | 0 | 0.531441 | 0.3720087 | 0.14880348 |
| 7 | 0 | 0 | 0 | 0.4782969 | 0.38263752 |
| 8 | 0 | 0 | 0 | 0 | 0.43046721 |
| Total Probability | 1 | 1 | 1 | 1 | 1 |

- The probability of producing less than 4 good castings equals:

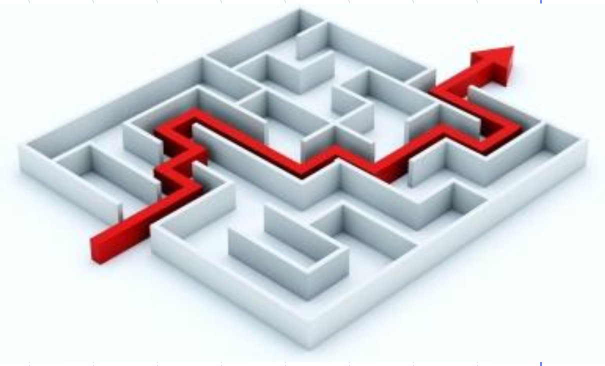
$$0.00001 + 0.00045 + 0.0081 + 0.0729 = 0.0816$$

# Chapter 3

# Chapter 3

# Flow Systems, Activity Relationships, and Space Requirements

# Introduction



- **Flow**
  - Flow of materials, people, equipment, information, money, etc.
  - Flow into, within and from manufacturing facility

Raw materials, Part order

people, process inf

finish product, money (flow out of the facility)

D26
D25
D14
D24
D18
D20
D19
D9
D13
D6
D10
D17
D7
D48
D21
D3
D22
D8
D4
D41
D31
D30
D39
D27
D52
D40
D37
D15
D29
D62
D42
D46

- **Space**
  - The amount of space required in the facility
  - Workstation specification, department specification and other space requirements
- **Activity relationships**

Quantitative like flow

Qualitative

The Relationship between the depatments

  - Activity relationship is the key input in facilities design
  - Defined by flow relationships, organizational relationships, environmental relationships, process relationships and control relationships

# Introduction (Contd.)

- Data Needed for Layouts:

- Frequency of trips or flows of materials measure the interaction between facilities
  - Flow (example: production quantity)

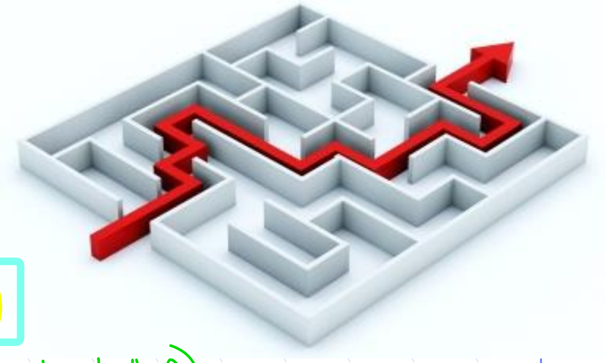
- Floor space available and space requirements
  - Space (example: the space in the facility)

- Adjacency requirements between pairs of activities
  - Activity relationships

قربهم من بعض

- Shape and size and Location **restrictions** for facility

# Flow Systems



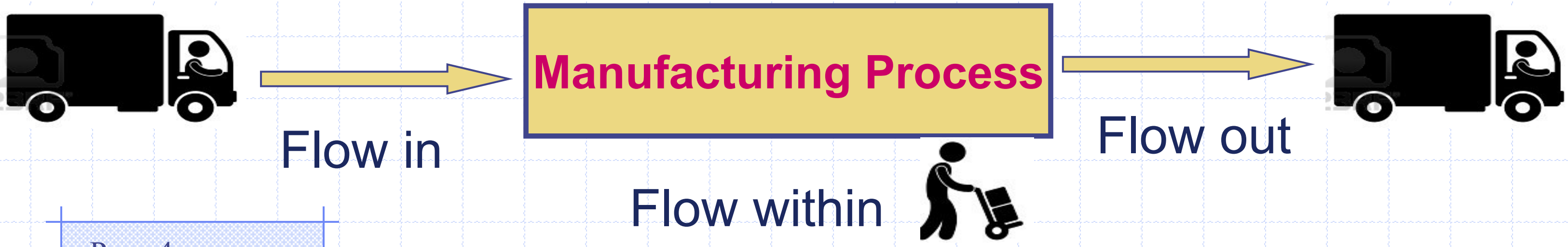
لأي نوع flow
into whithin out

**Flow process** have three characteristics:

1. Subject or item to be processed. (شوال subject الذي يتحرك)
2. Resources required for processing or transportation.
3. Communication: procedures that coordinate the resources.

Types of Manufacturing Flows:

1. Flow into the facility (Material Management System) From the supplier to the facility
2. Flow within the facility (**Material Flow System**)
3. Flow out of the facility (Physical Distribution System) from the supplier to the customer


Manufacturing Process
Flow in
Flow within
Flow out

# Flow Systems (contd.)

Flow in → **Manufacturing Process**

1. Flow into the facility:

Raw material ← **Resources:**

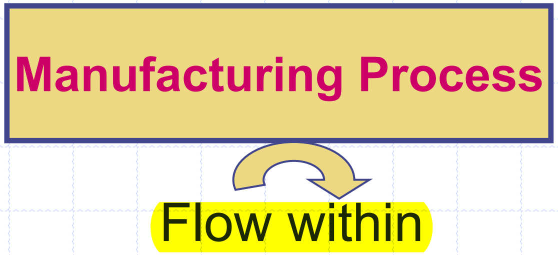
- Production control and purchasing functions
- Vendors الباعة (suppliers)
- Transportation and material handling to move the material or parts
- Receiving and storage

**Communication:**

- Production forecasts
- Inventory records
- Purchase order
- Move tickets way of communication (procedure that helps us to Know where the raw material is now)
- Electronic data Interchange (EDI) مهم for payment (نظام تبادل معلومات بين الشركات)
- Kanbans
- Etc.

# Flow Systems (contd.)

التركيز عليها في مادتنا


**Manufacturing Process**

Flow within

## 2. Flow within the facility:

- Determined by the type of departments.

product ← **Resources:**

- Production control and quality control depts.
- Manufacturing, assembly, and storage depts.
- Material handling to move materials, parts, supplies.
- Warehouse inside the facility

**Communication:**

- Production schedules
- Work order release
- Move tickets
- Kanbans
- Route sheets to Know the operation in the parts
- Warehouse records to Know how many we have on shells, on process parts (not finished)

# Flow Systems (contd.)

Manufacturing Process
Flow out

Final
Product

## 3. Flow out of the facility:

### Resources:

- The customer.
- Sales and accounting departments and warehouses.
- The material handling system and transportation equipment.
- Distributors of the finished product.

### Communication:

- Sales orders
- Shipping reports and releases
- EDI invoices
- etc

# Material Flow Systems

Patterns of flow may be viewed from the perspective of flow within workstations, within departments, and between departments.

1. **Flow within workstation:** (the Simplest)
   - Motions studies and ergonomics considerations are important in establishing the flow within workstations.
   - For example, flow within workstations should be simultaneous, symmetrical, natural, rhythmical, and habitual.

# Material Flow Systems (contd.)

**2. Flow within department:**

flow from workstation to workstation

- Examples:

  Locating machines within a department

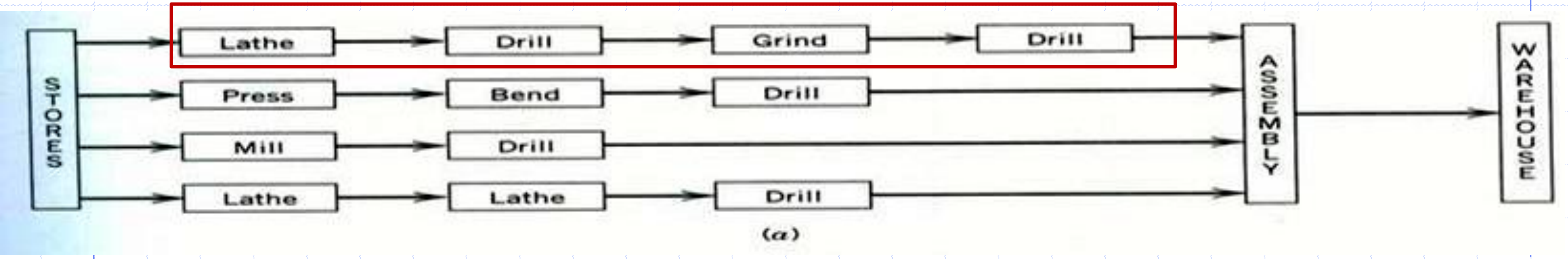
  Laying out a hospital emergency room.

- Dependent on the type of department (process or product department).

- For a product department, the flow will follow the layout of the machines. The possible flow patterns are:
  - End-to-end, back-to-back
  - Front-to-front
  - Circular

(Combine)

put all machines that need to produce a particular product have a high mass production



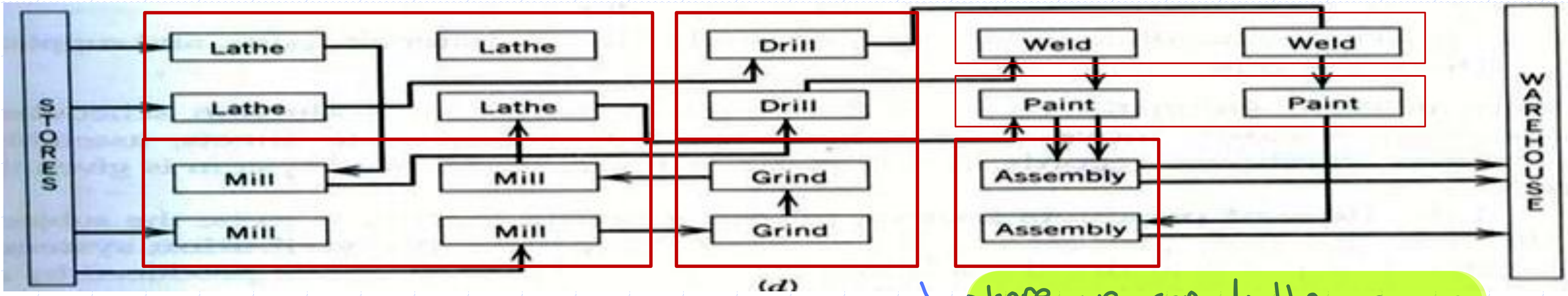
(a)

## Product Department

(for Mass Production)

(different operation in one department)

variety هنا
جداً قليلة



(d)

here we can do the process for the variety product

movement ال معظم
will be from a department
to an Aisle

## Process Department

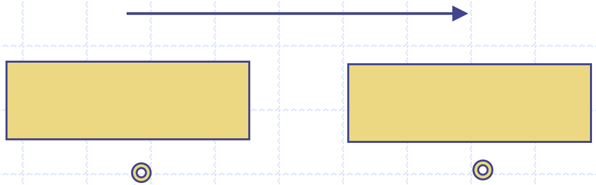
(Same operation)

Low quantity
with high variety

# Material Flow Systems (contd.)

For a product department :-

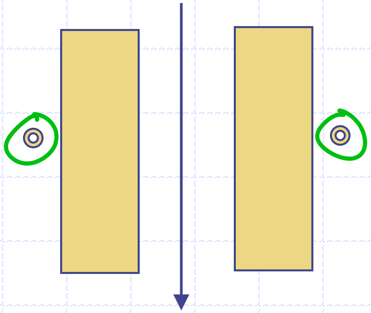
(the boxes represents Machines (workstations))



worker

End-to-end

2 workers

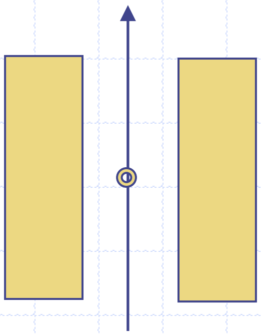


back-to-back

(parrallel)

2 workers

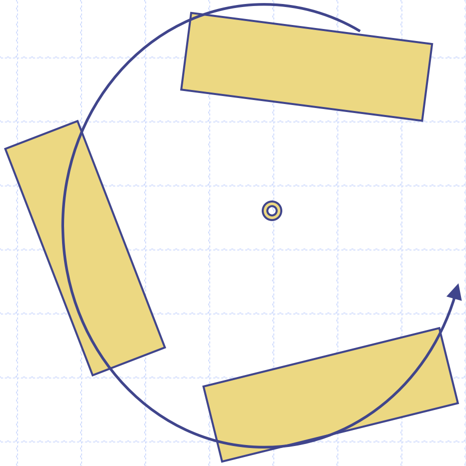
(بتروح على واحدة فيهم بعدين الثانية)



Front-to-front

(one worker for two machines)

1 worker



Circular

(one worker works on more than two machines)

1 worker

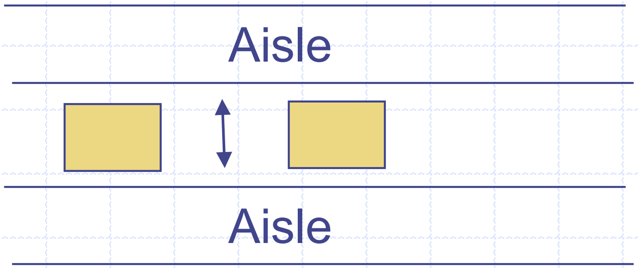
# Material Flow Systems (contd.)

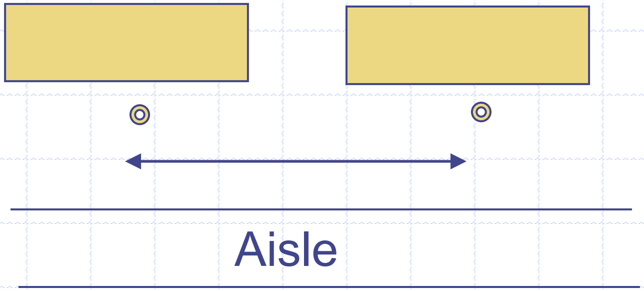
put all machines that do the same process in one place (similar process machines)

داخل القسم

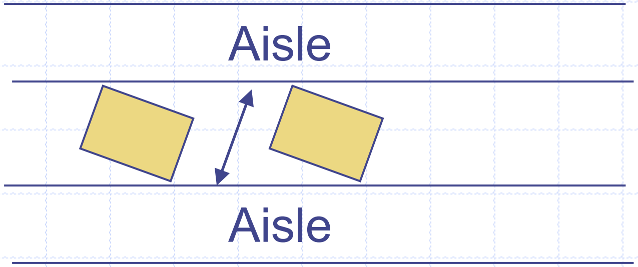
- For a process department, little intradepartmental flow. Most is between the department and aisles.
- Three examples of configurations:
  - Parallel
  - Perpendicular
  - Diagonal (not used often, assume one way aisles which are not common)

الايجابية تبعته (Require less space) but it is less flexible





move the parts from department to another one



Diagonal characteristic
- less space
- not flexible
- Aisle one way

# Material Flow Systems (contd.)

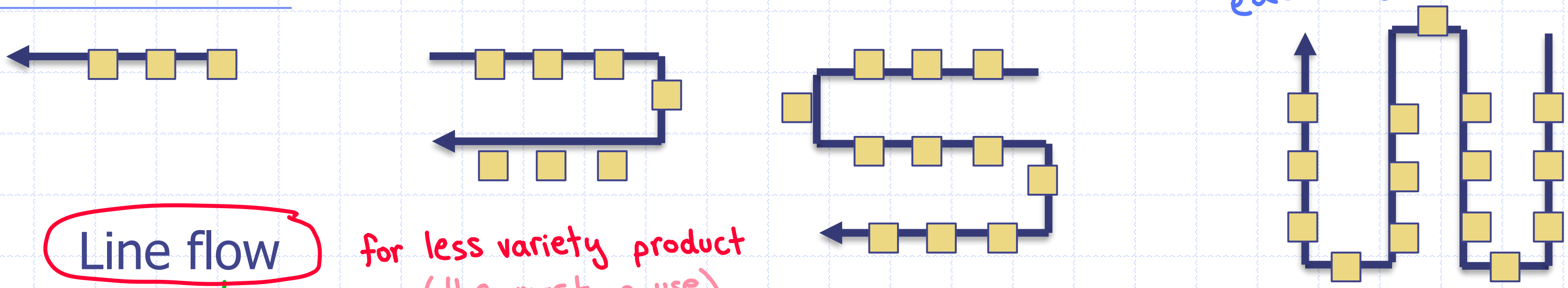
- In the case of mechanized and automated systems involving the use of continuously running conveyors, shuttle carts, automated guided vehicles, robots, and others.

- Several primitive flow structures or patterns:

1. The line flow pattern:
    - Straight-line
    - U-shaped
    - S-shaped
    - W-shaped
2. The spine flow pattern
3. The loop flow pattern
4. The tree flow pattern

# Material Flow Systems (contd.)

page 91
very important
each type when we use it

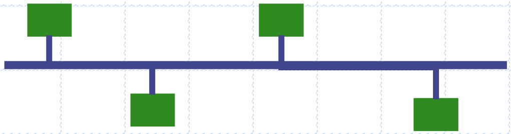


Line flow

تستخدم مثلاً
في صناعة السيارات

for less variety product
(the most we use)

Spine flow

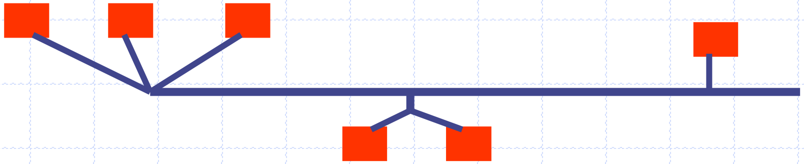


→ two or one direction

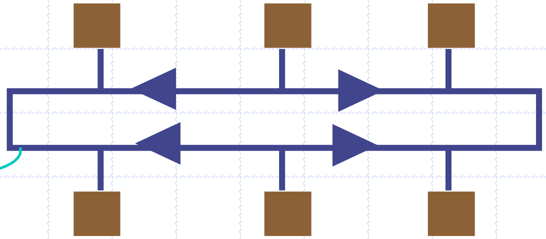
Tree flow

Robotic Material handling

مهم



Inner loop
(the flow is inside the loop)



in the machine

# Material Flow Systems (contd.)

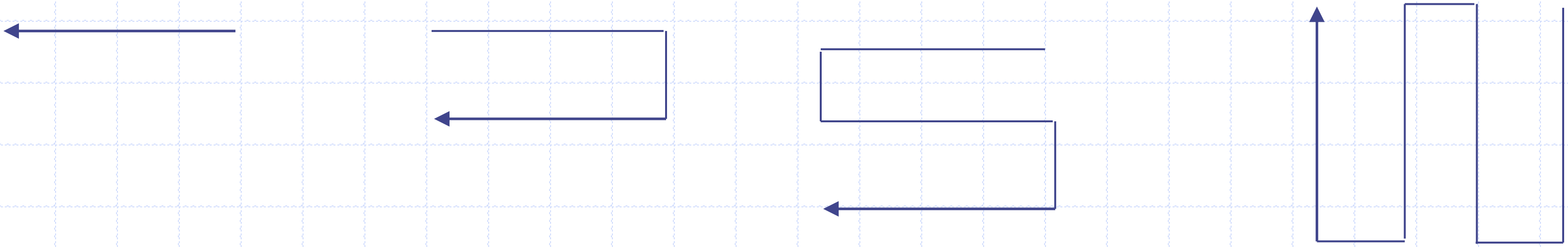
3. **Flow between departments:** (whithin the Facility)

Flow typically consists of a combination of the four general flow patterns:

line flow

- Straight-line
- U-shaped
- S-shaped
- W-shaped

and spine flow (we can use it between departments)



# Material Flow Systems (contd.)

- An important consideration in combining the general flow patterns is the location of the ① entrance (receiving department) and ② exit (shipping department).
- Often these locations are fixed due to building construction
- Flow within facility should conform to the restricted locations of the entrance and exit.
- Examples, see Figure 3.25:
  - Entrance and exit can be: at the same location, on adjacent sides, same side but opposite ends, and on opposite sides

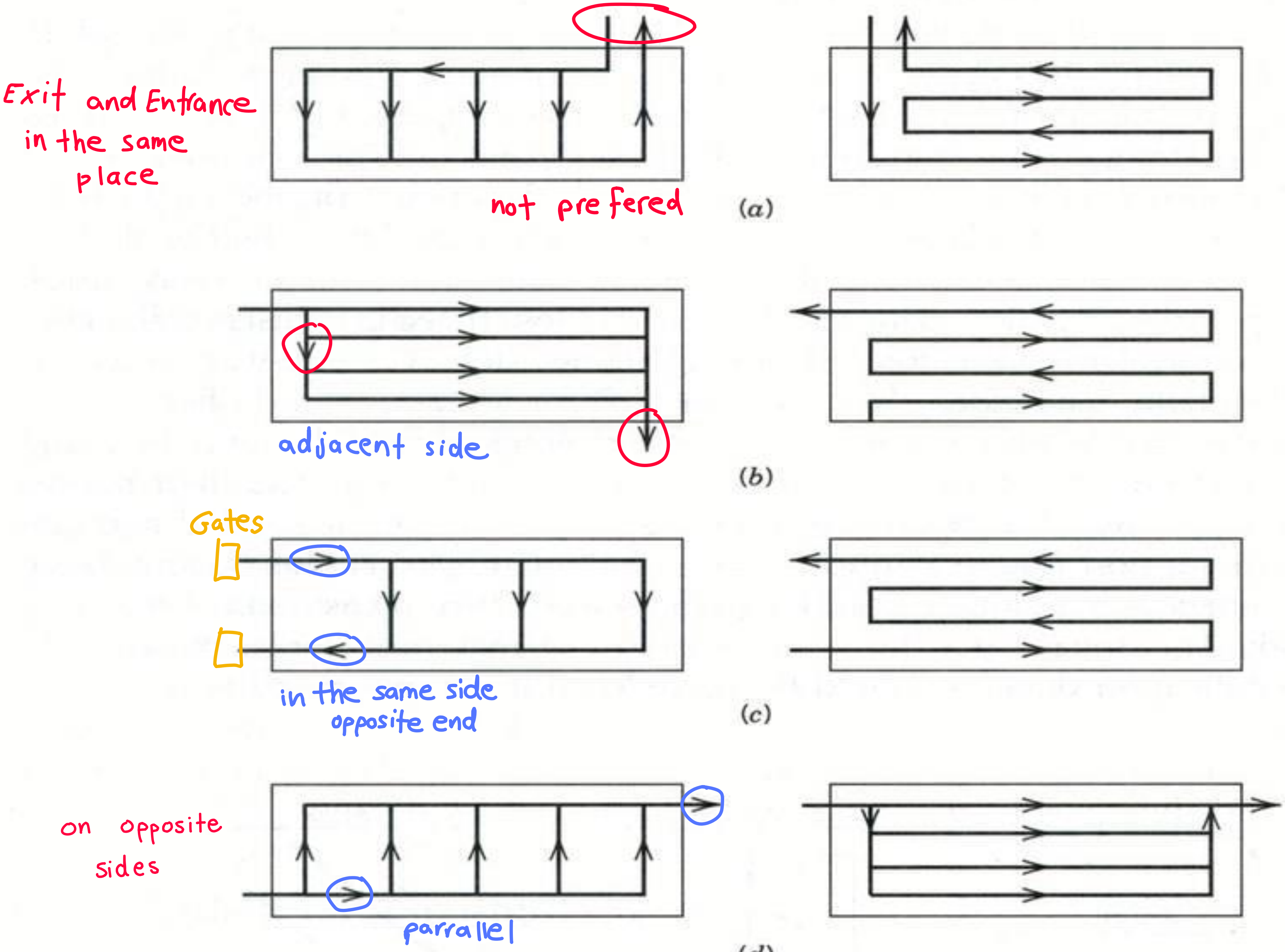


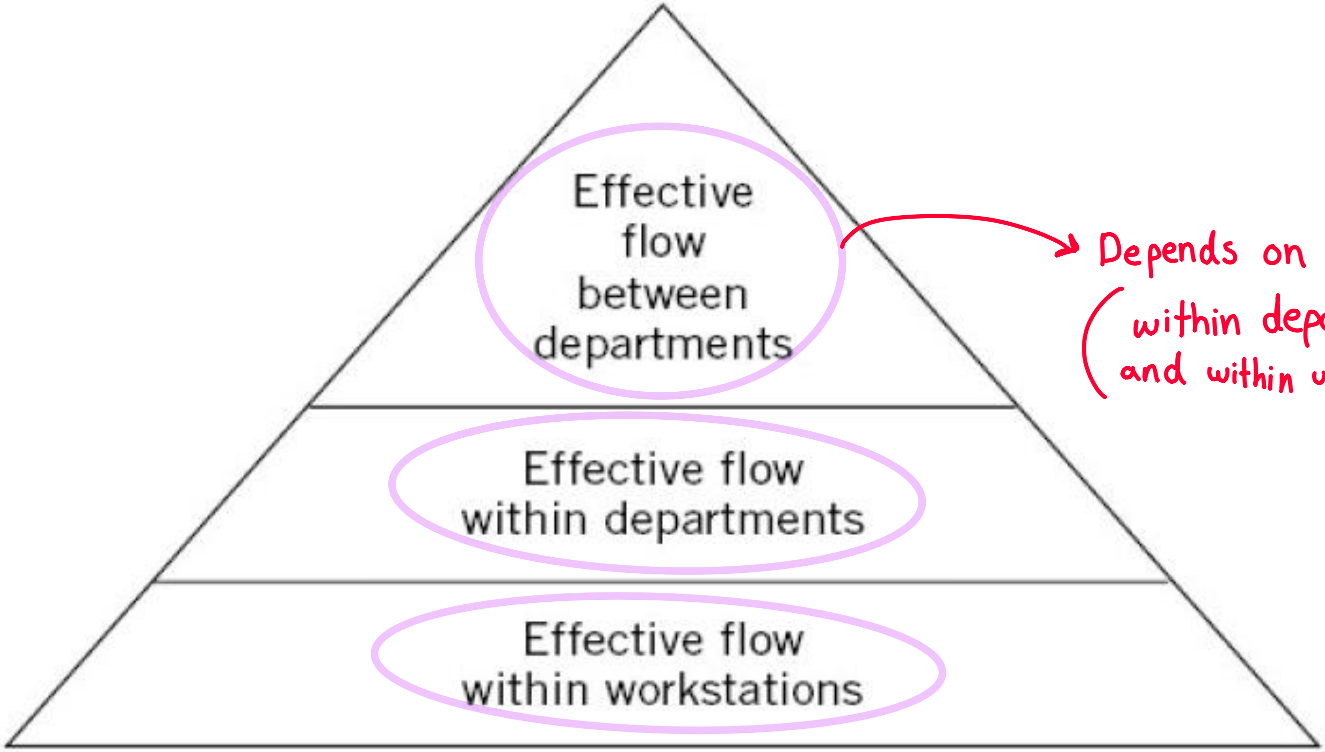
**Figure 3.25** Flow within a facility considering the locations of the entrance and exit. (*a*) At the same location. (*b*) On adjacent sides. (*c*) On the same side but at opposite ends. (*d*) On opposite sides.

لازم في ال Flow نراعي ال entrance وال exit

# Material Flow Systems (contd.)

## Flow Planning

- Effective flow planning is a hierarchal planning process.
- Effective flow between departments depends on effective flow within departments, which in turn depends on effective flow within workstations.


Effective flow between departments
Effective flow within departments
Effective flow within workstations

Depends on ( within departments and within wokstations )

# Material Flow Systems (contd.)

## Flow Planning

- **Flow planning principles:**

Max dirrect flow path
Min flow
Min cost of the flow

1. Maximize direct flow path:

ما يكون في تقاطع مع flows ثانية

- Maximize directed uninterrupted flow paths. That is, the path does not intersect with other paths.
- Avoid backtracking which increases the length of the flow.

aviod comming back to a previous process

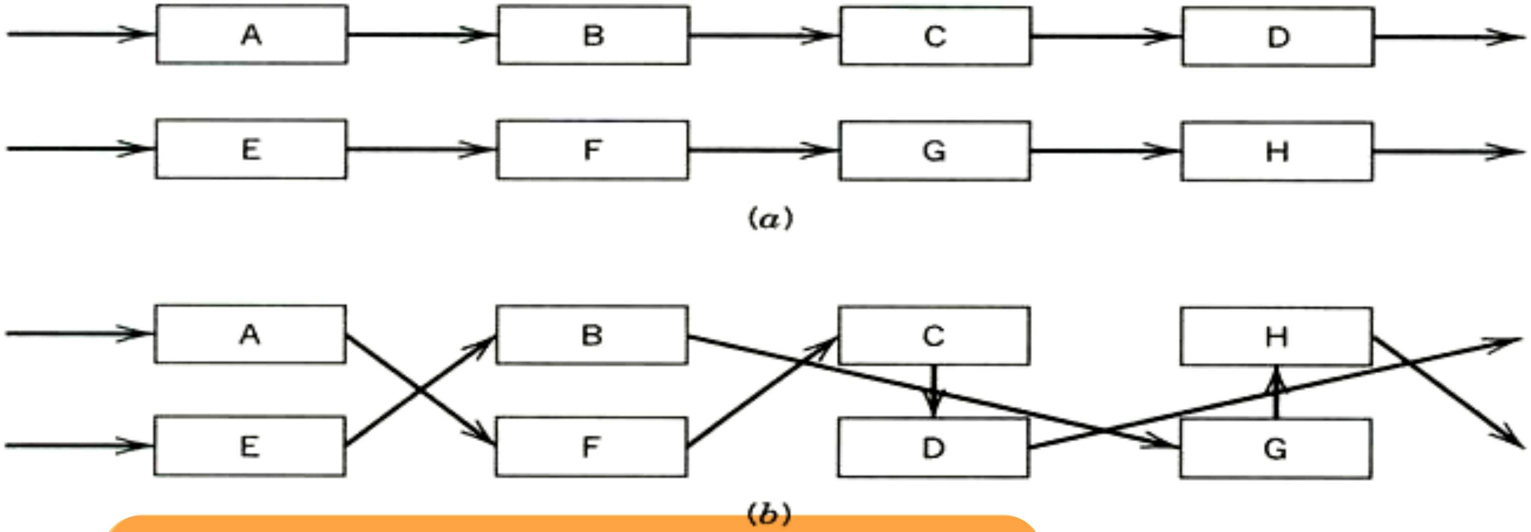
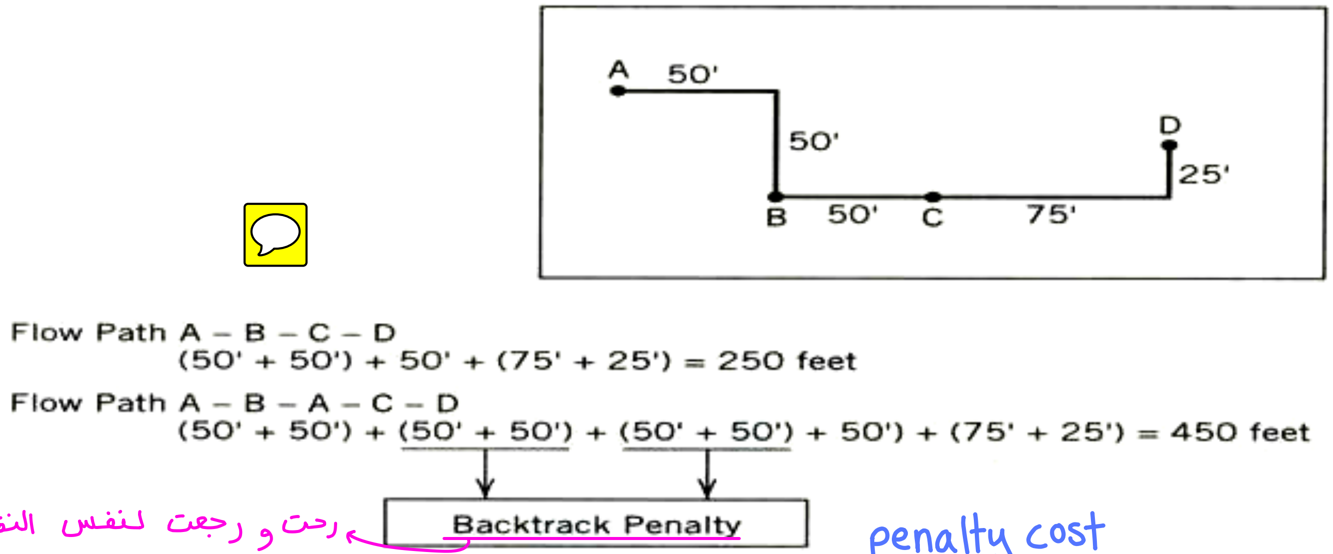


**Figure 3.27** The impact of interruptions on flow paths. (*a*) Uninterrupted flow paths. (*b*) Interrupted flow paths.



Flow Path A – B – C – D
(50' + 50') + 50' + (75' + 25') = 250 feet

Flow Path A – B – A – C – D
(50' + 50') + (50' + 50') + (50' + 50') + 50') + (75' + 25') = 450 feet

Backtrack Penalty

رحت و رجعت لنفس النقطة

penalty cost

Back Tracking بسبب ال
ممكن زيادة ال defects
الحلول
① زيادة machine
② تغيير ال design
لل product
بحيث ما احتاج
ال back tracking

**Figure 3.28** Illustration of how backtracking impacts the length of flow paths.

# Material Flow Systems (contd.)

## Flow Planning

Eliminate Unnecessary flow

2. **Minimize flow: work simplification approach**

   1. Eliminating flow by delivering materials, information, or people directly to the point of ultimate use and therefore eliminate intermediate steps.

   2. Plan for the flow between two consecutive points to require as few movements as possible – preferably one. متتال

   3. Combine flows or operations where possible. Plan for the movement of material, information, or people to occur simultaneously with processing.

# Material Flow Systems (contd.)

## Flow Planning

### 3. Minimize the cost of the flow:

1. Minimize manual handling by minimizing walking, manual travel distances, and motions.

2. Eliminate manual handling by automation or mechanizing the flow . This lets workers devote their time to their operations – not material handling.

# Material Flow Systems (contd.)

## Flow Planning

- Possible indicators that the flow needs improvement:

1. Many units on carts, shelves, or conveyors waiting to be assembled.
2. Parts on the floor in bulk containers waiting to be assembled.
3. Shelving along the walls full of rejected parts or other items that may not have been disposed of.
4. Numerous rework benches, or a large amount of rework being performed on production benches.
5. Expensive machinery that is idle.
6. People expediting high-priority work orders.

   عندما يصبح كل اشي high priority
   و ابطل ملحقة معناه في مشكلة بالتخطيط

7. Production status meetings being held every day.

   يعني لو كلشي واضح ومنيح
   ما بكون في داعي للاجتماع

8. Trash on the floor.
9. Anything in the aisles except people and transport equipment.
10. Operators making partial assemblies because of a part shortage.

# Material Flow Systems (contd.)

## Flow Planning

- Signs of a good general flow pattern:
  - A flow starts at receiving and terminates at shipping.
  - Straight and short lines of flow
  - Minimum backtracking
  - Materials moved directly to point of use
  - Minimum WIP
  - Flow pattern is easily expandable, new processes can easily be merged in

# Departmental Planning

تخطيط الاقسام

# Department Planning

- Concerned with **forming** planning department (production, service, support ,..etc.)

- Production Planning departments are collections of workstations to grouped together during the facility layout process.

- As a general rule, planning department needs to combine workstations that perform "like" functions.
- "Like" Functions
  - Similar products
  - Similar components
  - Similar processes

# Department Planning (contd.)

مهم الرجوع للكتاب

## General Types of Layouts

- Production line layout –
  - Large stable demand for a standardized product (engine, automobile)

product Layout
(combine different machines that produce one product in one department)

No Variety

- Fixed position layout –
  - Demand exists for large, awkward, difficult to move product such as aircraft

All the operations come to the place where the product that is difficult to move is placed

Finish group of products

- Product family layout –
  - Medium demand for medium number of similar components

(machines are combined together in one place to produce more than one product)

Just Finish one operation

- Process layout –
  - Combine workstations that perform similar processes

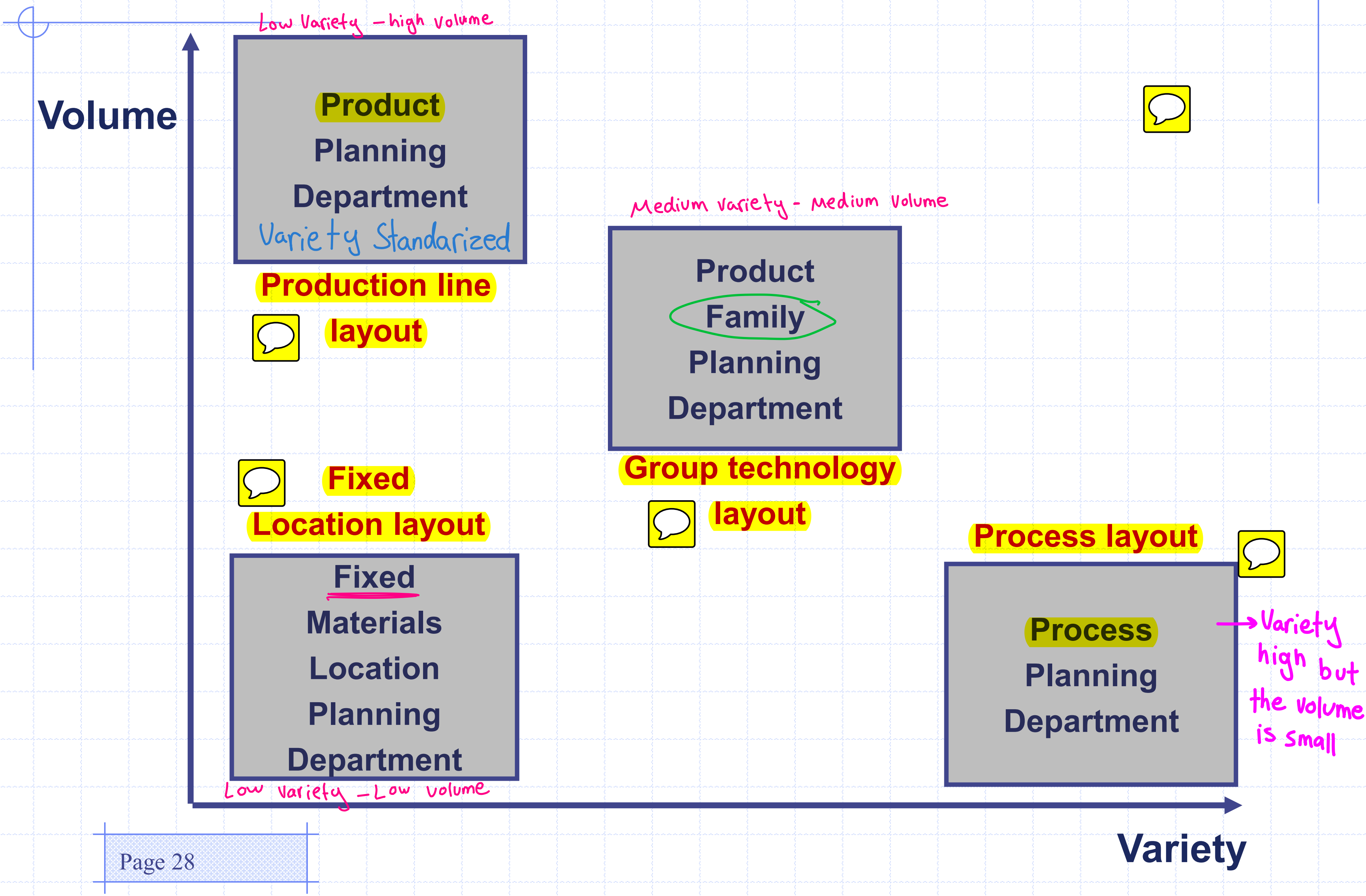
مثلاً كل الـ Milling مع بعض و هكذا

- Hybrid layout –
  - Composition of several of the different types of layouts

# Department Planning (contd.)

(ممكن يجي سؤال احنا نرسمها !!)

## Volume/Variety Classification



Volume

Low Variety – high volume

**Product** Planning Department

Variety Standarized

Production line layout

Fixed Location layout

**Fixed** Materials Location Planning Department

Low Variety – Low volume

Medium variety - Medium volume

Product Family Planning Department

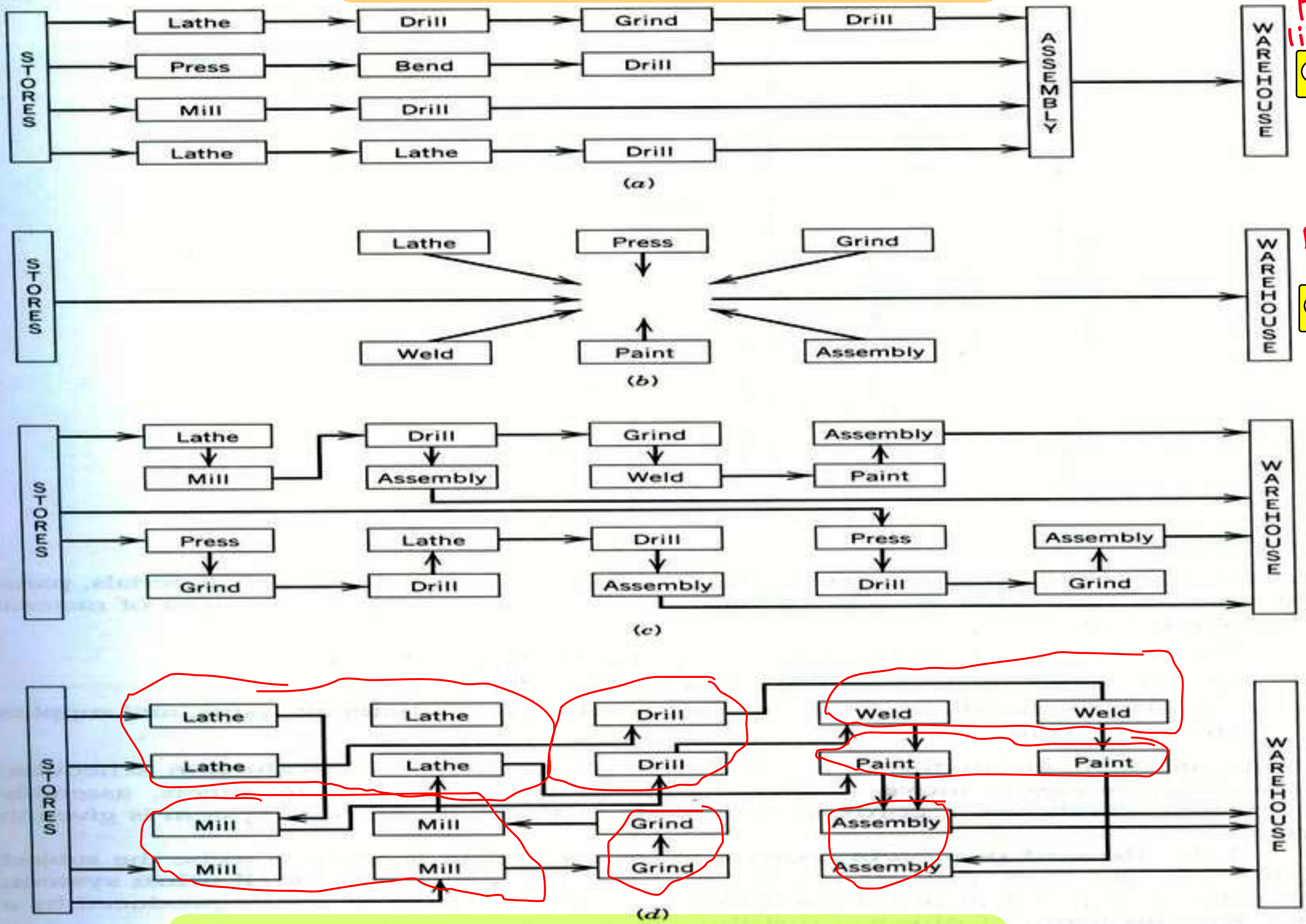
Group technology layout

Process layout

**Process** Planning Department

→ Variety high but the volume is small

Variety



Production line Layout

Fixed Layout

Family Layout

Process Layout

**Figure 3.18** Material flow systems for various types of departments. (*a*) Product planning departments. (*b*) Fixed materials location planning departments. (*c*) Product family planning departments. (*d*) Process planning departments.

# Guide for Combining Workstations Table 3.1

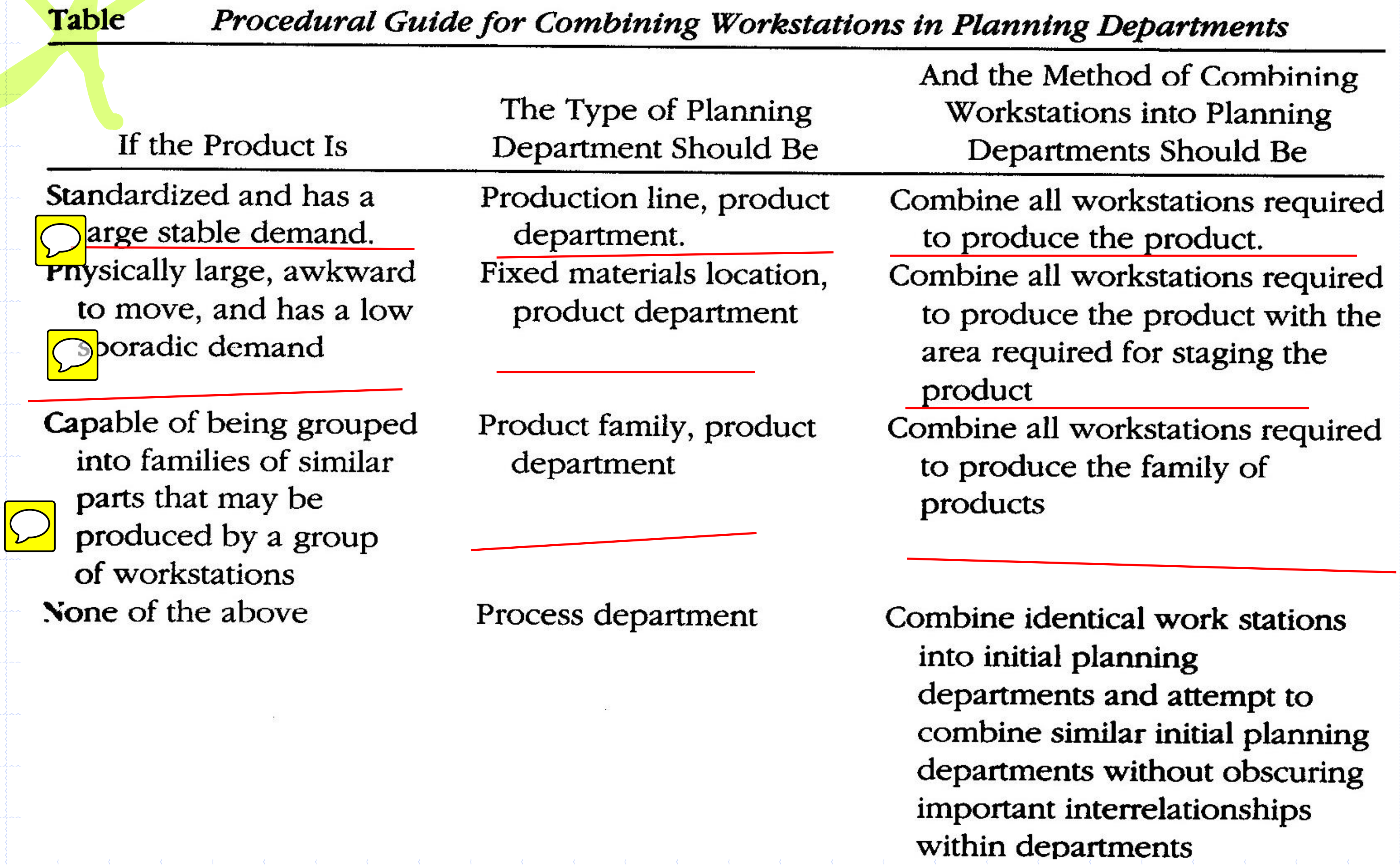


**Table** *Procedural Guide for Combining Workstations in Planning Departments*

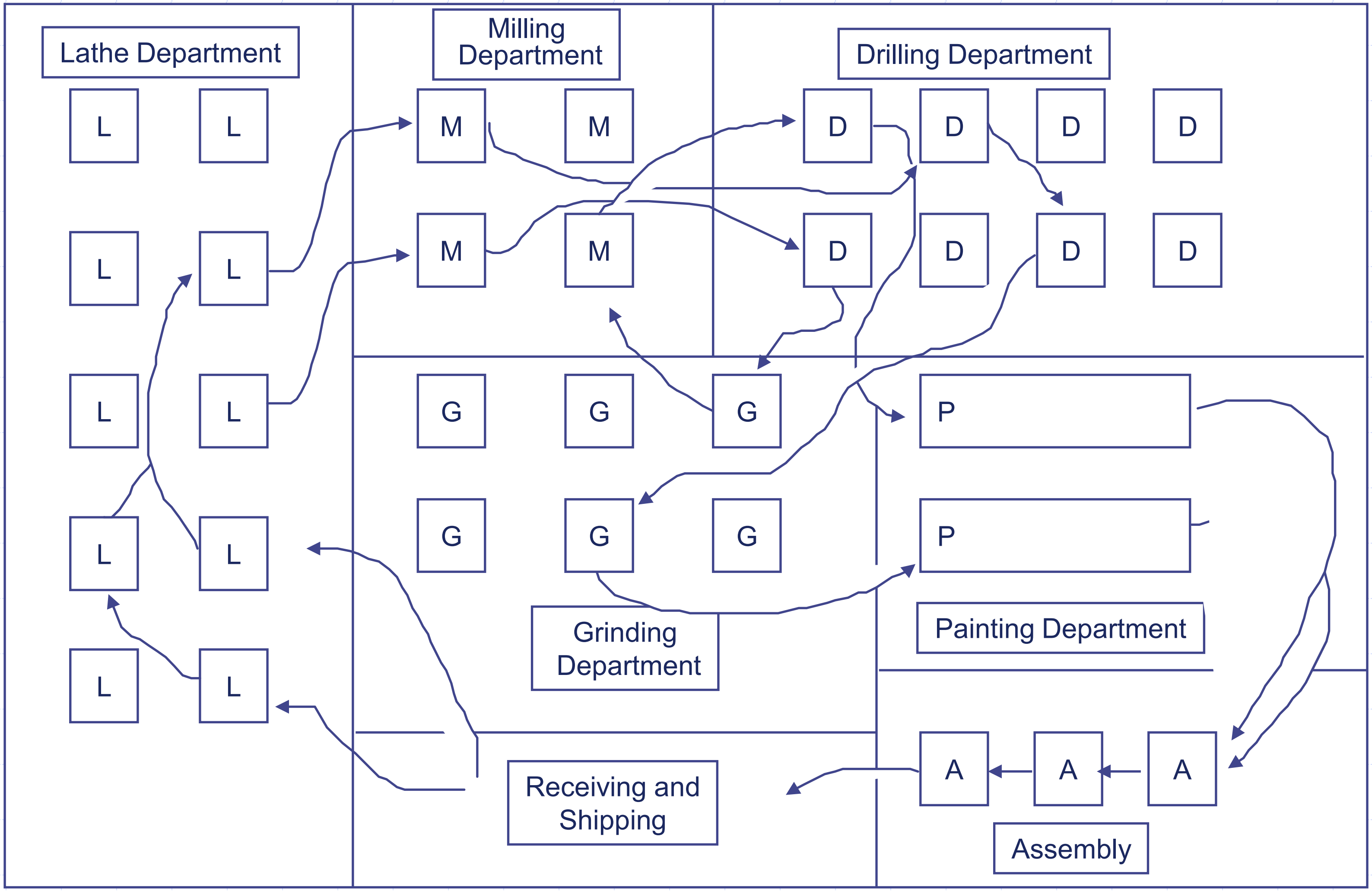
| If the Product Is | The Type of Planning Department Should Be | And the Method of Combining Workstations into Planning Departments Should Be |
|---|---|---|
| Standardized and has a large stable demand. | Production line, product department. | Combine all workstations required to produce the product. |
| Physically large, awkward to move, and has a low sporadic demand | Fixed materials location, product department | Combine all workstations required to produce the product with the area required for staging the product |
| Capable of being grouped into families of similar parts that may be produced by a group of workstations | Product family, product department | Combine all workstations required to produce the family of products |
| None of the above | Process department | Combine identical work stations into initial planning departments and attempt to combine similar initial planning departments without obscuring important interrelationships within departments |

Support, administrative, and service planning departments have been traditionally treated as "process" departments, because similar activities are performed

Page 30

# Process Layout Example

Most of the flow will be from departement to Aisle

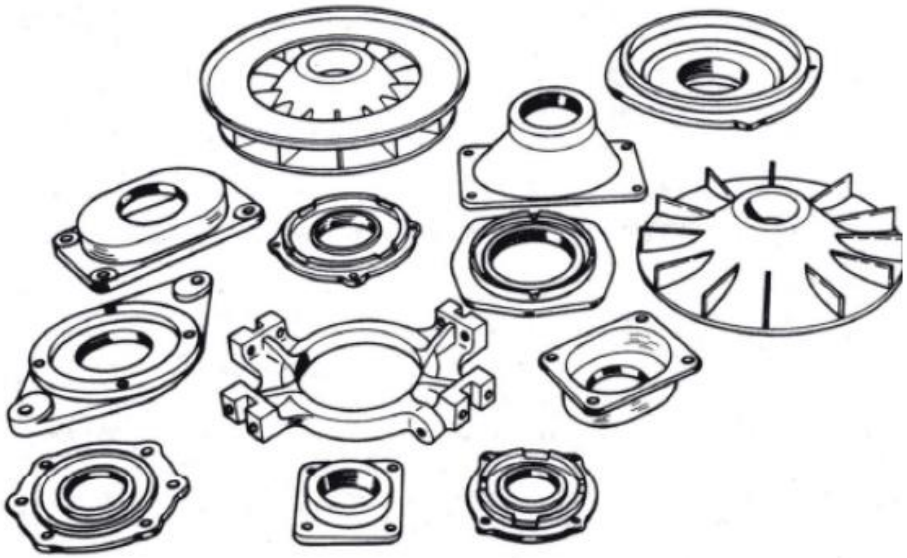


3

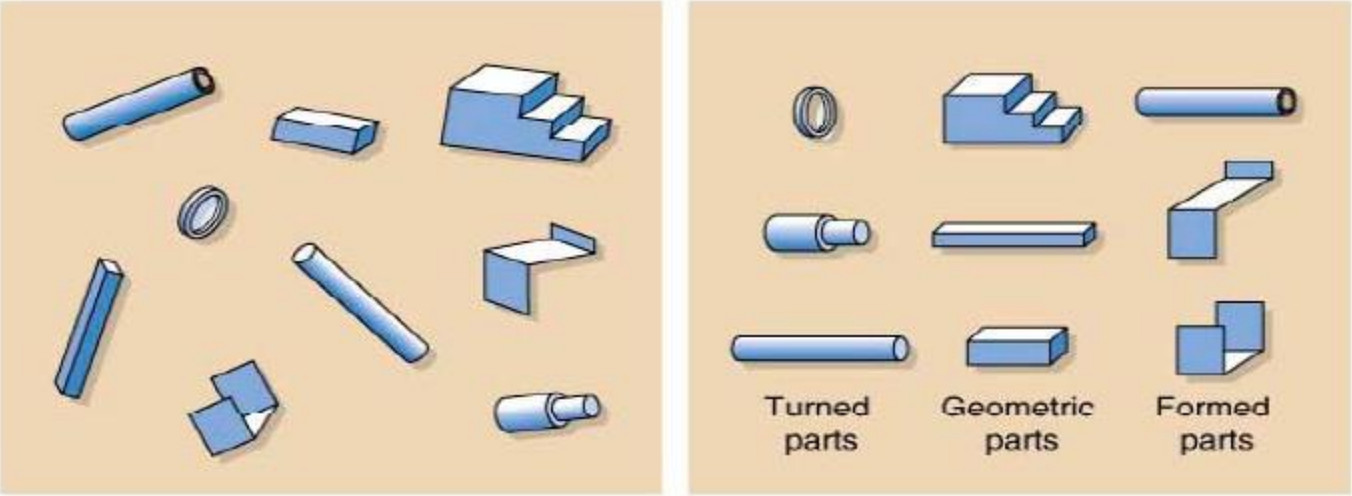
# Product Family Departments

## Manufacturing cells (Group Technology)

- *Product Family* or *Group Technology departments* aggregates medium volume-variety parts into families.
- Machines required to manufacture the part family are grouped to form cells (*cellular manufacturing*)
- Cells are formed in different ways based on similarity
  - Machines
  - Employees
  - Materials
  - Tooling

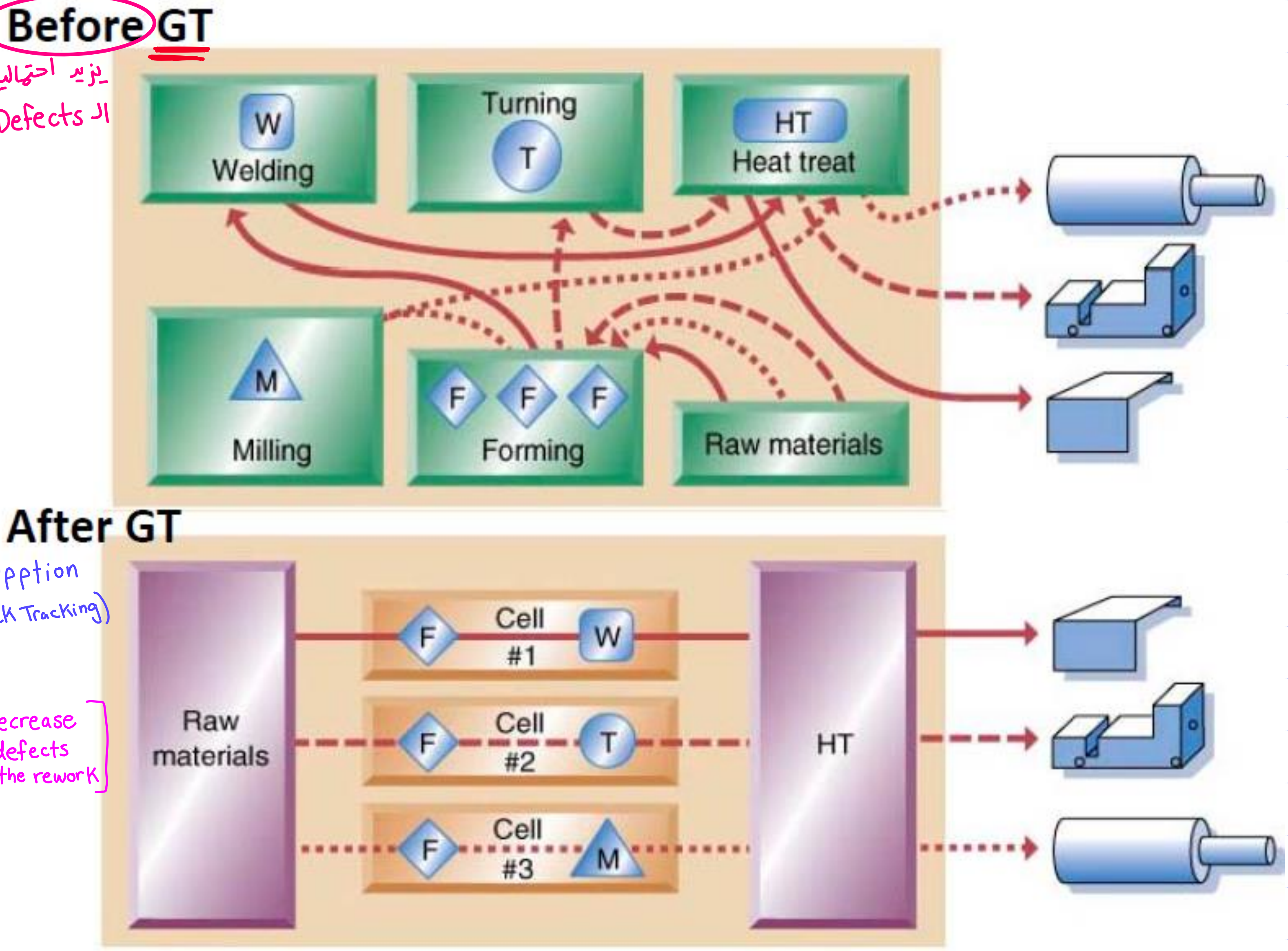


Different design attributes,
similar manufacturing requirements



**Unorganized parts** **Parts organized by families**

Group Technology



يزيد احتمالية
ال Defects

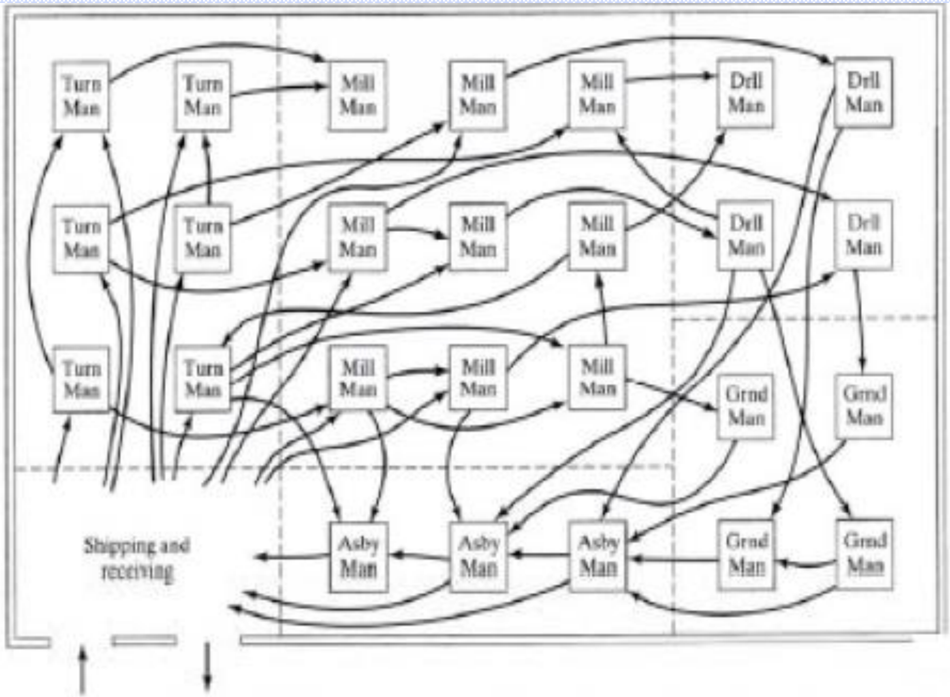
Unintrupption
(No Back Tracking)

to decrease
the defects
and the rework

- Before GT

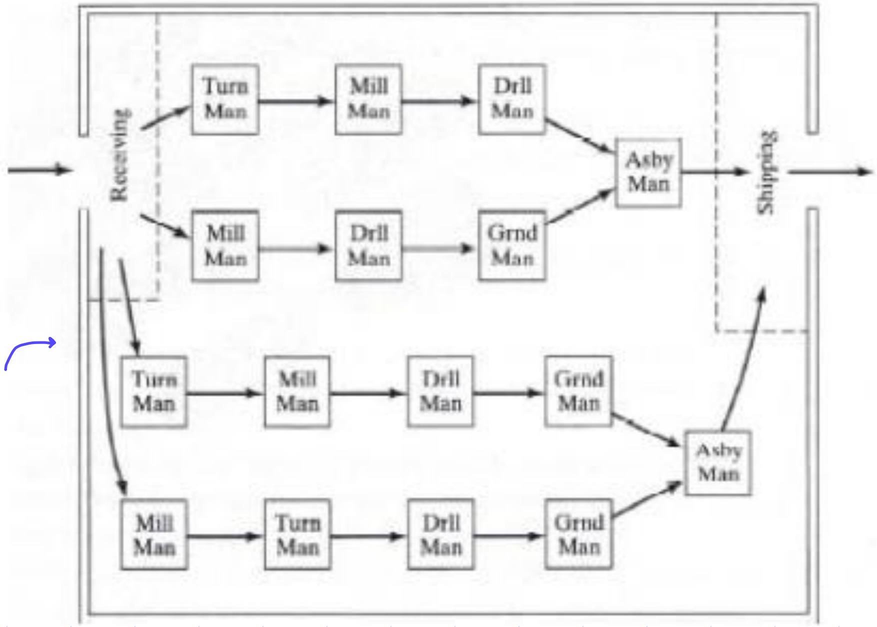
أكبر inventory

work in process inventory ↑
inventory ↑



- After GT

أقل inventory



# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

- Manufacturing cell operation needs minimum external Support.
- Often designed, controlled and operated using *JIT, TQM and Lean manufacturing concepts*
- Benefits of cell manufacturing:
  - Reduction: inventories, space, paperwork, equipment, transportation, etc.
  - Simplification: communication, handling, scheduling, etc.
  - Improvement: productivity, flexibility, quality, customer satisfaction, etc.

improvement
for the product
and the process

# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

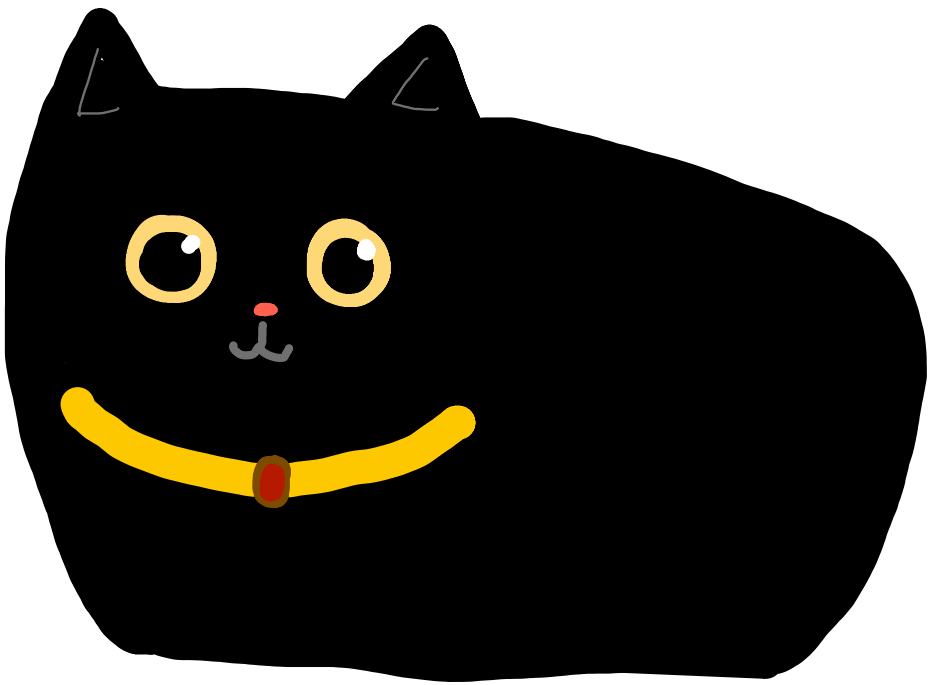
- Successful implementation of cells requires addressing:
  - أهم نقطة * Selection: identification of machine and part types for cell
  - Design: layout, production and material handling requirements
  - Operation: determining lot sizes, scheduling, number of operators
  - Control: methods used to measure the performance of the cell

- Several approaches for selection issues e.g. heuristics, mathematical models and **clustering techniques**.

- Different ways of clustering algorithms
  - One simple clustering techniques is called direct clustering algorithm (DCA)
  - Example of DCA : see page 102 (text book)

# Clustering Approach (3 Methods)

- Direct clustering algorithm
- Rank order clustering algorithm
- Cluster identification algorithm



Method 1

~~optimization~~

# Direct Clustering Algorithm (DCA)

1. Sum the 1s in each column and each row of the machine-part matrix.

تنازلي

2. Order the rows (top to bottom) in descending order of the number of 1s in the rows.

تصاعدي

3. Order the columns (left to right) in ascending order of the number of 1s in each.
4. Sort the columns. Beginning with the first row of the matrix, shift to the left all columns having a 1 in the first row. Continue row-by-row until no further opportunity exists for shifting columns.
5. Sort the rows. Beginning with the leftmost column, shift rows upward when opportunities exist to form blocks of 1s.
6. Form cells such that all processing for each part occurs in a single cell.

# Example 3.1:

## Applying the DCA method to group 5 machines

### Step 1

Rows → part number يمثل
Columns → machine number

**machine #**

| **part #** | 1 | 2 | 3 | 4 | 5 | **# of 1s** |
|---|---|---|---|---|---|---|
| 1 | 1 | | 1 | | | 2 |
| 2 | 1 | | | | | 1 |
| 3 | | 1 | | 1 | 1 | 3 |
| 4 | 1 | | 1 | | | 2 |
| 5 | | 1 | | | | 1 |
| 6 | | | | 1 | 1 | 2 |
| # of 1s | 3 | 2 | 2 | 2 | 2 | |

sum the rows

sum the columns

Part one needs machine one and three

P1 {1, 3]
P2 {1}
P3 {2,4,5}
P4 {1,3 }
P5 {2}
P6 {4,5}

## Steps 2&3

**machine #**

| **part #** | 5 | 4 | 3 | 2 | 1 | # of 1s |
|---|---|---|---|---|---|---|
| 3 | 1 | 1 |  | 1 |  | 3 |
| 6 | 1 | 1 |  |  |  | 2 |
| 4 |  |  | 1 |  | 1 | 2 |
| 1 |  |  | 1 |  | 1 | 2 |
| 5 |  |  |  | 1 |  | 1 |
| 2 |  |  |  |  | 1 | 1 |
| # of 1s | 2 | 2 | 2 | 2 | 3 |  |

## Step 4

**machine #**

| **part #** | 5 | 4 | 2 | 3 | 1 | # of 1s |
|---|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 |  |  | 3 |
| 6 | 1 | 1 |  |  |  | 2 |
| 4 |  |  |  | 1 | 1 | 2 |
| 1 |  |  |  | 1 | 1 | 2 |
| 5 |  |  | 1 |  |  | 1 |
| 2 |  |  |  |  | 1 | 1 |
| # of 1s | 2 | 2 | 2 | 2 | 3 |  |

## Step 5

**machine #**

| **part #** | 5 | 4 | 2 | 3 | 1 | # of 1s |
|---|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 |  |  | 3 |
| 6 | 1 | 1 |  |  |  | 2 |
| 5 |  |  | 1 |  |  | 2 |
| 4 |  |  |  | 1 | 1 | 2 |
| 1 |  |  |  | 1 | 1 | 1 |
| 2 |  |  |  |  | 1 | 1 |
| # of 1s | 2 | 2 | 2 | 2 | 3 |  |

## Step 6

**machine #**

| **part #** | 5 | 4 | 2 | 3 | 1 | # of 1s |
|---|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 |  |  | 3 |
| 6 | 1 | 1 |  |  |  | 2 |
| 5 |  |  | 1 |  |  | 2 |
| 4 |  |  |  | 1 | 1 | 2 |
| 1 |  |  |  | 1 | 1 | 1 |
| 2 |  |  |  |  | 1 | 1 |
| # of 1s | 2 | 2 | 2 | 2 | 3 |  |

CEll (1) = $\{M_2, M_4, M_5\} \Longrightarrow P_3, P_6, P_5$

CEll (2) = $\{M_1, M_2\} \Longrightarrow P_1, P_2, P_4$

# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

- "Bottleneck" machines in cellular manufacturing are those bind two cells together.
- When bottleneck condition exist:
    - Locate bottleneck machines at the boundary between cells.
    - Duplicate machines
    - Consider redesign of parts
    - Consider outsourcing processing

# "Bottleneck" machines

two cells يعتمدو على نفس ال machine

Machine #

| Part # | 5 | 4 | 2 | 3 | 1 |
|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 | | |
| 6 | 1 | 1 | | | |
| 5 | | | 1 | 1 | |
| 4 | | | | 1 | 1 |
| 1 | | | | 1 | 1 |
| 2 | | | | | 1 |

(a)

Machine (2) is the bottleneck

Machine #

| Part # | 5 | 4 | 2 | 3 | 1 |
|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 | | |
| 6 | 1 | 1 | | | |
| 5 | | | 1 | 1 | |
| 4 | | | | 1 | 1 |
| 1 | | | | 1 | 1 |
| 2 | | | | | 1 |

(b)

Machine #

| Part # | 5 | 4 | 2 | 3 | 1 |
|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 | | |
| 6 | 1 | 1 | | | |
| 5 | | | 1 | 1 | |
| 4 | | | | 1 | 1 |
| 1 | | | | 1 | 1 |
| 2 | | | | | 1 |

(c)

What can we do?

شغلنا سلايدات

cluster Algorithim

ممكن ما تنحل الـ Matrix فيها
(طريقة غير مضمونة)

* بالامتحان الدكتورة بتحدد الطريقة

direct
or
cluster

# Clustering Approach

- Direct clustering algorithm
- Rank order clustering algorithm
- Cluster Identification algorithm

Method 2

# Rank Order Clustering Algorithm

**Step 1**: Assign binary weight $BW_j = 2^{m-j}$ to each column $j$ of the part-machine processing indicator matrix.

**Step 2**: Determine the decimal equivalent *DE* of the binary value of each row *i* using the formula

$$DE_i = \sum_{j=1}^{m} 2^{m-j} a_{ij}$$

**Step 3**: Rank the rows in decreasing order of their *DE* values. Break ties arbitrarily. Rearrange the rows based on this ranking. If no rearrangement is necessary, stop; otherwise go to step 4.

# Rank Order Clustering Algorithm

**Step 4**: For each rearranged row of the matrix, assign binary weight $BW_i = 2^{n-i}$.

**Step 5**: Determine the decimal equivalent of the binary value of each column *j* using the formula

$$DE_j = \sum_{i=1}^{m} 2^{n-i} a_{ij}$$

**Step 6**: Rank the columns in decreasing order of their *DE* values. Break ties arbitrarily. Rearrange the columns based on this ranking. If no rearrangement is necessary, stop; otherwise go to step 1.

# Sample part-machine processing indicator matrix

$P_1 = \{M_1, M_4, M_6\}$

$P_2 = \{M_2, M_3, M_5\}$

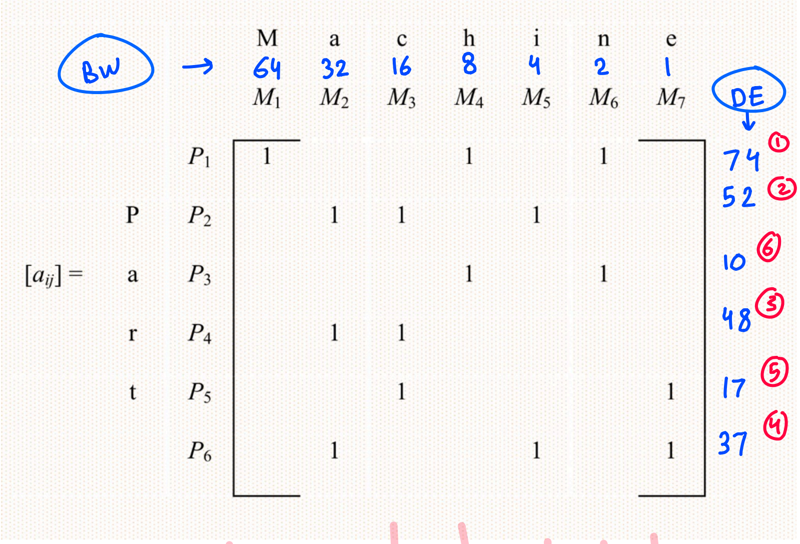
$P_3 = \{M_4, M_6\}$

$P_4 = \{M_2, M_3\}$

$P_5 = \{M_3, M_7\}$

$P_6 = \{M_2, M_5, M_7\}$

$$[a_{ij}] = \begin{array}{cc|ccccccc|}
 & & \text{M} & \text{a} & \text{c} & \text{h} & \text{i} & \text{n} & \text{e} \\
 & & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 \\
\hline
 & P_1 & 1 & & & 1 & & 1 & \\
\text{P} & P_2 & & 1 & 1 & & 1 & & \\
\text{a} & P_3 & & & & 1 & & 1 & \\
\text{r} & P_4 & & 1 & 1 & & & & \\
\text{t} & P_5 & & & 1 & & & & 1 \\
 & P_6 & & 1 & & & 1 & & 1 \\
\hline
\end{array}$$



$$\begin{array}{ccc|ccccccc|cc}
 & & & \text{M} & \text{a} & \text{c} & \text{h} & \text{i} & \text{n} & \text{e} & & \\
\text{BW} & & \rightarrow & 64 & 32 & 16 & 8 & 4 & 2 & 1 & & \\
 & & & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & \text{DE} & \\
 & & P_1 & 1 & & & 1 & & 1 & & 74 & \text{①} \\
 & \text{P} & P_2 & & 1 & 1 & & 1 & & & 52 & \text{②} \\
[a_{ij}] = & \text{a} & P_3 & & & & 1 & & 1 & & 10 & \text{⑥} \\
 & \text{r} & P_4 & & 1 & 1 & & & & & 48 & \text{③} \\
 & \text{t} & P_5 & & & 1 & & & & 1 & 17 & \text{⑤} \\
 & & P_6 & & 1 & & & 1 & & 1 & 37 & \text{④}
\end{array}$$

Now order
the DE
in decreasing
order

$$\begin{array}{c|ccccccc|c}
 & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & \text{BW} \\
\hline
P_1 & 1 & & & 1 & & 1 & & 32 \\
P_2 & & 1 & 1 & & 1 & & & 16 \\
P_4 & & 1 & 1 & & & & & 8 \\
P_6 & & 1 & & & 1 & & 1 & 4 \\
P_5 & & & 1 & & & & 1 & 2 \\
P_3 & & & & 1 & & 1 & & 1 \\
\hline
\text{DE} & 32 & 28 & 26 & 33 & 20 & 33 & 6 & \\
 & \text{③} & \text{④} & \text{⑤} & \text{①} & \text{⑥} & \text{②} & \text{⑦} &
\end{array}$$

$$\begin{array}{c|ccccccc|c}
 & 64 & 32 & 16 & 8 & 4 & 2 & 1 & \\
 & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & \\
\hline
P_1 & & 1 & 1 & & & & & 48 \\
P_2 & & & & 1 & 1 & 1 & & 12 \\
P_4 & & & & 1 & 1 & & & 10 \\
P_6 & & & & 1 & & 1 & 1 & 11 \\
P_5 & & & & & 1 & & 1 & 5 \\
P_3 & 1 & 1 & & & & & & 96
\end{array}$$

$$\begin{array}{c|ccccccc}
 & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 \\
\hline
P_3 & 1 & 1 & & & & & \\
P_1 & & 1 & 1 & & & & \\
P_2 & & & & 1 & 1 & 1 & \\
P_4 & & & & 1 & 1 & & \\
P_6 & & & & 1 & & 1 & 1 \\
P_5 & & & & & 1 & & 1
\end{array}$$

# Rank Order Clustering – Example 1

$$\begin{array}{lc|ccccccc|c}
 & & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & \\
\text{Binary weight} & & 64=2^6 & 32=2^5 & 16=2^4 & 8=2^3 & 4=2^2 & 2=2^1 & 1=2^{7-7}=2^0 & \text{Binary value} \\
 & P_1 & 1 & & & 1 & & 1 & & 74 \\
 & P_2 & & 1 & 1 & & 1 & & & 52 \\
[a_{ij}] = & P_3 & & & & 1 & & 1 & & 10 \\
 & P_4 & & 1 & 1 & & & & & 48 \\
 & P_5 & & & 1 & & & & 1 & 17 \\
 & P_6 & & 1 & & & 1 & & 1 & 37
\end{array}$$

→ D.E

Decimal Equivilant

$BW_j = 2^{m-j}$

$a_{ij} = 1$

ⓘ index for row

ⓙ index for column

ⓜ ※ of total machines

ⓝ ※ of part

$P_1$
$P_2$
$P_4$
$P_6$
$P_5$
$P_3$

$2^{\overset{7}{\textcircled{m}}-j}$

# Rank Order Clustering – Example 1

$$\begin{array}{ll|ccccccc|c}
 & & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & \\
\text{Binary value} & & 32 & 28 & 26 & 33 & 20 & 33 & 6 & \text{Binary weight} \\
\hline
 & P_1 & 1 & & & 1 & & 1 & & 32 \\
 & P_2 & & 1 & 1 & & 1 & & & 16 \\
[a_{ij}] = & P_4 & & 1 & 1 & & & & & 8 \\
 & P_6 & & 1 & & & 1 & & 1 & 4 \\
 & P_5 & & & 1 & & & & 1 & 2 \\
 & P_3 & & & & 1 & & 1 & & 1 \\
\hline
\end{array}$$

# Rank Order Clustering – Example 1

$$
\begin{array}{llccccccccc}
 & & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & & \\
\text{Binary weight} & & 64 & 32 & 16 & 8 & 4 & 2 & 1 & & \text{Binary value} \\
 & P_1 & 1 & 1 & 1 & & & & & & 112 \\
 & P_2 & & & & 1 & 1 & 1 & & & 14 \\
[a_{ij}] = & P_4 & & & & 1 & 1 & & & & 12 \\
 & P_6 & & & & 1 & & 1 & 1 & & 11 \\
 & P_5 & & & & & 1 & & 1 & & 5 \\
 & P_3 & 1 & 1 & & & & & & & 96
\end{array}
$$

# Rank Order Clustering – Example 1

وصلنا مرحلة ما فيها improvement

(ال Decimal equivilant للـ Row و ال column مرتبين جاهزين)

$$
[a_{ij}] = \begin{array}{c|ccc|cccc|c}
 & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & \\
\text{Binary value} & 48 & 48 & 32 & 14 & 12 & 10 & 3 & \text{Binary weight} \\
\hline
P_1 & 1 & 1 & 1 & & & & & 32 \\
P_3 & 1 & 1 & & & & & & 16 \\
\hline
P_2 & & & & 1 & 1 & 1 & & 8 \\
P_4 & & & & 1 & 1 & & & 4 \\
P_6 & & & & 1 & & 1 & 1 & 2 \\
P_5 & & & & & & & 1 & 1
\end{array}
$$

Cell (1) : { $M_1$, $M_4$, $M_6$ } responsible for producing $P_1$ , $P_3$

Cell (2) : { $M_1$, $M_2$, $M_3$, $M_5$, $M_7$ } responsible for producing $P_2$, $P_4$, $P_6$, $P_5$

# ROC Algorithm Solution – Example 1

$$\begin{array}{ll|ccc|cccc|c}
 & & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & \\
\text{Binary value} & & 48 & 48 & 32 & 14 & 12 & 10 & 3 & \text{Binary weight} \\
\cline{3-9}
 & P_1 & 1 & 1 & 1 & & & & & 32 \\
 & P_3 & 1 & 1 & & & & & & 16 \\
\cline{3-9}
[a_{ij}] = & P_2 & & & & 1 & 1 & 1 & & 8 \\
 & P_4 & & & & 1 & 1 & & & 4 \\
 & P_6 & & & & 1 & & 1 & 1 & 2 \\
 & P_5 & & & & & & & 1 & 1 \\
\cline{3-9}
\end{array}$$

# * Problem (3.22)

$$\begin{array}{c|cccc|}
 & 8 & 4 & 2 & 1 \\
\hline
6 & & 1 & 1 & \\
8 & 1 & & & \\
2 & & & 1 & \\
9 & 1 & & & 1
\end{array}$$

DE
6
8
2
9

$\downarrow$

$$\begin{array}{c|cccc|}
 & \overset{12}{M_1} & \overset{2}{M_2} & \overset{3}{M_3} & \overset{8}{M_4} \\
\hline
P_4 & 1 & & & 1 \\
P_2 & 1 & & & \\
P_1 & & 1 & 1 & \\
P_3 & & & 1 &
\end{array}$$

$2^3 = 8$
$2^2 = 4$
$2^1 = 2$
$2^0 = 1$

$P_1 = M_2 \, M_3$
$P_2 = M_1$
$P_3 = M_3$
$P_4 = M_1, M_4$

$\downarrow$

ناقص

$$\begin{bmatrix} & \\ & \end{bmatrix}$$

Cell (1) : $\{M_1 \; M_4\} \longrightarrow P_2 , P_4$
Cell (2) : $\{M_2 , M_3\} \longrightarrow P_1 , P_3$

Method 3

# Cluster Identification algorithm

1. Select any row and cross it
2. For each crossed 1 make a vertical line
3. For each crossed 1 make a horizontal line
4. Repeat until all the 1s are crossed by a vertical line or by a horizontal line
5. Form a cell from all the machines and components which were crossed
6. Remove all the crossed elements (machines and components) and start again

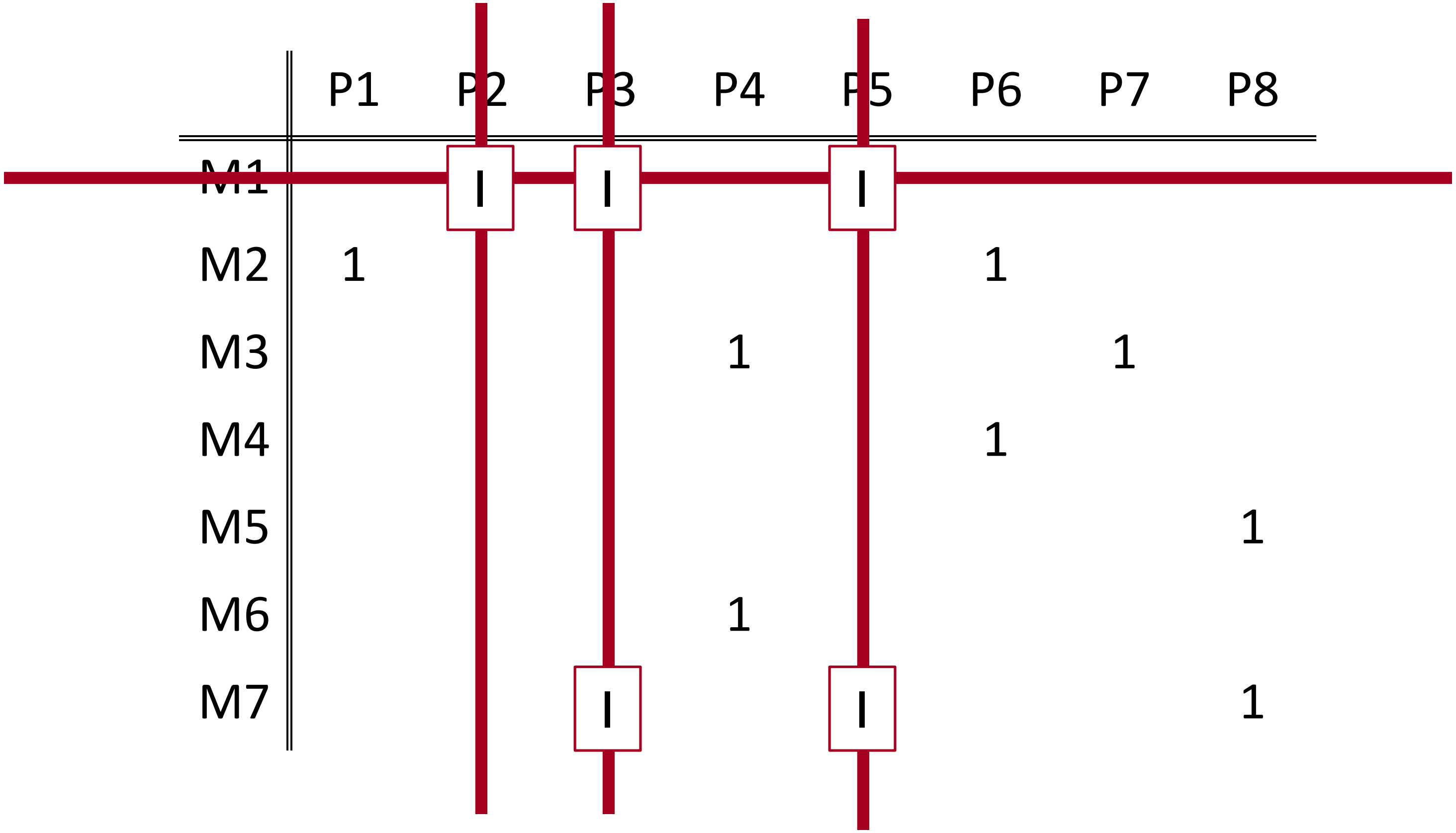
# Cluster Identification algorithm

1. Select any row and cross it

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|
| ~~M1~~ | | $\boxed{1}$ | $\boxed{1}$ | | $\boxed{1}$ | | | |
| M2 | 1 | | | | | 1 | | |
| M3 | | | | 1 | | | 1 | |
| M4 | | | | | | 1 | | |
| M5 | | | | | | | | 1 |
| M6 | | | | 1 | | | | |
| M7 | | | 1 | | 1 | | | 1 |

# Cluster Identification algorithm

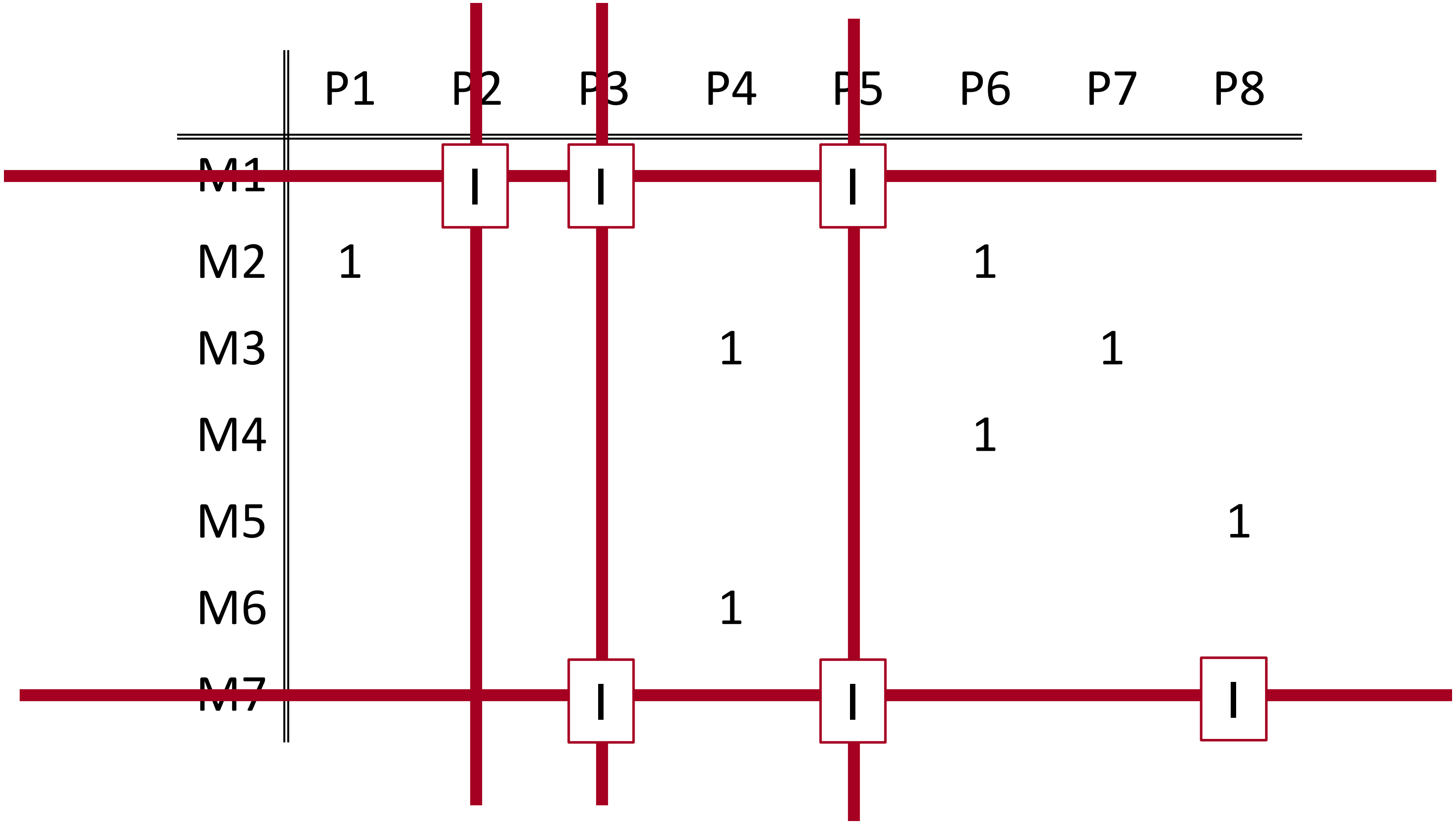
2. For each crossed 1 make a vertical line



| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|
| M1 | | 1 | 1 | | 1 | | | |
| M2 | 1 | | | | | 1 | | |
| M3 | | | | 1 | | | 1 | |
| M4 | | | | | | 1 | | |
| M5 | | | | | | | | 1 |
| M6 | | | | 1 | | | | |
| M7 | | | 1 | | 1 | | | 1 |

# Cluster Identification algorithm

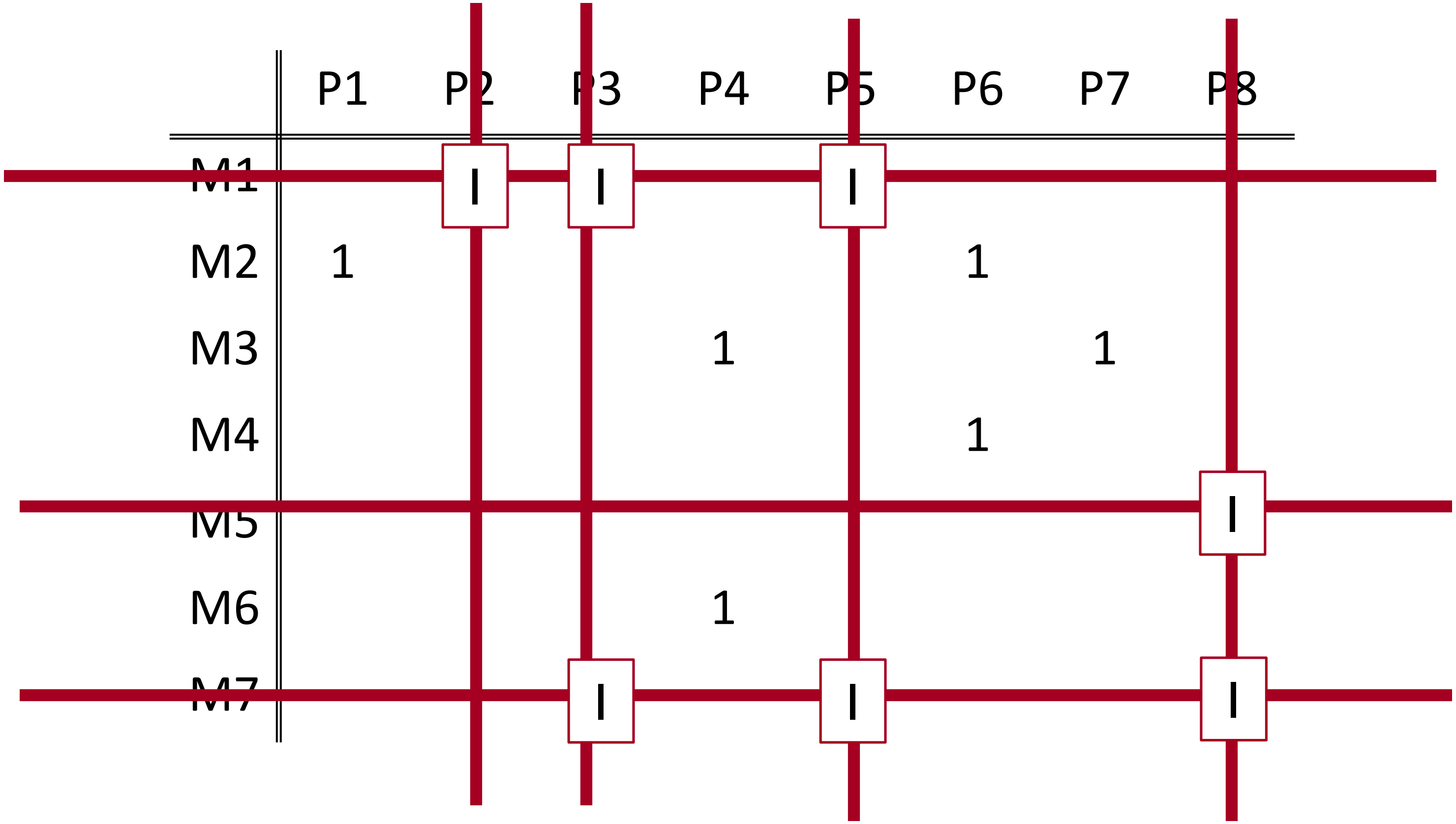
3. For each crossed 1 make a horizontal line



| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|
| M1 | | I | I | | I | | | |
| M2 | 1 | | | | | 1 | | |
| M3 | | | | 1 | | | 1 | |
| M4 | | | | | | 1 | | |
| M5 | | | | | | | | 1 |
| M6 | | | | 1 | | | | |
| M7 | | | I | | I | | | I |

# Cluster Identification algorithm

4. Repeat until all the 1s are crossed by a vertical line or by a horizontal line



| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|
| M1 | | I | I | | I | | | |
| M2 | 1 | | | | | 1 | | |
| M3 | | | | 1 | | | 1 | |
| M4 | | | | | | 1 | | |
| M5 | | | | | | | | I |
| M6 | | | | 1 | | | | |
| M7 | | | I | | I | | | I |

# Cluster Identification algorithm

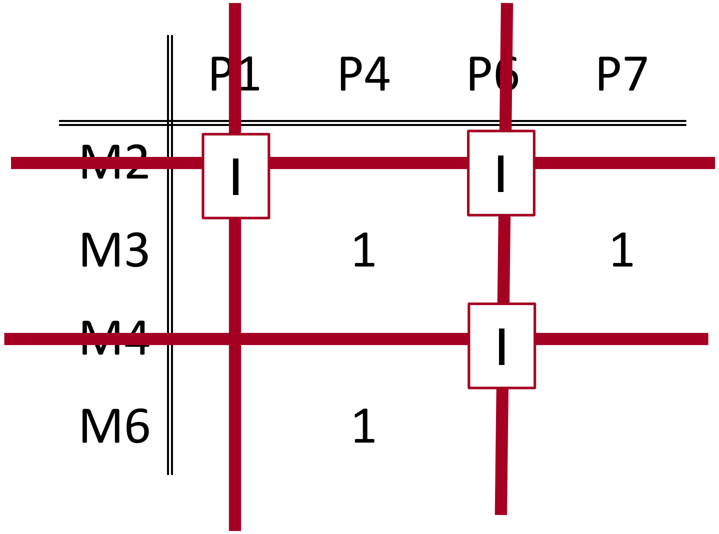
5. Form a cell from all the machines and components which were crossed

| | | P2 | P3 | | P5 | | | P8 |
|---|---|---|---|---|---|---|---|---|
| **M1** | | 1 | 1 | | 1 | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| **M5** | | | | | | | | 1 |
| | | | | | | | | |
| **M7** | | | 1 | | 1 | | | 1 |

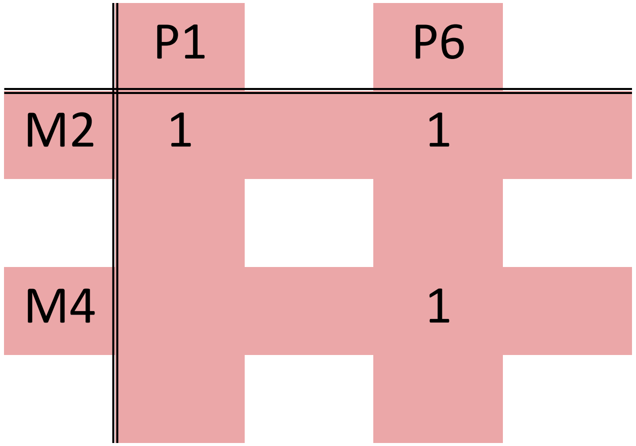
First cell is identified!
Cell #1 will produce parts P2, P3, P5 and P8 with Machines M1, M5 and M7

# Cluster Identification algorithm

6. Remove all the crossed elements (machines and components) and start again



|  | P1 | P4 | P6 | P7 |
|---|---|---|---|---|
| M2 | I |  | I |  |
| M3 |  | 1 |  | 1 |
| M4 |  |  | I |  |
| M6 |  | 1 |  |  |

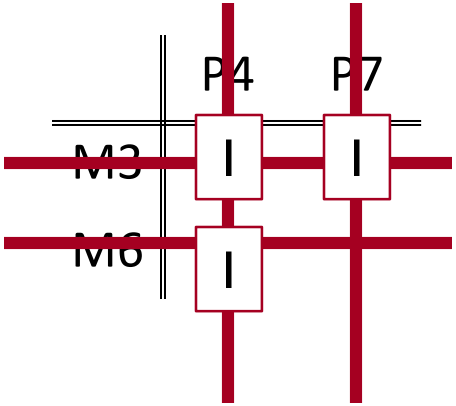


|  | P1 | P6 |
|---|---|---|
| M2 | 1 | 1 |
| M4 |  | 1 |

Cell #2 will produce parts P1 and P6 with Machines M2 and M4

# Cluster Identification algorithm

6. Remove all the crossed elements (machines and components) and start again

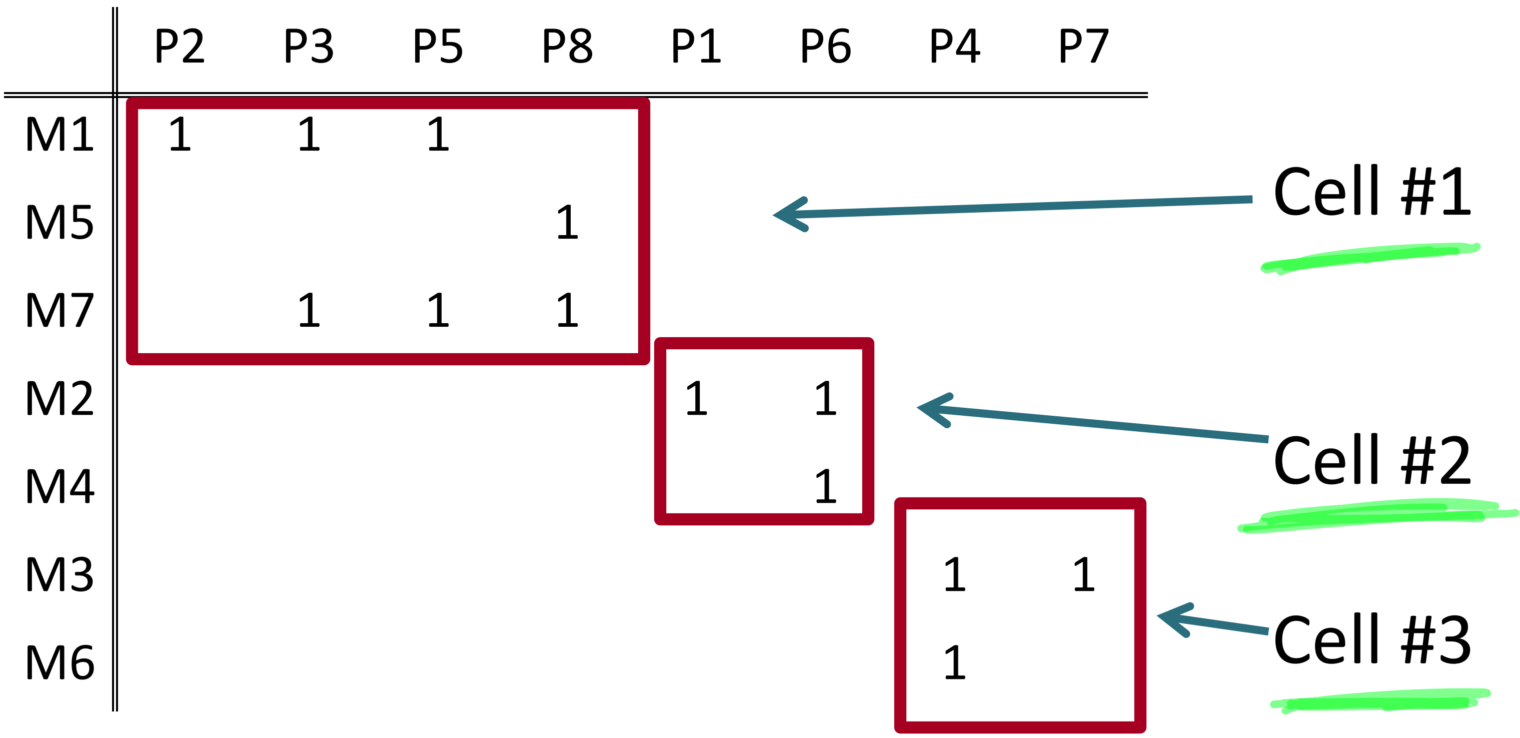


| | P4 | P7 |
|---|---|---|
| M3 | 1 | 1 |
| M6 | 1 | |

Cell #3 will produce parts P4 and P7 with Machines M3 and M6

# Cluster Identification algorithm

- Three resulting cells:

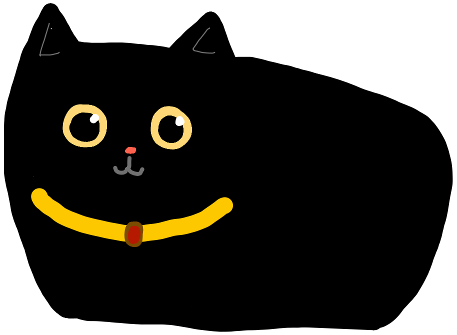


| | P2 | P3 | P5 | P8 | P1 | P6 | P4 | P7 |
|---|---|---|---|---|---|---|---|---|
| M1 | 1 | 1 | 1 | | | | | |
| M5 | | | | 1 | | | | |
| M7 | | 1 | 1 | 1 | | | | |
| M2 | | | | | 1 | 1 | | |
| M4 | | | | | | 1 | | |
| M3 | | | | | | | 1 | 1 |
| M6 | | | | | | | 1 | |

Cell #1

Cell #2

Cell #3



Continue (Chapter 3) …

# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

- The design of the cellular manufacturing system can be *Decoupled cells* *or* *Integrated cells* :

1. **Decoupled cells**: 💬

كلياً منفصلة عن الباقي

   - uses a storage area to store parts after the cell has finished with them
   - that acts as a decoupler (making the cells and departments independent of each other).
   - If another cell needs them, it would retrieve them from there.
   - This lead to excessive material handling and poor responsiveness.

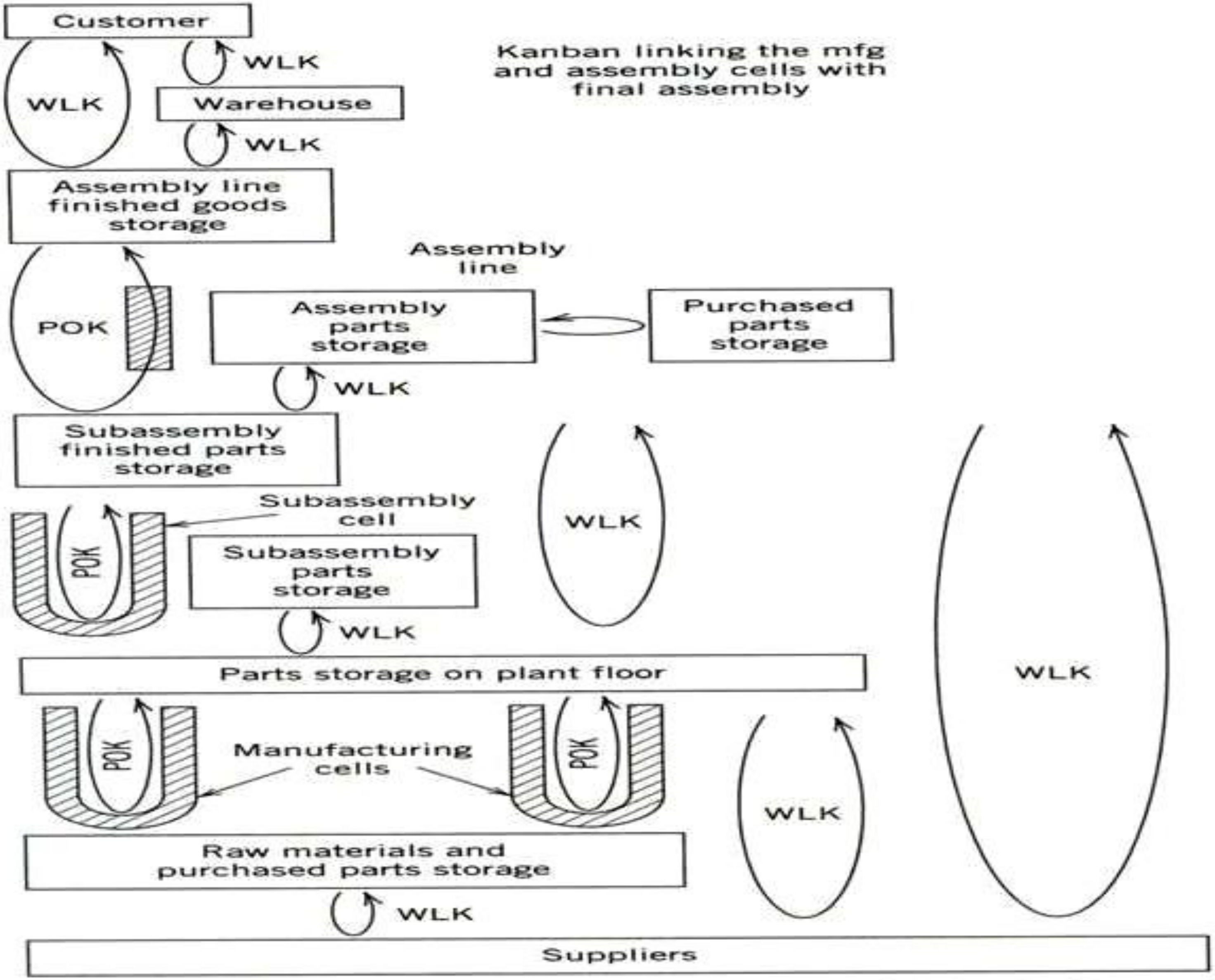
# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

2. **Integrated cells**:
   - Cells and departments are linked through the use of Kanbans or cards.

     signal

   - **Production cards (POK)**: to authorize production of more components or subassemblies.
   - **Withdrawal cards (WLK)**: to authorize delivery of more components, subassemblies, or raw materials.

- Kanban:
  - means “signal” and commonly uses cards to signal the supplying workstation that is consuming workstation requests more parts


Customer
WLK
WLK
Kanban linking the mfg and assembly cells with final assembly
Warehouse
WLK
Assembly line finished goods storage
Assembly line
POK
Assembly parts storage
Purchased parts storage
WLK
Subassembly finished parts storage
WLK
WLK
Subassembly cell
POK
Subassembly parts storage
WLK
Parts storage on plant floor
POK
Manufacturing cells
POK
WLK
Raw materials and purchased parts storage
WLK
Suppliers

POK: Production card
WLK: Withdrawal card

**Figure 3.15** Integrated ~~cellular manufacturing~~ system.

# Product Family Departments
## Manufacturing cells (Group Technology) (contd.)

- In general there are two types of production control systems:

1. "Push" production control system:
   - When workstation completes its set of operations, it pushes its finished parts to next workstation. If the supplying workstation operates faster than consuming workstation, parts will begin to build up.
2. "Pull" production control system:
   - Supplying workstation did not produce any parts until its consuming workstation requested parts. This system called Kanban which means signal.

نستخدمها أكثر في الـ Pull

- The final step is the layout of each cell:

U-shaped arrangement of workstations significantly enhance visibility.

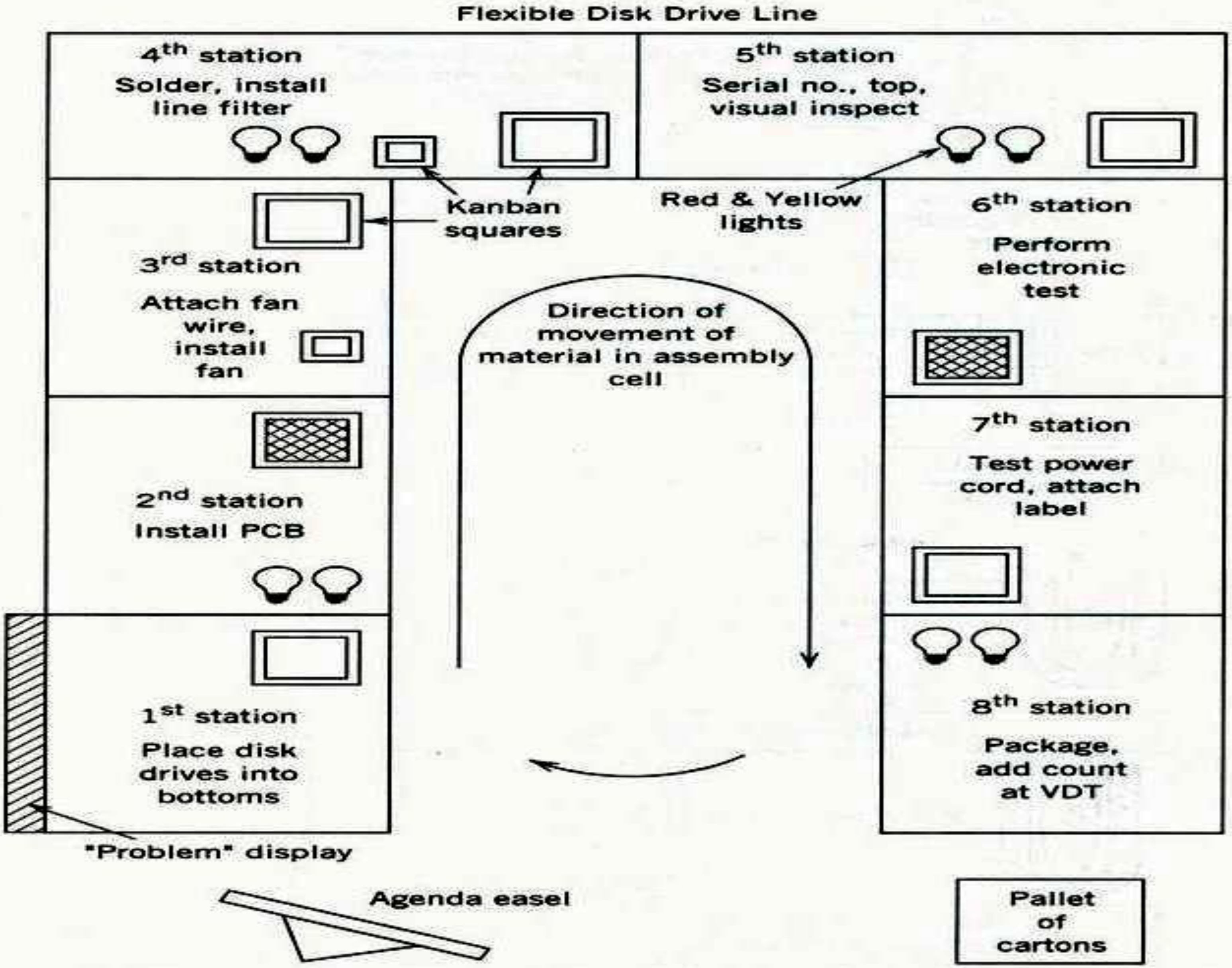


**Figure 3.16** An assembly cell for disk drives, designed by workers at Hewlett-Packard, Greely Division.

# Activity Relationships

+

Space Requirement

و بتخلص ال chapter

# Activity Relationships

Five main types:

- Organizational relationships – influenced by span of control and reporting relationships.
- Flow relationships – including the flow of material, people, equipment, information, and money. أهم نقطة ←
- Control relationships – level of automation, centralized vs. decentralized material control.
- Environment relationships – including safety considerations like temp, noise, humidity, and dust.
- Other process relationships - such as floor loading, water required by machines, etc.

# Measuring Flow

- Measuring flow is very important in evaluating alternative arrangement of departments within a facility.

- Quantitative: If large volumes of materials, information, and people moving between departments.

- Qualitative: If not a lot of physical movement between departments, but significant communication or organizational relationships.

# Measuring Flow

- Quantitative flow measurement:
- **Mileage chart:**
  - distance between departments
  - Note the diagonal values are zero
  - Not necessarily symmetric: one way aisles, different entry and exit points in the department.
  - Measures of distance
    - Euclidean, Squared Euclidean, Rectilinear, Aisle Distance, Adjacency, Shortest path
  - We will discuss them in detail later.

AB ≠ BA

| | A | B | C |
|---|---|---|---|
| A | | 12 | 18 |
| B | 6 | | 6 |
| C | 18 | 14 | |

Example of Mileage chart

# Measuring Flow

- Quantitative flow measurement:
- **From-to chart:**
  - Flow between departments. AB = BA
  - does not have to be symmetric (Example: No definite reason for the flows from stores to milling to be the same as the flows from milling to stores)

| To / From | A | B | C |
|---|---|---|---|
| A | | 420 | 125 |
| B | 60 | | 350 |
| C | 75 | 25 | |

ما في flow
من ال departement
إلى نفسه

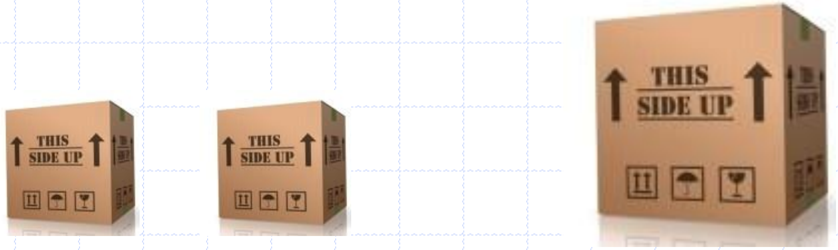
# Measuring Flow

- A From-to chart is constructed as follows:

1. List departments in logical sequence.
2. Establish a measure of flow for the facility that accurately indicates equivalent flow volumes. (Some common unit of measure).
3. Based on the flow paths for the items to be moved and the established measure of flow, record the flow volumes on the from-to chart.

# Measuring Flow

1) x
2) x
3) 2x



- Example:

  A firm produces three products, 1, 2, and 3. Product 1 and 2 are of the same size and weight, while product 3 is twice as the size of products 1 and 2 and requires twice effort to move it.
  - The departments include five departments A, B, C, D and E.
  - The overall quantities to be produce daily and routes are
  - Product 1 : 30; A →C → B →D →E
  - Product 2 : 12; A → B → D → E
  - Product 3 : 7; A → C → D →B →E
- Construct the from –to matrix.

# Measuring Flow

- Example (contd.). From-to matrix

| To<br>From | A | B | C | D | E |
|---|---|---|---|---|---|
| A | | 12 | 30+2*7=44<br>twice the size | 0 | 0 |
| B | 0 | | 0 | 30+12=42 | 2*7=14 |
| C | 0 | 30 | | 2*7=14 | 0 |
| D | 0 | 14 ~~0~~ | 0 | | 30+12=42 |
| E | 0 | 0 | 0 | 0 | |

ممكن يكون storing departement

# Measuring Flow

- Qualitative flow measurement:
- **Relationship chart:**
  - Determine the relative importance of different departments being close to each other.
  - 6 Closeness Relationship Values:

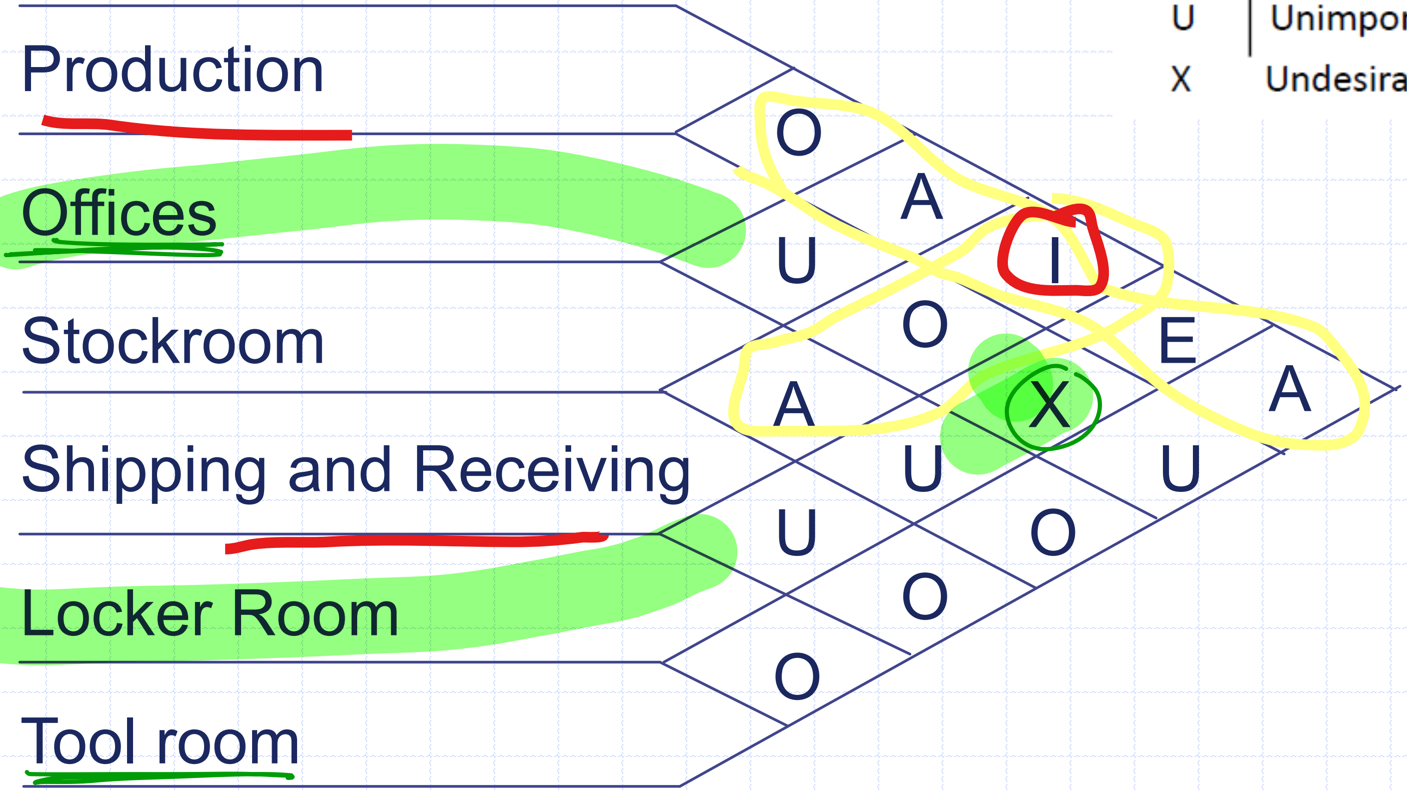
A - Absolutely necessary
E - Especially important
I - Important
O - Ordinary Closeness okay → يعني ما بيفرق اذا قرّاب او بعاد
U - Unimportant
غير مرغوب فيه
X - Undesirable

مطلوب حفظهم

# Measuring Flow

| Rating | Definition |
|---|---|
| A | Absolutely Necessary |
| E | Especially Important |
| I | Important |
| O | Ordinary Closeness |
| U | Unimportant |
| X | Undesirable |

## Example of Relationship chart:



# Measuring Flow

- To construct the Relationship chart:

1. List all the departments.
2. Get closeness information. How to get this information.
3. Define the criteria for assigning closeness values and itemize and record this information on the chart. (example: frequency of use high, medium, low)
4. Get feedback from sources of information.

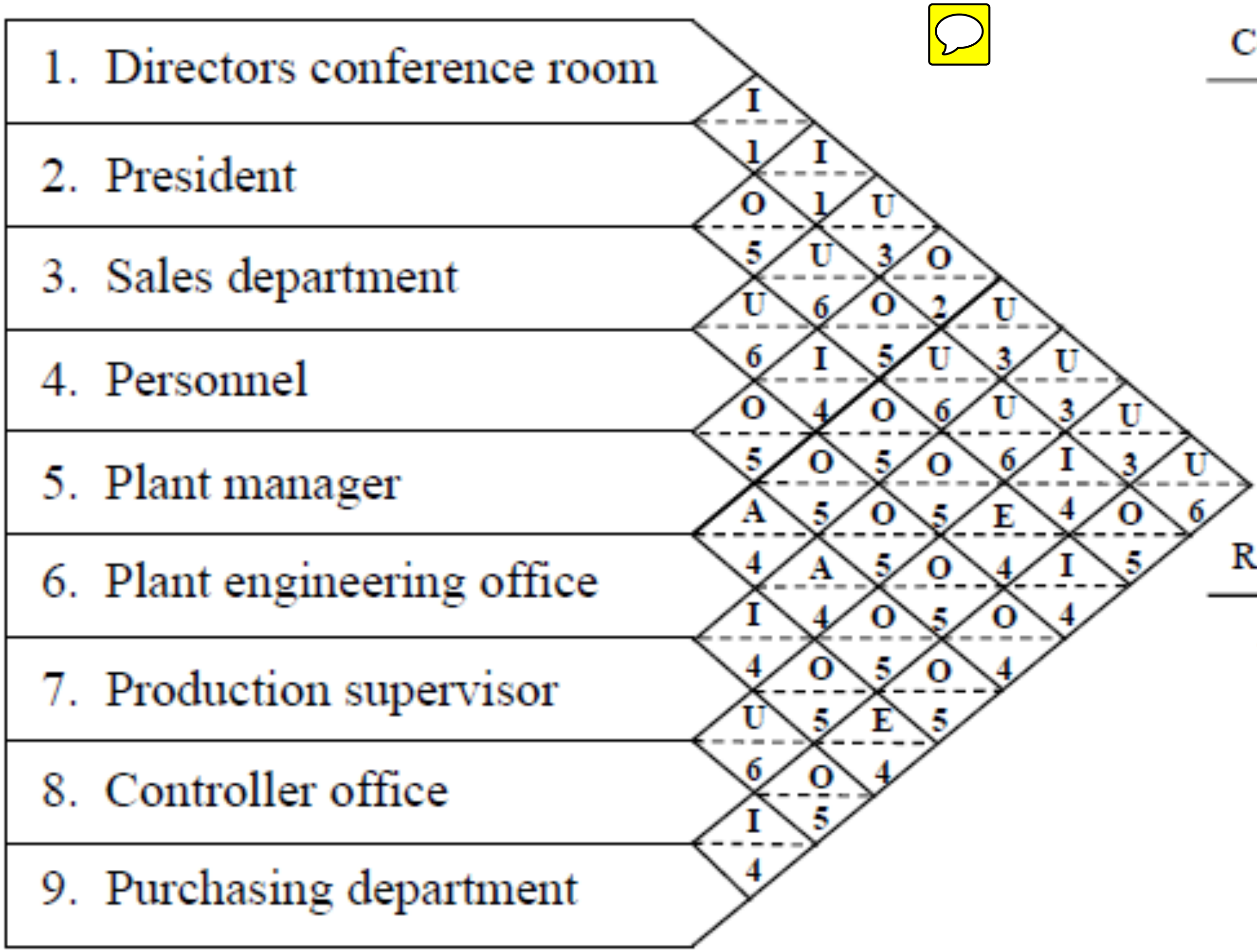
Avoid too many A's and X's.

# Relationship Chart may include the closeness values in conjunction with reasons for the value

# of departments → 9

# of cells → $\frac{9 \times 8}{2} = 36$

$$\boxed{\frac{n(n-1)}{2}}$$



| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1. Directors conference room | I / 1 | I / 1 | U / 3 | O / 2 | U / 3 | U / 3 | U / 3 | U / 6 |
| 2. President | | O / 5 | U / 6 | O / 5 | U / 6 | U / 6 | I / 4 | O / 5 |
| 3. Sales department | | | U / 6 | I / 4 | O / 5 | O / 5 | E / 4 | I / 4 |
| 4. Personnel | | | | O / 5 | O / 5 | O / 5 | O / 5 | O / 4 |
| 5. Plant manager | | | | | A / 4 | A / 4 | O / 5 | O / 5 |
| 6. Plant engineering office | | | | | | I / 4 | O / 5 | E / 4 |
| 7. Production supervisor | | | | | | | U / 6 | O / 5 |
| 8. Controller office | | | | | | | | I / 4 |
| 9. Purchasing department | | | | | | | | |

| 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 |

| Rating | Definition |
|---|---|
| A | Absolutely Necessary → 1,4 |
| E | Especially Important |
| I | Important |
| O | Ordinary Closeness |
| U | Unimportant |
| X | Undesirable |

→ 3,6

# Converting From-to chart to Relationship chart

*حل ما في gap
يتغير الرمز

تشبه تحويل العلامات إلى رموز

## From-To Chart

الأفضل بالبداية نسوي
Matrix in
one direction

| | Stores | Milling | Turning | Press | Plate | Assembly | Warehouse |
|---|---|---|---|---|---|---|---|
| Stores | – | 24 | 12 | 16 | 1 | 8 | – |
| Milling | – | – | – | – | 14 | 3 | 1 |
| Turning | – | 3 | – | – | 8 | – | 1 |
| Press | – | – | – | – | 3 | 1 | 1 |
| Plate | – | 3 | 2 | – | – | 4 | 3 |
| Assembly | 2 | – | – | – | – | – | 7 |
| Warehouse | – | – | – | – | – | – | – |

A
E
I
O
U
X

## Frequency table

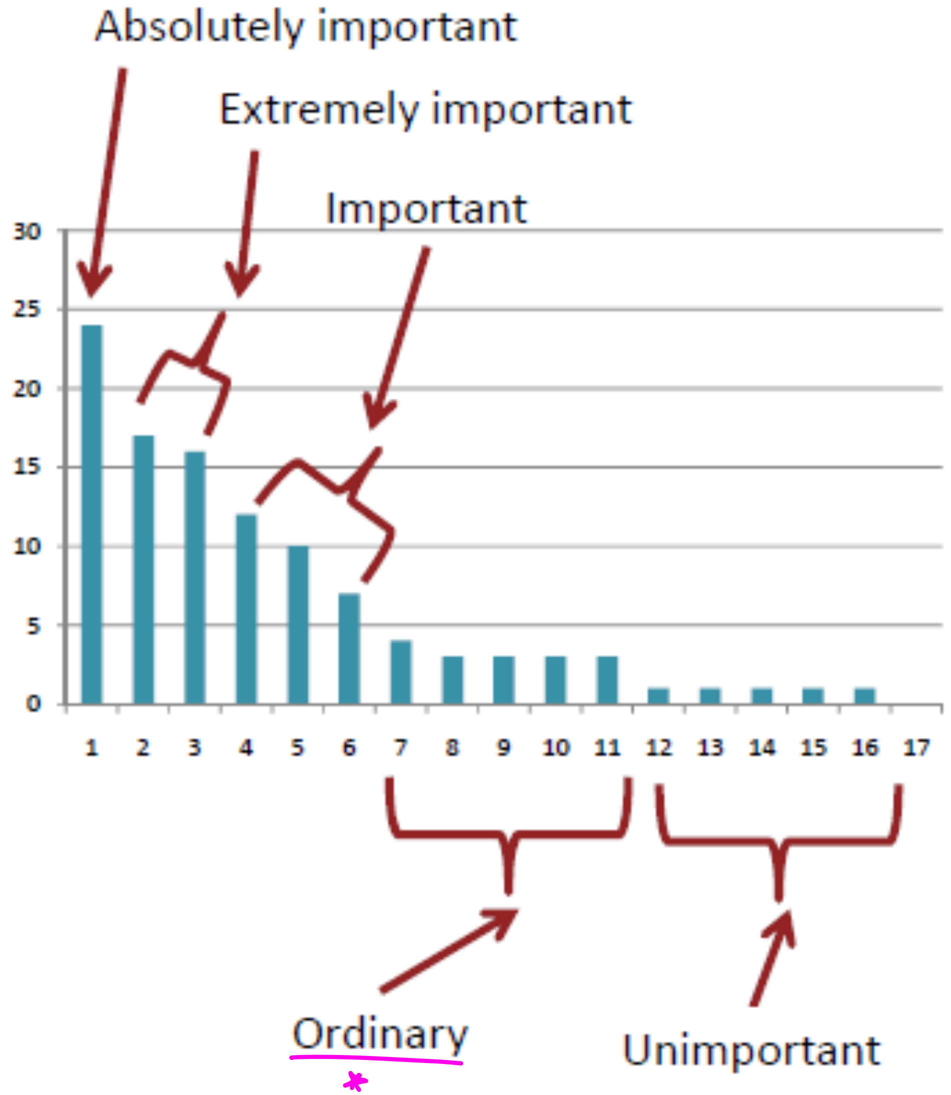
in Decreasing order

| | *Departments* | *Frequency* | |
|---|---|---|---|
| 1 | Stores-Milling | 24 | A |
| 2 | Milling Plate | 14+3=17 | E |
| 3 | Stores-Press | 16 | |
| 4 | Stores-Turning | 12 | I |
| 5 | Stores-Assembly | 8+2=10 | |
| 6 | Turning-Plate | 8+2=10 | |
| 7 | Assembly-Warehouse | 7 | O |
| 8 | Plate-Assembly | 4 | U |
| 9 | Milling-Assembly | 3 | |
| 10 | Turning- Milling | 3 | |
| 11 | Press-Plate | 3 | |
| 12 | Plate-Warehouse | 3 | |
| 13 | Stores-Plate | 1 | X |
| 14 | Milling -Warehouse | 1 | |
| 15 | Turning-Warehouse | 1 | |
| 16 | Press-Assembly | 1 | |
| 17 | Press-Warehouse | 1 | |

# Converting From-to chart to Relationship chart

## Frequency table

| | *Departments* | *Frequency* |
|---|---|---|
| 1 | Stores-Milling | 24 |
| 2 | Milling-Plate | 14+3=17 |
| 3 | Stores-Press | 16 |
| 4 | Stores-Turning | 12 |
| 5 | Stores-Assembly | 8+2=10 |
| 6 | Turning-Plate | 8+2=10 |
| 7 | Assembly-Warehouse | 7 |
| 8 | Plate-Assembly | 4 |
| 9 | Milling-Assembly | 3 |
| 10 | Turning- Milling | 3 |
| 11 | Press-Plate | 3 |
| 12 | Plate-Warehouse | 3 |
| 13 | Stores-Plate | 1 |
| 14 | Milling -Warehouse | 1 |
| 15 | Turning-Warehouse | 1 |
| 16 | Press-Assembly | 1 |
| 17 | Press-Warehouse | 1 |



Absolutely important

Extremely important

Important

Ordinary

Unimportant

# Space Requirements

# Space Requirements

- The amount of space required in the facility is difficult to estimate because:

أشياء مو متأكدين منها ←

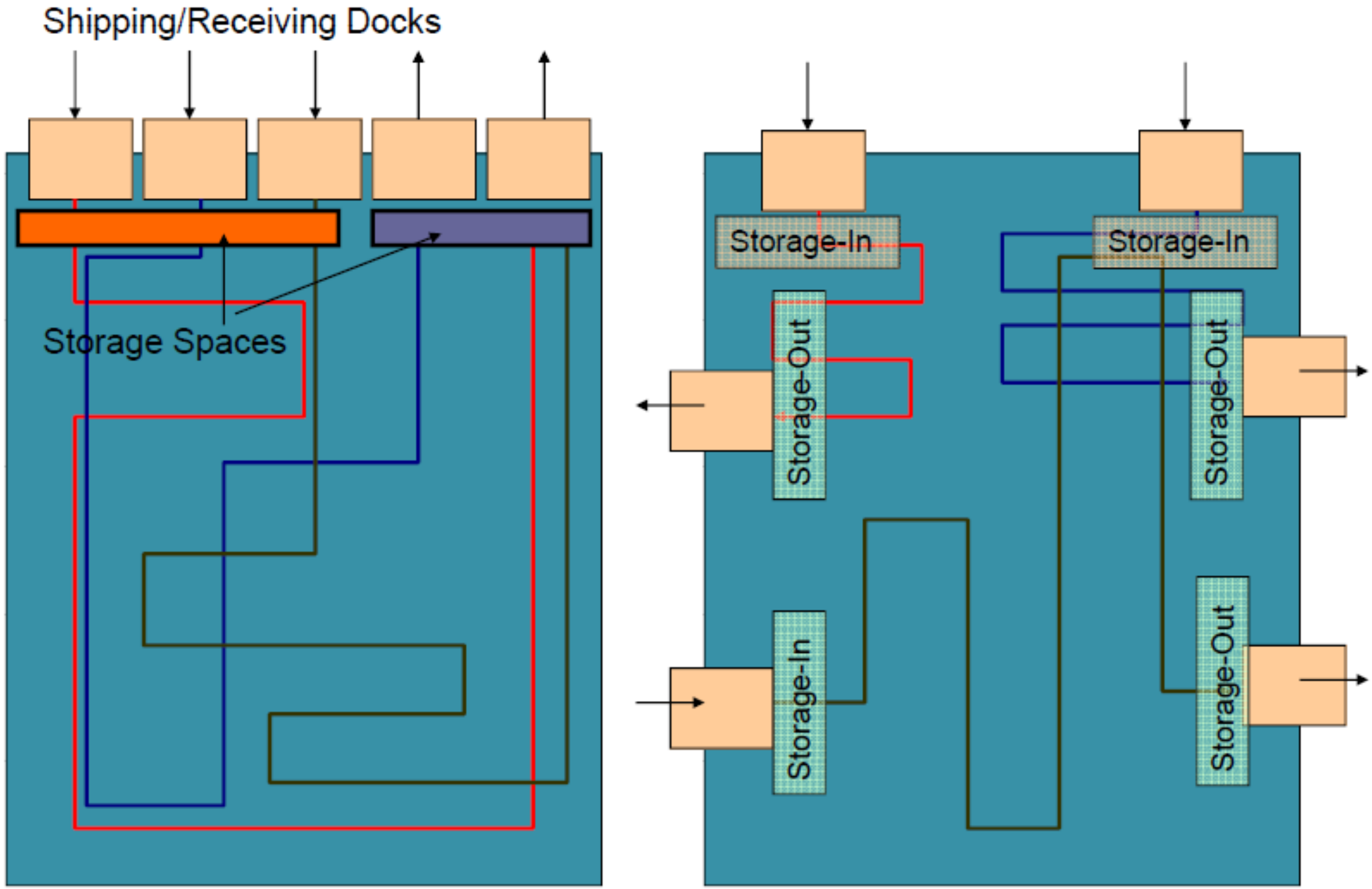
1. **Uncertainty**: change in demand, change in product mix, new technology, new methods.
2. Department managers tend to overstate their needs.
3. **Parkinson's Law**: Department expands to fill up its space.

# Space Requirements (contd.)

- Modern Manufacturing methods are reducing space requirements:
  - Product are delivered to point of use in small batches.
  - Decentralized storage.
  - Less inventory (products are pulled with Kanbans).
  - More efficient layout arrangements (manufacturing cells).
  - Quality control at the source
  - Companies are downsizing (leaner organizations, focused factories, outsourcing, etc.)
  - Offices are shared

For **manufacturing**: Start with the **workstations**, then **departments**

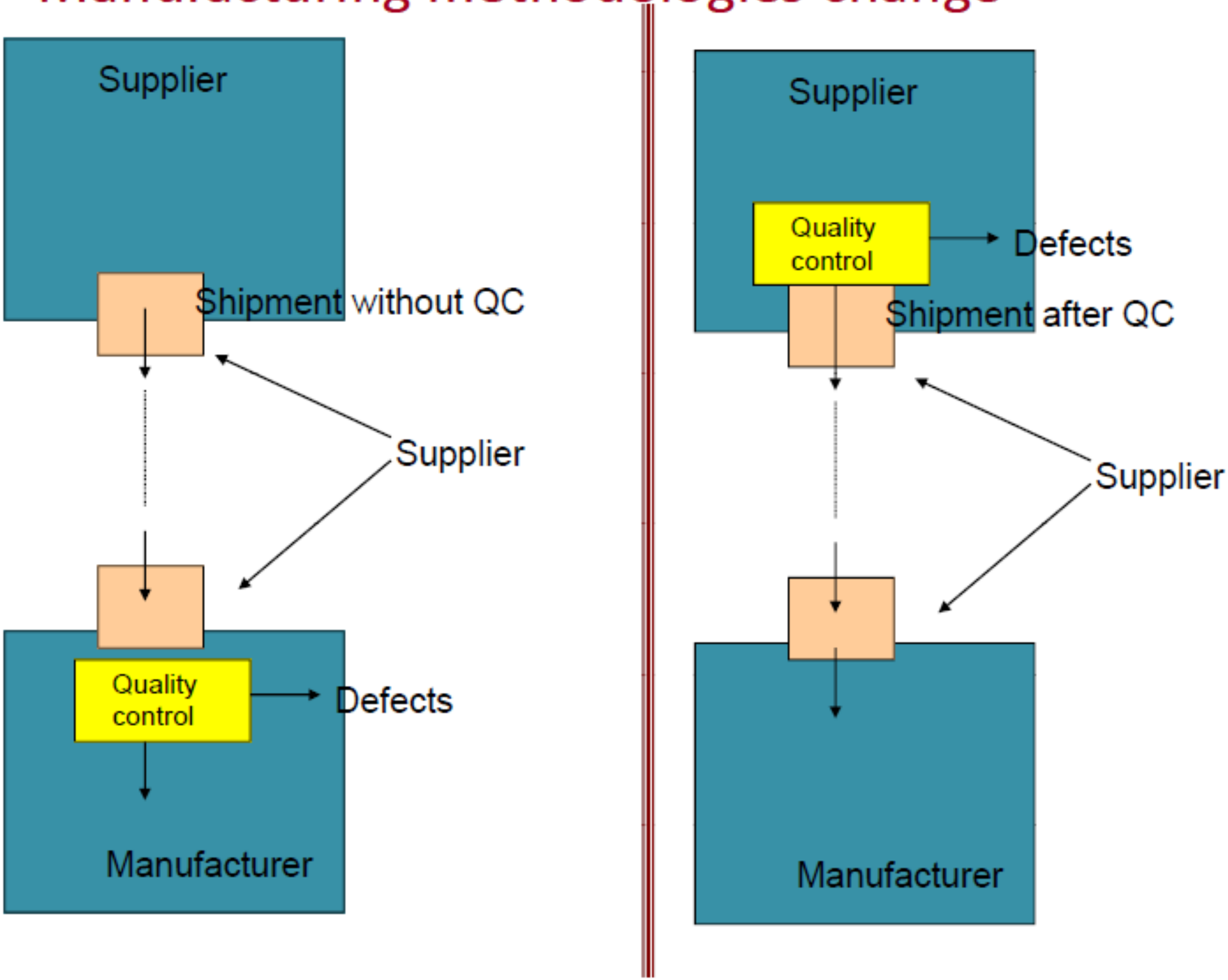
# Manufacturing methodologies change



Shipping/Receiving Docks

Storage Spaces

# Manufacturing methodologies change



Supplier

Shipment without QC

Supplier

Quality control

Defects

Manufacturer

Supplier

Quality control

Defects

Shipment after QC

Supplier

Manufacturer

# Space Requirements
## Workstation Specification

- Three components: Equipment, materials, personnel:
- **Equipment:**
  - Footprint of machines (machinery data sheets)
  - Machine travel (all directions)
  - Machine Maintenance
  - Plant services

- **Materials:**
  - Receiving area (and storing inbound materials)
  - Holding In-process materials (WIP)
  - Storing outbound materials
  - Waste and scrap
  - Tools, Fixtures, jigs, dies, and maintenance materials.

# Space Requirements
## Workstation Specification

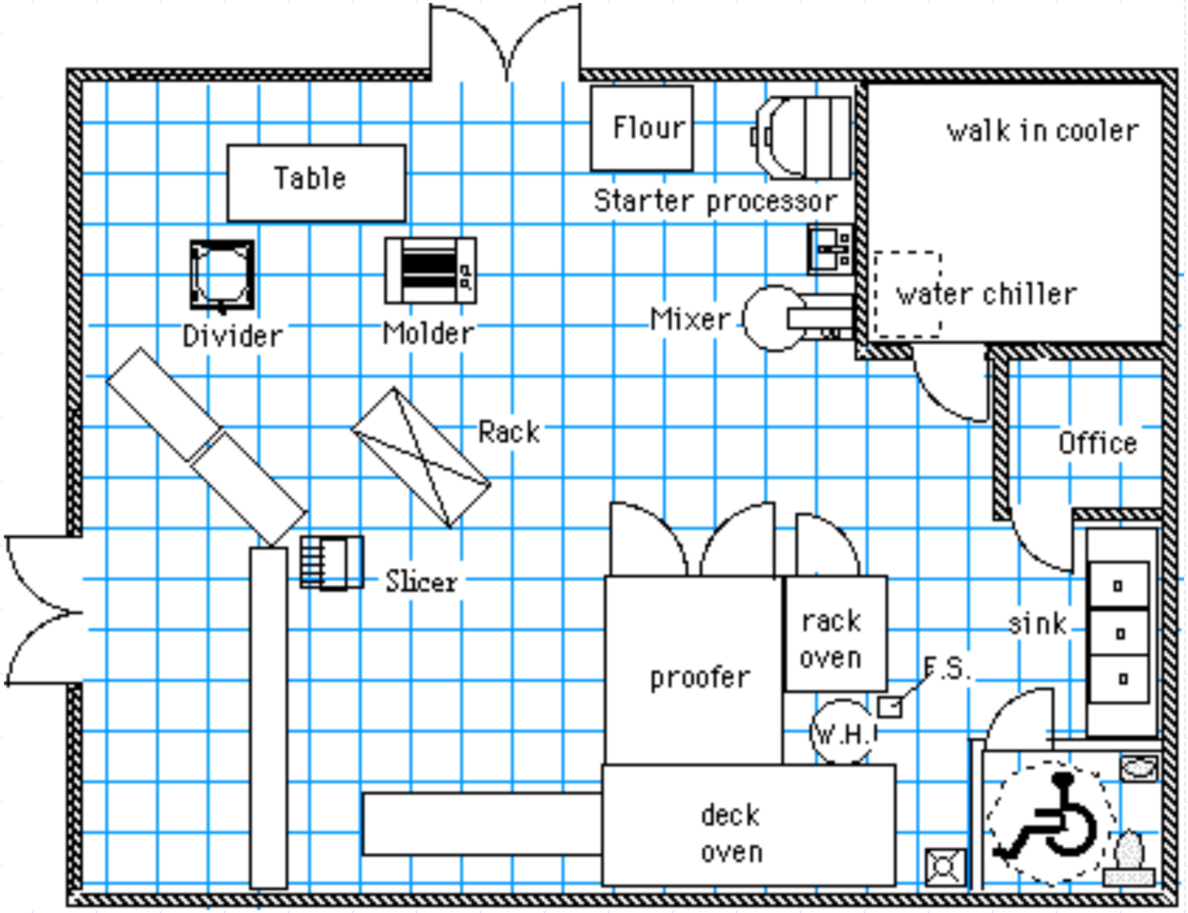
- **Personnel:**
  - The operator
  - Material handling
  - Operator ingress and egress

- For the first two points consider ergonomic principles:
  - No long reaches
  - Minimize manual handling
  - Safety
- For operator ingress and egress:
  - Min 30 inch aisle if two stationary objects.
  - Min 36 inch aisle if one stationary and one working machine.
  - Min 42 inch aisle if two working machines.

Usually a good idea to simulate operator tasks to verify the validity of estimates.

# Space Requirements
## Department Specification

- Departmental area requirements are not simply the sum of the areas of the individual workstations.



Bakery – Production department

# Space Requirements
## Department Specification

- Some areas can be shared between workstations:
    - tools, housekeeping items, storage areas, operators, Kanban boards, etc.

work in process

- Additional space is required for material handling, WIP buffers, storage cabinets, office areas, visual displays, aisles, etc.

- For both workstation and department often end up with a range on space estimates. (allowance factor)

# Space Requirements
## Aisle Specification

Right Angle → 90°

Two types:
  - Main – this is the current focus
  - Departmental (Aisle allowance estimate – see table 3.4)
- Want the aisle to promote effective flow
- How wide depends on how big the moving things. See table 3.5 in the book for examples.
- Do people and material need to be pass at the same time. Two way flow?
- Minimize curves, non-right angle intersections, and dead ends.
- Aisles should lead to doors if possible.
- Be certain to note where columns are located so that they are not located in the aisles.

# Table 3.4

مو حفظ

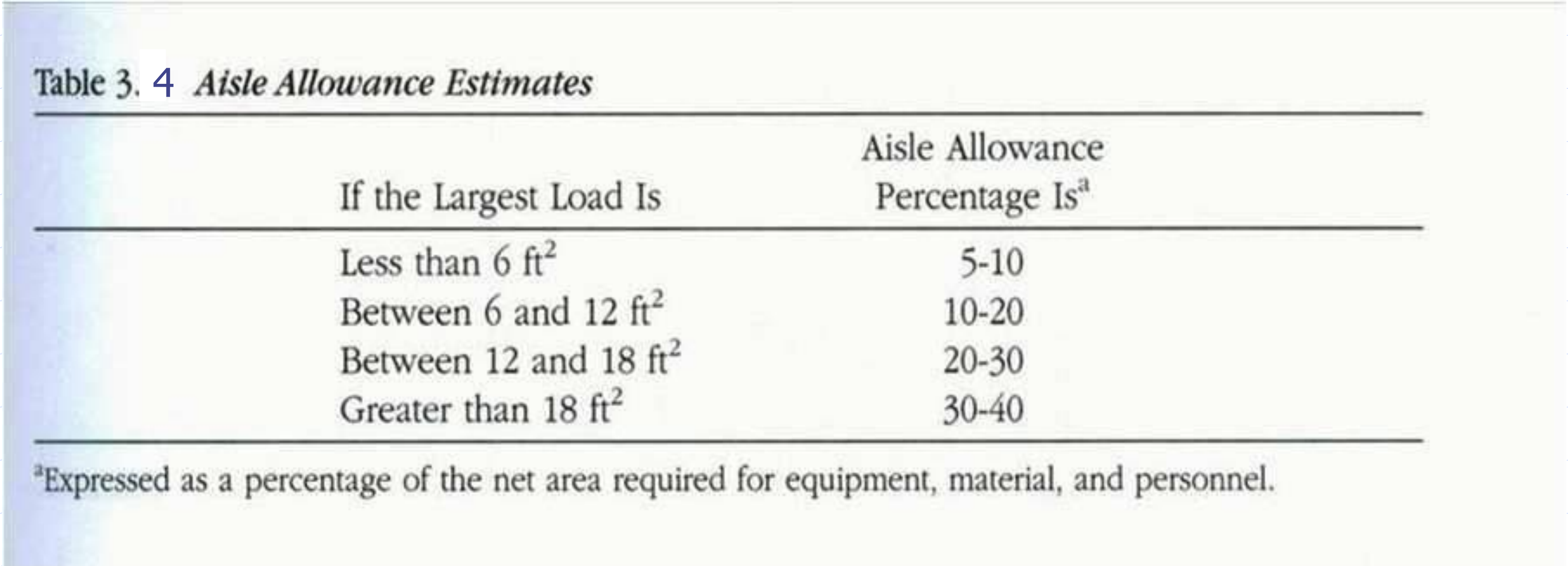


Table 3. 4 *Aisle Allowance Estimates*

| If the Largest Load Is | Aisle Allowance Percentage Is[a] |
|---|---|
| Less than 6 $\text{ft}^2$ | 5-10 |
| Between 6 and 12 $\text{ft}^2$ | 10-20 |
| Between 12 and 18 $\text{ft}^2$ | 20-30 |
| Greater than 18 $\text{ft}^2$ | 30-40 |

[a] Expressed as a percentage of the net area required for equipment, material, and personnel.

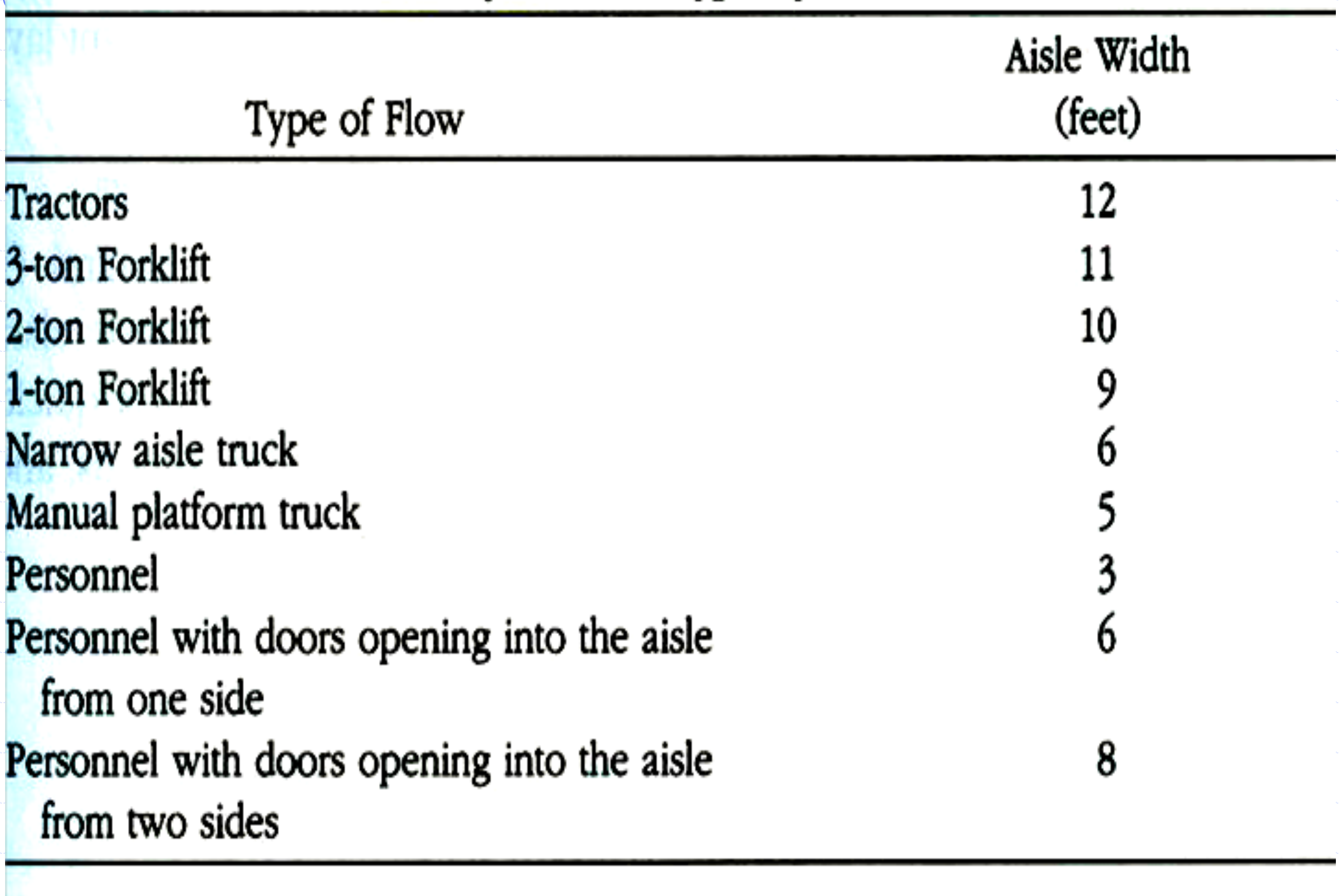
Page 72

بالعادة المعلومات يلي بال tables
ليست حفظ

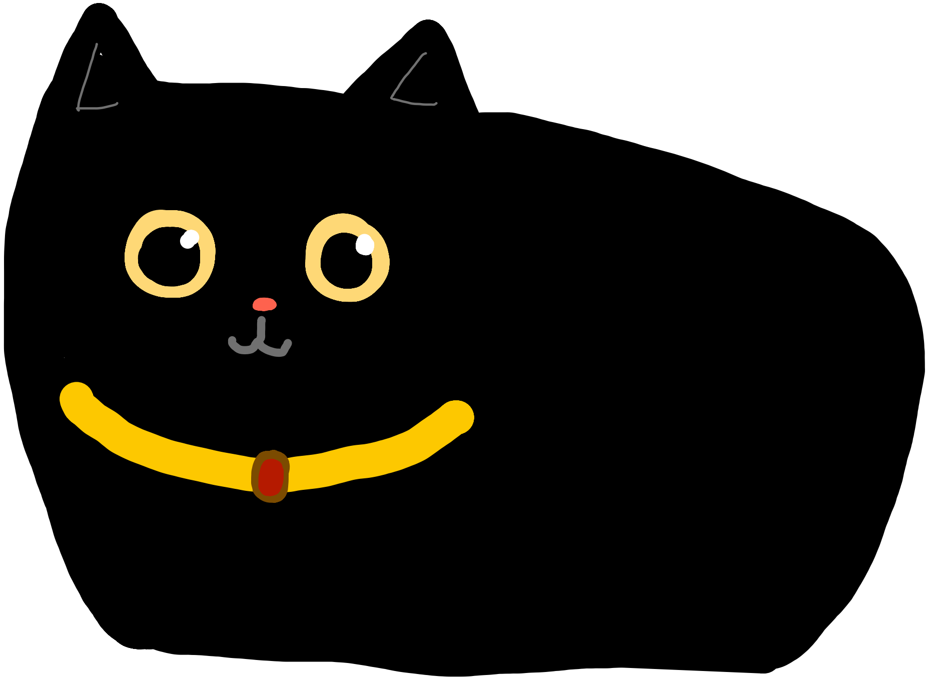
# Table 3.5

مو حفظ

***Recommended Aisle Widths for Various Types of Flow***



| Type of Flow | Aisle Width (feet) |
|---|---|
| Tractors | 12 |
| 3-ton Forklift | 11 |
| 2-ton Forklift | 10 |
| 1-ton Forklift | 9 |
| Narrow aisle truck | 6 |
| Manual platform truck | 5 |
| Personnel | 3 |
| Personnel with doors opening into the aisle from one side | 6 |
| Personnel with doors opening into the aisle from two sides | 8 |



ملخص قوي للمادة

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+

آخر صفحتين في الملف مكتوب فيهم اسئلة امتحان
الفاينل للفصل الثاني ٢٠٢٣/٢٠٢٤

# Chapter 4

# Personnel Requirements

# Introduction

- How much **space** to allocate for **personnel** can be dictated by the corporation **philosophy** concerning employees.

- **Examples** include:

1. "Employees spend one third of their life within our facility; we must help them enjoy working here"
2. "A happy worker is a productive worker"
3. "Personnel considerations are of little importance in our facility. We pay people to work, not to have a good time".
4. Etc.

# The Employee-Facility Interface

- The planning of **personnel requirements** includes planning for employee:
  - Parking
  - Locker rooms
  - Restrooms
  - Food services
  - Drinking fountains
  - Health services
  - Etc.

# Employee Parking

www.alriyadh.com

# of cars required depends on
# of employees

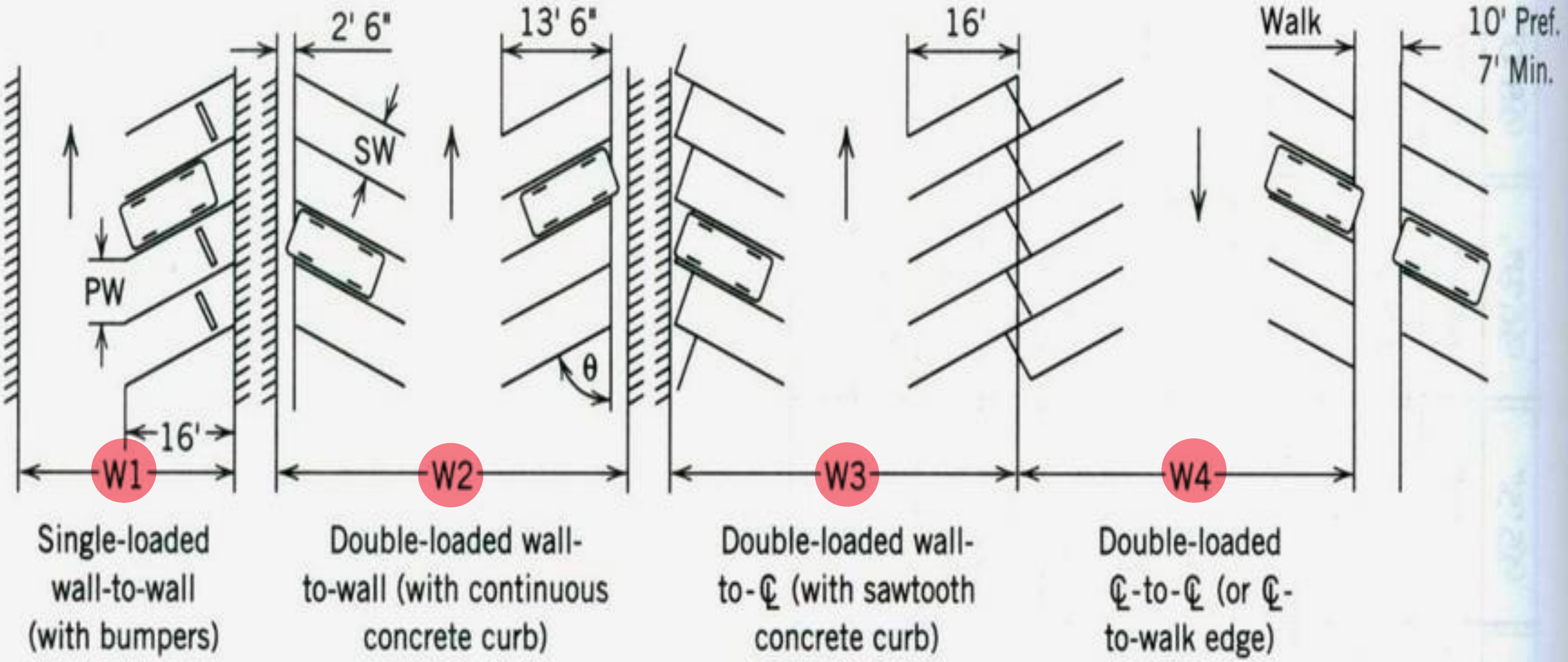
- **Procedure:**
  - Determine number of cars
    - 1 space for every 1.25 employees (public transportation is not available)
    - 1 space for every 3 employees (transportation available)
  - Determine type and space requirement for each car
    - Compact cars, standard, luxury, or handicapped (see table 4.1) and Fig. 4.2
    - Equals: Stall width X Stall depth
  - Determine the available space for parking
  - Determine alternative parking layout
    - The parking angle, and the aisle width (single or double-loaded module options)
  - Select the best layout that best utilizes space and maximizes convenience

|| ← الاصطفاف الـ (Regular) له space أقل لكن الاصطفاف اصعب

// ← الاصطفاف المائل (with Angle) له space أكبر لكن الاصطفاف فيه اسهل

Table 4.1 *Module Width for Each Car Group as a Function of Single and Double Loaded Module Options*

| | | | θ ANGLE OF PARK | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | W | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° | 85° | 90° |
| Group I: small cars | 8'0" | 1 | 25'9' | 26'6" | 27'2" | 29'4" | 31'9" | 34'0" | 36'2" | 38'2" | 40'0" | 41'9" |
| | | 2 | 40'10" | 42'0" | 43'1" | 45'8" | 48'2" | 50'6" | 52'7" | 54'4" | 55'11" | 57'2" |
| | | 3 | 38'9" | 40'2" | 41'5" | 44'2" | 47'0" | 49'6" | 51'10" | 53'10" | 55'8" | 57'2" |
| | | 4 | 36'8" | 38'3" | 39'9" | 42'9" | 45'9" | 48'6" | 51'1" | 53'4" | 55'5" | 57'2" |
| Group II: standard cars | 8'6" inch | 1 | 32'0" | 32'11" | 34'2" | 36'2" | 38'5" | 41'0" | 43'6" | 45'6" | 46'11" | 48'0" |
| | ÷12 | 2 | 49'10" | 51'9" | 53'10" | 56'0" | 58'4" | 60'2" | 62'0" | 63'6" | 64'9" | 66'0" |
| 8'6" in inch =8.5 in ft | = ft<br>=0.5 | 3 | 47'8" | 49'4" | 51'6" | 54'0" | 56'6" | 59'0" | 61'2" | 63'0" | 64'6" | 66'0" |
| | | 4 | 45'3" | 46'10' | 49'0" | 51'8" | 54'6" | 57'10" | 60'0" | 62'6" | 64'3" | 66'0" |
| | 9'0" | 1 | 32'0" | 32'9" | 34'0" | 35'4" | 37'6" | 39'8" | 42'0" | 44'4" | 46'2" | 48'0" |
| | | 2 | 49'4" | 51'0" | 53'2" | 55'6" | 57'10" | 60'0" | 61'10" | 63'4" | 64'9" | 66'0" |
| | | 3 | 46'4" | 48'10" | 51'4" | 53'10" | 56'0" | 58'8" | 61'0" | 63'0" | 64'6" | 66'0" |
| | | 4 | 44'8" | 46'6" | 49'0" | 51'6" | 54'0" | 57'0" | 59'8" | 62'0" | 64'2" | 66'0" |
| | 9'6" | 1 | 32'0" | 32'8" | 34'0" | 35'0" | 36'10" | 38'10" | 41'6" | 43'8" | 46'0" | 48'0" |
| | 9.5 | 2 | 49'2" | 50'6" | 51'10" | 53'6" | 55'4" | 58'0" | 60'6" | 62'8" | 64'6" | 65'11" |
| | | 3 | 47'0" | 48'2" | 49'10" | 51'6" | 53'11" | 57'0" | 59'8" | 62'0" | 64'3" | 65'11" |
| | | 4 | 44'8" | 45'10" | 47'6" | 49'10" | 52'6" | 55'9" | 58'9" | 61'6" | 63'10" | 65'11" |


2' 6"
13' 6"
16'
Walk
10' Pref.
7' Min.
SW
PW
θ
16'
W1
W2
W3
W4
Single-loaded wall-to-wall (with bumpers)
Double-loaded wall-to-wall (with continuous concrete curb)
Double-loaded wall-to-℄ (with sawtooth concrete curb)
Double-loaded ℄-to-℄ (or ℄-to-walk edge)

$$PW = \frac{SW}{\text{Sine } \theta}$$

$\theta$ is the parking angle, PW is parking width and SW is the stall width. At an angle of 90° (sine 90° = 1), PW = SW. As the parking angle decreases, PW increases accordingly.

**Figure 4.2** Single- and double-loaded module options. (*Source:* Ramsey and Sleeper [9].)

# Employee Parking (contd.)

- Surveys of similar facilities in the area of the new facility will provide valuable data with respect to the required number of parking spaces.

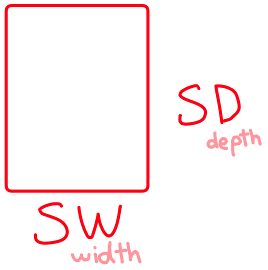
- At least 2 handicapped spaces per 100 parking spaces.

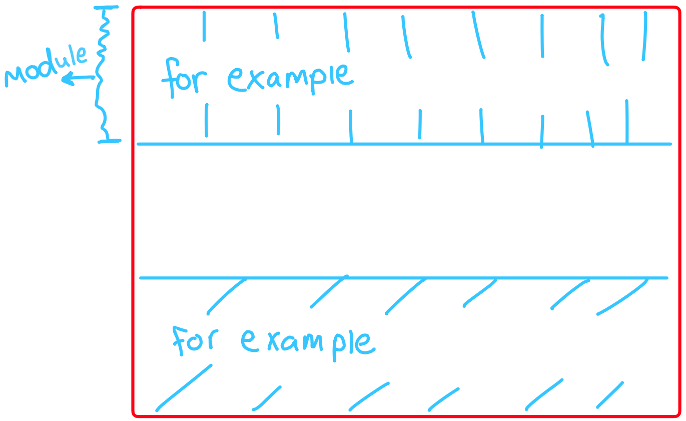
- **Parking location:** Employees should not be required to walk more than 300-400 feet from their parking place to the entrance of the facility.

# Employee Parking (contd.)

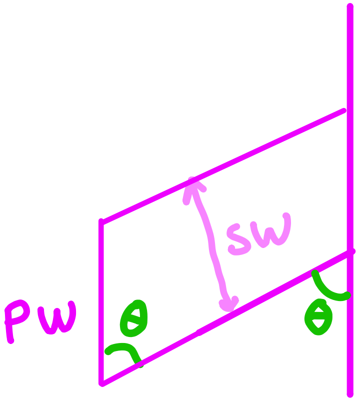
- The factors to be considered:
  1. The percentage of compact cars (33% if data not available).
  2. Increasing the area provided for parking decreases the time required to park and de-park.
  3. Angular configurations allow quicker turnover. Perpendicular parking often yields greater space utilization, although it also requires wider aisles.
  4. As the angle of parking increases, so does the required space allocated to aisles.

Parking Space





* in angular



$$\sin\theta = \frac{SW}{PW}$$

$$\boxed{PW = \frac{SW}{\sin\theta}}$$

# Employee Parking (contd.)

- **Example 4.1:**

بعتبرها 33 % اذا ما حدد

- 200 employees, 1 space for every 2 employees, 30% ~~40~~ % compact cars, 5% for handicap, and available parking space 180X200ft
- Assuming no walls, and no walking edge. } → $W_4$
- Use SW of 8' 6" for standard cars
- Determine the best parking layout

space for handicapped ⇒ 12′ each one
حفظ

## ◆ Example 4.1:

بعتبرها 33 % اذا ما حدد

- ◆ 200 employees, 1 space for every 2 employees, ~~40~~ 30% % compact cars, 5% for handicap, and available parking space 180X200ft
- ◆ Assuming no walls, and no walking edge. → $W_4$
- ◆ Use SW of 8' 6" for standard cars
- ◆ Determine the best parking layout

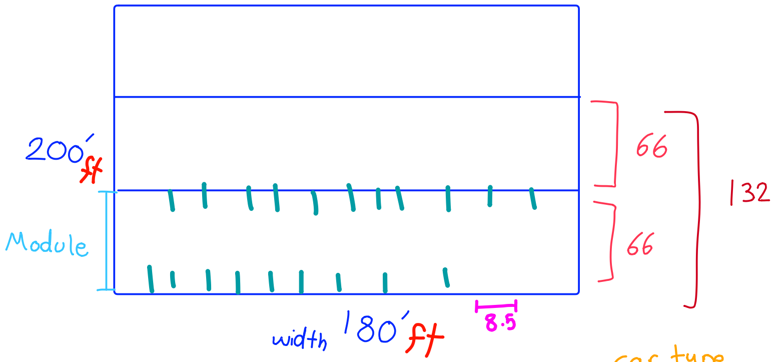
(90°, $W_4$)

$200$ ~~employee~~ $\times \frac{1 \text{ parking space}}{2 \text{ ~~employee~~}} = 100$ parking space required

%40 . 100 = ~~40~~ space for comp
30 space for compact

30 compact
70 standard

* The Parking Layout



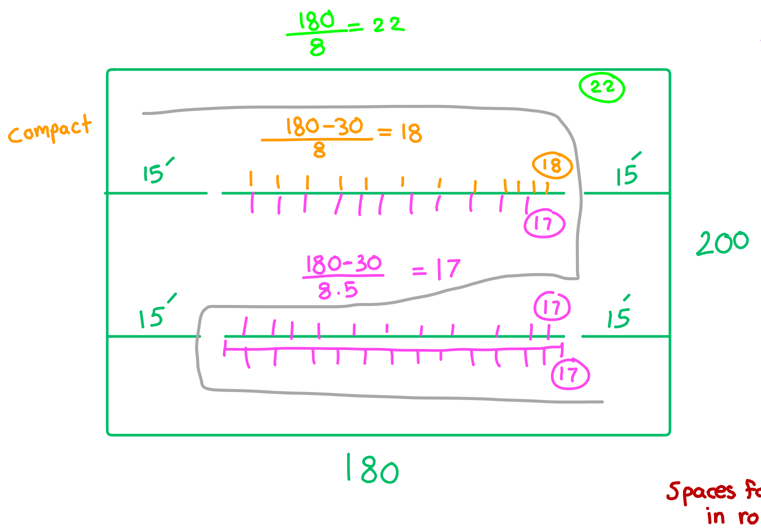
car type
* compact (90, 8′) $W_4$ → 57′ 2″
* standard (90) $W_4$ → 66

* we need to see if the depth of the (200 ft) can accomodate a parking Layout using 2 module ?? → (X) standard, (Y) compact
عن طريق التجريب

* the most important is to satisfy customer

1S + 1C = 123 ≪ 200
2S + 2C = 132 + 114 = 246 ≫ 200 ✗
2S + 1C = 2(66) + 1 (57′ 22″) = 189′ 2″ ≪ 200 ✓ the best

$\frac{180}{8} = 22$



* the suggested Layout is

$\frac{2 \text{ rows}}{\text{Module}} \times 2S + \frac{2 \text{ rows}}{\text{Module}} \times 1C = 6_{\text{Rows}}$

$W_4$

$\overset{C}{44} + \overset{S}{\boxed{84}} = 128 > 100$ ✓

5 % handicapped
12′ → handicapped
12′ x 5 = 60′

Spaces for Standard in row 1 → $\frac{180-60}{8.5}$ = 14 spaces for Standard
5 spaces for handicapped

| Module | # of Rows | # of Space |
|---|---|---|
| 1-S | 1 | 5 handicapped, 14 Standard |
| | 2 | 17 S |
| 2-S | 3 | 17 S |
| | 4 | 17 S |
| 3-C | 5 | 18 C |
| | 6 | 22 C |

$\#$ of spaces for compact $= 18 + 22 = 40 > 30$ ✓

$\#$ of spaces for Standard $= 14 + 17(3) = \underset{\text{Standard}}{65} + 5_{\text{handicapped}}$ ✓

# Employee Parking (contd.)

- **Solution:**
- Starting layout
  - Assume No walls and no walking edge (W4)
  - SW for standard (8′-6″)
  - 100 spaces needed (200 employee/2)
  - 40 compact ( we use 30, because not all of compact car drivers will park in a compact space)
  - Use 90° angle for stalls angle
  - Using table 4.1 for 90° and W4 (module width 57′-2″ for compact and 66′ for standard)

# Employee Parking (contd.)

- Table 4.1 Module width for each car group

| | | | ANGLE OF PARK (ɵ) | | | |
|---|---|---|---|---|---|---|
| | SW | W | 45 | 50 | … | 90 |
| **Group I: Small cars** | 8' 0" | 1 | **25' 9"** | **26' 6"** | | **41' 9"** |
| | | 2 | | | | |
| | | 3 | | | | |
| | | 4 | | | | **57’ 2”** |
| **Group II: Standard cars** | 8' 6" | 1 | **32' 0"** | **32' 11"** | | **48' 0"** |
| | | 2 | | | | |
| | | 3 | | | | |
| | | 4 | | | | **66’ 0”** |

# Employee Parking (contd.)

- **Solution (contd.)**
- We will use 2 modules for standard and one module for compact cars
    - 2*66+1*57′-2″ = 189′-2″<200′ (parking depth)
    - # of spaces for compact = (180/8)*2 = 44 potential compact cars
    - For standard = (180/8.5)*2modules*2=84 potential standard cars
    - 44+84= 128>100…we have enough

# Employee Parking (contd.)

- **Solution (contd.)**
- We need to calculate for handicap and turning aisles
  - We have (3 modules *2 rows)=6 rows
  - We can add handicap to row1
    - **5** spaces*12’(depth) = 60’
    - # of spaces of standard cars in row1 = (180-60)/8.5 **= 14** spaces
  - Row 2,3,4 (we will have turning aisles of 15’)
    - # of spaces for standard cars = 180-(15*2)/8.5 = **17**
  - Row 5,6 is for compact
    - # of space for row 5 = (180 -30)/8 = **18**
    - # of spaces for row 6 = 180/8 = **22**
  - Total = 5 handicapped + 40 Compact + 65 Standard
    = 110 spaces >100…we have enough

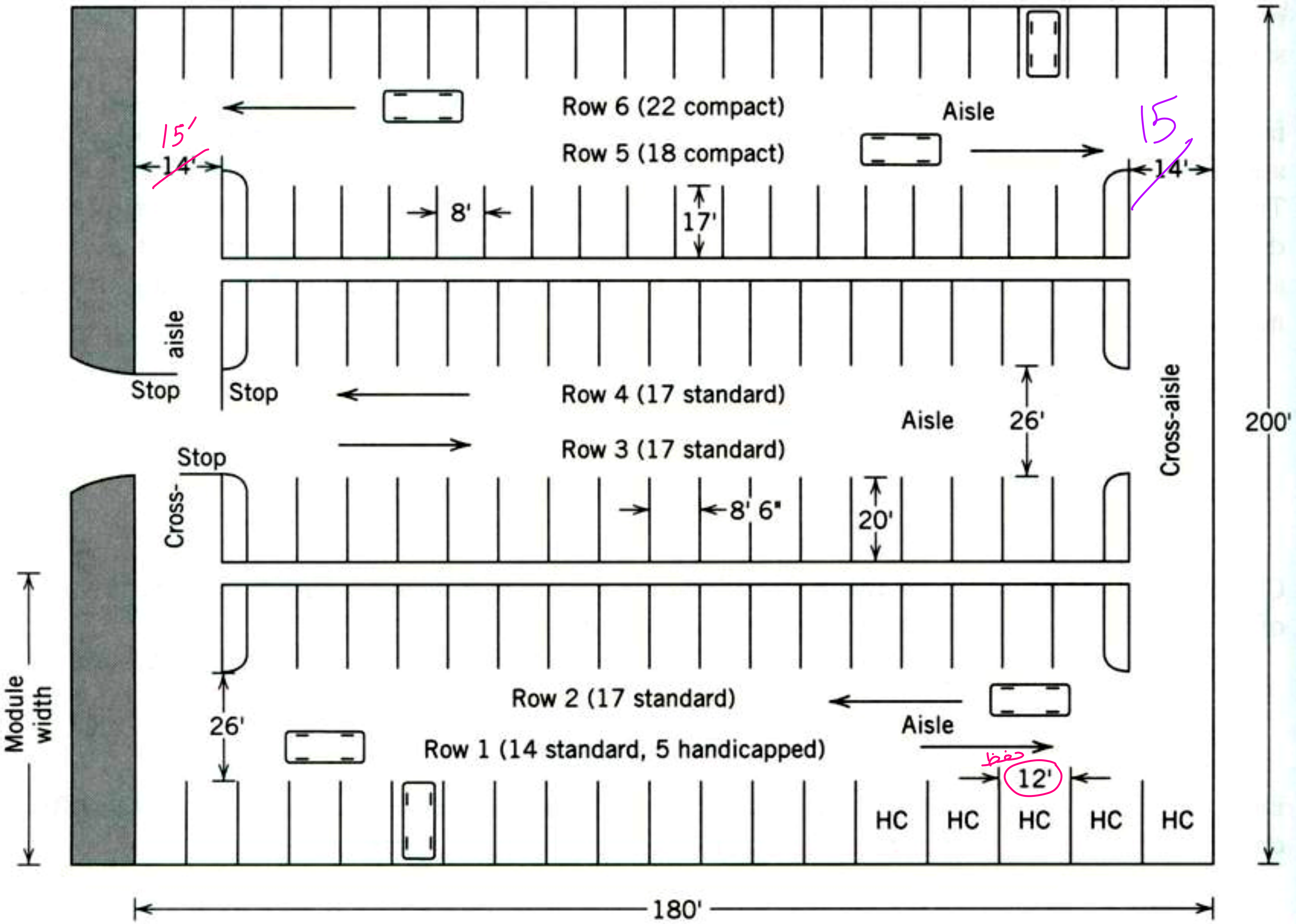


**Figure 4.3** Parking lot for Example 4.1.

## *Example 4.2*

→ important

Using the same data given for Example 4.1, let us compute the number of standard car stalls that can be placed along the module depth, assuming a stall depth of 16 feet (SD = 16′) and a parking angle of 60 degrees ($\theta = 60$). Before we compute the above number, it is instructive to compare the module widths. With 90° parking under option W4, earlier we obtained a

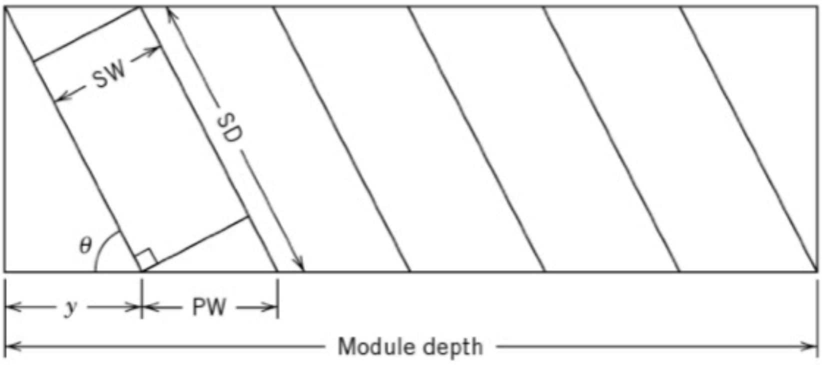


**Figure 4.4** Module outline for Example 4.2.

module width of 66′-0″ from Table 4.1 for standard cars. With 60° parking, however, from Table 4.1, we obtain 51′-8″ for the module width for standard cars. Hence, parking at an angle reduced the module width by more than 14 feet, which is a positive outcome (since it may allow us to place more modules in a given lot). However, as we next show, the number of stalls per module decreases when the parking angle is reduced from 90° to 60°.

We first compute the parking width (PW). Recall that PW = SW/sine $\theta$. That is, PW = 8.5/sine 60 = 9.8′. In reference to Figure 4.4, we next compute the value of $y$, which represents the distance lost due to parking at an angle.

By definition, $y$ = SD cosine $\theta$ = 16 cosine 60 = 8′. Since the lot width is equal to 180′, we have

Module depth = $y$ + (no. of stalls × PW) = 180,

which yields number of stalls = 17.55. That is, we can place 17 standard car stalls along the module depth, assuming a parking angle of 60°. Using a 90° parking angle in Example 4.1, we had obtained 180/8.5 = 21 cars. Hence, we reduced the module width by about 14′ but lost 4 × 2 = 8 cars per module in the process. Also, parking at angles other than 90° almost always requires the aisles to be one-way. The parking angle that will maximize the number of cars parked, in general, depends on the dimensions of the lot and how the individual modules are arranged within the lot. With increasing demand for parking spaces in virtually every major city and airport around the world—not to mention university campuses—parking lot design and management continues to be a topic of interest.

# *Example (4.2)

Using the same data given for example 4.1

- available parking Lot space is $\underset{\text{width}}{\underline{180ft}} \times \underset{\text{depth}}{\underline{200ft}}$

- assume No walls - No walking edges

*Determine the best parking Layout using SW of 8´6˝ for standard cars.

- Assume a stall depth is 16 feet and parking angle is 60°

## *Solution :-

https://youtu.be/xfDNihx84Vw?si=LVAStTQXX0jPfhH0

فيديو شرح الدكتورة للمثال

200 employees

$200 \times \frac{1 \text{ parking}}{2 \text{ employee}} = 100$ space needed

→ 30 % → $\frac{30}{100} \times 100 = 30$ space needed for compact

*Note :- Parking at an angle reduce module width

66 - 51.5 = 14.5´ (difference)

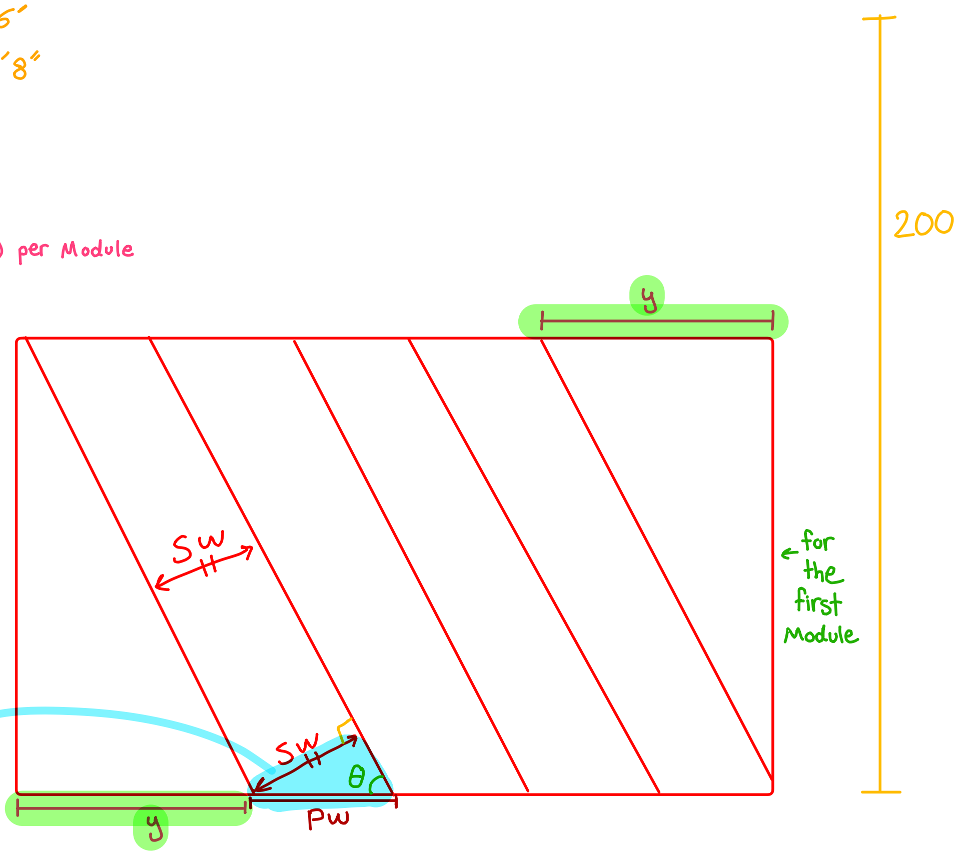
*** For Standard cars**

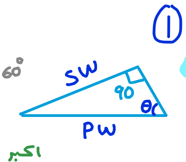
| | SW | Module |
|---|---|---|
| for 90° → | 8´ 6˝ → | 66´ |
| for 60° → | 8´ 6˝ → | 51´8˝ |

- we need to determine the ※ of spaces

(51.5) 2 + 42´ 9˝ $\overset{\text{تقريبا}}{\approx}$ 145

- we need to determine ※ of spaces (stall) per Module





$\sin\theta = \frac{SW}{PW} = \frac{8.5}{PW} = \sin 60°$

$PW = \frac{SW}{\sin\theta} = \frac{8.5}{\sqrt{3}/2} = 9.8´$ → اكبر من example 4.1 (الاصطفاف العمودي)

y: distance Lost due to parking at an angle

θ: parking angle

SD: stall depth (given)

SW: stall width

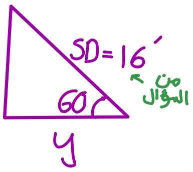
PW: parking width

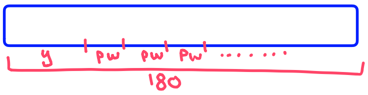
$\cos 60° = \frac{y´}{SD}$

$\rightarrow y = SD \cdot \cos 60°$

$= 16 \cdot \frac{1}{2} = \textcircled{8}$

خسر هاي الdistance من كل سطر



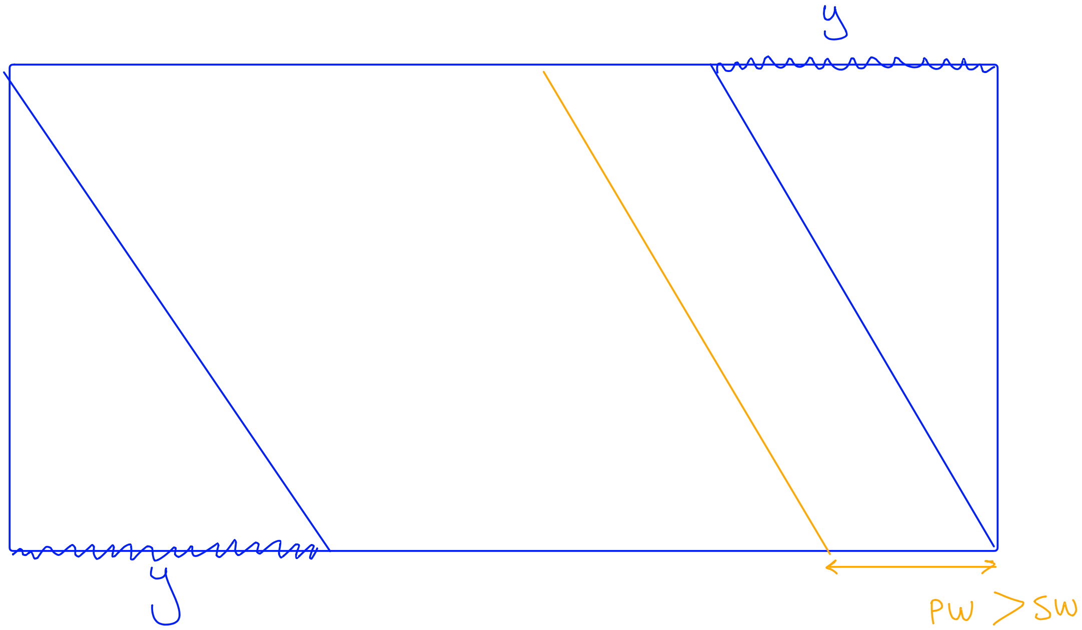


هدفي الان → اعرف ※of stall in 1st row

$\underset{\text{depth}}{\text{Module}} = y + \text{no.}$

$180 = y + \text{※of stall} \times \underset{\text{Parking width}}{\underline{(9.8)}}$

$\text{※of stall} = \frac{180-8}{9.8} = 17.55 \text{ stall} \underset{\text{Round down}}{\approx} 17 \text{ stall}$



This means we have Less stalls (Parking spaces) per Module for angular parking

However angular parking reduce Module with (14' (in this example))

# Angular parking

Monday, May 6, 2024 8:05 AM

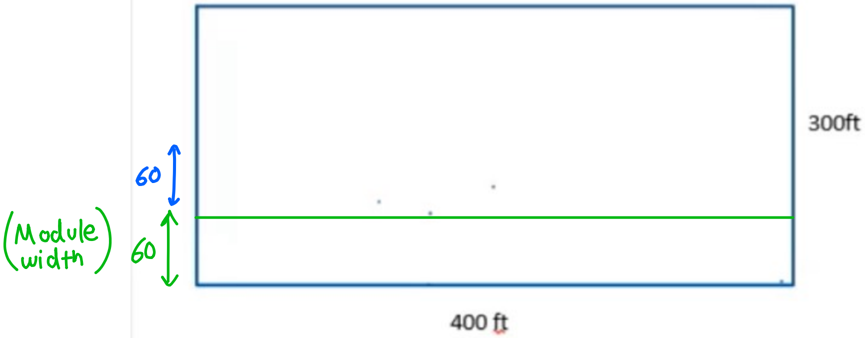
$\theta = 75$ $SD = 16'$

A parking lot is to be 400 feet wide and 300 feet deep. How may standard-sized cars fit in this lot? Use W4 Module, where the parking is angular with angle of 75, assume a stall depth of 16 feet. Determine the best parking layout using stall width, SW=8'6". , + the managers wants exactly 10 stalls for handicapped and all are in the first row.

$SW = 8.5'$

السؤال يريد
only standard cars

Module width for standard $(8.5')$ → $60'$

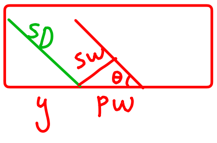


$$\#\text{ of Modules} = \frac{300\text{ ft}}{60\text{ ft}} = 5 \text{ modules} \rightsquigarrow \#\text{ of Rows} = \underset{\text{double Loaded}}{2} \times \underset{\#\text{of Modules}}{5} = 10 \text{ Rows}$$

$$* \boxed{\text{Row } 1} = \frac{\overset{\text{parking width}}{400} - \overset{\text{distance lost due to parking at angle}}{y} - (PW_{(HC)} \times \overset{\#\text{of stalls for HC}}{10})}{PW}$$

$$= \frac{400 - \overset{y}{4.1411} - \boxed{\overset{12.42}{PW_{HC}}} \times 10}{8.8}$$

$$= 30.87 \xrightarrow{\text{Round down}} 30 \text{ for row 1}$$



$$\boxed{PW = \frac{SW}{\sin\theta}} = \frac{8.5}{\sin 75} = 8.799 \text{ ft}$$

$$\boxed{y = SD \times \cos\theta} = 16 \times \cos 75 = 4.1411 \text{ ft}$$

$$PW_{HC} = \frac{SW_{HC}}{\sin\theta} = \frac{12'}{\sin 75} = 12.42$$

$$\boxed{\text{Row } 2 - \text{Row } 9} = \frac{400 - \overset{y}{4.1411} - \overset{\text{Turning aisles}}{(15)2}}{8.8} = 41.574 \underset{\text{Round down}}{\approx} 41$$

$$\boxed{\text{Row } 10} = \frac{400 - \overset{y}{4.1411}}{8.8} = 44.98 \approx 44$$

| | |
|---|---|
| Row(1) | 10 HC<br>30 SC |
| Row(2-9) | 41 SC |
| Row (10) | 44 SC |

شرح الدكتورة للسؤال

https://fisjo.sharepoint.com/:v:/s/Dr.Nibal/EfB-m-RfJkJJub1Rc3WlClQBYTwtqnTKpBWRzUKepUtRRg?nav=eyJyZWZlcnJhbEluZm8iOnsicmVmZXJyYWxBcHAiOiJTdHJlYW1XZWJBcHAiLCJyZWZlcnJhbFZpZXciOiJTaGFyZURpYWxvZy1MaW5rIiwicmVmZXJyYWxBcHBQbGF0Zm9ybSI6IldlYiIsInJlZmVycmFsTW9kZSI6InZpZXcifX0%3D&e=RU9PbX

# Storage of employees personal belongings

- Storage of Employees Personal properties
    - Coats, clothes, purses, and lunches
- Change of clothes not required
    - Lunches and personal belongings can be stored at the employees workspace (coat rack)
- Change of clothes required
    - Locker should be provided (preferable near the entrance)
    - Separate lockers for male and female with **6 ft$^2$** allocated for each person using the locker room
    - If showers are provided, should be separate from toilets facilities
    - Locker rooms are often located along an outside wall beside entrance. To provide ventilation, convenience and not interfere with flow of work in the facility.

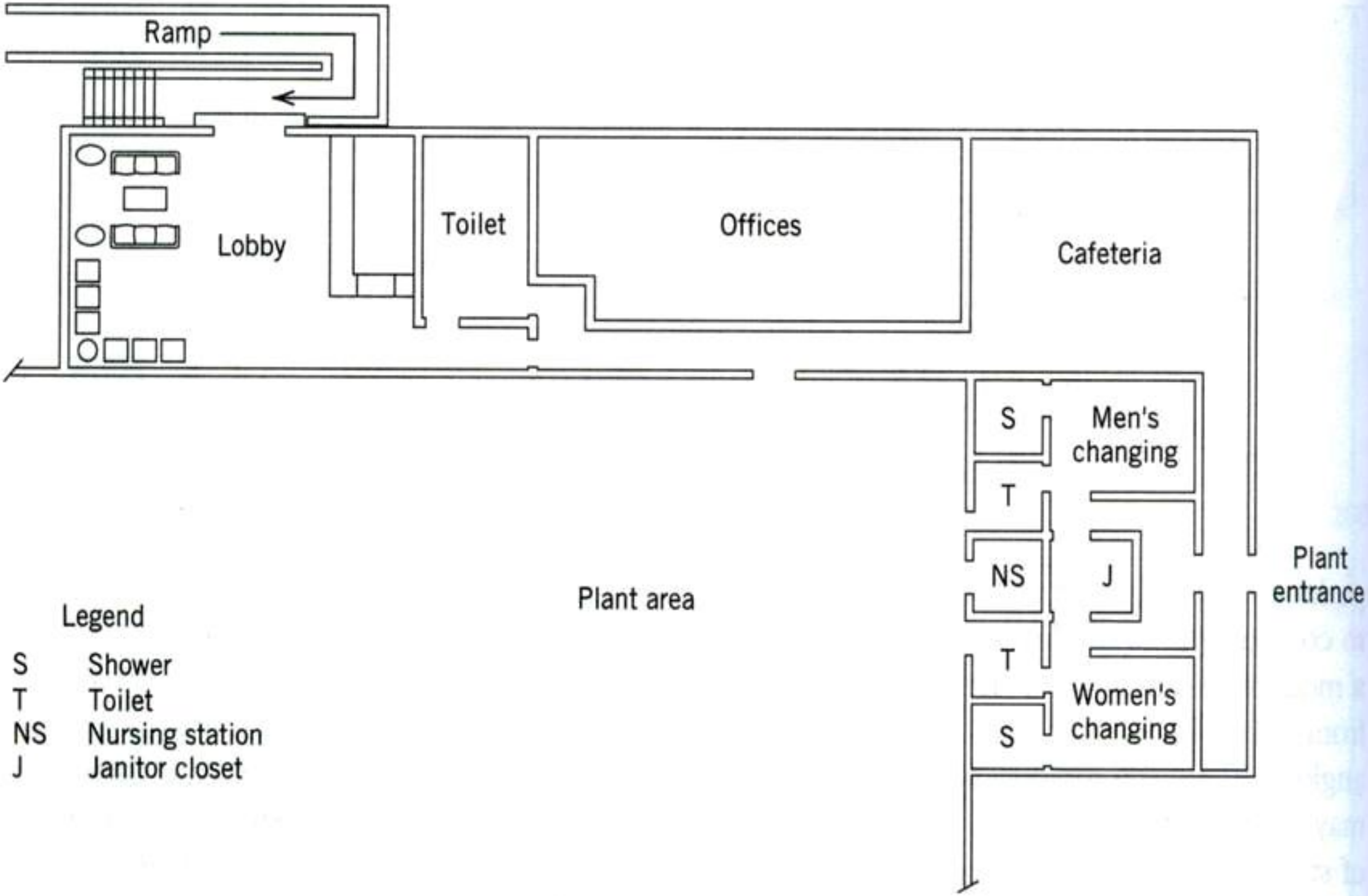


**Figure 4.5** Plant entrance and changing room layout.

https://youtu.be/qymGDp3oq7Y?si=WhnTV5gQZmY_1jaX

شرح

# Restrooms

- Main point to be made, a restroom should be located within 200 ft of every permanent workstation.

حفظ

- Smaller decentralized restrooms are more convenient than large centralized ones.
- Determine number of toilets, sinks, urinals, etc., to place in each restroom.
  - See table 4.2 for # of employees and plumbing fixtures requirements.
- Should not be able to see into the restroom from outside even when the door is open.
- Figure 4.6 shows an example of clearance requirements for bathrooms.

**Table 4.2** *Plumbing Fixture Requirements for Number of Employees*

مهم جداً

Business, Mercantile, Industrial Other than Foundry and Storage

| Water Closets | Employees | Lavatories | Employees |
|---|---|---|---|
| 1 | 1–15 | 1 | 1–20 |
| 2 | 16–35 | 2 | 21–40 |
| 3 | 36–55 | 3 | 41–60 |
| 4 | 56–80 | 4 | 61–80 |
| 5 | 81–110 | 5 | 81–100 |
| 6 | 111–150 | 6 | 101–125 |
| 7 | 151–190 | 7 | 126–150 |
|  |  | 8 | 151–175 |
| One additional water closet for each 40 in excess of 190 |  | One additional lavatory for each 30 in excess of 175 |  |

لازم نسوي Range !!

continue for the table
9 (175–205)
10 (205–235)

Industrial, Foundries, and Storage

| Water Closets | Employees | Lavatories | Employees |
|---|---|---|---|
| 1 | 1–10 | 1 | 1–8 |
| 2 | 11–25 | 2 | 9–16 |
| 3 | 26–50 | 3 | 17–30 |
| 4 | 51–80 | 4 | 31–45 |
| 5 | 81–125 | 5 | 46–65 |
| One additional water closet for each 45 in excess of 125 |  | One additional lavatory for each 25 in excess of 65 |  |

Assembly, Other than Religious, and Schools

| Water Closets | Occupants | Urinal | Male Occupants | Lavatories | Occupants |
|---|---|---|---|---|---|
| 1 | 1–100 | 1 | 1–100 | 1 | 1–100 |
| 2 | 101–200 | 2 | 101–200 | 2 | 101–200 |
| 3 | 201–400 | 3 | 201–400 | 3 | 201–400 |
| 4 | 401–700 | 4 | 401–700 | 4 | 401–700 |
| 5 | 701–1100 | 5 | 701–1100 | 5 | 701–1100 |
| One additional water closet for each 600 in excess of 1100 |  | One additional urinal for each 300 in excess of 1100 |  | One additional lavatory for each 1500 in excess of 1100. Such lavatories need not be supplied with hot water. |  |

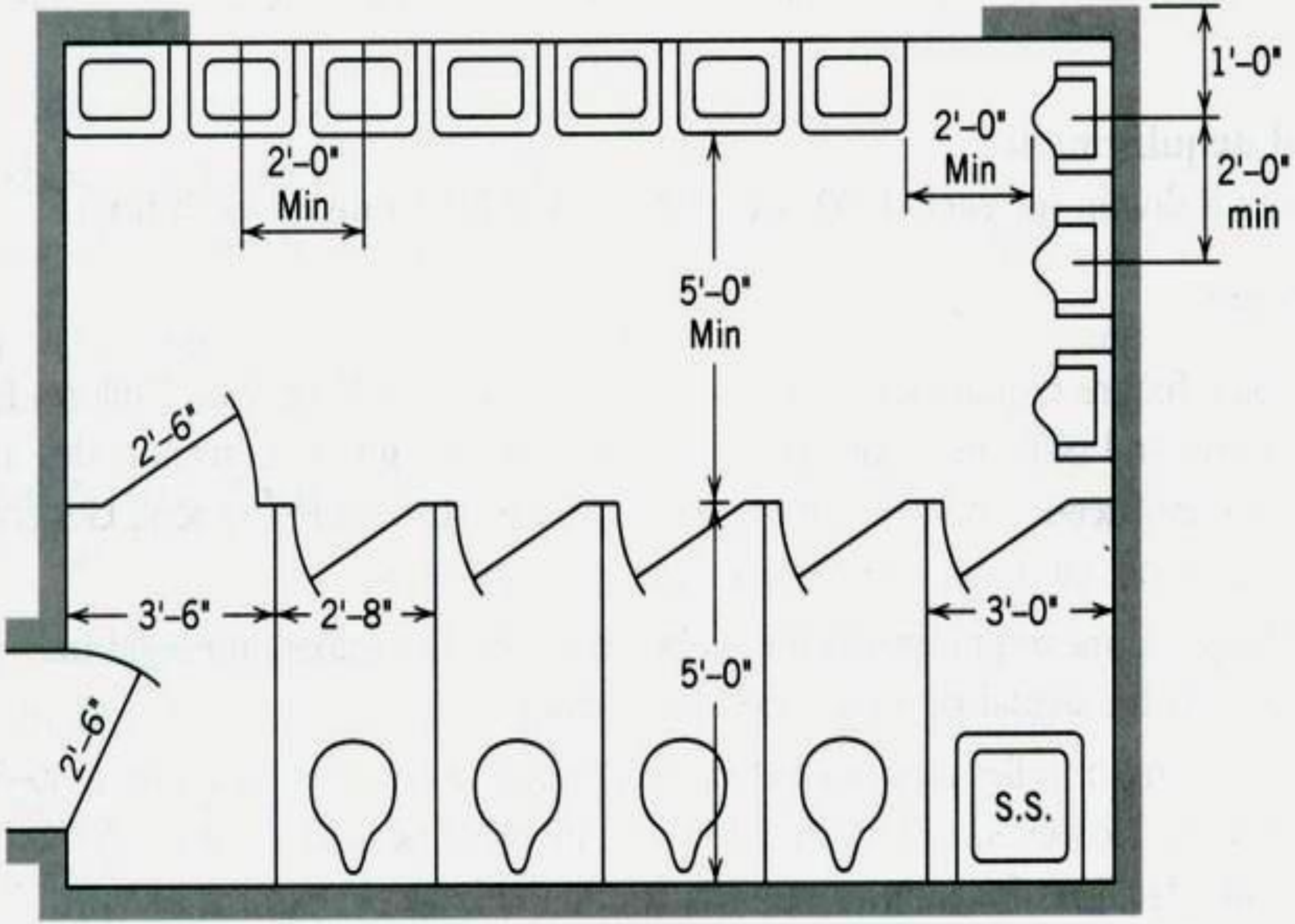


**Figure 4.6** Restroom layout with typical fixture clearances. Based on New York State Labor Code. (Taken from [1] with permission of The McGraw-Hill Companies.)

حفظ

# Some important numbers from the book :-

---

## RESTROOMS

in Table 4.2 [8]. In restrooms for males, a urinal may be substituted for a toilet, provided that the number of toilets is not reduced to less than two-thirds the minimum recommended, noted in Table 4.2. For space planning purposes, 12.5 ft$^2$ (2.5′ × 5′) or 15 ft$^2$ (3′ × 5′) should be allowed for each toilet, and 6 ft$^2$ for each urinal. Toilets

---

per three toilets be provided. When multiple users may use a sink at a time, 24 linear inches of sink or 20 inches of circular basin may be equated to one sink. For planning purposes, 6 ft$^2$ should be allowed for each sink.

Entrance doorways into restrooms should be designed such that the interior of the restroom is not visible from the outside when the door is open. A space allowance of 15 ft$^2$ should be used for the entrance.

---

In some women's restrooms, especially in offices and administration buildings, a coach or bed/cot is provided. If bed(s) are to be provided, the following guidelines are used: (1) the area should be segregated from the restroom by a partition or curtain; (2) if between 100 and 250 women are employed, two beds should be provided, and one additional bed should be provided for each additional 250 female employees; and (3) a space allowance of 60 ft$^2$ should be used for each bed. In any case, both the men's and the women's restrooms must conform to local codes that apply to the type of facility for which the restrooms are being planned.

---

## HEALTH SERVICES

a bed, and two chairs. A minimum of 100 ft$^2$ is required. If a nurse is to be employed, the first aid room should have two beds and should be expanded to 250 ft$^2$. In addition, a 75 ft$^2$ waiting room should be included. For each additional nurse to

be employed, 250 ft$^2$ should be added to the space requirements for the first aid room, and 25 ft$^2$ should be added to the space requirements for the waiting room.

## SECTION 4.3

4.7 A facility is to house 50 female and 50 male employees. Using a 40% allowance for aisles and clearances, how much space should be planned for the restrooms?

| Men (50) | Women (50) |
|---|---|
| - Water Closet $= 15\,ft^2 \times 3 = 45\,ft^2$ | - Water Closet $= 15\,ft^2 \times 3 = 45\,ft^2$ |
| - Lavatories $= 6\,ft^2 \times 3 = 18\,ft^2$ | - Lavatories $= 6\,ft^2 \times 3 = 18\,ft^2$ |
| - Entrance $= 15\,ft^2 \times 1 = 15\,ft^2$ | - Entrance $= 15\,ft^2 \times 1 = 15\,ft^2$ |
| - Urinal $= 6\,ft^2 \times 1 = 6\,ft^2$<br>هذه الارقام حفظ | - bed or cot $= 60\,ft^2 \times 1 = 60\,ft^2$<br>من الفقرة وليس الجدول |
| Subtotal $= 84\,ft^2$<br>Allowance $= 0.4 \times 84\,ft^2 = 33.6\,ft^2$ | Subtotal $= 138\,ft^2$<br>Allowance $= 0.4 \times 138\,ft^2 = 55.2$ |
| Total Area $= 84 + 33.6 = 117.6\,ft^2$ | Total Area $= 138 + 55.2 = 193.2\,ft^2$ |

From (table 4.2)

الدكتورة بتجيبها بالامتحان

50 empolyees $\longrightarrow$ 3 water closet
$\longrightarrow$ 3 Lavatories

https://youtu.be/uOT1mq2Dtns?si=wFNfDrGQF4t_I7p8

شرح

# Food Service

- Firms view food service as necessity, convenience or luxury

- Four main meal options:
  - Dinning away
  - vending machines and cafeteria(1ft$^2$/employee)
  - serving line and cafeteria(200 employee or more)
    - Caterer is needed and 300 ft$^2$/line (each line can serve 70 person)
  - full kitchen and cafeteria (over 400 employees).

- See table 4.4 for cafeteria space requirements and table 4.5 for full kitchen space requirements

**Table 4.4** *Space Requirements for Cafeterias*

| Classification | Square Footage Allowance per Person |
|---|---|
| Commercial | 16–18 |
| Industrial | 12–15 |
| Banquet | 10–11 |

سوف نختار ال Lower

**Table 4.5** *Space Required for Full Kitchens*

| Number of Meals Served | Area Requirements (ft$^2$) |
|---|---|
| 100–200 | 500–1000 |
| 200–400 | 800–1600 |
| 400–800 | 1400–2800 |
| 800–1300 | 2400–3900 |
| 1300–2000 | 3250–5000 |
| 2000–3000 | 4000–6000 |
| 3000–5000 | 5500–9250 |

*Source:* Kotschevar and Terrall [5].

هنا اما باخد Lower مع Lower

او upper مع upper

او عن طريق ال interpolation

# Food Service (contd.)

- Generally try to discourage dining away:

1. Meal breaks must be longer
2. Lose employee supervision:
   - Return to work late
   - Return intoxicated
   - Don’t return
3. Loss of worker interaction
4. Less worker concentration on the tasks to be performed.

# Food Service (contd.)

- General food service location guidelines:
  1. Located within 1000 feet of permanent employee workstations. If this is not the case, consider decentralized food services.
  2. Central location (though may not want this because then you cannot have windows)
  3. Consider that you need easy access for delivery of food and trash pick-up.
  4. تهوية

     Need good ventilation- don’t want smell food in the facility since that is disruptive.
- Water fountains within 200 feet of workstations.

# Food Service (contd.):
## Example 4.3

- Industrial facility, 600 employees eat on 3 equal 30 minuets shifts
  - Vending and cafeteria option
    - 12 $ft^2$ *200 (cafeteria) +200 *1 $ft^2$(vending)=2600 $ft^2$
  - Service line and cafeteria
    - Service line could service 70 people/shift so we need 3/shift
    - $3*300\ ft^2 = 900\ ft^2$
    - Total= 2400 (cafeteria) +900 = 3300 $ft^2$
  - For full kitchen and cafeteria
    - Total space = Kitchen space +service line space +cafeteria space

      بستخدم عدد الemployees الكامل
    - Total pace = 2100(from table) +3300 = 5400 $ft^2$

      حسبناها بالفرع الثاني

# Health Services

https://youtu.be/XGoWChHha7I?si=Na-L_0so_TYG8rj5

شرح

- Health facility requirements depends on the type of facility and local cost
- At the very least, a small first aid room should be available (first aid kit, bed, 2 chairs)
- Minimum space 100 square feet
- If a nurse added 250 ft$^2$ needed for the room and 75ft$^2$ waiting area and 2 beds
- See figure 4.9 for the layout
- If a part time physician added, 150 ft$^2$ exam room needed
- Health service should be close to hazards tasks in quite area

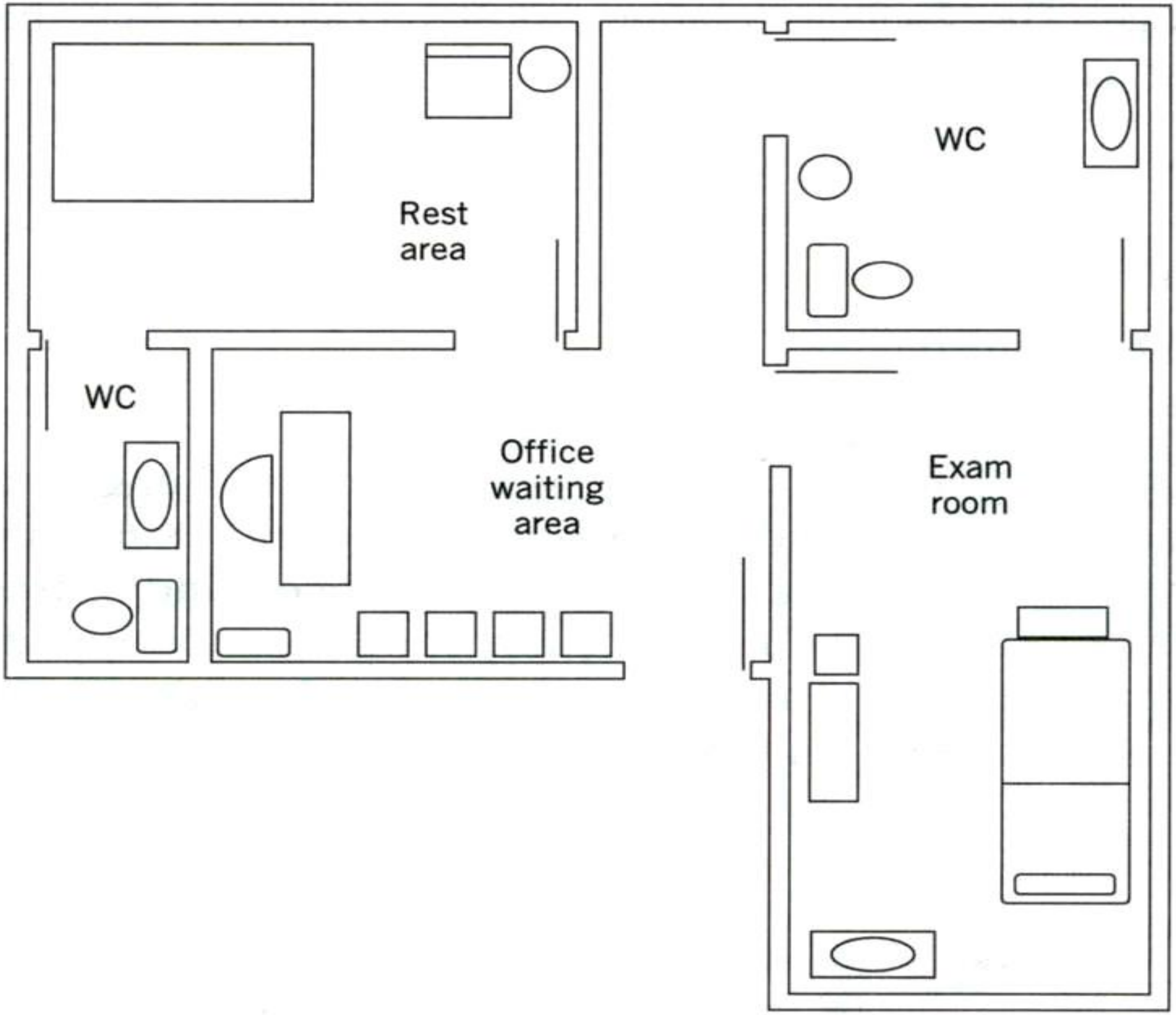


Figure 4.9 Nursing station layout.

**4.12** If two nurses and a part-time physician are to be employed in a health services area, how much space should be allowed in the facilities plan?

- Waiting Room → 2 nurses, 75 $ft^2$ for the 1st nurse + 25 $ft^2$ per additional ≈ (100 $ft^2$)
  حفظ
- First Aid Room → 2 nurses, 250 $ft^2$ per nurse → (500 $ft^2$)
  حفظ
- Examination Room → 1 physician, 150 $ft^2$ per physician → (150 $ft^2$)
  حفظ

Total Area = 100 + 500 + 150
= 750 $ft^2$

الامتثال الخالي من العوائق

# Barrier-Free Compliance

يجب الالتزام به

- American Disabilities Act (ADA) must be adhered.
  - All barriers that would impede the use of the facility by the disabled person must be removed, thereby making the facility barrier free.
- Examples:
  - Doorways must accommodate wheelchairs.
  - Ramps or elevators as an alternative to stairs.
  - See figure 4.10 vs. 4-11

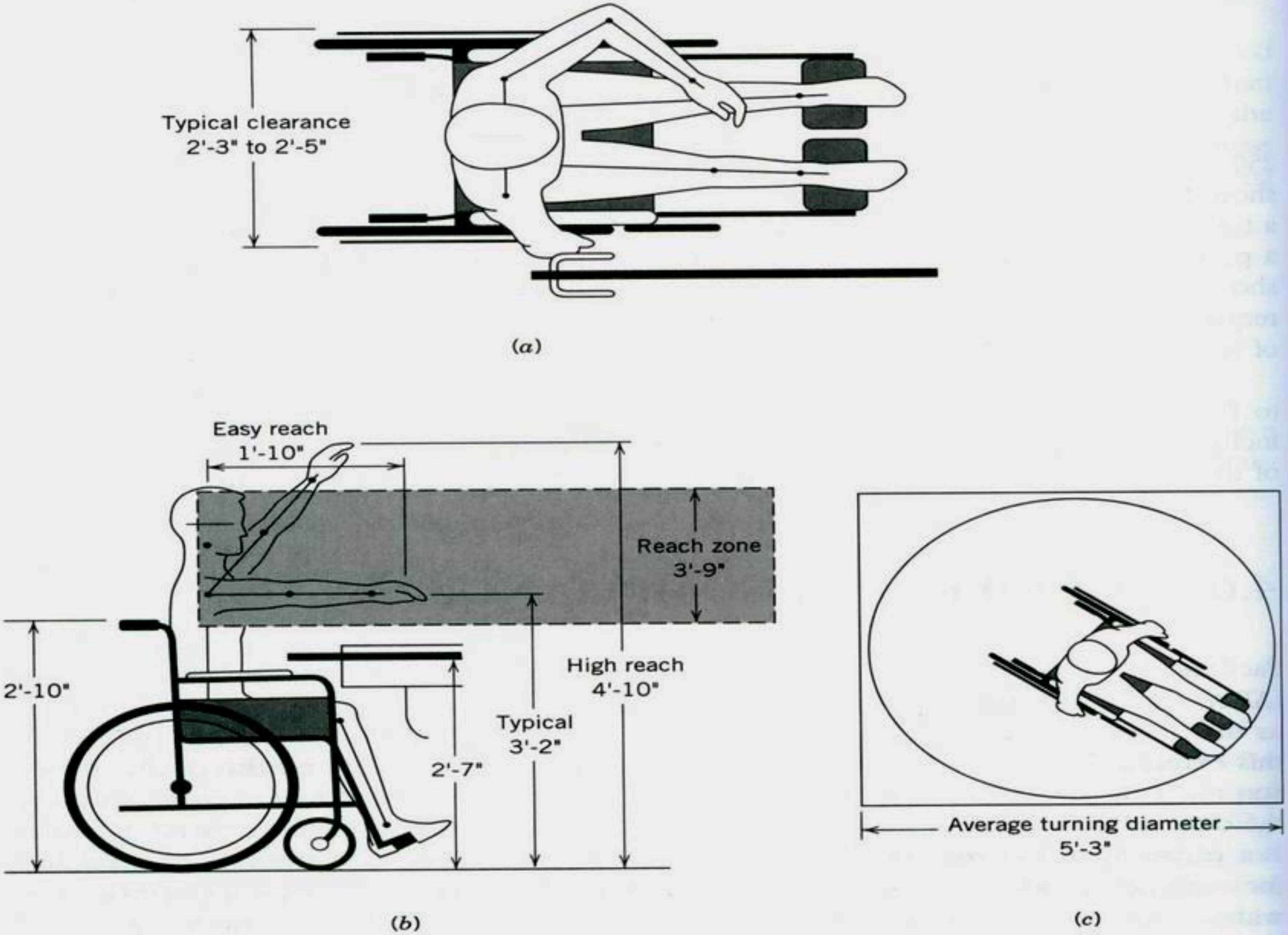


**Figure 4.10** Wheelchair dimensions and turning radius.

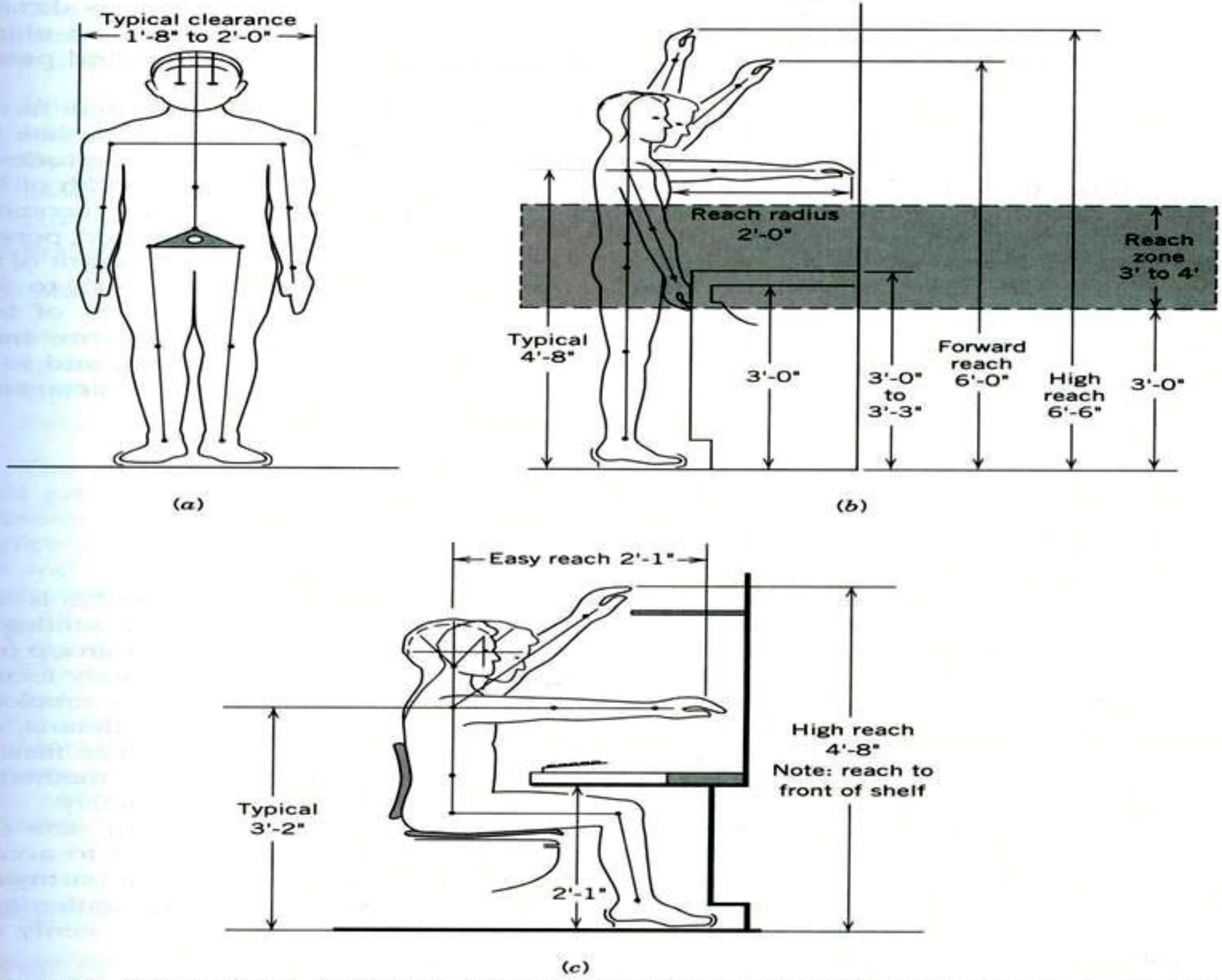
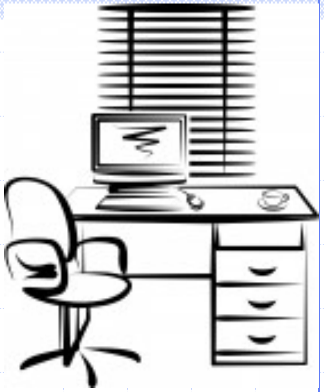


**Figure 4.11** Able-bodied anthropomorphic clearance and reach requirements in standing and sitting positions.

# Office Facility planning



قرب

- Office design should consider the size, proximity (coffee, cafeteria, elevator, windows, etc.), and noise.
- Office planning should start by collecting information about department relationships and department requirements

# Approaches to office planning

- **Open office** design: no floor to ceiling walls exist (temporary. or permanent)
  - Advantages: good communication, better access for common files, lower maintenance cost, and improved communications and supervision.
  - Disadvantage: mainly lack of privacy
  - Figure 4-12 shows different layouts
- We use **close office** layout if privacy and tasks needed concentration
- Most offices are a combination between Open and closed.
- Space requirements: see your book page 161

# Chapter 5

Slides are enough
(No problems)
in the book

# Material Handling

# Material Handling Defined

- The *layout design* and *material handling system* design are inseparable.

- Material handling accounts for
  - 25% of all employees
  - 55% of all factory space
  - 87% of production time
  - 15 to 70% of the total cost of a manufactured product

- Cost reduction can be achieved not by eliminating material handling but by more efficient material flow

# Material Handling Defined

**Definitions:**

1. Material handling is the art and science of moving, storing, protecting, and controlling material.

The Right Definition:

2. Providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position, in the right sequence, and for the right cost, by using the right method(s).

# Material Handling Defined

a. Right amount

(ما باخذ احتياطات) (to prevent stock out)

   i. just in time vs. just in case inventory management.
   ii. Small load size is preferred
   iii. Match production lot size with transfer batch

b. Right material

   i. Automatic identification system is key to accurate identification
   ii. Simplify the part numbering system
   iii. Maintain good database system

# Material Handling Defined

c. Right condition
   i. Delivery to customer requirements (packed or unpacked…)
   ii. The absence of damage

d. Right sequence
   i. Simplify work (eliminate unnecessary operations, and improve the remaining)
   ii. Change sequence of operations, or combine operations.

e. Right Orientation
   i. Position for ease of handling (critical in automated systems)
   ii. Changing the design (by including handling tabs)

f. Right Place
   i. For transportation or storage
   ii. Central storage vs. distributed storage

# Material Handling Defined

g. **Right time**
  - i. Not early neither tardy → ليس مبكر
و ليس متأخر
  - ii. Use low variance transportation (forklift vs. AGV’s) → نحاول تكون
ال variability
اقل ما يمكن
  - iii. Cycle time reductions not lower delivery time
  - iv. The emphasis is on the right time, not the fastest time.

h. **Right cost**
  - i. The right cost is not necessarily the lowest cost
  - ii. On-time delivery increases customer satisfaction

# Material Handling Defined

i. Right methods
  i. Requirements-driven materials handling systems over solution-driven system.
    - Solution-driven systems are those in which technologies are chosen without consideration for how the technologies match requirements; instead of defining requirements and matching technology options to requirements, the solution-driven approach force-fits a technology on the system.
  ii. Equipments should be the last step

# Material handling principles

Provide guidance and perspective to material handling system designers.

1. Planning principle: define in advance what material when and where to move and how to move it
2. Standardization process: less variation in methods and equipments.
3. Work principle: material flow (volume, weight..) *distance
4. Ergonomic principle: fit task to man
5. Unit load principle: that can be stored or moved as a single entity such as pallet or container
6. Space utilization principle: utilize the 3-D space (cubic space)

نستغل ال space الموجود هنا

# Principles…continue

7. System principle: collection of interacting entities that form a unified whole.
8. Automation principle
9. Environmental principle: Not to waste natural resources, and reduce negative effects on the environment.
10. Life Cycle Cost principle:

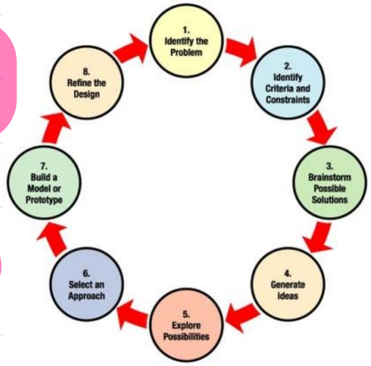
See table 5.1 for checklist ( to facilitate the identification of opportunities to improve existing material handling systems, or to serve in designing new systems)

# Material Handling System Design

Factors to be considered in analyzing material handling problems include:

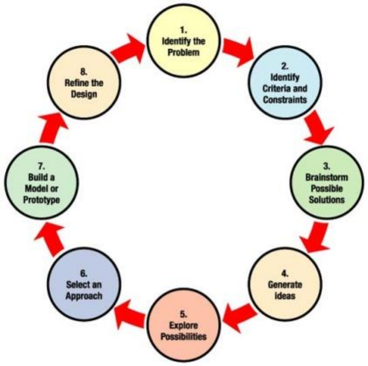
- Types of materials
- Their physical characteristics
- Quantities to be moved
- Sources and destinations for each move
- Frequencies or rates at which moves must be made
- Equipment alternatives
- Units to be handled

# Designing Material Handling Systems



1. Define the objectives and scope for the material handling system.
2. Analyze the requirements for moving, storing, protecting, and controlling material.
3. Generate alternative designs for meeting material handling system requirements.
4. Evaluate alternative material handling system designs.

# Designing Material Handling Systems



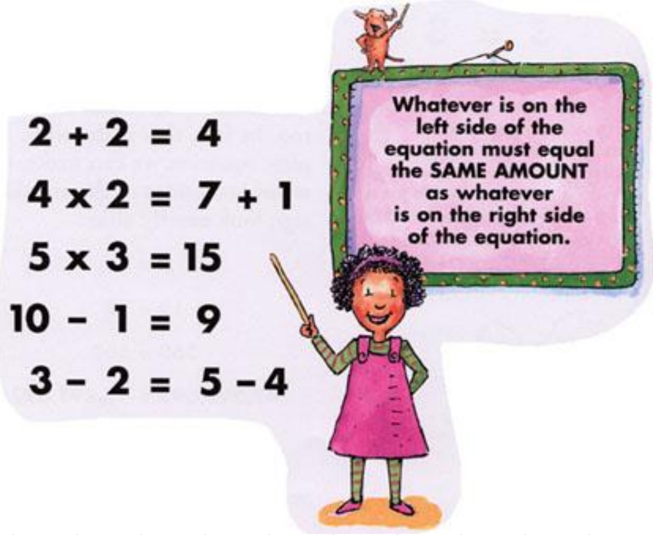
5. Select the preferred design for moving, storing, protecting, and controlling material.

6. Implement the preferred design, including the selection of suppliers, training of personnel, installation, debug and startup of equipment, and periodic audits of system performance.

# Material Handling System Equation

- Provides means to identify opportunities for improvement.

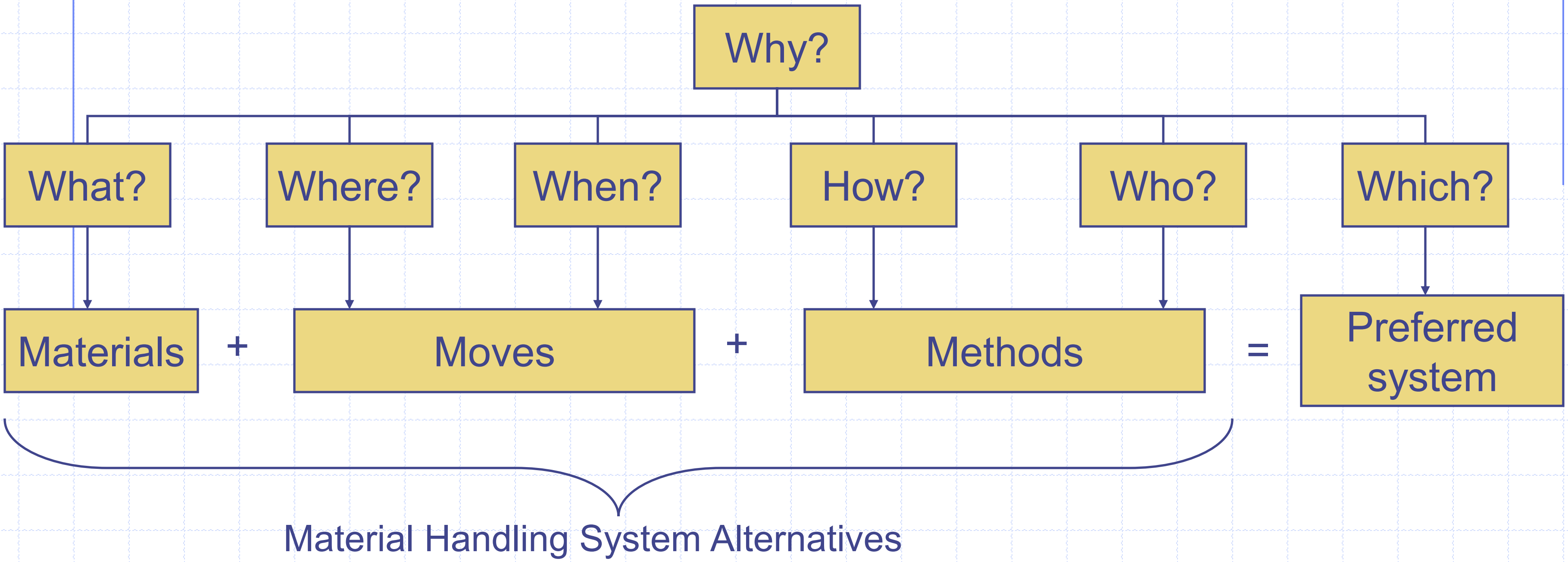
- It gives us a framework for identifying solutions to material handling problems.


2 + 2 = 4
4 x 2 = 7 + 1
5 x 3 = 15
10 - 1 = 9
3 - 2 = 5 - 4
Whatever is on the left side of the equation must equal the SAME AMOUNT as whatever is on the right side of the equation.

- The what defines the type of materials moved, the where and when identify the place and time requirements, the how and who point to the material handling methods. Leads us to:

Materials (what )+ Moves (where, when) + Methods (how, who) = Recommended System (which)

# Material Handling System Equation



Why?

What? Where? When? How? Who? Which?

Materials + Moves + Methods = Preferred system

Material Handling System Alternatives

# Material Handling System Equation

- The What Question:
  1. What are the types of material to be moved?
  2. What are their characteristics?
  3. What are the amounts moved and stored?

- The Where Question:
  1. Where is the material coming from? Where should it come from?
  2. Where is the material delivered? Where should it be delivered?
  3. Where is the material stored? Where should it be stored?
  4. Where can material handling be tasks be eliminated, combined, and simplified?
  5. Where you can apply mechanization, or automation?

See other Questions in the Text Book.

For each question we ask *Why* it is necessary or not.

# Material Handling Planning Chart

- A material handling planning chart can be used to gather information pertaining to a specific material handling problem and to provide a preliminary examination of the alternative solution.

- The result from analyses using this chart can then be used to further refine solution strategies using methods such as the simulation of alternative solutions. P.185

| Step # | O | T | S | I | Description | Depart. | Size | Wt. | Freq. | Dis. | Method of MH |
|---|---|---|---|---|---|---|---|---|---|---|---|

# Unit Loads

## Unit load Definition:

A single item, a number of items or bulk material which is arranged so that the load can be stored, and picked up and moved between two locations as a single mass.

- This definition suggests that the nature of the unit load could change each time an item, or a number of items, or bulk material is moved.
- Primary advantage of using unit loads is the capability of handling more items at a time and reducing the number of trips, handling cost, loading and unloading times, and product damage.

# Unit Loads (contd.)

- Examples of unit load:
  - A single item picked and moved manually between two locations.
  - One pallet load of nonuniform-size cartons with different products picked and moved by a lift truck from packaging area to the shipping dock.
  - One full load of products delivered by a truck-trailer from warehouse to customer store.
  - If the trailer is half full, it is still one unit load. It is the move that defines the unit load.

# Unit Loads (contd.)

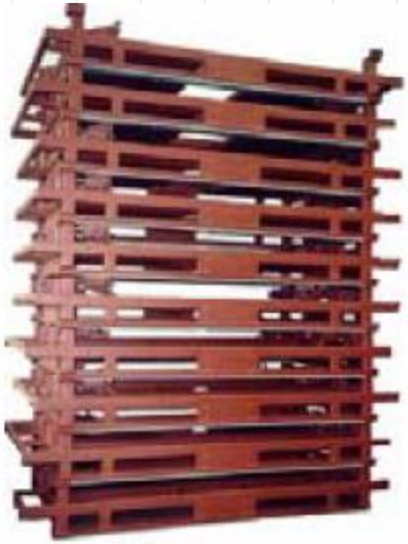
- The unit load size specification has a major impact on the specification and operation of the material handling system.
- Large unit load: } needs more material handling
  - Required bigger and heavier equipments, wider aisles.
  - Increase work-in-process (WIP) inventory.
  - Major advantage is fewer moves
- Small unit load:
  - Required simple MH methods (such as push carts).
  - Reduce work-in-process
  - Support JIT production
  - But increase the transportation requirements.
- The Optimal Unit Load is the quantity where system idle time, WIP and transportation cost are minimized

# Unit Loads (contd.)

- Two important elements in determining the size of the unit load are:
  - "Cube" limit.
  - Weight limit.
  - Example: a cartoon with outside dimension 16"X12"X6" and a gross weight limit of 65 lbs)
- The integrity of the unit load can be maintained in a variety of ways:
  - Boxes, cartons, pallets (wooden)
  - Strapping, shrink wrapping, and stretch wrapping.

# Unit Loads (contd.)

Pallet



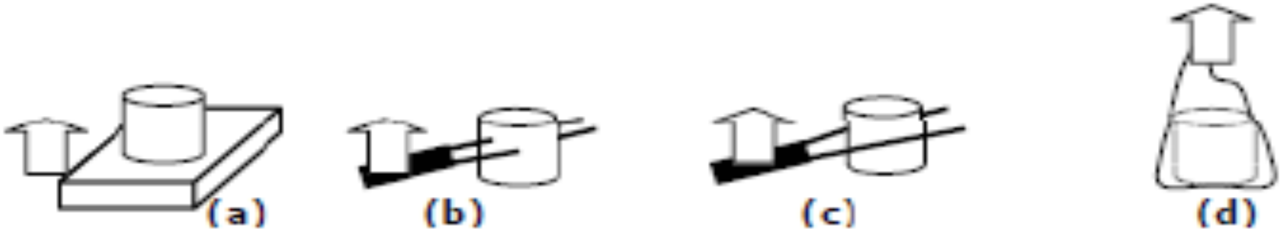
Skids

Stretch wrapping

Shrink wrapping

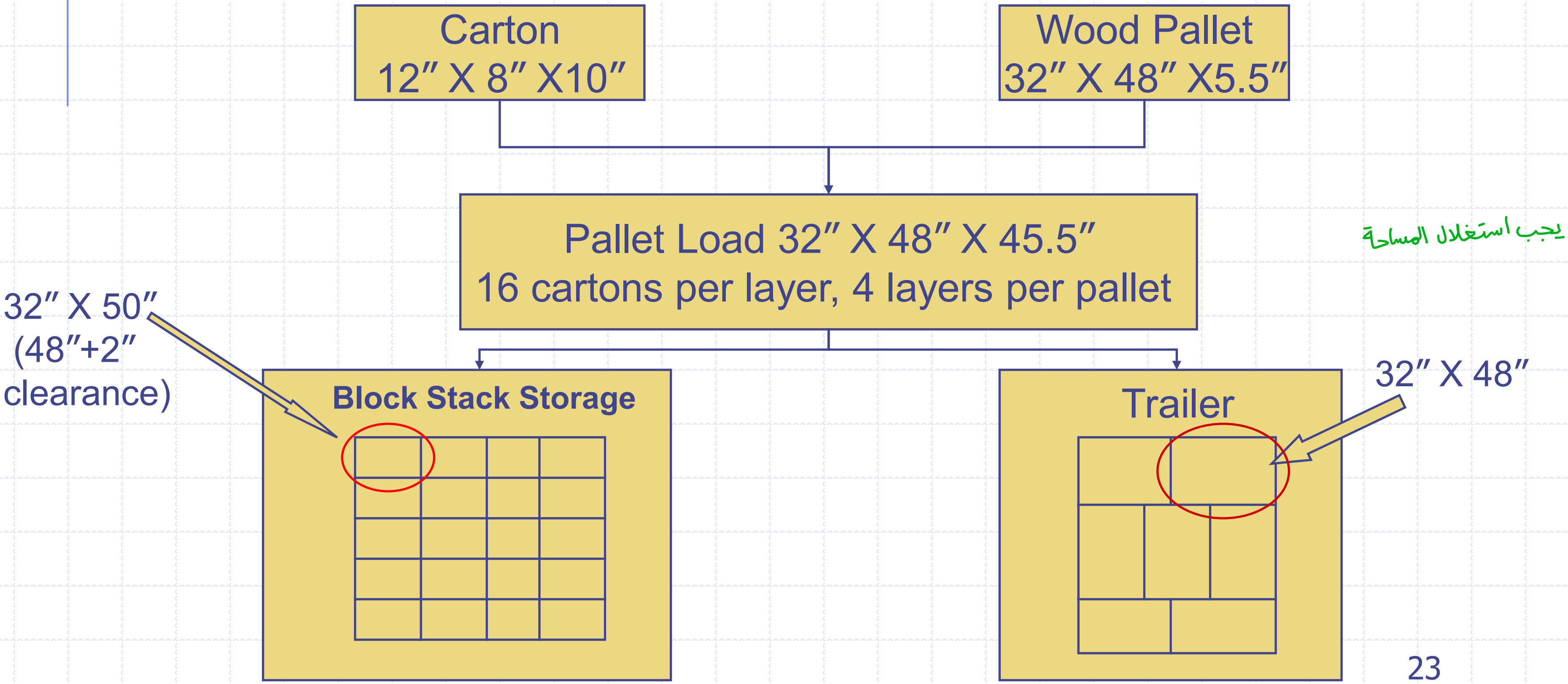
# Unit Loads (contd.)

- The methods by which the unit load can be moved:
  1. Lifting under the mass
  2. Inserting the lifting element into the body of the unit load.
  3. Squeezing the load between two lifting surfaces.
  4. Suspending the load.



# Unit Loads (contd.)

- The dimensional relationships between the various forms the unit load takes.
- The cartoons are stacked on pallets, and the full pallet loads are loaded to a trailer or staked in a warehouse



Carton
12″ X 8″ X10″

Wood Pallet
32″ X 48″ X5.5″

Pallet Load 32″ X 48″ X 45.5″
16 cartons per layer, 4 layers per pallet

يجب استغلال المساحة

32″ X 50″
(48″+2″
clearance)

**Block Stack Storage**

Trailer

32″ X 48″

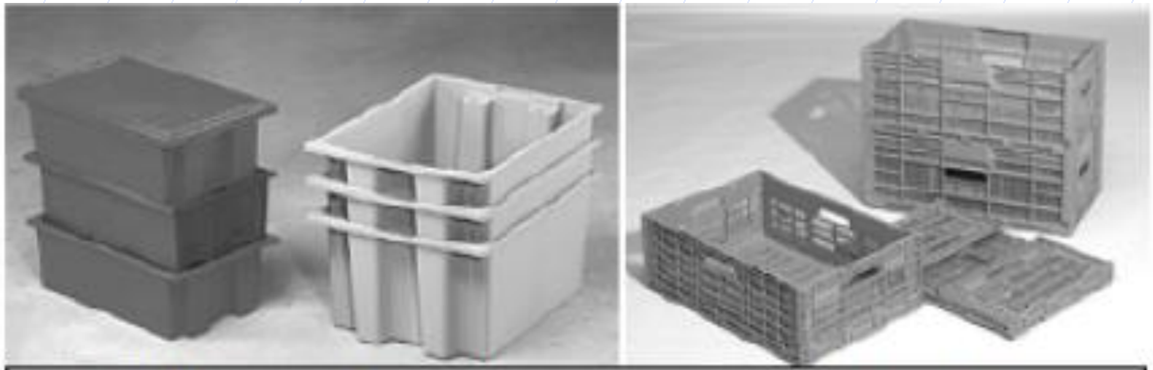
# Unit Loads (contd.)

## Efficiency of containers

يمكن استخدامه أكثر من مرة

- Returnable containers should have good *stacking* and *nesting* features can provide significant reduction in material handling costs

- *Stackability* means that a full container can be stacked on top of another full container in the same orientation.
- *Nestability* means that the shape of the containers permits an empty container to be inserted into another empty container.



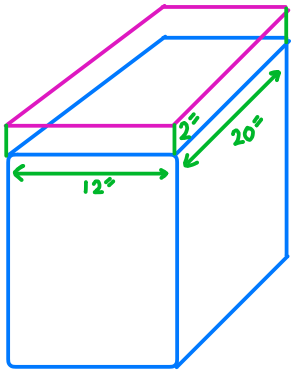
Stackable Nestable Collapsible

شرح ← https://youtu.be/xAyfk6MyvqI?si=3yAMrl1FltUGpcmh (نفس سؤال السلايدات)

Example:
Given the following dimensions of a particular type of plastic reusable containers:

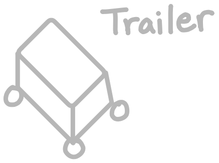
- ■ Inside dimensions 18”x 11”x11”
- ■ Outside dimensions 20”x12”x12”
- ■ Each nested container 20”x12”x2” → الارتفاع الظاهر لما ندخل two containers
- ■ A trailer inside dimension 240”x120”x120”
- ■ Containers are not palletized. Assume no clearance is needed between containers, and between containers and the walls of the trailer

يعني لا نضع تحتها pallete



Determine the following:

1. Container space utilization.
2. Container nesting ratio.
3. Trailer space utilization (if all containers stacked vertically in only one orientation).
4. Trailer return ratio.



① Container Space utilization $= \frac{\text{inside dimension}}{\text{outside dimension}} = \frac{18 \times 11 \times 11}{20 \times 12 \times 12} = 75.625 \approx \boxed{76\%}$

② Container nesting Ratio $= \frac{\text{container outside hieght}}{\text{nesting height}} = \frac{12}{2} = \boxed{6}$

(نهتم فقط بال Height)

← كل ما كانت أقل كل ما كان أفضل

⟹ so (6) nested container use the Same space as one closed container

③ Trailer Space Utilization =

↪ ※ of Loaded containers that the trailer can take

(we need to determine how much container are in the

- Length → $\frac{240}{20} = \underline{12}$ containers along the Length
- and width → $\frac{120}{12} = \underline{10}$ containers along the width
- and height → $\frac{120}{12} = \underline{12}$ containers along the height

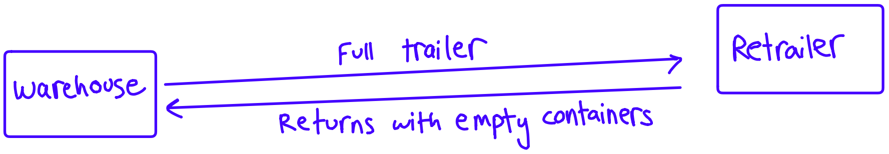
※ so Total number of containers $= 12 \times 10 \times 10 = 1200$ full containers

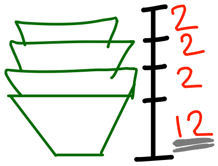
and now the trailer Utilization $= \frac{\text{※ of container} \times \text{container inside dimension}}{\text{Trailer inside dimension}}$

$$= \frac{1200 \times (18 \times 11 \times 11)}{240 \times 120 \times 120} = \boxed{76\%}$$

④ Trailer Retail Ratio $= \dfrac{\text{\# of empty containers fit in the trailer}}{(\text{\# of full containers fit in the trailer})}$

من الفرع القبل
1200





so number of containers stacked vertically $= \underset{\text{دائماً}}{1} + \dfrac{(\overset{\text{the height of the trailer}}{120} - \overset{\text{the first height}}{12})}{\underset{\text{the nested height}}{2}} = 1 + \dfrac{108}{2} = \boxed{55}$ empty containers vertically

*so total # of empty containers $= 55 \times 12 \times 10 = 6600$ empty container

*Trailer Return Ratio $= \dfrac{\text{\# of empty containers fits in the trailer}}{\text{\# of full containers fits in the trailer}}$

$= \dfrac{6600}{1200}$

$= \boxed{5.5}$ → we want this number to be as high as possible

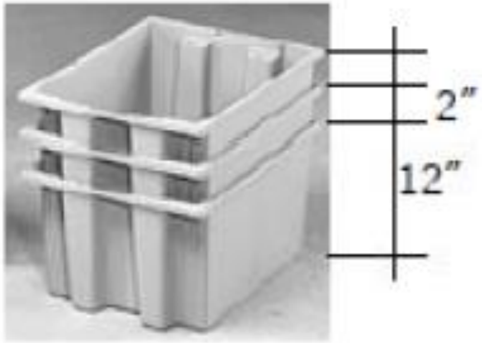
# Unit Loads (contd.)

## Efficiency of containers

- Efficiency of Returnable Containers:

  Example:

- Given the following dimensions of a particular type of plastic reusable containers:
  - Inside dimensions 18″x 11″x11″
  - Outside dimensions 20″x12″x12″
  - Each nested container 20″x12″x2″
  - A trailer inside dimension 240″x120″x120″
  - Containers are not palletized. Assume no clearance is needed between containers, and between containers and the walls of the trailer.



# Unit Loads (contd.)

## Efficiency of containers

Example (contd.):

- Determine the following:

1. Container space utilization.
2. Container nesting ratio.
3. Trailer space utilization (if all containers stacked vertically in only one orientation).
4. Trailer return ratio.

# Unit Loads (contd.)

## Efficiency of containers

Example (contd.)

◆ Container space utilization:

- Divide the usable cube by the exterior envelope of the container. The container efficiency is:
- (18″x11″x11″)/(20″x12″x12″)=0.76 or **76%**

◆ The container nesting ratio:

- Divide the overall container height by the nested height:
- 12″/2″=6 (the ratio is **6:1**). Six nested containers use the same space as one closed container.

# Unit Loads (contd.)

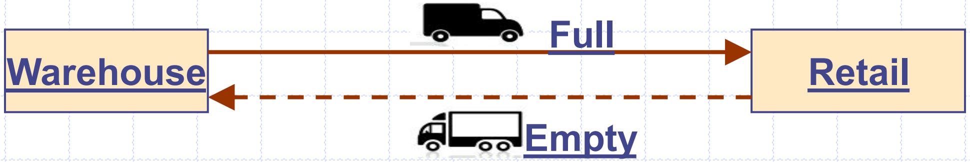
## Efficiency of containers

- The trailer space utilization:
  - Number of loaded containers that the trailer can take:

    240″/20″=12 container along the length, 120″/12″=10 containers along the width, and 120″/12″=10 containers stacked vertically. The total number is 12x10x10=1200.
  - The trailer space utilization is:

    (18″x11″x11″)(1200)/(240″x120″x120″)= 0.76 or **76%**
- The trailer return ratio:
  - One stack of loaded containers has 120″/12″=10 containers
  - One stack of empty containers has: 1+(120″-12″)/2″=55
  - The total number of empty containers per trailer is:

    55x12x10=6600 containers
  - The trailer return ratio: 6600/1200 = **5.5**



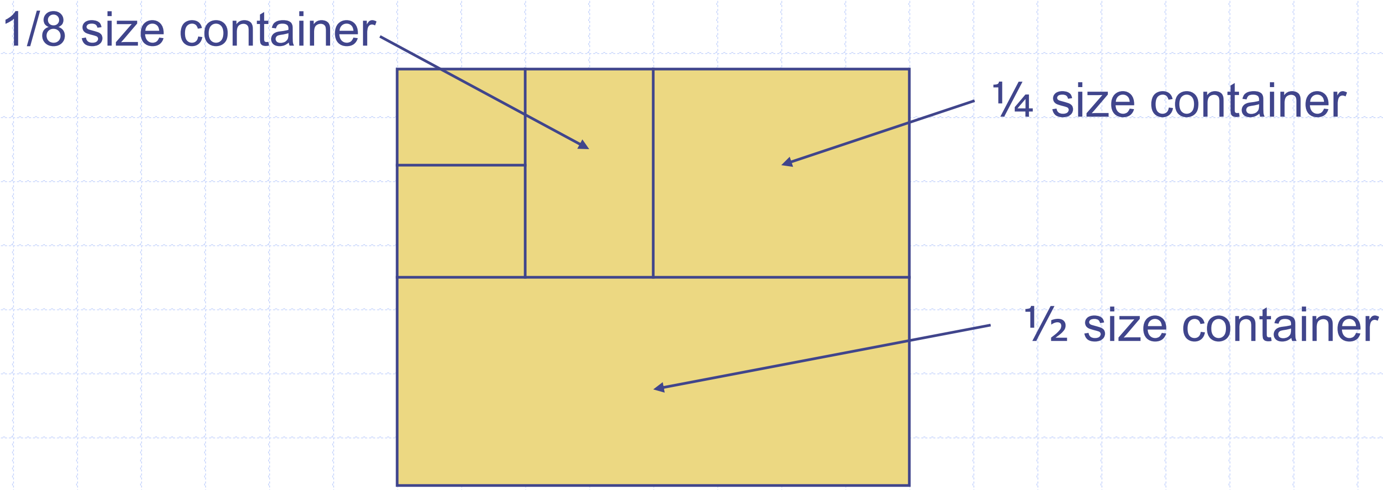
# Unit Loads (contd.)

## Efficiency of containers

- In selecting containers, size progression is one of the important consideration (e.g. a smaller container is half the size of the larger container: 1, 0.5, 0.25, 0.125,and so on).

مثلاً Large أصغر منه $\frac{1}{2}$ ب $\frac{1}{4}$ $\frac{1}{8}$

- These types of containers ① allows the efficient utilization of the load deck of an automated guided vehicle , also ② simplify the pallet loading of mixed-sized containers.



# Unit Loads (contd.)

Pallets and Pallet Sizes:

- Another common method of containing the unit load.
- Common pallet sizes: 32 in x 40 in , 36 in x 48 in
  40 in x 48 in , 42 in x 42 in, 48 in x 40 in, 48 in x 48 in
- The first dimension corresponds to the length of the stringer board , and the second dimension to the length of deck-board of the pallet.

- Two-way pallet: the fork entry can be only on two opposite sides of the pallet and is parallel to the stringer side.
- Four-way pallet: the fork entry can be on any side.

Pallet

# Unit Loads (contd.)

- Pallets and Pallet Sizes:
- Table 5.2 shows a comparison of various types of pallets (wood, plastic ,metal, etc.).
- The relationship between the container and the pallet, referred to as the *pallet loading problem*.
  - The objective is to maximize the use of space.
  - Another objectives are load stability and low cost.

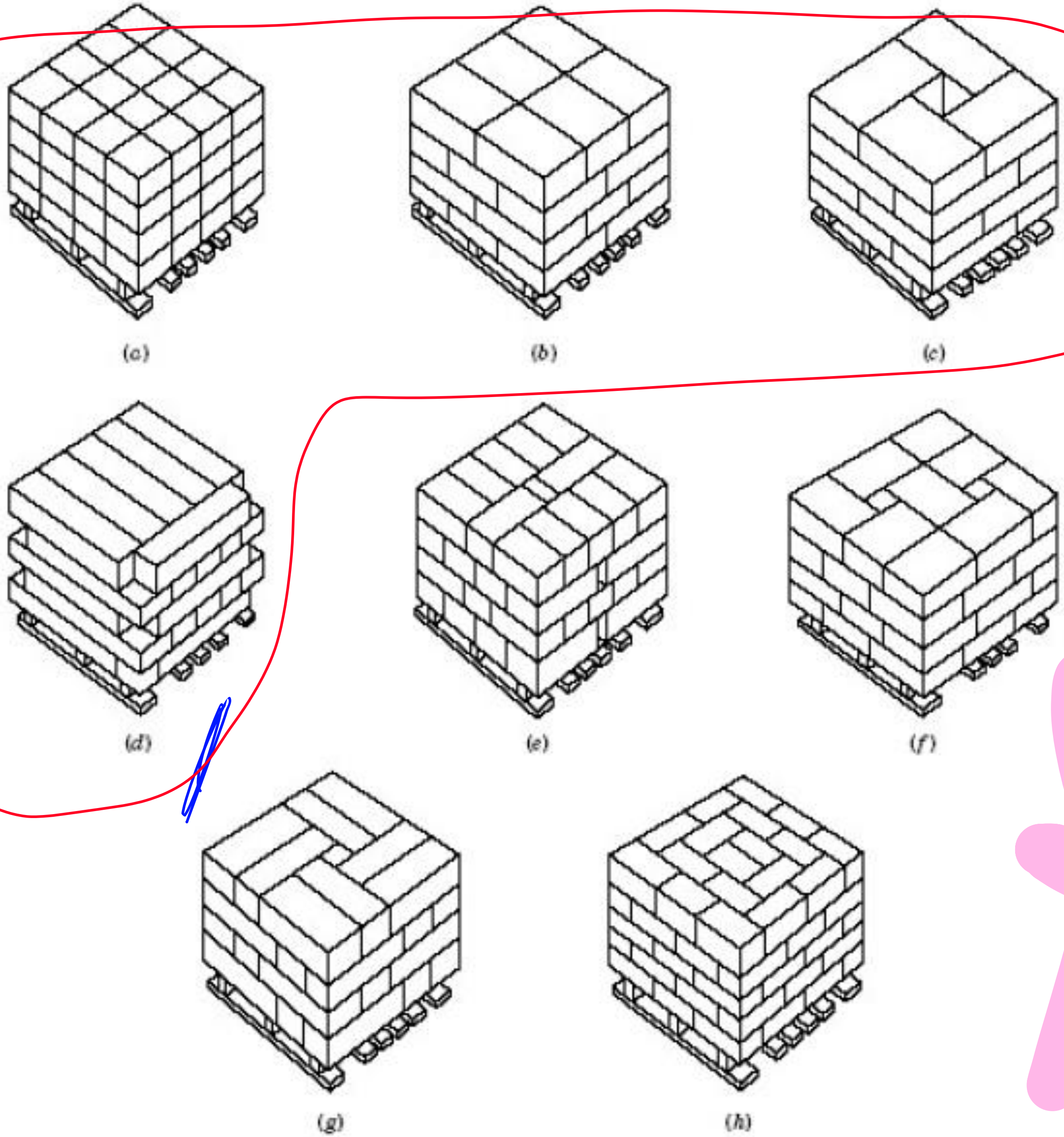


Figure 5.9 Stacking patterns for different pallet sizes. (*a*) Block pattern. (*b*) Row pattern. (*c*) Pinwheel pattern. (*d*) Honeycomb pattern. (*e*) Split-row pattern. (*f*) Split-pinwheel pattern. (*g*) Split-pinwheel pattern for narrow boxes. (*h*) Brick pattern. (*From [7] with permission.*)

# Unit Loads (contd.)

## Unit Load Interaction with Warehouse Components:

- The purpose is to illustrate the relationship between the unit load size and configuration and certain other system factors.
- Warehouse components include:
  - the packaging, palletizing, storing, and shipping operations.
- Critical factors in this interaction are:
  - the specifications of the carton used, and the pallet size.
- These factors affect the selection of:
  - the material handling equipment, the physical configuration of the storage facility, and the utilization of both the warehouse and highway trailer.

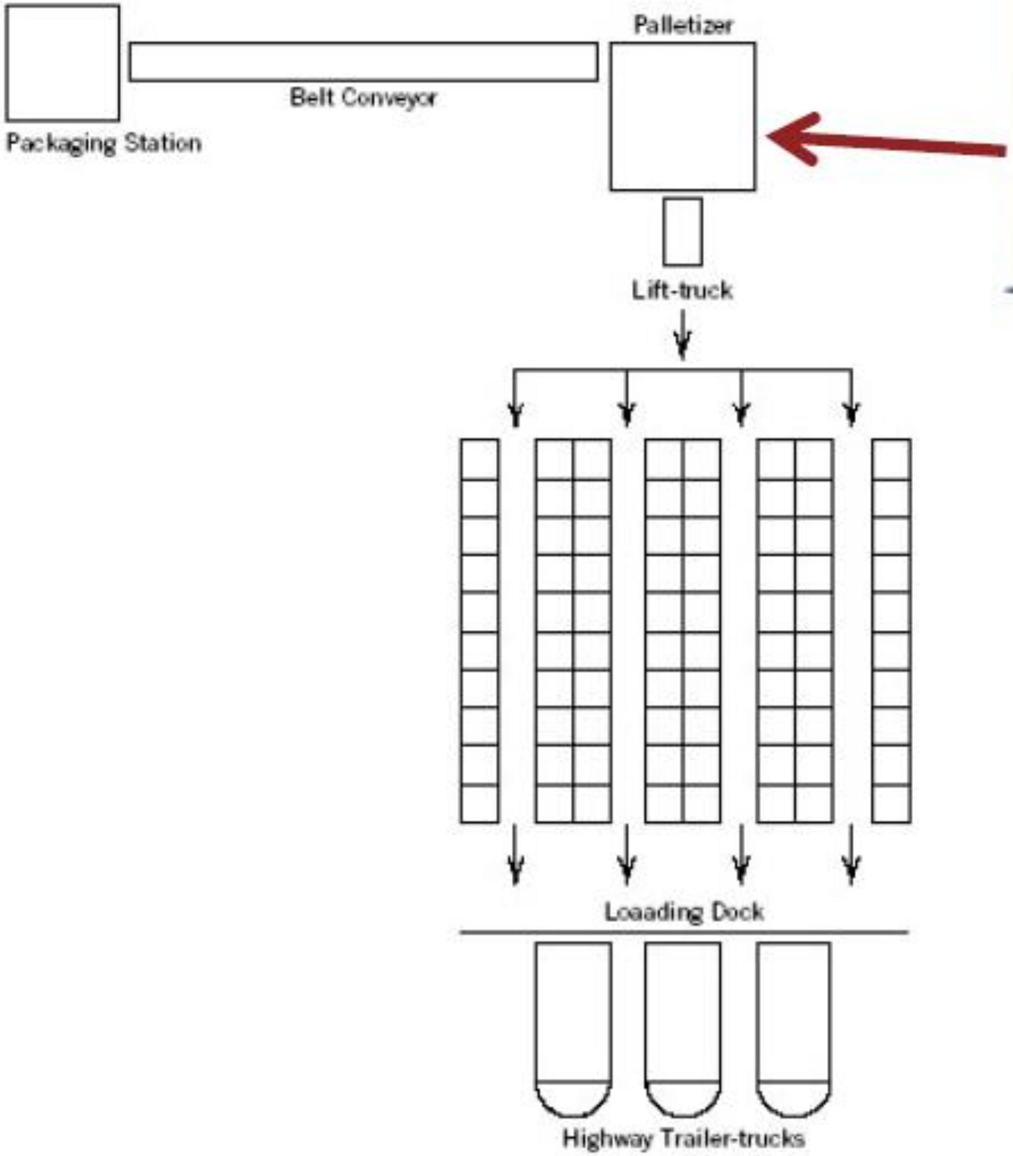
# Unit Loads

## Unit Load Interaction with Warehouse Components:

Example:

The operations included in this example are :

1. Finished goods are packaged using closed-top cartoons.
2. The cartons are transported to a palletizer.
3. The pallet loads are formed using a mechanized palletizer.
4. The full pallet loads are then stored in the finished goods warehouse using a powered lift truck.
5. Upon receipt of customer orders, full pallet loads are retrieved from the warehouse by a powered lift truck.
6. The pallets are then loaded on highway trailer trucks.



(warehouse componants)

- Manufacturing subsystem of
  - packaging
  - palletization
  - storage
  - shipping

# Unit Loads

## Unit Load Interaction with Warehouse Components:

Example (contd.):

- The specifications of the carton size is the most critical element in the design of the unit load system.
- The carton size dictates:
  - the number of parts contained in each carton, and total number of cartons that may be packaged and transported to the palletizer.
- The carton flow rate to the palletizer depends on:
  - the parts flow rate to packaging stations, and the time required to package each carton.
- The rate at which full pallet loads are formed is a function of:
  - the capacity of the palletizer, the carton size, and pallet size.

أسرع ↑ ⟺ أكبر ↑

# Unit Loads

## Unit Load Interaction with Warehouse Components:

Example (contd.):

- A powered lift truck is used to pick up loads from the palletizer to warehouse, and from warehouse to delivery location. Hence, the type of material handling equipment will dictate the floor space requirements for the warehouse.
  - For instance, the use of a narrow-aisle truck can reduce the floor space requirements.
- The next step is loading of the pallet loads into highway trailer-truck for delivery to customers.
- The number of pallet loads delivered per truckload is constrained by:
  - the inside dimensions of the trailer, and the dimensions and capability of the dock lift truck to maneuver the load inside the trailer.

# Unit Loads

## Unit Load Interaction with Warehouse Components:

Example (contd.)

- Further tradeoffs must be considered between warehouse storage space utilization and the trailer-truck utilization. (Number of the trips).
- The above example highlighted the many interactions possible between unit load and warehouse components.
- See the numerical example that given in the text book page 197 to illustrate some of the interactions.

# Unit Loads (contd.)

## Container and Pallet Pooling:

- Instead of buying, rent containers and pallets for a fee per day per container or pallet.
- Advantages:
  - Minimize the movement of empty pallets.
  - Utilization is increased.
  - No need for allocating extra space to store them.
  - Reduce maintenance.
  - Much better quality, less product damage, and efficient interfacing with material handling equipment.

Should the material handling system be designed around the unit load or should The unit load system be designed to fit the material handling system?

# Material Handling Equipment

MH equipments are classified into the following categories:

1. Containers and Unitizing Equipment
2. Material Transport Equipment
3. Storage and Retrieval Equipment
4. Automatic Data Collection and Communication Equipment

③

②

①

④

②

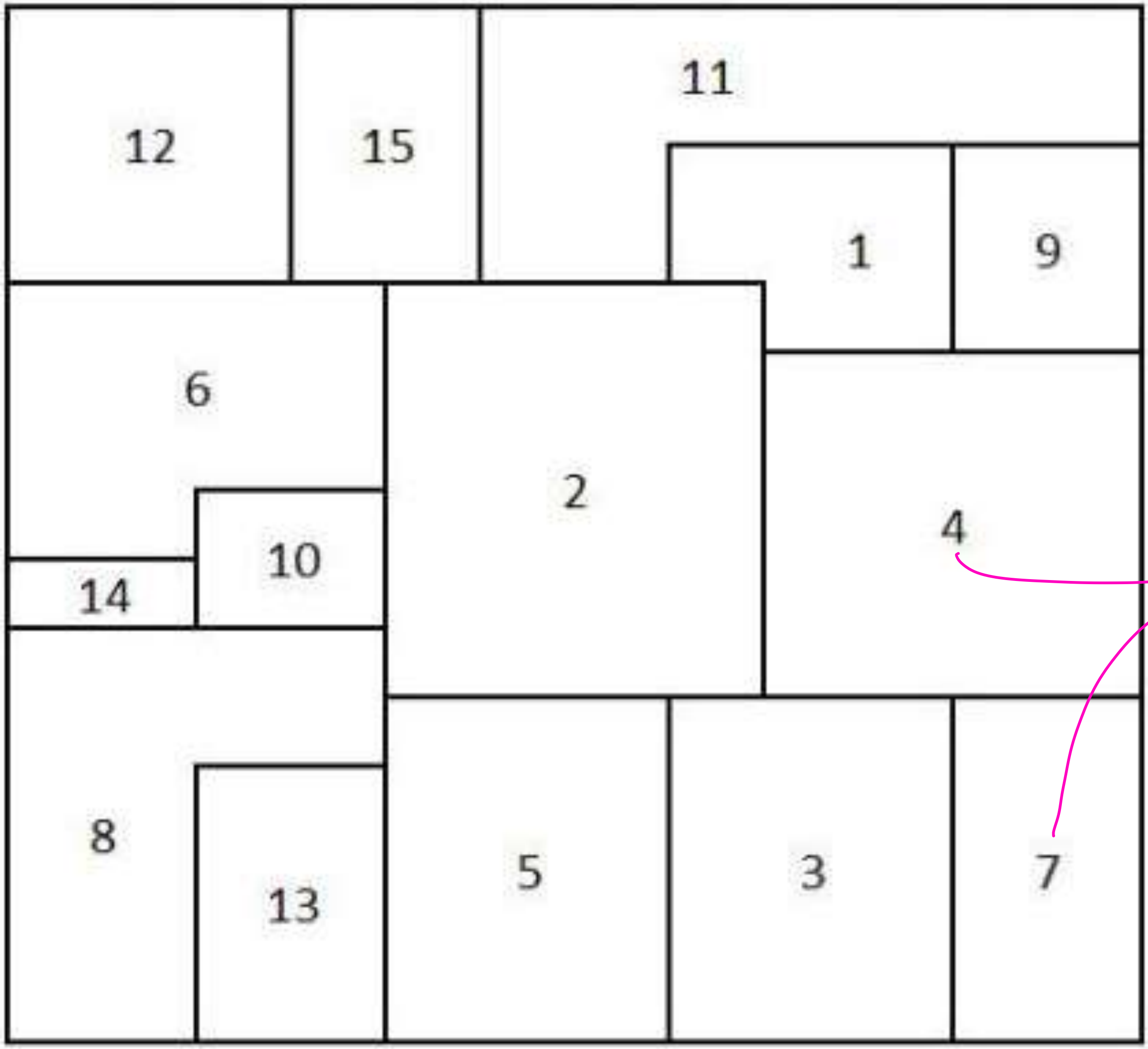
# Chapter 6

# Layout Planning Models and Design Algorithms

# Basic layout types

- Layout: will serve to establish the physical relationship between activities.
- Types of layout designs:
  - **Block layout**
    - Shows relative locations and sizes of the departments
  - **Detailed layout**
    - Show the exact locations of all the equipment, workstations, storage within the departments

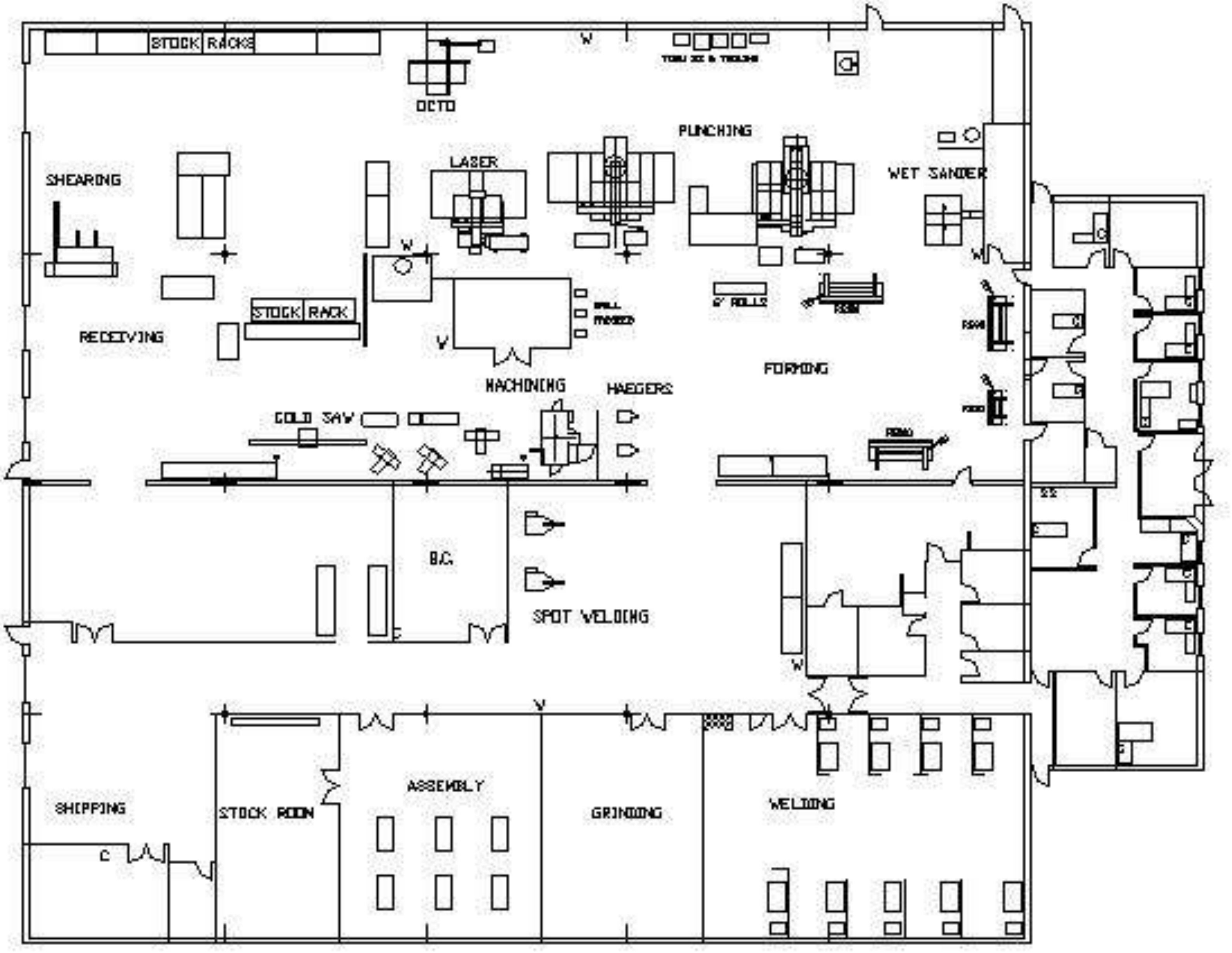
The final layout plan is the end result of Facilities Design.



ارقام
ال Departments

Block Layout

شكل ال Department
مساحة ال Department



# Detailed Layout

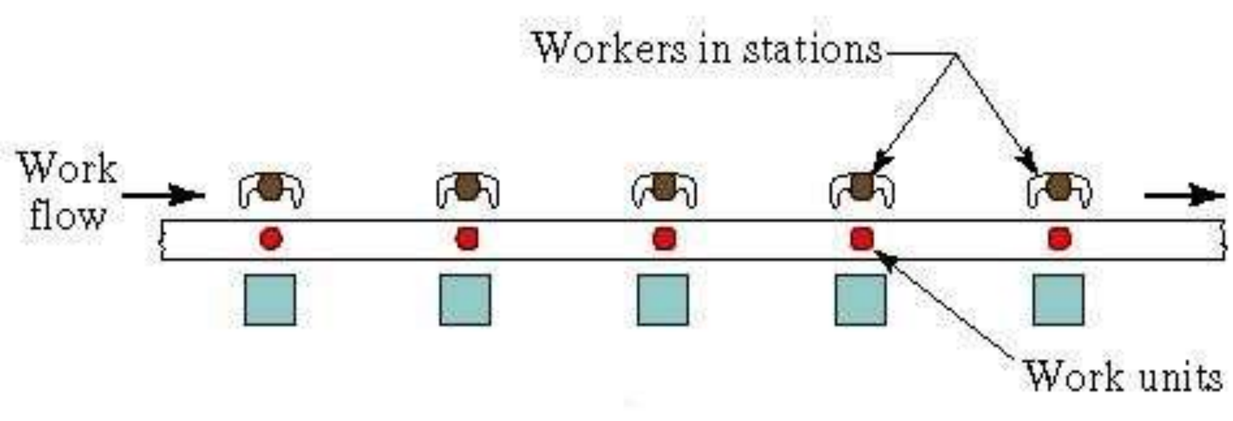
نرى من خلالها ال Department
بالإضافة إلى ال machines
+
storage
+
entrance

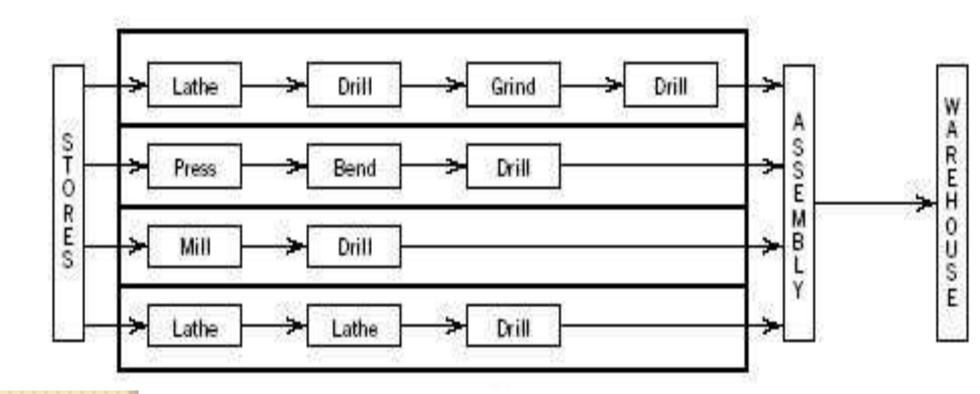
# Types of Layout

1. Product layout →
   يعني نحتاج الـ machine
   to produce products
   in the same place
2. GT based (or Product Family) layout
3. Process layout →
   ex:
   All the Milling machines
   are in the same departement
4. Fixed product layout →
   ال Product
   very Large
   فبنحتاج كل ال machines
   تكون حول ال product
5. Hybrid layout

* Advantages and Disadvantages of each Layout
(Read Table (3.2) (page 112))

# Product Layout





Product:

- Standardized
- Large stable demand

Layout:

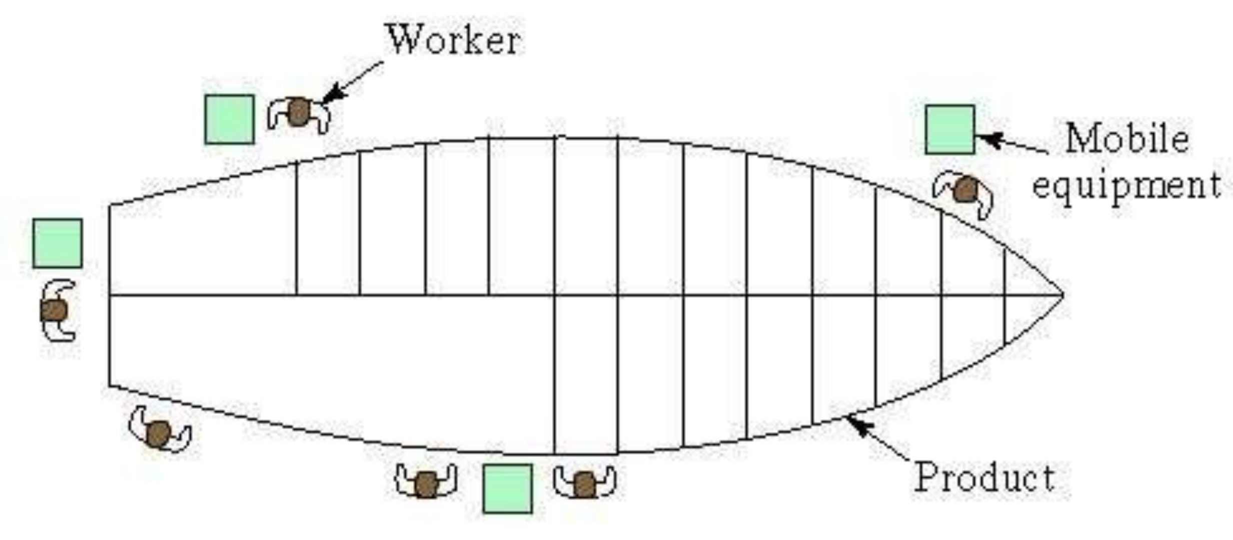
- Combines all workstations required to produce the product

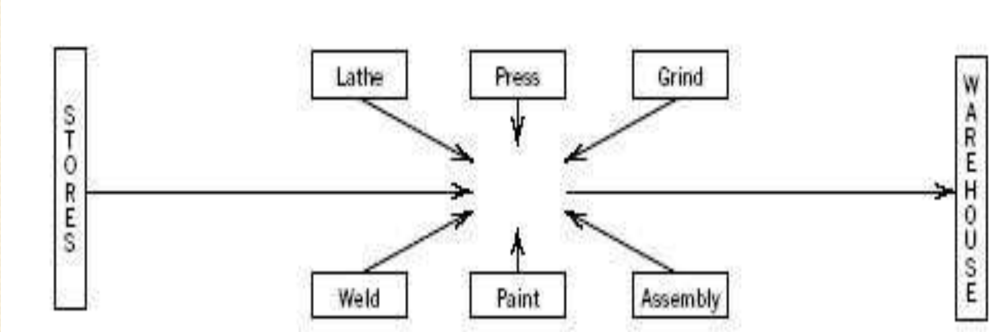
# Product Layout

The product flows through an assembly line while the personnel and equipment movements are limited

- Advantages
  - Smooth, simple, logical and direct flow
  - High Production Rate
  - Low cost per unit cost
  - High machine/worfkforce utilization
  - Lower material handling costs
  - Less personnel skill is required
  - Lower Work-In-Process Inventory (WIP)
- Disadvantages
  - High machine utilization is risky
  - Process performance depends on the bottleneck operation
  - May not be flexible enough for product design, volume changes
  - Decreased employee motivation
  - Huge investment is required

# Fixed Product Layout





Product:

- Physically large
- Awkward to move
- Low sporadic demand

Layout:

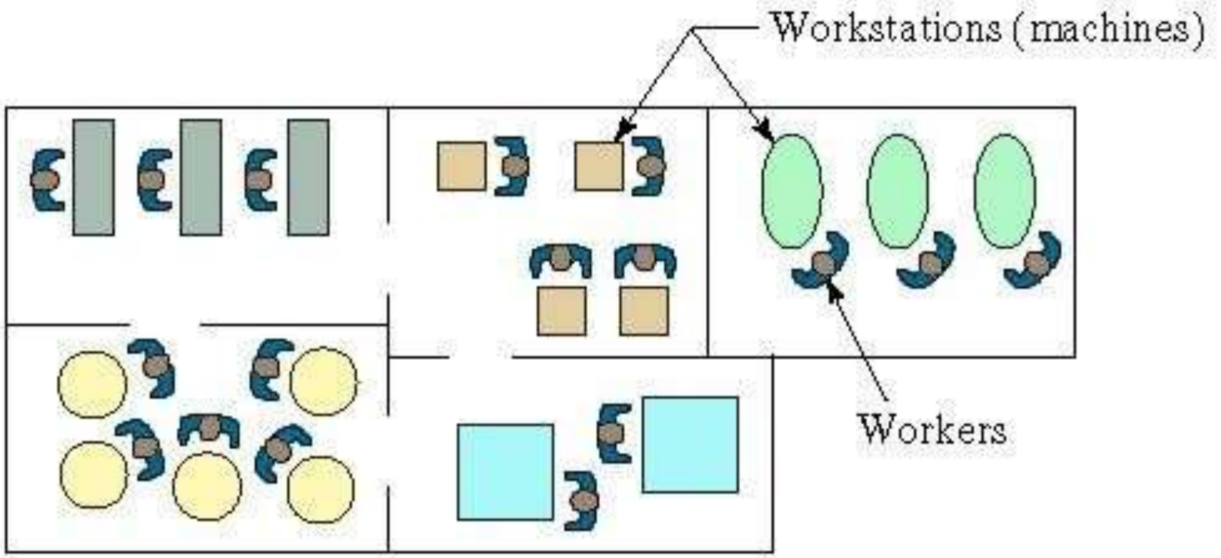
- Combines all workstations required to produce the product with the area required for staging the product

# Fixed Product Layout

Production is executed at a fixed location; materials, equipment, and personnel flow into this location.

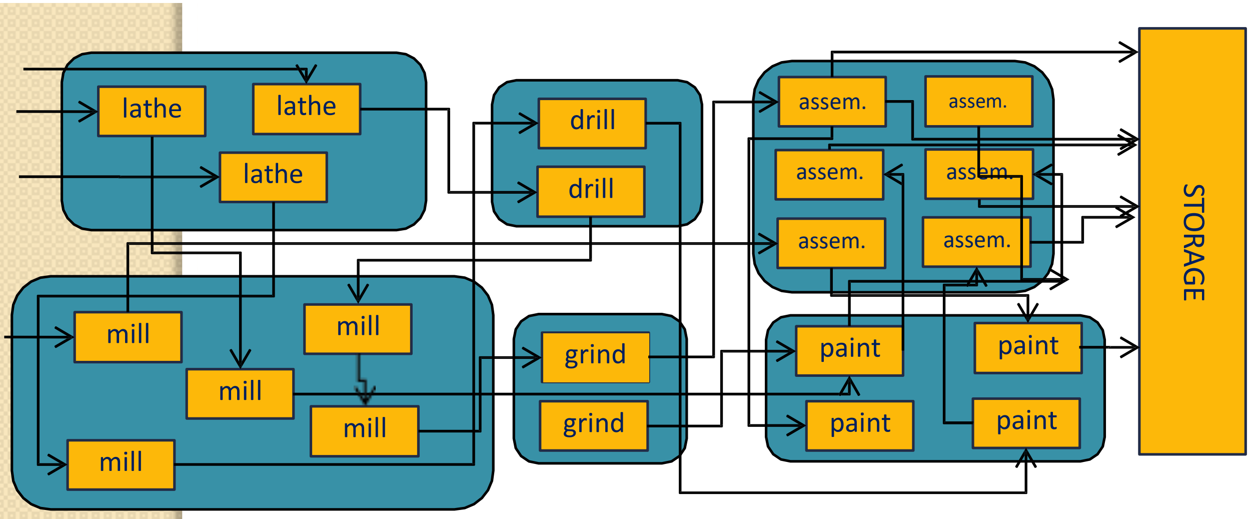
- Advantages
  - Material movement is reduced
  - An individual can complete the whole process
  - Job enrichment opportunities فرص الإثراء الوظيفي
  - Highly flexible; can accommodate any changes in design
- Disadvantages
  - Personal and equipment movement is increased
  - Risk of duplication of equipment خطر ازدواجية المعدات
  - Requires greater worker skills
  - Not suitable for high production volumes
  - Close control and coordination in scheduling

# Process Layout



Product:

- Great variety



Layout:

- Combines identical workstations into departments
- Combines similar departments

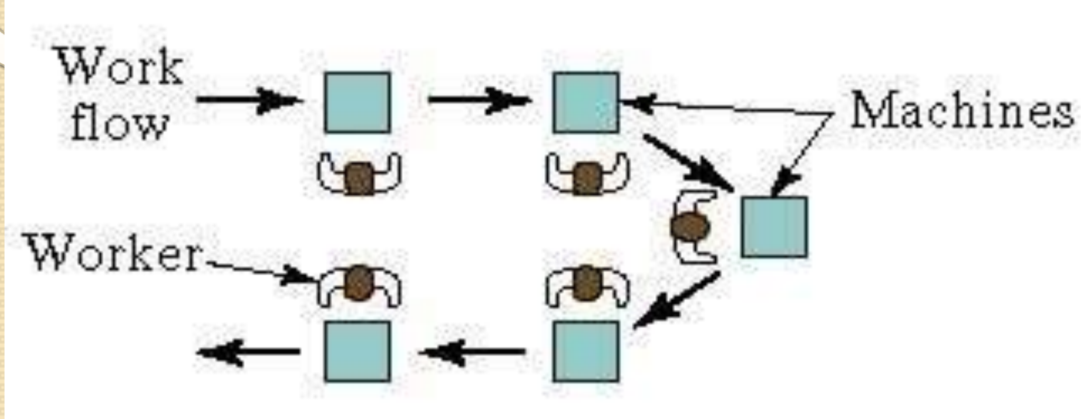
# Process Layout

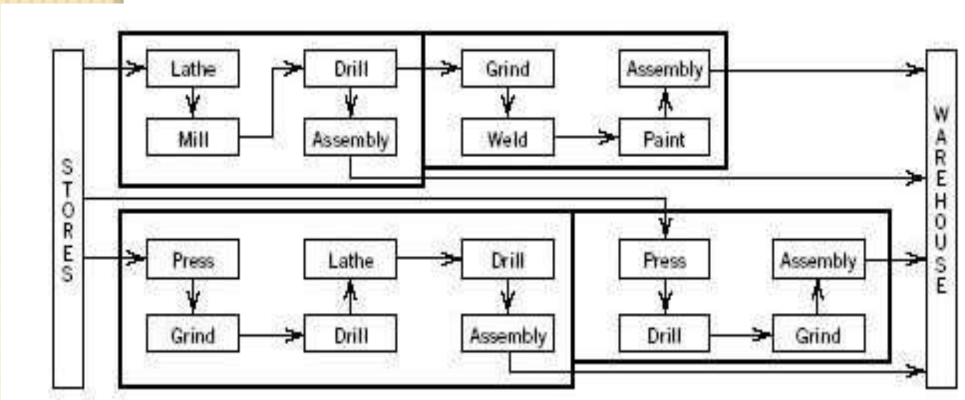
Similar/Same processes are grouped together.

- Advantages
  - Increased machine utilization
  - Flexible in allocating personnel and equipment
  - Robust against machine breakdowns
  - Robust against design, volume changes
  - Specialized supervision is possible

- Disadvantages
  - Material handling requirements are increased
  - Increased WIP
  - Longer production lines
  - Difficult to schedule the jobs
  - Higher skills are required
  - Difficult to analyze the process performance

# Product Family - Group Layout





Product:

- Capable of being grouped into families of similar parts

Layout:

- Combine all workstations required to produce the family of products

# Product Family - Group Layout

Product Family Layouts are like a combination of Product Layouts and Process Layouts

- Advantages
  - Combines benefits of product and process layouts
  - Higher machine utilization
  - Smoother flow lines and shorter distance
  - Team atmosphere
- Disadvantages
  - General supervision required
  - Greater labor skills requirement
  - Balancing manufacturing cells are difficult and unbalanced cells may increase WIP

# Layout Procedures

Two different categories:

1. Construction type: involves developing a new layout "from scratch“. General questions:
   a) How to construct the layout? In what sequence will we consider the departments, i.e. which department do we place in first, which second, etc.?
   b) How do we place the departments into the layout? Where do we put them?
   c) How do we “score” the layout?

نبدأ من الصفر

2. Improvement type: generate layout alternatives based on an existing layout. General questions:
   a) How to rearrange the departments? How to measure improvement? How do we “score” the layout?

# Layout Techniques

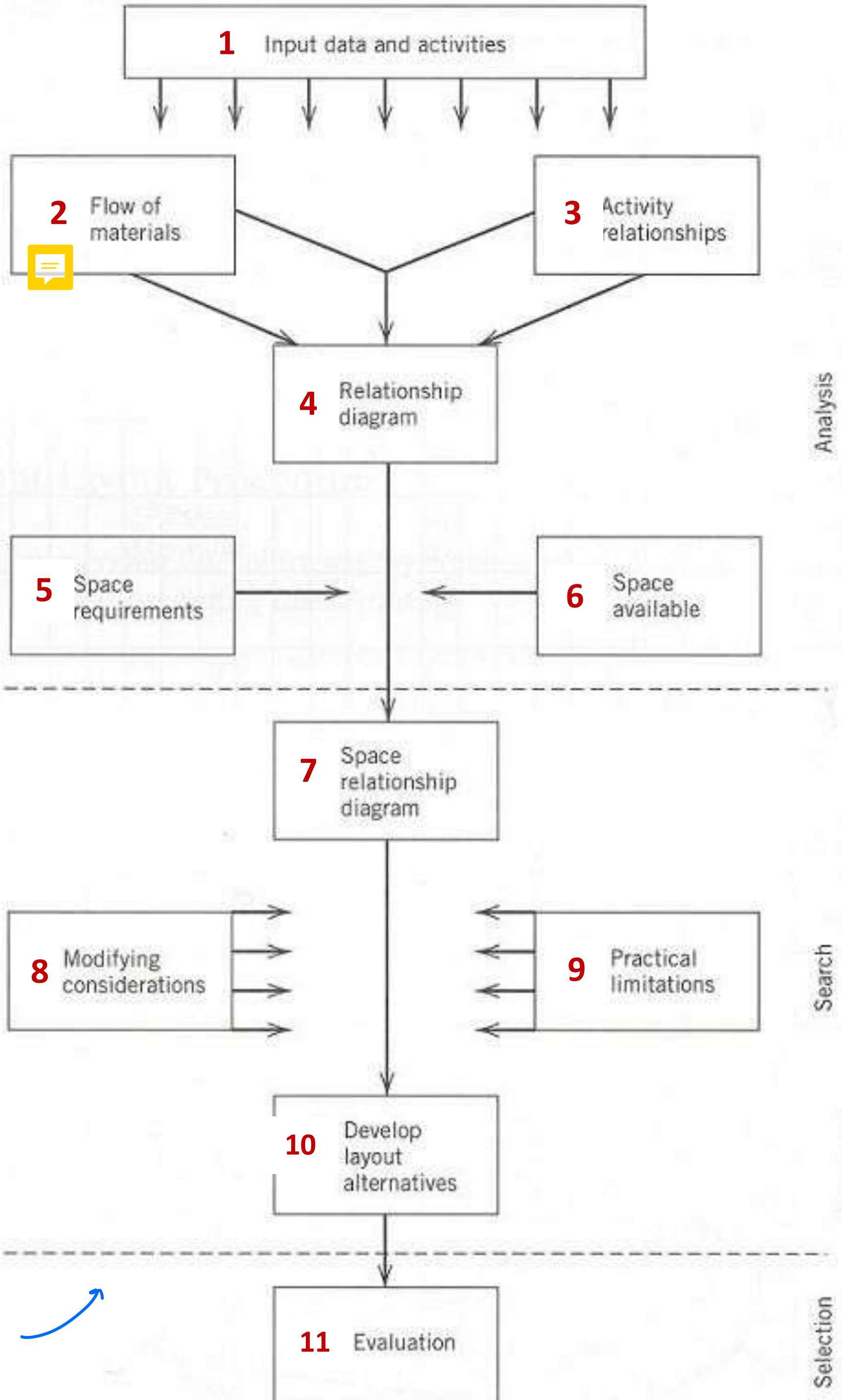
1. Manual: Examples:
   1. Apple's method (read the description in the text book)
   2. Reed's method (read the description in the text book)
   3. ✓ Systematic Layout Planning (SLP)
   4. ✓ Graph based method

يلي راح نشرحهم

2. Computerized: Examples:
   1. ✓ CRAFT
   2. BLOCPLAN
   3. MIP
   4. LOGIC
   5. MULTIPLE

✓

# Systematic layout planning procedure (SLP)



1 Input data and activities

2 Flow of materials

3 Activity relationships

4 Relationship diagram

5 Space requirements

6 Space available

7 Space relationship diagram

8 Modifying considerations

9 Practical limitations

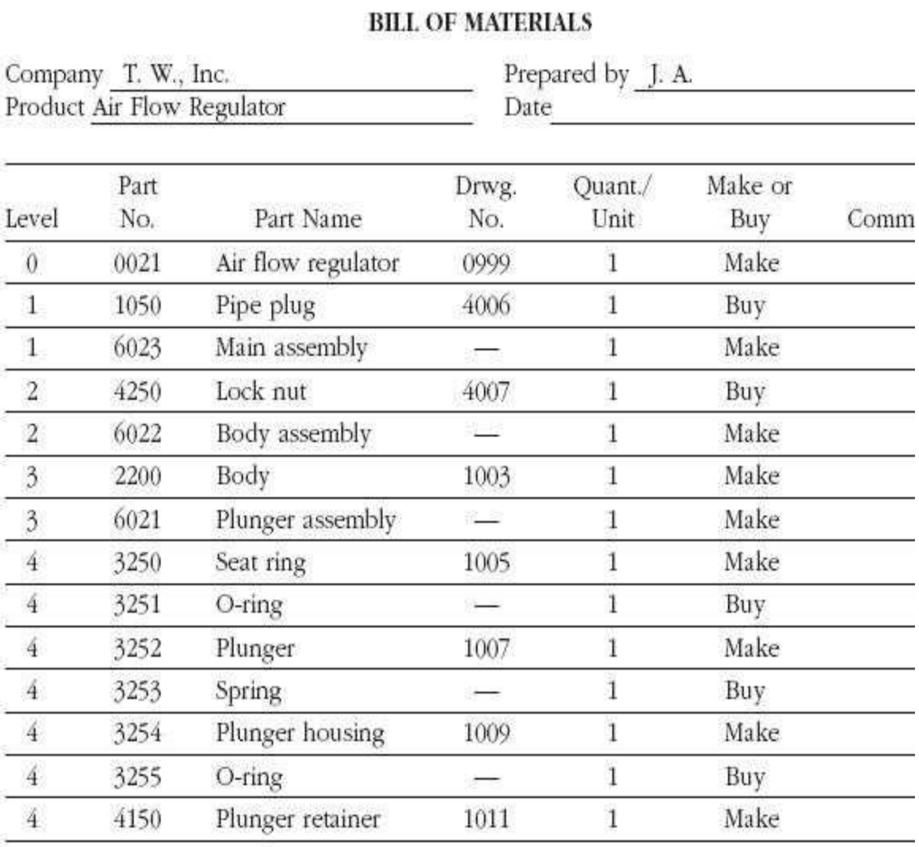
10 Develop layout alternatives

11 Evaluation

in book
Figure 6.3

# 1. Input data and activities

- Bill of materials
- Operation process chart

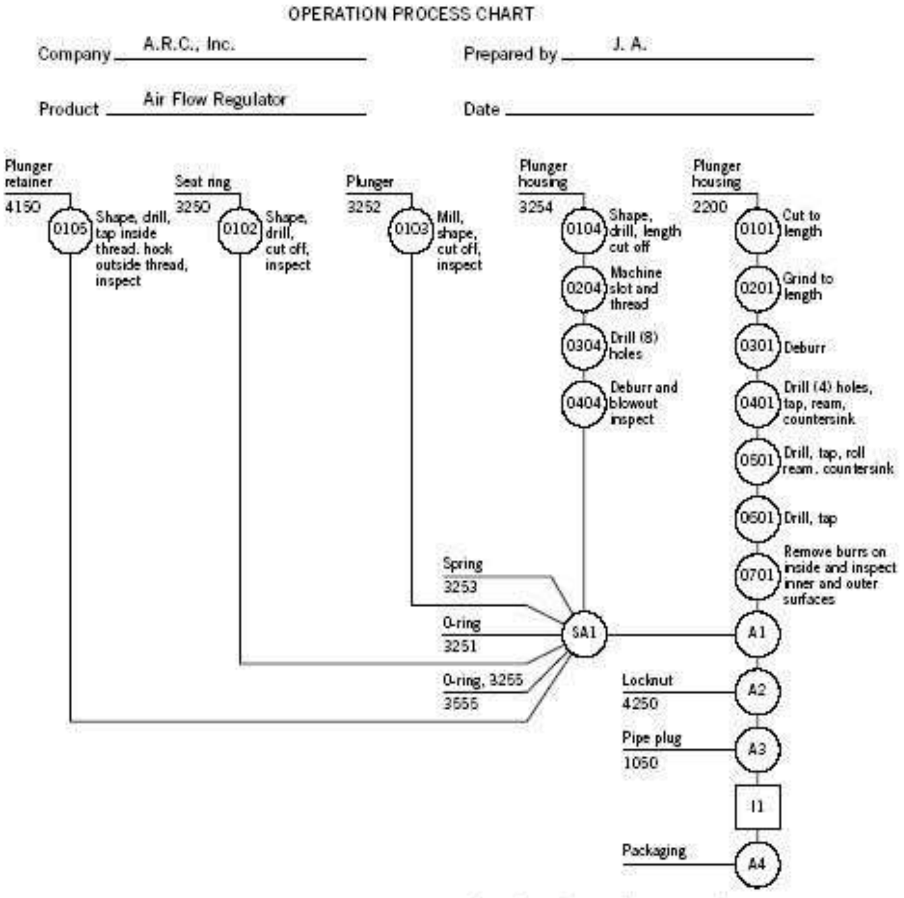


BILL OF MATERIALS

Company T. W., Inc.
Prepared by J. A.
Product Air Flow Regulator
Date

| Level | Part No. | Part Name | Drwg. No. | Quant./ Unit | Make or Buy | Comm |
|---|---|---|---|---|---|---|
| 0 | 0021 | Air flow regulator | 0999 | 1 | Make | |
| 1 | 1050 | Pipe plug | 4006 | 1 | Buy | |
| 1 | 6023 | Main assembly | — | 1 | Make | |
| 2 | 4250 | Lock nut | 4007 | 1 | Buy | |
| 2 | 6022 | Body assembly | — | 1 | Make | |
| 3 | 2200 | Body | 1003 | 1 | Make | |
| 3 | 6021 | Plunger assembly | — | 1 | Make | |
| 4 | 3250 | Seat ring | 1005 | 1 | Make | |
| 4 | 3251 | O-ring | — | 1 | Buy | |
| 4 | 3252 | Plunger | 1007 | 1 | Make | |
| 4 | 3253 | Spring | — | 1 | Buy | |
| 4 | 3254 | Plunger housing | 1009 | 1 | Make | |
| 4 | 3255 | O-ring | — | 1 | Buy | |
| 4 | 4150 | Plunger retainer | 1011 | 1 | Make | |

**Figure 2.8** Bill of materials for an air flow regulator.



OPERATION PROCESS CHART

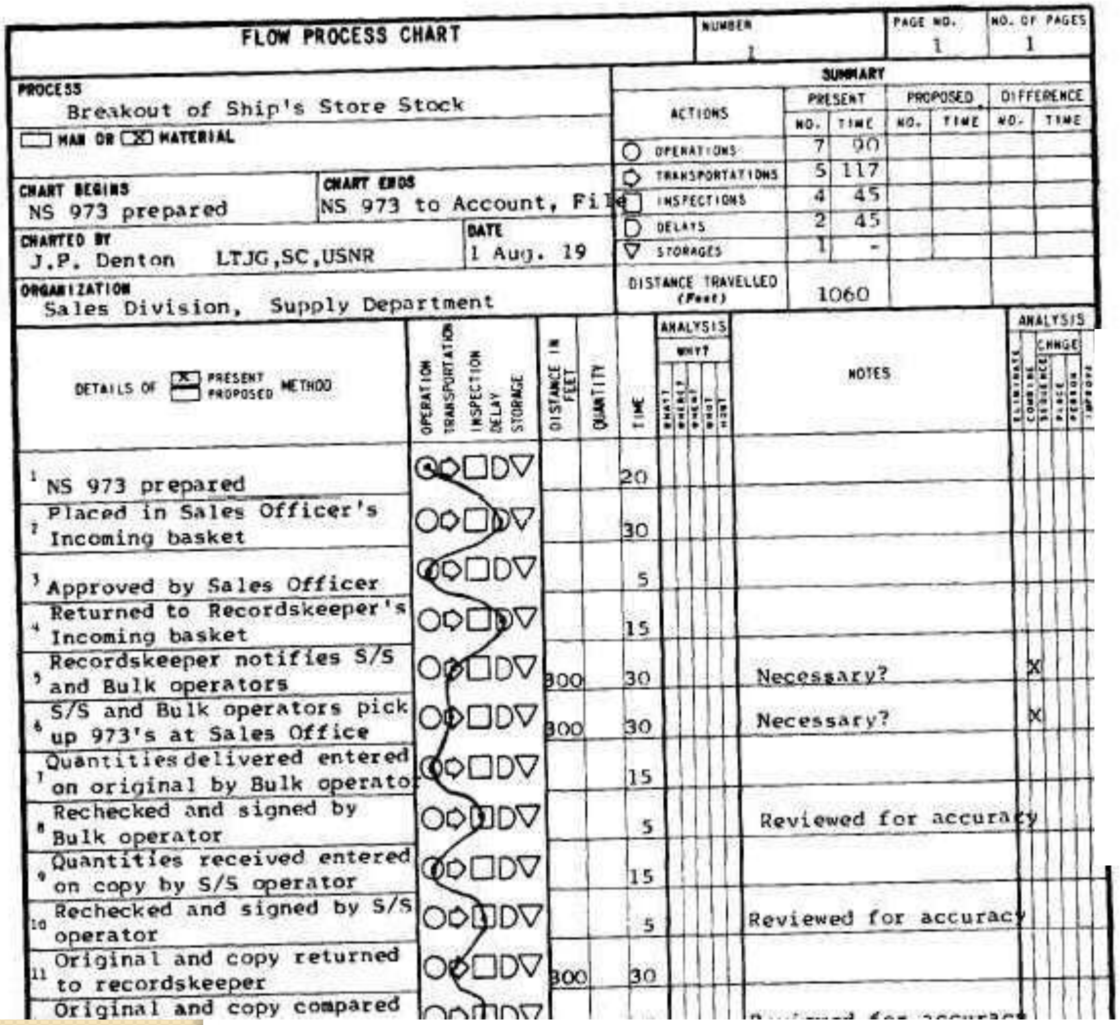
Company A.R.C., Inc.
Prepared by J. A.
Product Air Flow Regulator
Date

Plunger retainer
4150
0105
Shape, drill, tap inside thread. hook outside thread, inspect
Seat ring
3250
0102
Shape, drill, cut off, inspect
Plunger
3252
0103
Mill, shape, cut off, inspect
Plunger housing
3254
0104
Shape, drill, length cut off
0204
Machine slot and thread
0304
Drill (8) holes
0404
Deburr and blowout inspect
Plunger housing
2200
0101
Cut to length
0201
Grind to length
0301
Deburr
0401
Drill (4) holes, tap, ream, countersink
0501
Drill, tap, roll ream, countersink
0601
Drill, tap
0701
Remove burrs on inside and inspect inner and outer surfaces
Spring
3253
O-ring
3251
O-ring, 3255
3555
SA1
A1
Locknut
4250
A2
Pipe plug
1050
A3
I1
Packaging
A4

Figure 2.13 Operation process chart for the air flow regulator.

# 2. Flow of materials

## Flow process chart



**FLOW PROCESS CHART**

| | | | |
|---|---|---|---|
| NUMBER<br>1 | PAGE NO.<br>1 | NO. OF PAGES<br>1 | |

PROCESS
Breakout of Ship's Store Stock

☐ MAN OR ☒ MATERIAL

CHART BEGINS
NS 973 prepared

CHART ENDS
NS 973 to Account, File

CHARTED BY
J.P. Denton LTJG,SC,USNR

DATE
1 Aug. 19

ORGANIZATION
Sales Division, Supply Department

**SUMMARY**

| ACTIONS | PRESENT | | PROPOSED | | DIFFERENCE | |
|---|---|---|---|---|---|---|
| | NO. | TIME | NO. | TIME | NO. | TIME |
| ○ OPERATIONS | 7 | 90 | | | | |
| ⇨ TRANSPORTATIONS | 5 | 117 | | | | |
| □ INSPECTIONS | 4 | 45 | | | | |
| D DELAYS | 2 | 45 | | | | |
| ▽ STORAGES | 1 | - | | | | |
| DISTANCE TRAVELLED (Feet) | 1060 | | | | | |

DETAILS OF ☒ PRESENT ☐ PROPOSED METHOD

| | DETAILS | OPERATION / TRANSPORTATION / INSPECTION / DELAY / STORAGE | DISTANCE IN FEET | QUANTITY | TIME | ANALYSIS WHY? WHAT / WHERE / WHEN / WHO / HOW | NOTES | ANALYSIS CHNGE: ELIMINATE / COMBINE / SEQUENCE / PLACE / PERSON / IMPROVE |
|---|---|---|---|---|---|---|---|---|
| 1 | NS 973 prepared | ○ | | | 20 | | | |
| 2 | Placed in Sales Officer's Incoming basket | D | | | 30 | | | |
| 3 | Approved by Sales Officer | ○ | | | 5 | | | |
| 4 | Returned to Recordskeeper's Incoming basket | D | | | 15 | | | |
| 5 | Recordskeeper notifies S/S and Bulk operators | ⇨ | 300 | | 30 | | Necessary? | X |
| 6 | S/S and Bulk operators pick up 973's at Sales Office | ⇨ | 300 | | 30 | | Necessary? | X |
| 7 | Quantities delivered entered on original by Bulk operato | ○ | | | 15 | | | |
| 8 | Rechecked and signed by Bulk operator | □ | | | 5 | | Reviewed for accuracy | |
| 9 | Quantities received entered on copy by S/S operator | ○ | | | 15 | | | |
| 10 | Rechecked and signed by S/S operator | □ | | | 5 | | Reviewed for accuracy | |
| 11 | Original and copy returned to recordskeeper | ⇨ | 300 | | 30 | | | |
| | Original and copy compared | | | | | | | |

## From-to chart

| | Stores | Milling | Turning | Press | Plate | Assembly | Warehouse |
|---|---|---|---|---|---|---|---|
| Stores | – | 24 | 12 | 16 | 1 | 8 | – |
| Milling | – | – | – | – | 14 | 3 | 1 |
| Turning | – | 3 | – | – | 8 | – | 1 |
| Press | – | – | – | – | 3 | 1 | 1 |
| Plate | – | 3 | 2 | – | – | 4 | 3 |
| Assembly | 2 | – | – | – | – | – | 7 |
| Warehouse | – | – | – | – | – | – | – |

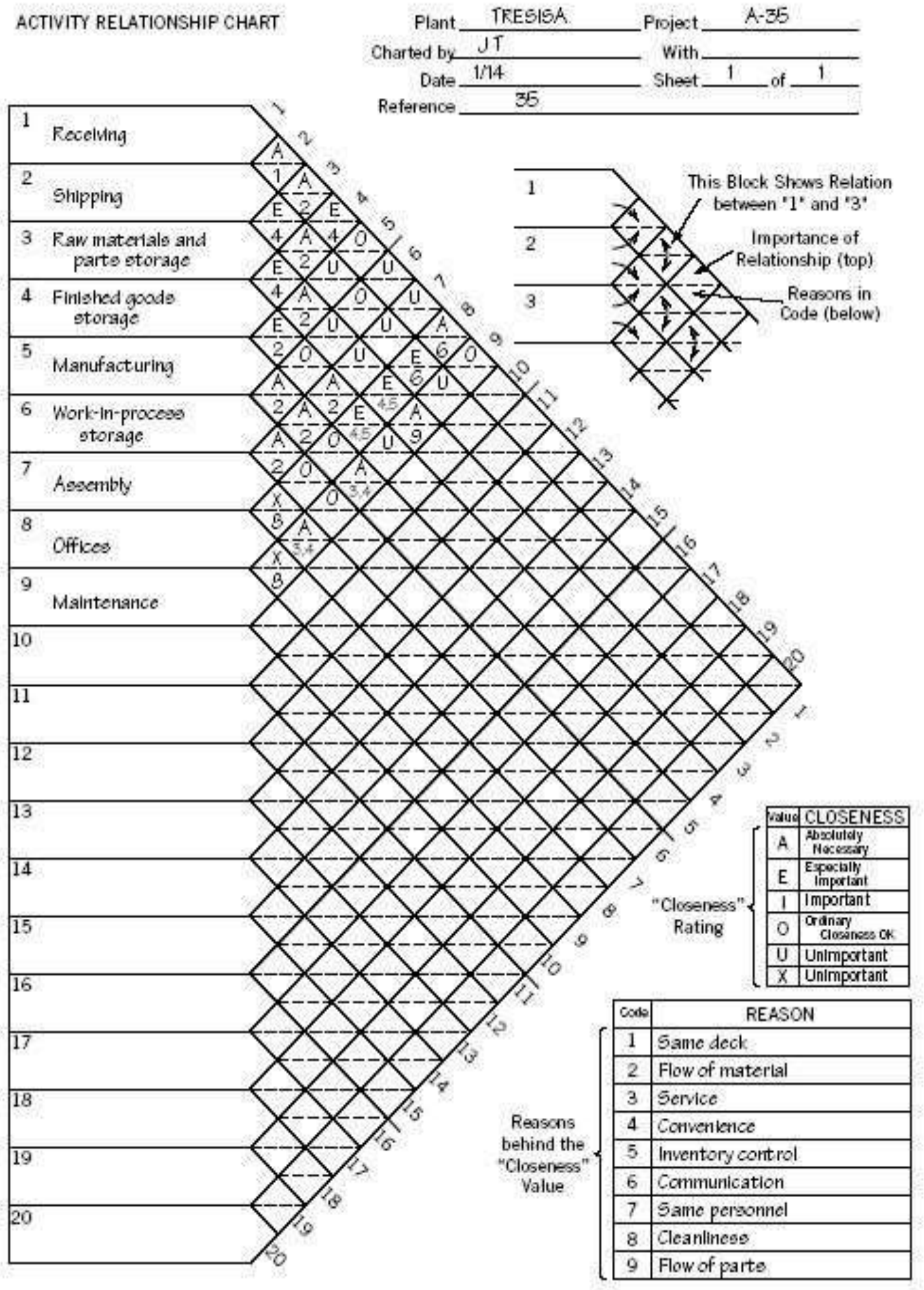
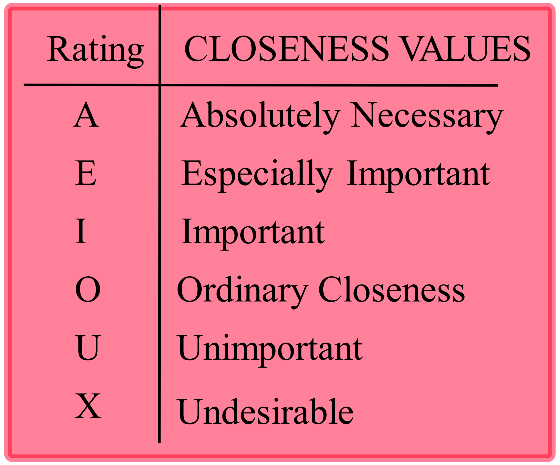


Figure 6.4 Activity relationship chart.

# 3. Activity relationships

- Relationship Chart measures the flows qualitatively using the **closeness relationships values**



| Rating | CLOSENESS VALUES |
|---|---|
| A | Absolutely Necessary |
| E | Especially Important |
| I | Important |
| O | Ordinary Closeness |
| U | Unimportant |
| X | Undesirable |

# 4. Relationship diagram

- The relationship diagram positions activities spatially مكانيا
  - Proximities reflect the relationship between pairs of activities تعكس القرب
  - Usually two dimensional 2-D

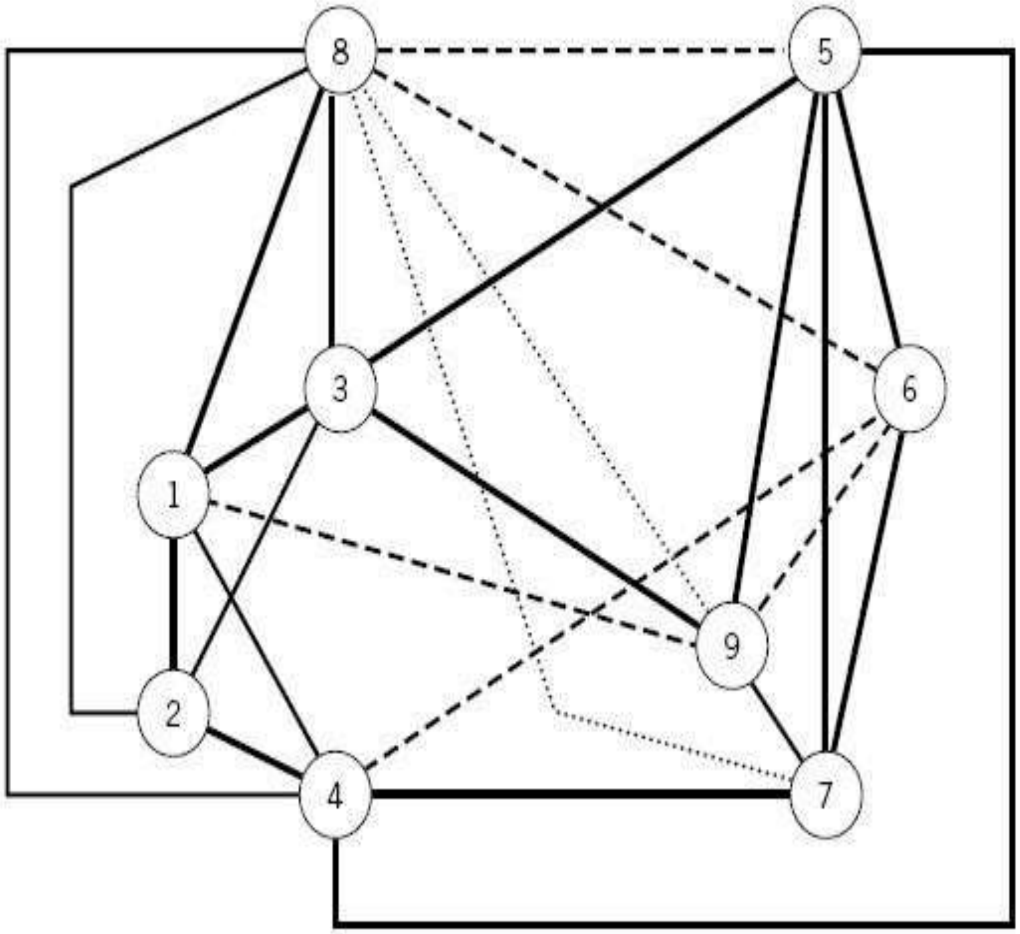


Figure 6.5 Relationship diagram.

# 5. Space requirements

- Required departmental area

| Depart. | Function | Area (ft$^2$) |
|---|---|---|
| D1 | Receiving | 12,000 |
| D2 | Milling | 8,000 |
| D3 | Press | 6,000 |
| D4 | Screw machine | 12,000 |
| D5 | Assembly | 8,000 |
| D6 | Plating | 12,000 |
| D7 | Shipping | 12,000 |

# 7. Space relationship diagram

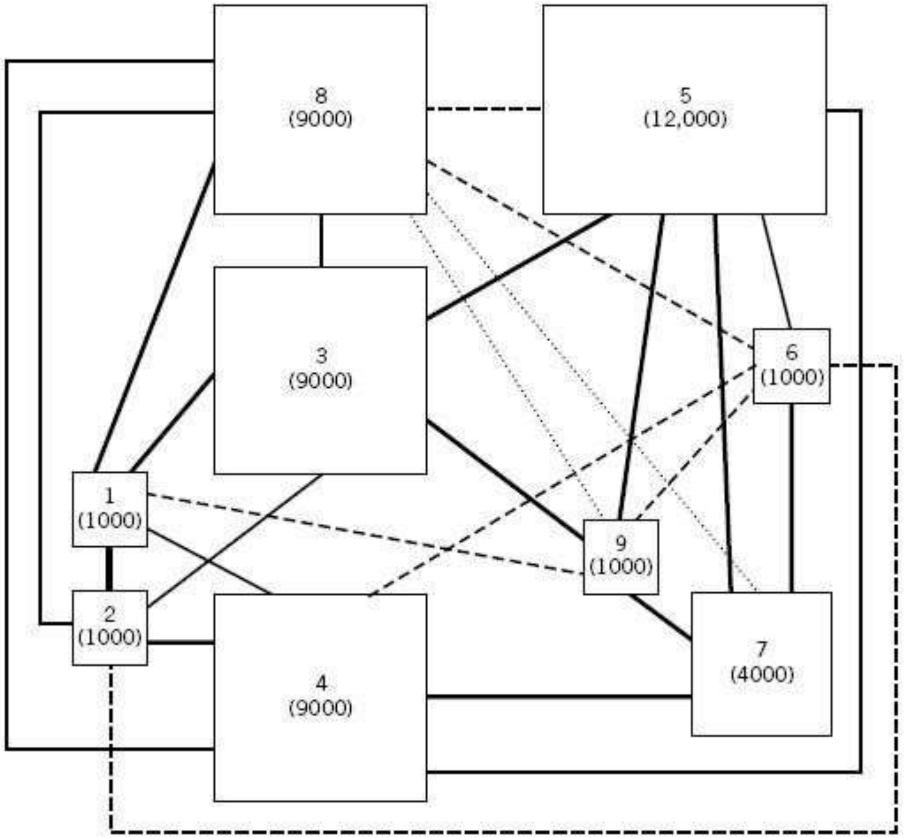
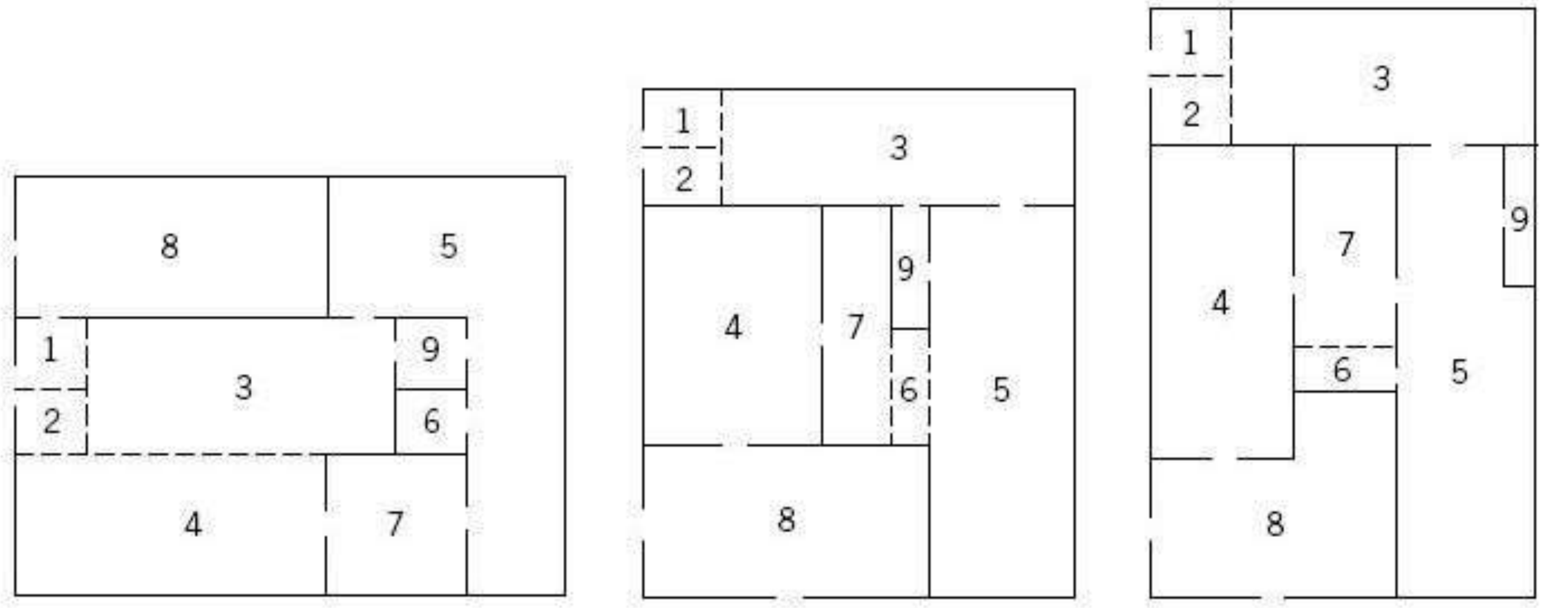


Figure 6.6 Space relationship diagram.

- Space relationship diagram combines space requirements with relationship diagram

# 10. Layout alternatives



- Conversion of a space relationship diagram into several feasible alternative **block layouts**
  - not a mechanical process

    حَدْس
  - importance of intuition, judgment and experience

# *Systematic Layout Planning (SLP)

6.7 Four departments are to be located in a building of 600′ × 1000′. The expected personnel traffic flows and area requirements for the departments are shown in the tables below. Develop a block layout using SLP.

| Dept. | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 250 | 25 | 240 |
| B | 125 | 0 | 400 | 335 |
| C | 100 | 0 | 0 | 225 |
| D | 125 | 285 | 175 | 0 |

| Department | Department Dimension |
|---|---|
| A | 200′ × 200′ |
| B | 400′ × 400′ |
| C | 600′ × 600′ |
| D | 200′ × 200′ |

https://www.youtube.com/watch?v=1Nd8rVjQ7Dg

شرح

## *Step ① Develop from to chart

( ما بهمني
الـ Direction )

| | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 375 | 125 | 365 |
| B | | 0 | 400 | 620 |
| C | | | 0 | 400 |
| D | | | | 0 |

| | |
|---|---|
| 620 | A |
| 400<br>400 | E |
| 375<br>365 | I |
| 125 | O |

## *step ② Develop Activity Relationship (matrix)

| | A | B | C | D |
|---|---|---|---|---|
| A | — | I | O | I |
| B | | — | E | A |
| C | | | — | E |
| D | | | | — |

من السؤال

B = 400 x 400

A = 200 x 200

D = 200 x 200

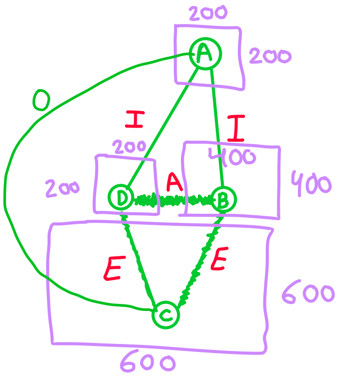
C = 600 x 600

→ square

## *step ③ Relationship Diagram

Proximity

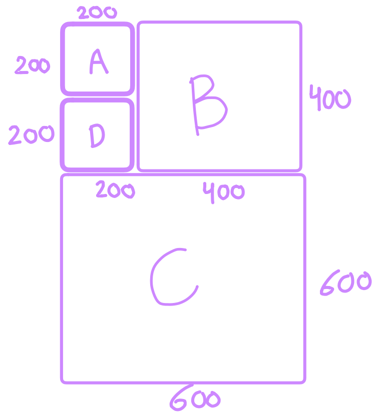
line boolches



طول الـ line
يعتمد على الـ score

→ The purple color is for step ④

## *step ④ space Relationship Diagram



Block Layout

→ Dimension for the facility

1000 x 600

6.8 XYZ Inc. has a facility with six departments (A, B, C, D, E, and F). A summary of the processing sequence for 10 products and the weekly production forecasts for the products are given in the tables below.

a. Develop the from-to chart based on the expected weekly production.

b. Develop a block layout using SLP.

https://youtu.be/TW0MfQ434ng

شرح

| Product | Processing Sequence | Weekly Production |
|---|---|---|
| 1 | ABCDEF | 960 |
| 2 | ABCBEDCF | 1200 |
| 3 | ABCDEF | 720 |
| 4 | ABCEBCF | 2400 |
| 5 | ACEF | 1800 |
| 6 | ABCDEF | 480 |
| 7 | ABDECBF | 2400 |
| 8 | ABDECBF | 3000 |
| 9 | ABCDF | 960 |
| 10 | ABDEF | 1200 |

| Dept. | Dimension |
|---|---|
| A | 40′ × 40′ |
| B | 45′ × 45′ |
| C | 30′ × 30′ |
| D | 50′ × 50′ |
| E | 60′ × 60′ |
| F | 50′ × 50′ |

directions are not important
↓ (A → B) + (B → A)

Ranges (ممكن تجيبه بالسؤال)

U: 0 – 1,999
O: 2,000 – 3,999
I: 4,000 – 6,999
E: 7,000 – 9,999
A: 10,000 ↑

Step ① From to chart

960 + 1200 + 720 + 2400 + 480 + . . . . .

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 0 | 13,320<br>(A-B+B-A) | 1,800<br>(A-C+C$\overset{to}{-}$A) | 0 | 0 | 0 |
| B | | 0 | 15,720 | 6,600 | 3,600 | 5400 |
| C | | | 0 | 4,320 | 9,600 | 3,600 |
| D | | | | 0 | 9,960 | 960 |
| E | | | | | 0 | 5,160 |
| F | | | | | | 0 |

⟹

[Closeness Rating]

Orderd Table ($\frac{6 \times 5}{2} = 15$ Departments)

| | | |
|---|---|---|
| BC | 15,720 | A |
| AB | 13,320 | |
| DE | 9,960 | E |
| CE | 9,600 | |
| BD | 6,600 | I |
| BF | 5,400 | |
| EF | 5,160 | |
| CD | 4,320 | |
| BE | 3,600 | O |
| CF | 3,600 | |
| AC | 1,800 | U |
| DF | 960 | |
| AD | 0 | |
| AE | 0 | |
| AF | 0 | |

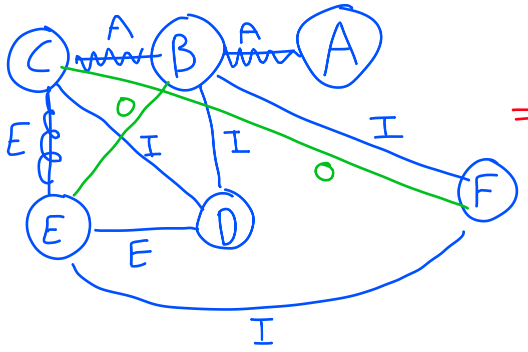
# Develop Activity Relationship Matrix

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | — | A | U | U | U | U |
| B | | — | A | I | O | I |
| C | | | — | I | E | O |
| D | | | | — | E | U |
| E | | | | | — | I |
| F | | | | | | — |

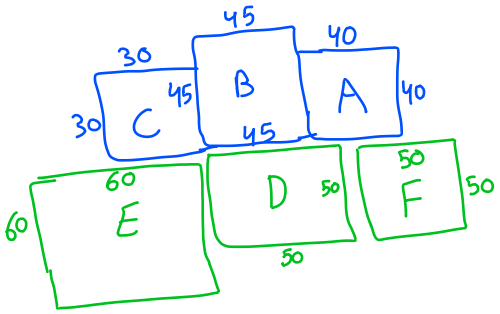
A
E } → اهم اشي
يكونو adjacent

| Dept. | Dimension |
|---|---|
| A | 40′ × 40′ |
| B | 45′ × 45′ |
| C | 30′ × 30′ |
| D | 50′ × 50′ |
| E | 60′ × 60′ |
| F | 50′ × 50′ |

# Develop Activity Relationship Diagram



# Block Layout



https://youtu.be/Nv1buxBf1Zc

Method ① شرح

# Pairwise Exchange Method

https://www.youtube.com/watch?v=IL0sLAx7dgQ

Method ② شرح

- Improvement-type layout algorithm.
- Although it can be used with both an adjacency-based and distance-based objective, it is often used with the later.
- Example:

To

From

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | 10 | 15 | 20 |
| 2 | | - | 10 | 5 |
| 3 | | | - | 5 |
| 4 | | | | - |

Material Flow Matrix

To

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | 1 | 2 | 3 |
| 2 | | - | 1 | 2 |
| 3 | | | - | 1 |
| 4 | | | | - |

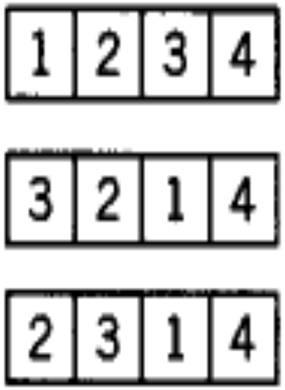
Distance matrix based on existing layout

# Pairwise Exchange Method

- Example (contd.):
- Phase I: Construct Phase. Initial Solution (1,2,3,4)
- Phase II: Improvement – Pair Wise Exchange
    - (a) Exchange two departments
    - (b) If results in better solution, accept; go to (a)
    - otherwise stop

# Pairwise Exchange Method

- Example (contd.):



(a) Iteration 0

(b) Iteration 1 (exchange 1 and 3)

(c) Iteration 2

**Figure 6.10** Layouts on iteration.

Flow without taking the direction into consideration

To Department

| From Department | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | — | 10 | 15 | 20 |
| 2 |  | — | 10 | 5 |
| 3 |  |  | — | 5 |
| 4 |  |  |  | — |

$$TC_{1234} = 10(1) + 15(2) + 20(3) + 10(1) + 5(2) + 5(1) = 125$$

# Pairwise Exchange Method

$\frac{n\times(n-1)}{2}$

$\frac{4\times 3}{2} = \frac{12}{2} = 6$ choices

- Example (contd.): Iteration 0

$TC_{2134}(1\text{-}2) = 10(1) + 15(1) + 20(2) + 10(2) + 5(3) + 5(1) = 105$

$\boxed{TC_{3214}(1\text{-}3)} = 10(1) + 15(2) + 20(1) + 10(1) + 5(2) + 5(3) = 95 \leftarrow$

$TC_{4231}(1\text{-}4) = 10(2) + 15(1) + 20(3) + 10(1) + 5(1) + 5(2) = 120$

$TC_{1324}(2\text{-}3) = 10(2) + 15(1) + 20(3) + 10(1) + 5(1) + 5(2) = 120$

$TC_{1432}(2\text{-}4) = 10(3) + 15(2) + 20(1) + 10(1) + 5(2) + 5(1) = 105$

$TC_{1243}(3\text{-}4) = 10(1) + 15(3) + 20(2) + 10(2) + 5(1) + 5(1) = 125$

# Pairwise Exchange Method

- Example (contd.): Iteration 1

$$TC_{3124}(1\text{-}2) = 10(1) + 15(1) + 20(2) + 10(1) + 5(1) + 5(3) = 95$$

$$TC_{1234}(1\text{-}3) = 10(1) + 15(2) + 20(3) + 10(1) + 5(2) + 5(1) = 125$$

$$TC_{3241}(1\text{-}4) = 10(2) + 15(3) + 20(1) + 10(1) + 5(1) + 5(2) = 110$$

$$TC_{2314}(2\text{-}3) = 10(2) + 15(1) + 20(1) + 10(1) + 5(3) + 5(2) = 90 \leftarrow$$

$$TC_{3412}(2\text{-}4) = 10(1) + 15(2) + 20(1) + 10(3) + 5(2) + 5(2) = 105$$

$$TC_{4213}(3\text{-}4) = 10(1) + 15(1) + 20(2) + 10(2) + 5(1) + 5(3) = 105$$

# Pairwise Exchange Method

- Example (contd.): Iteration 2

$$TC_{3214}(1\text{-}2) = 10(1) + 15(2) + 20(1) + 10(1) + 5(2) + 5(3) = 95$$

$$TC_{1324}(1\text{-}3) = 10(2) + 15(1) + 20(3) + 10(1) + 5(1) + 5(2) = 120$$

$$TC_{3421}(1\text{-}4) = 10(1) + 15(3) + 20(2) + 10(2) + 5(1) + 5(1) = 125$$

$$TC_{2134}(2\text{-}3) = 10(1) + 15(1) + 20(2) + 10(2) + 5(3) + 5(1) = 105$$

$$TC_{3142}(2\text{-}4) = 10(2) + 15(1) + 20(1) + 10(3) + 5(1) + 5(2) = 100$$

$$TC_{4123}(3\text{-}4) = 10(1) + 15(2) + 20(1) + 10(1) + 5(2) + 5(3) = 95$$

أقل cost هو أعلى
من ال iteration يلي قبلها
ف توقفنا

# Pairwise Exchange Method

- **Limitations:**
  - No guarantee of optimality,
    - The final solution depends on the initial layout
    - Leads to suboptimal solution
  - Does not consider size and shape of departments
    - Additional work has to be done (re-arrange the departments) if shapes are not equal.

Different shapes and sizes
needs additional work

https://youtu.be/XEIUy2OzXyo

شرح

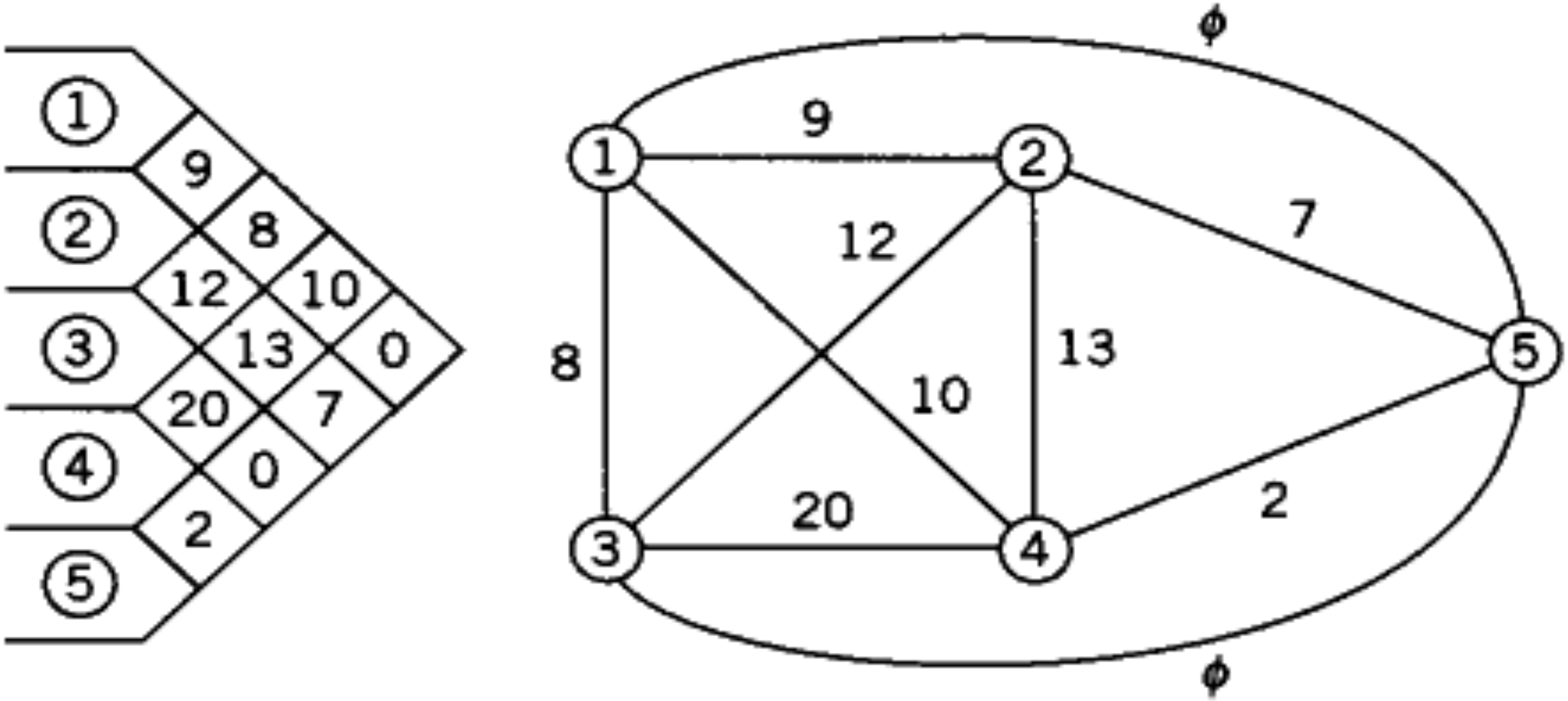
# Graph Based Method

- Graph based method dates back to the later 1960s and early 1970s.
- It is a construction-type layout algorithm.
- The method starts with an adjacency relationship chart.
- Then, we assign weight to the adjacency relationships between departments.
- A graph, called adjacency graph is constructed:
  - Node: to represent department.
  - Arc : to represent adjacency.
  - Weight on arc: represents the adjacency score.

# Graph Based Method

- Adjacency graph should be **planar**. (The graph obtained from the relationship diagram is usually a nonplanar graph).
  - A planar graph is a graph where there is no intersection of arcs (flow of material).
- Goal: To find a graph with maximum sum of arc weights (adjacency-based objective).

# Graph-based Method

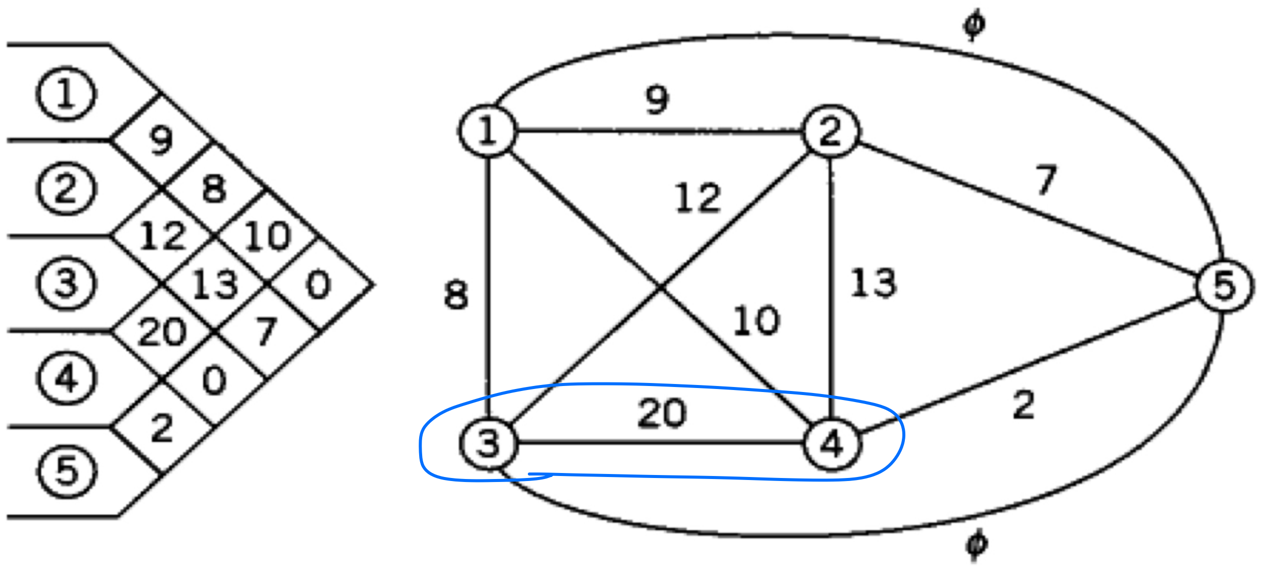


(a) Relationship Chart

(b) Relationship Diagram

**Figure 6.12** Relationship chart and relationship diagram for graph-based example.

# Graph-based Method

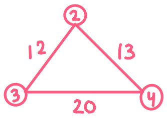


(a) Relationship Chart (b) Relationship Diagram

**Figure 6.12** Relationship chart and relationship diagram for graph-based example.

my goal is to maximize flow or maximize weight

| | 3 | 4 | Sum |
|---|---|---|---|
| 1 | 8 | 10 | 18 |
| 2 | 12 | 13 | 25 |
| 5 | 0 | 2 | 2 |

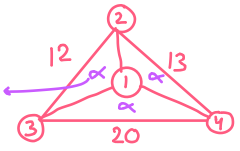


| | 2 | 3 | 4 | Sum |
|---|---|---|---|---|
| 1 | 9 | 8 | 10 | 27 |
| 5 | 7 | 0 | 2 | 9 |

✓the best

اذاً بضيف الواحد

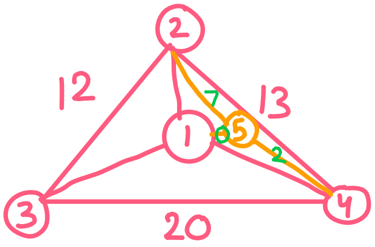
face (بدي احدد وين احط 5)



| | 1 | 2 | 3 | 4 | Sum |
|---|---|---|---|---|---|
| 5 | 0 | 7 | 0 | 2 | |

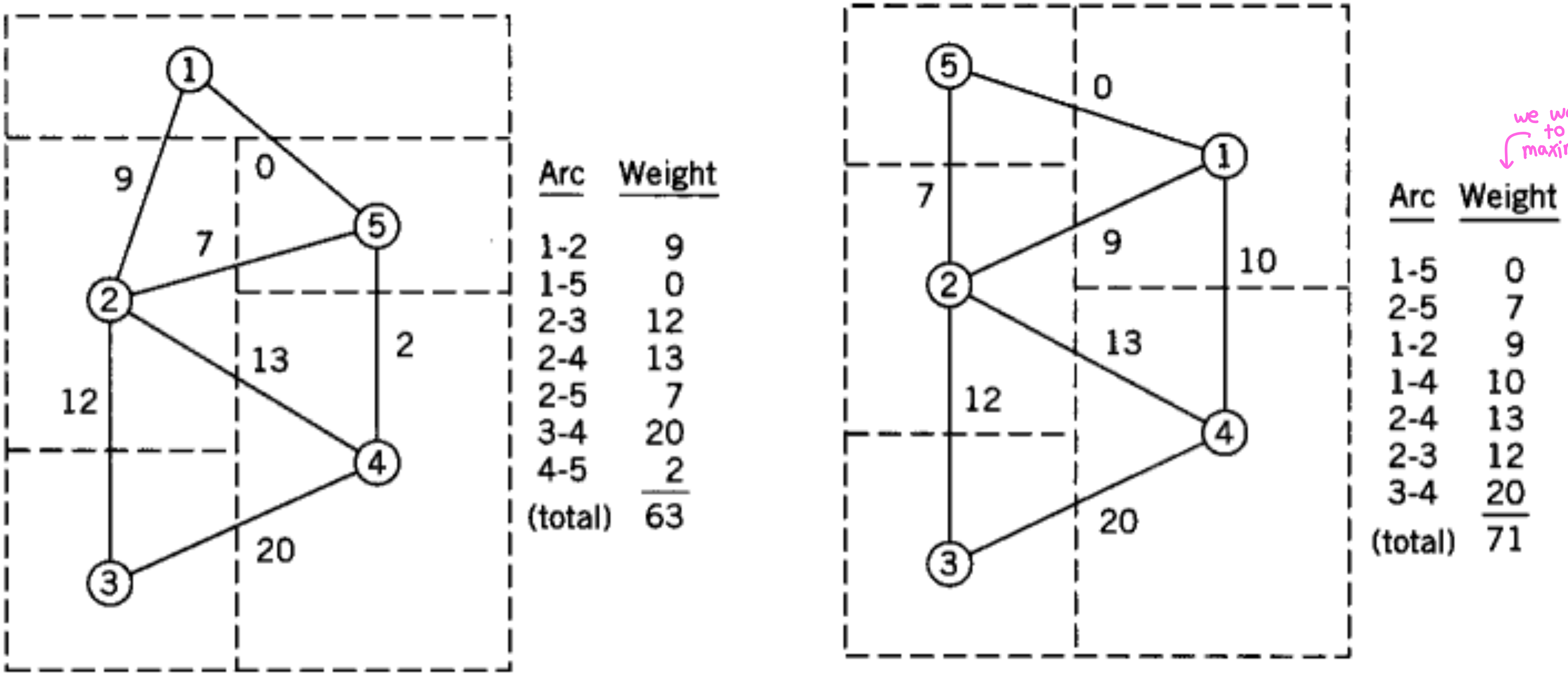
| Faces | |
|---|---|
| 1-2-3 | 7 |
| 1-2-4 | 9 |
| 1-3-4 | 2 |
| 2-3-4 | 9 |

I have two alternatives (I choose any of them)



وآخر اشي بعمل Block Layout

# Graph-based Method



| Arc | Weight |
|---|---|
| 1-2 | 9 |
| 1-5 | 0 |
| 2-3 | 12 |
| 2-4 | 13 |
| 2-5 | 7 |
| 3-4 | 20 |
| 4-5 | 2 |
| (total) | 63 |

(*a*)

we want to maximize

| Arc | Weight |
|---|---|
| 1-5 | 0 |
| 2-5 | 7 |
| 1-2 | 9 |
| 1-4 | 10 |
| 2-4 | 13 |
| 2-3 | 12 |
| 3-4 | 20 |
| (total) | 71 |

(*b*)

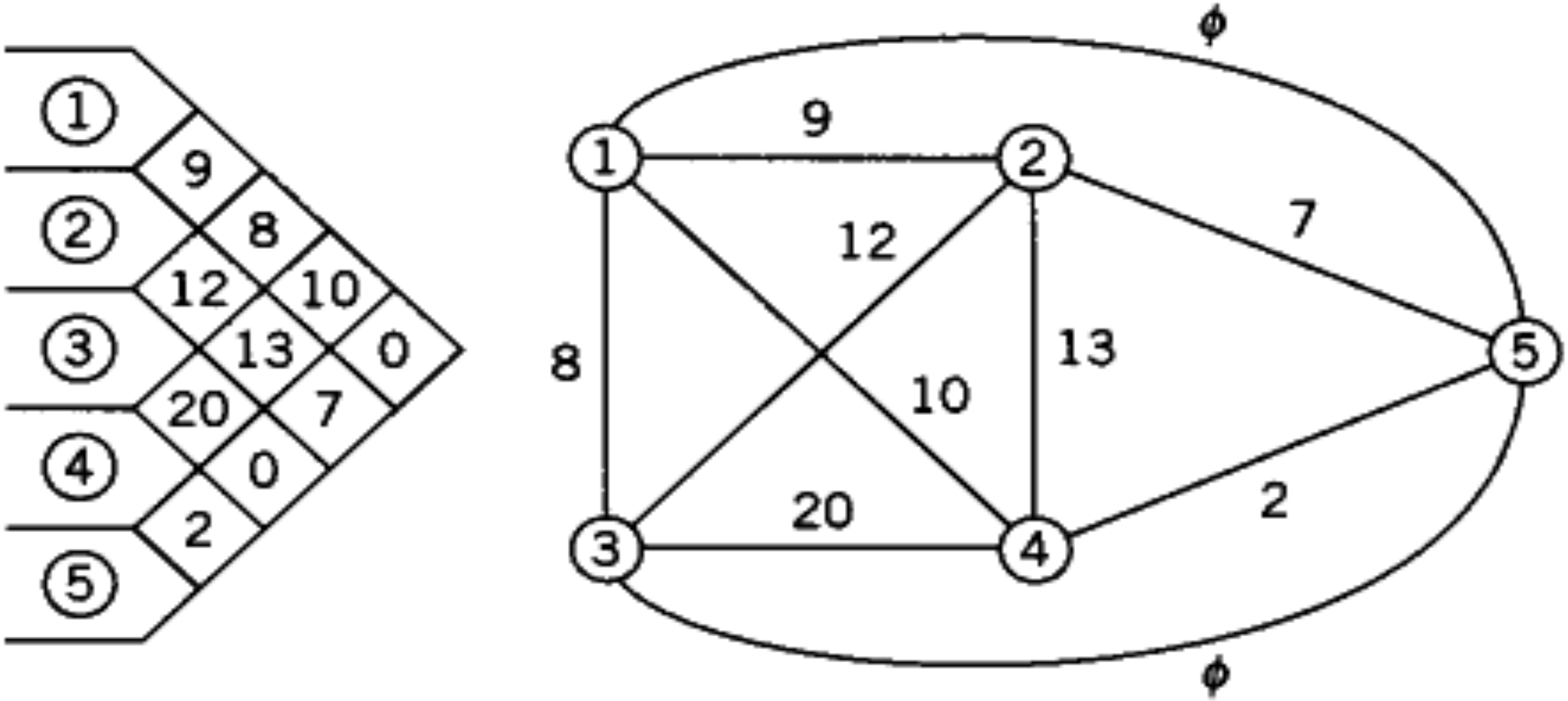
**Figure 6.11** Adjacency graphs for alternative block layouts.

# Procedure to Find Maximum Weight Adjacent Planar Graph

- Step 1: Select a department pair with largest weight
- Step 2: Select a third department based on the sum of the weights with the two departments selected.
- Step 3: Select next unselected department to enter by evaluating the sum of weights and place the department on the face of the graph.
  - Here, a face of a graph is a bounded region of a graph
- Step 4: Continuing the Step 3 until all departments are selected
- Step 5: Construct a block layout from the planar graph

# Graph-based Method

Constuction type method

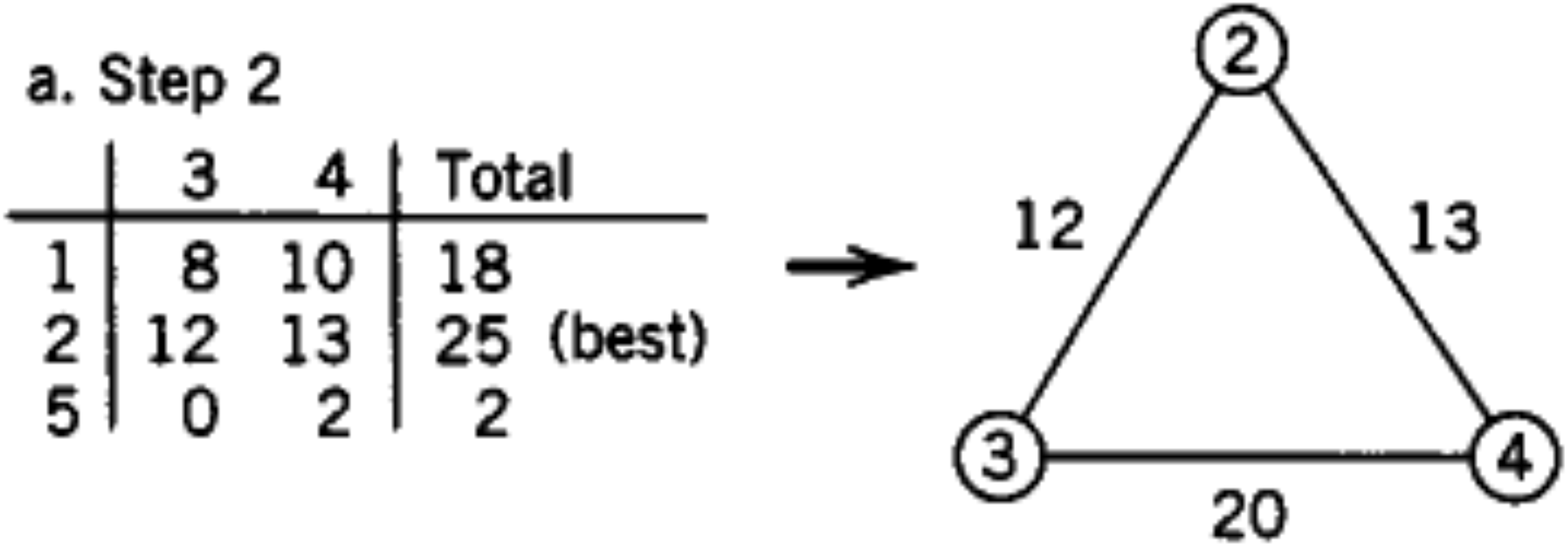


(*a*) Relationship Chart

(*b*) Relationship Diagram

**Figure 6.12** Relationship chart and relationship diagram for graph-based example.

# Graph-based Method



a. Step 2

| | 3 | 4 | Total |
|---|---|---|---|
| 1 | 8 | 10 | 18 |
| 2 | 12 | 13 | 25 (best) |
| 5 | 0 | 2 | 2 |

Figure 6.13 graph-based procedure.

# Graph-based Method

b. Step 3

| | 2 | 3 | 4 | Total |
|---|---|---|---|---|
| 1 | 9 | 8 | 10 | 27 (best) |
| 5 | 7 | 0 | 9 | 9 |

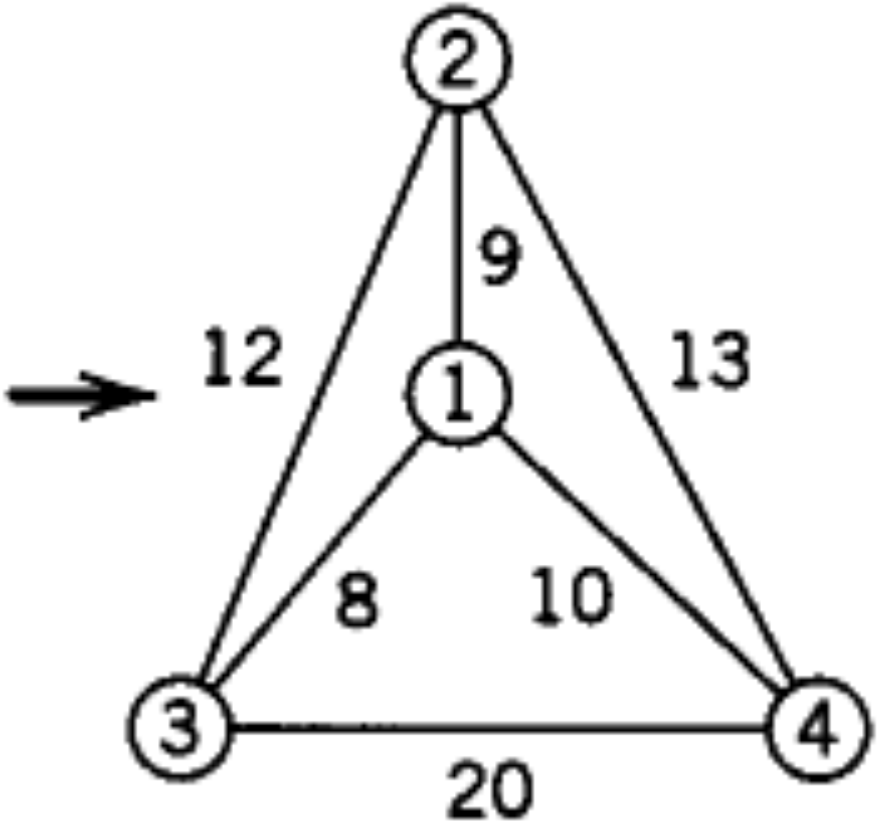


Figure 6.13 graph-based procedure.

# Graph-based Method

c. Step 4

|   | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 5 | 0 | 7 | 0 | 2 |

| Faces | Total |
|---|---|
| 1-2-3 | 7 |
| 1-2-4 | 9 (best) |
| 1-3-4 | 2 |
| 2-3-4 | 9 (best) |

→

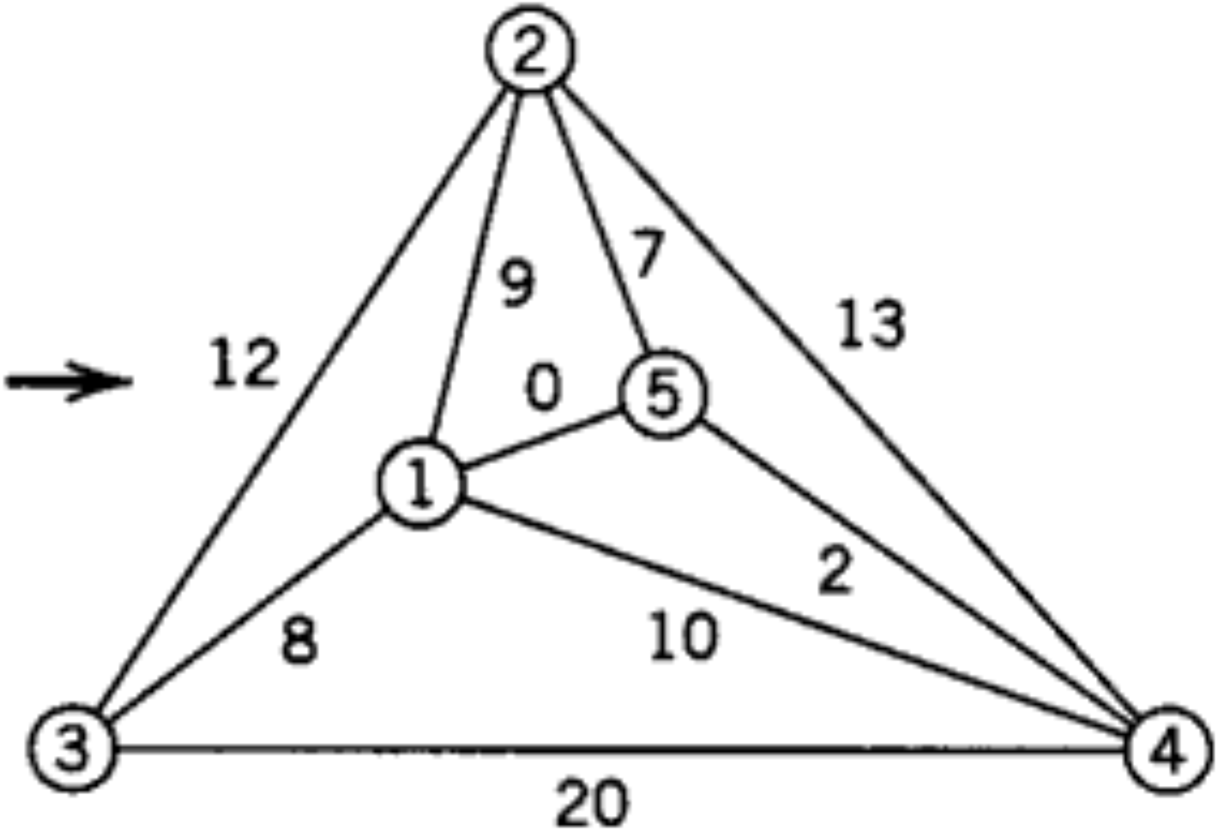
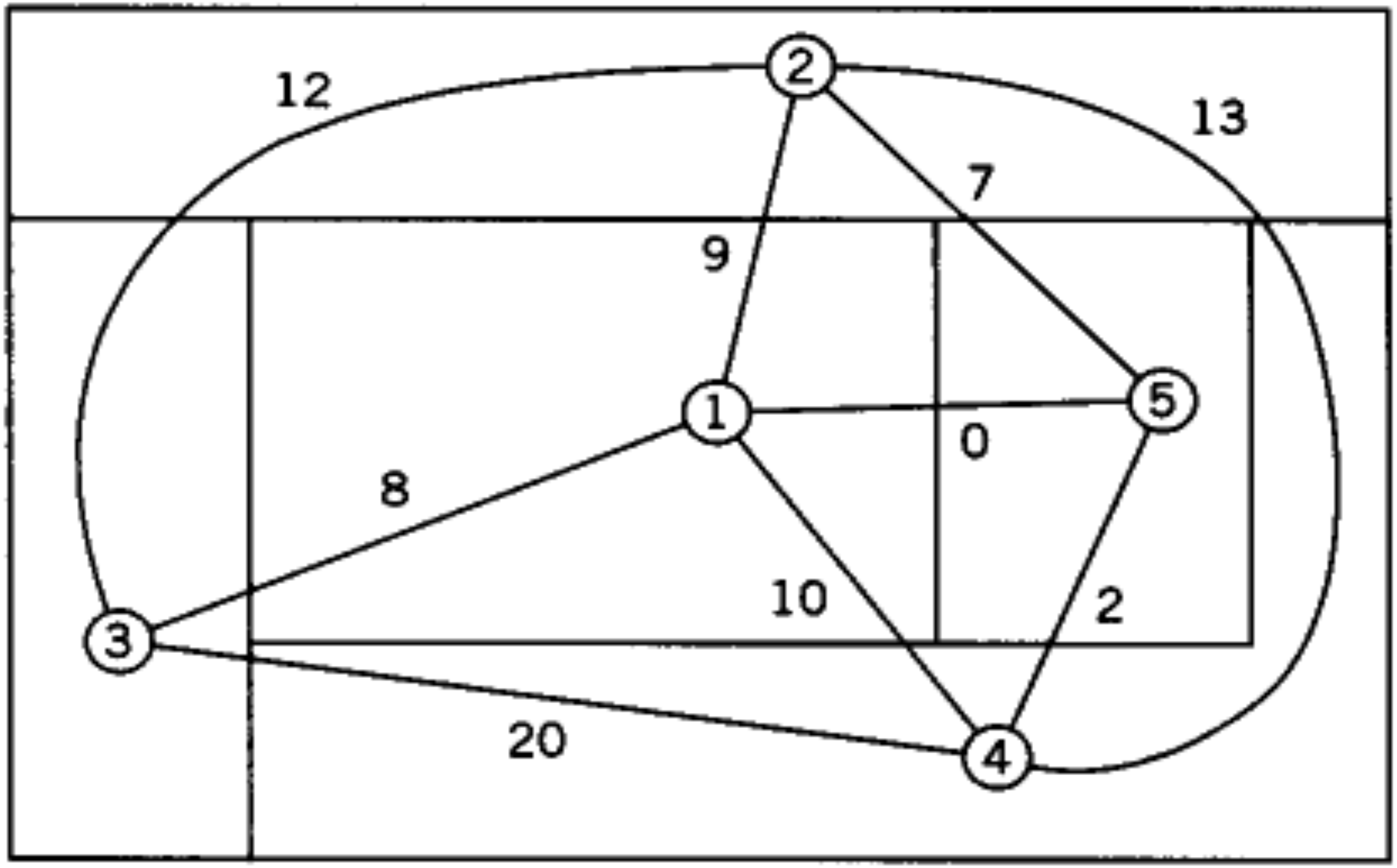


**Figure 6.13** graph-based procedure.

# Graph-based Method



| Arc | Weight |
|---|---|
| 1-2 | 9 |
| 1-3 | 8 |
| 1-4 | 10 |
| 1-5 | 0 |
| 2-3 | 12 |
| 2-4 | 13 |
| 2-5 | 7 |
| 3-4 | 20 |
| 4-5 | 2 |
| (total) | 81 |

**Figure 6.14** Block layout from the final adjacency graph.

# Limitation of Graph Based Method

- **Limitations**
  - The adjacency score does not account for distance, nor does it account for relationships other than those between adjacent department.
  - Although size is considered in this method, the specific dimension is not, the length between adjacent departments are also not considered.
  - We are attempting to construct graphs, called planar graphs, whose arcs do not intersect.
  - The final layout is very sensitive to the assignment of weights in the relationship chart.

# Algorithm Classification

- The basis of the layout planning is the closeness ratings or material flow intensities.

- Layout algorithms can be classified according to the type of input data they require:
  - Some algorithms accept only **qualitative flow data** (relationship chart).
  - Some algorithms work with **quantitative flow data** (from-to chart)
  - Some algorithms **accept both**.

# Algorithm Classification

- Layout algorithms can be also classified according to their objective function:

1. Minimize the sum of flows times distance:

$f.d.\underline{c}$

اذا مو موجود ال cost
بعتبره (1 $)
per unit Distance
per unit Load

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

Where m: number of departments

$f_{ij}$: the flow from department i to j.

$c_{ij}$: the cost of moving one unit load one distance unit from i to j.

$d_{ij}$: the distance from department i to j.

More suitable when the input data is expressed as from-to chart.

# Algorithm Classification

## 2. Maximize the closeness (adjacency):

flow between all deparment

$$\max z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} x_{ij}$$

Binary Variable

- 0 (if not adjacent)
- 1 (if adjacent)

Where

$f_{ij}$: the flow from department i to j.

$x_{ij}$=1 if department i and j are adjacent (share a border)

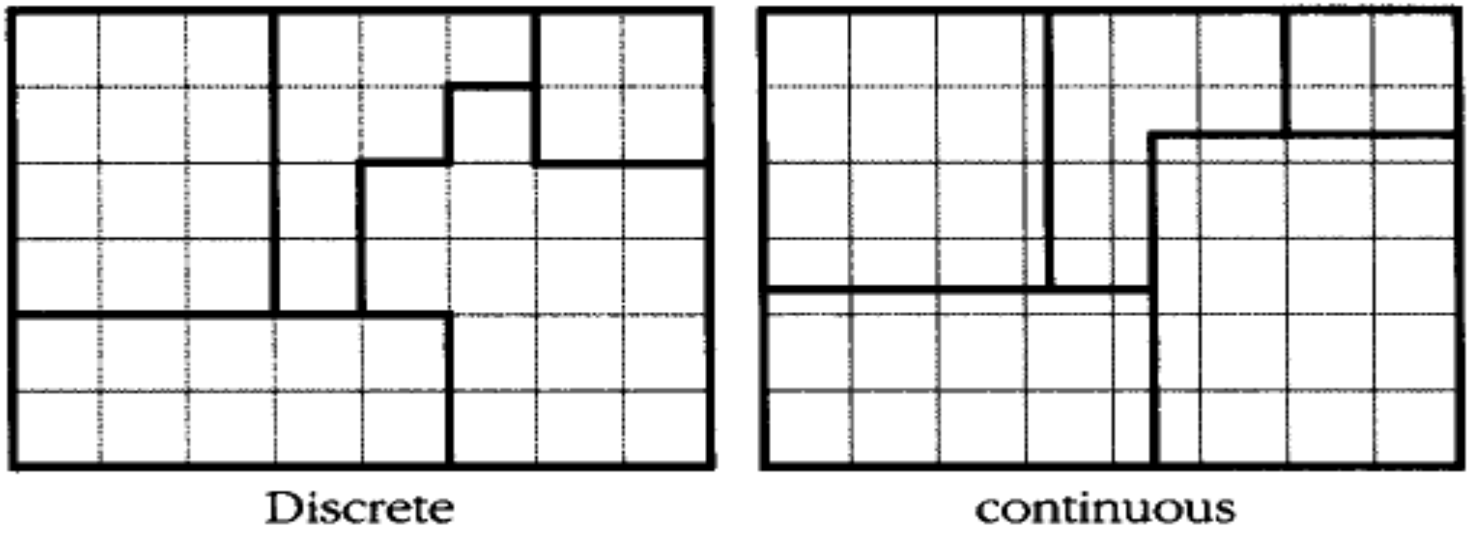
0 otherwise

- Helpful in comparing two or more alternate layouts.
- But, it disregards the distance or separation between non-adjacent departments.

# Algorithm Classification

- Layout algorithms can be also classified according to the format for layout representation :

1. Discrete representation: (Integers)
    - The area for each department is rounded off to the nearest integer number of grids.
    - Selecting the appropriate grid size is an important decision.
2. Continuous representation: no grids, restricted to rectangular buildings and departments.



# Algorithm Classification

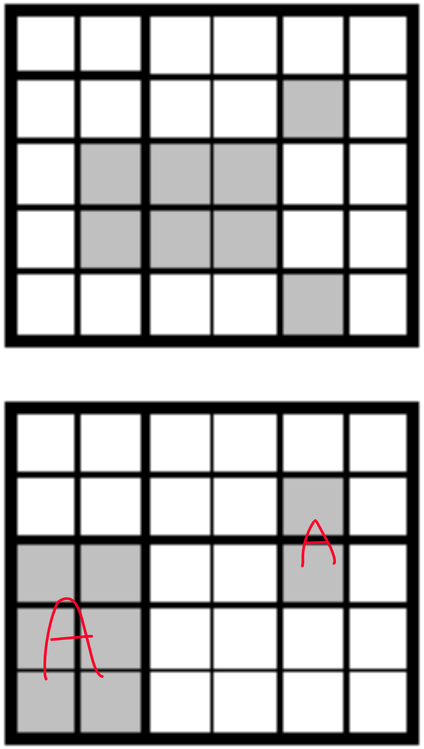
- Layout algorithms can be also classified according to their primary function: improvement versus construction.

1. Improvement-type algorithms:
   - start with an initial layout and seek to improve the objective function through incremental changes in the layout

2. Construction-type layout algorithms:
   1. Assume the building dimensions are given.
   2. Assume the building dimensions are Not given.

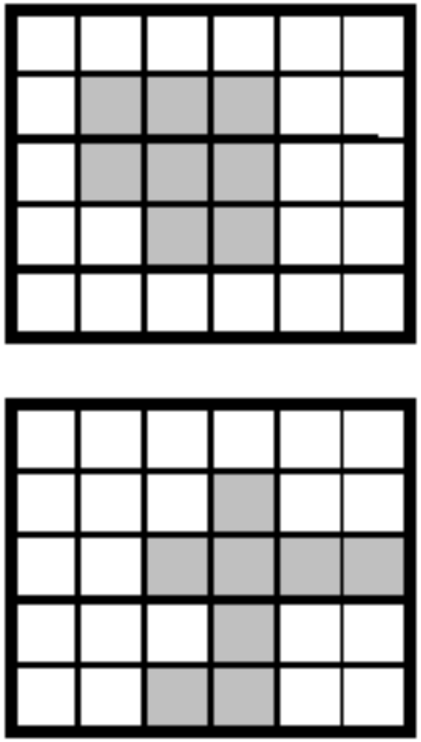
# Algorithm Classification

- A layout algorithm should not "split" a department into two or more pieces.

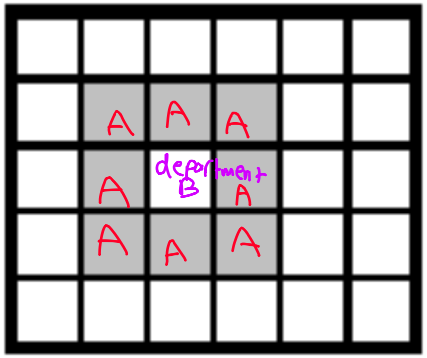


a. Split ( يجب تجنبها )

X don't split



b. Unsplit



Avoid it

c. Void

# Layout Evaluation

An algorithm needs to distinguish between "good" layouts and "bad" ones

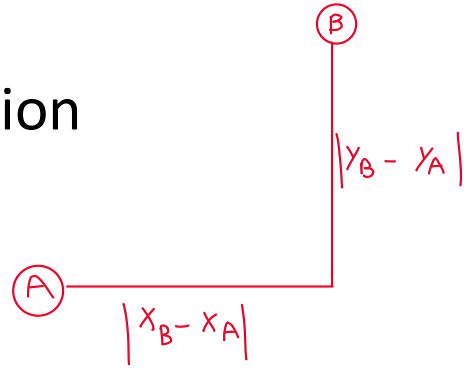
- Minimize the total cost/traveling/load etc: (Distance Based Scoring)

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

- Maximize the total relationship: (Adjacency Score)

$$\max z = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij} x_{ij}$$

- Maximize the total satisfaction (Prioritization Matrix)



# Layout Evaluation

## Distance Based Scoring

- Suitable for input data from From-to chart
- Approximates the cost of flow between activities
- Requires explicit evaluation of the flow volumes and costs

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{m} \overset{\text{From to chart}}{\overset{\uparrow}{f_{ij}}}\, c_{ij}\, \overset{\text{Mailage Matrix}}{\overset{\uparrow}{d_{ij}}}$$

***m***: number of departments

$f_{ij}$: flow from department ***i*** to department ***j***

$c_{ij}$: cost of moving from ***i*** to ***j***

$d_{ij}$: the distance between departments ***i*** and ***j***

- Distance often depends on the aisle layout and material handling equipment
- Distance is often calculated as the rectilinear distance between department centroids

# Layout Evaluation

## Adjacency Based Scoring

- Adjacency-based scoring is based on the relationship chart and relationship diagram

$$\max z = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \underline{\underline{f_{ij}}}\, \underline{\underline{x_{ij}}}$$

1 (adjacent)

0 (not adjacent)

Relationship value between departement i and j

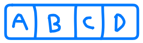
***m****:* number of departments

$x_{ij}$: *1* if ***i*** and ***j*** are adjacent, *0* otherwise

$f_{ij}$= Relationship value between department ***i*** to department ***j***

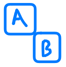
The weights $f_i$ can also be represented by the flow amounts between the adjacent departments instead of scores assigned to A, E, I, O, U, X.

example to understand



$x_{AB} = 1$

$x_{AD} = 0$



$x_{AB} = 0$ Not adjacent (doesn't share a boarder)

# Layout Evaluation

## Adjacency Based Scoring

- **Efficiency rating:** When we compare the alternatives, we normalize each objective function

$$z = \frac{\sum_{i=1}^{m} \sum_{j=i}^{m} f_{ij} x_{ij}}{\sum_{i=1}^{m-1} \sum_{j=1}^{m} f_{ij}}$$

بنختار الأعلى

$f_{ij}$

A
E
I
U
O
X

# Layout Evaluation

## Adjacency Based Scoring

- **Efficiency rating:** In some cases, the layout planner may represent an X relationship between departments i and j by assigning a negative value to $f_{ij}$.

$$z = \frac{\sum_{(i,j)\in F} f_{ij} x_{ij} \overset{-}{\cancel{+}} \sum_{(i,j)\in \bar{F}} f_{ij}(1 - x_{ij})}{\underbrace{\sum_{(i,j)\in F} f_{ij}}_{\text{when positive}} - \underbrace{\sum_{(i,j)\in \bar{F}} f_{ij}}_{\text{when negative}}}$$

## SECTION 6.4

6.12 Suppose five departments labeled A through E are located as shown in the layout below. Given the corresponding flow-between chart, compute the efficiency rating for the layout.

*initial Layout

<table>
<tr><td>A</td><td>B</td></tr>
<tr><td colspan="2">C</td></tr>
<tr><td>D</td><td>E</td></tr>
</table>

|   | A | B | C | D | E |
|---|---|---|---|---|---|
| A | — | 5 | 0 | 4 | −3 |
| B |  | — | 6 | −1 | 2 |
| C |  |  | — | −6 | 0 |
| D |  |  |  | — | 3 |
| E |  |  |  |  | — |

negative f
(flow = -ve)

$X \rightarrow -ve$

$$Z = \frac{\sum_{(i,j)\in F} f_{ij}x_{ij} - \sum f_{ij}(1-x_{ij})}{\underbrace{\sum_{(i,j)\in F^{+}} f_{ij}}_{\text{total positive flow between departments}} - \underbrace{\sum_{(i,j)\in F^{-}} f_{ij}}_{\text{total negative flow between departments}}} = \frac{(14)-(-4)}{(20)-(-10)} = \frac{18}{30} = 0.6$$

اذا كان في two Layouts

← بختار يلي عنده Efficiency (z) أعلى

$$\sum_{(i,j)\in F^{\oplus}} f_{ij} = 5+6+4+2+3 = 20$$

$$\sum_{(i,j)\in F^{\ominus}} f_{ij} = -1-6-3 = -10$$

Total positive adjacent score

$$\sum_{(i,j)\in F^{+}} f_{ij}\underbrace{X_{ij}}_{\substack{1 \quad 0\\ \text{adj} \quad \text{not adj}}} = 5(1)+4(0)+6(1)+2(0)+3(1) = 14$$

Total negative adjacent score

$$\sum_{(i,j)\in F} f_{ij}(1-X_{ij}) = -3(1-0)-1(1-0)-6\underset{0}{\cancel{(1-1)}} = -4$$

# Layout Evaluation

## Distance Based Scoring

اذا ماجاب سيرة ال cost نعتبرها واحد

Minimize

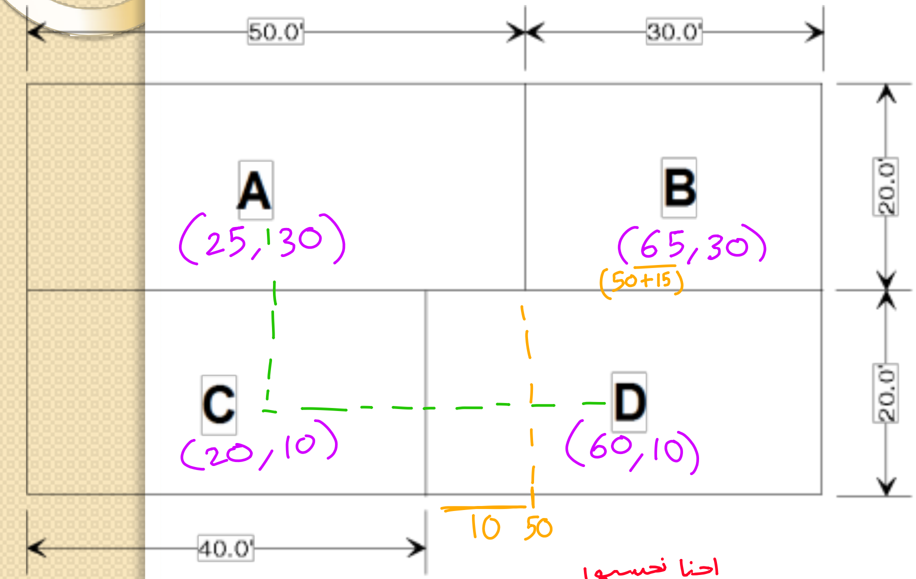
$$z = f_{ij} c_{ij} d_{ij}$$

$$|x_i - x_j| + |y_i - y_j|$$

**Example**

Initial Layout

أول اشي نحدد ال centroid between each department



**Flow Data** $f_{ij}$

| From/To | A | B | C | D |
|---|---|---|---|---|
| A | - | 2 | 4 | 4 |
| B | 1 | - | 1 | 3 |
| C | 2 | 1 | - | 2 |
| D | 4 | 1 | 0 | - |

|  | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 3 | 6 | 8 |
| B |  | 0 | 2 | 4 |
| C |  |  | 0 | 2 |
| D |  |  |  | 0 |

**Total Score (Cost)** $Z$ → $f_{ij} \times d_{ij}$

| From/To | A | B | C | D | Total |
|---|---|---|---|---|---|
| A | - | 80 | 100 | 220 | 400 |
| B | 40 | - | 65 | 75 | 180 |
| C | 50 | 65 | - | 80 | 195 |
| D | 220 | 25 | 0 | - | 245 |
| Total | 310 | 170 | 165 | 375 | 1020 |

احنا نحسبها

**Distance Data** $d_{ij}$

| From/To | A | B | C | D |
|---|---|---|---|---|
| A | - | 40 | 25 | 55 |
| B | 40 | - | 65 | 25 |
| C | 25 | 65 | - | 40 |
| D | 55 | 25 | 40 | - |

# Adjacency Based Scoring

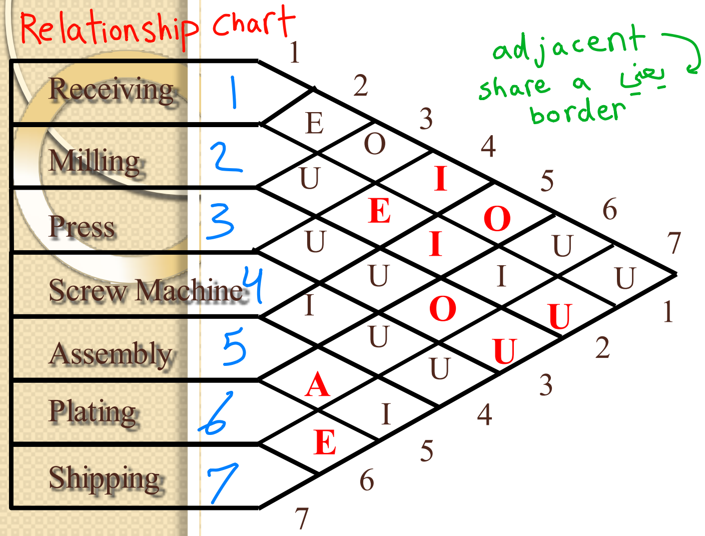
← أسهل

$$z = f_{ij}\boxed{x_{ij}}$$

0 1

## Example

Relationship Chart



adjacent يعني share a border

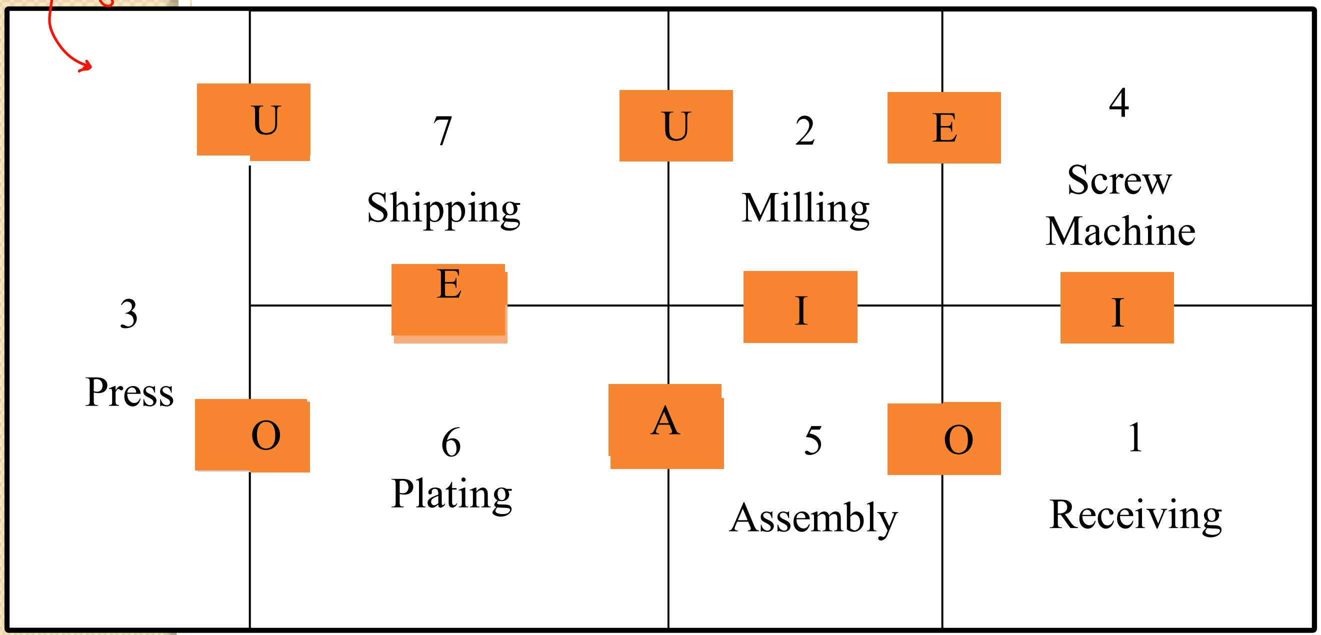
Not adjacent فـ ما كتبناهم

|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 |   |   |
|---|---|---|---|---|---|---|---|---|---|
| 1 |   |   |   | $_4$I | O$_1$ |   |   | 4+1 | =5 |
| 2 |   |   |   | $_{16}$E | I$_4$ |   | $_0$U | 16+4+0 | =20 |
| 3 |   |   |   |   |   | O$_1$ | U$_0$ | 1+0 | =1 |
| 4 |   |   |   |   |   |   |   | ---- |   |
| 5 |   |   |   |   |   | A$_{64}$ |   | 64 | =64 |
| 6 |   |   |   |   |   |   | E$_{16}$ | 16 | =16 |
| 7 |   |   |   |   |   |   |   |   |   |

كتبنا ال Adjacent only

**Total Score 106**

Layout



**Weights:**

A=64

E=16

I=4

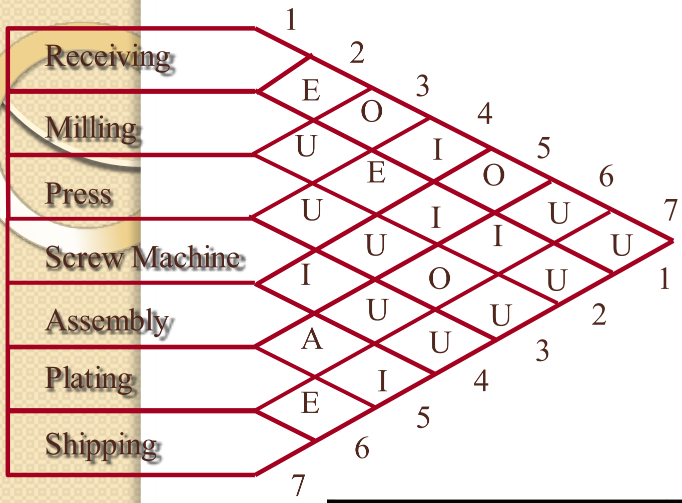
O=1

U=0

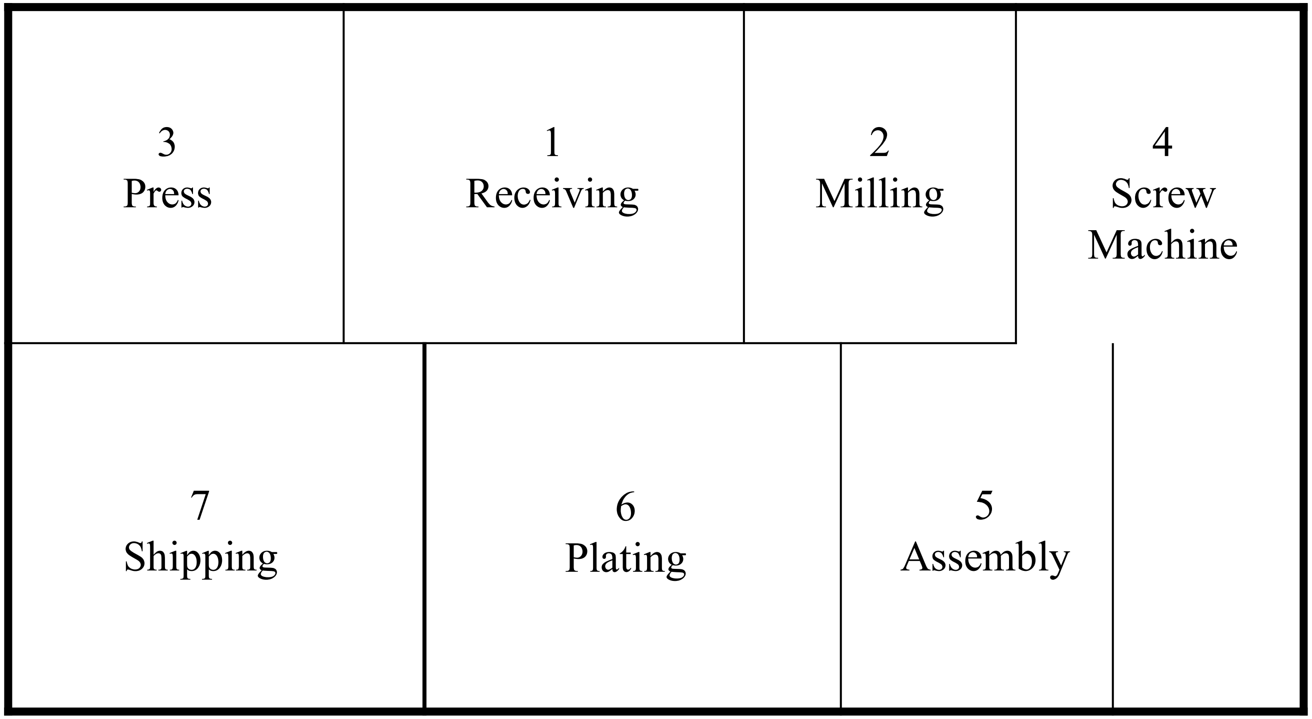
X=-1024 very Large negative

# Adjacency Based Scoring

## Example



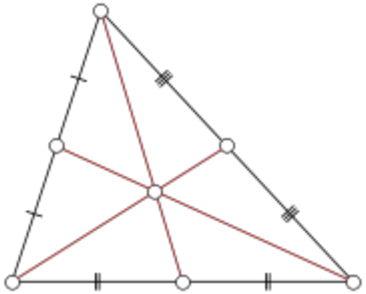
**Exercise:** Find the score of the layout shown below. Use A=8, E=4, I=2, O=1, U=0 and X=-8.

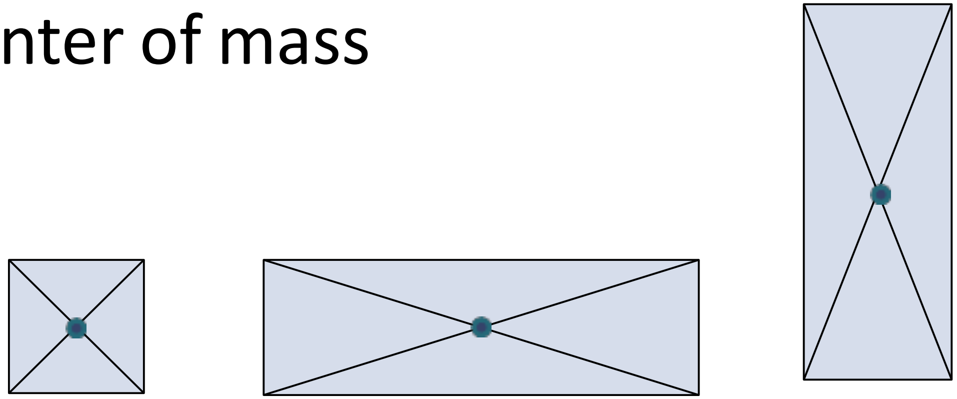


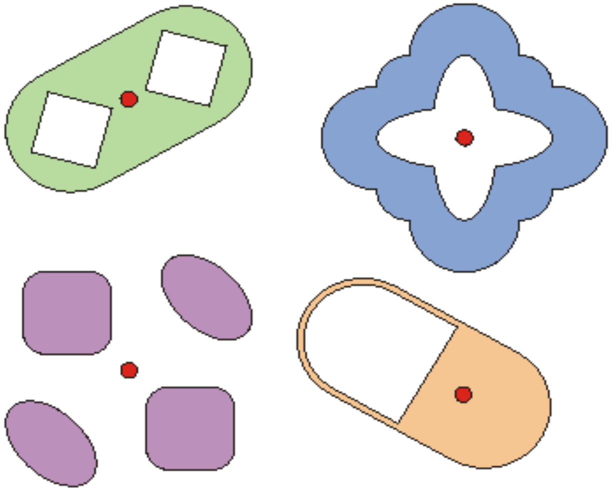
اهم اشي تحديد ال Centeroid

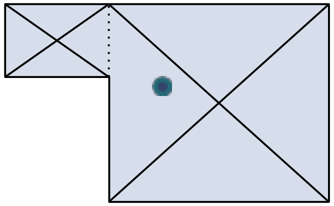
# Distance Calculations

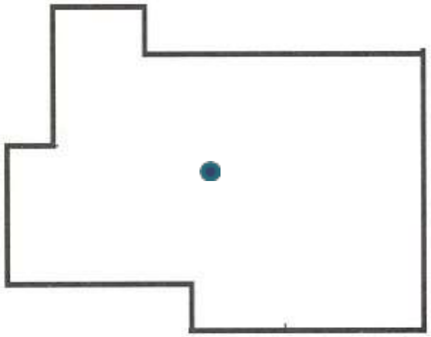
- Centroid is  a center of mass











# Distance Calculations

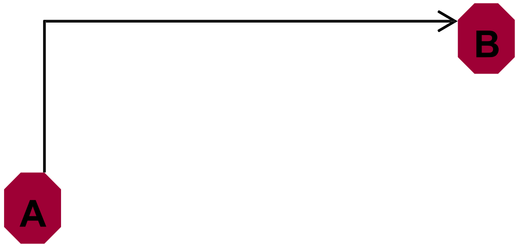
- If $(x_i,y_i)$ and $(x_j,y_j)$ represent the coordinates of two locations *i* and *j* then the distance model measures can be:

✓ we will use this one

## Rectilinear:

- distance between *i* and *j* is

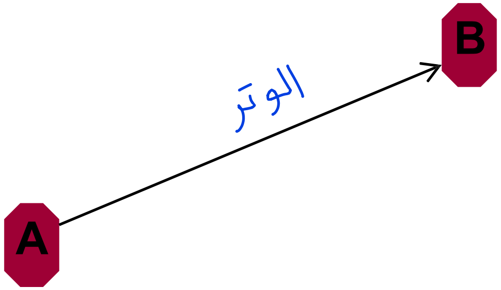
$$D = |x_i - x_j| + |y_i - y_j|$$



## Euclidean:

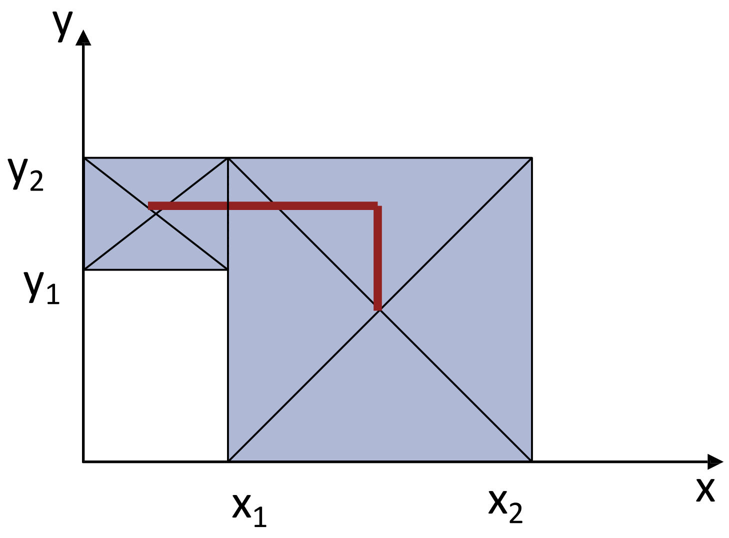
- distance between *i* and *j* is

$$D = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

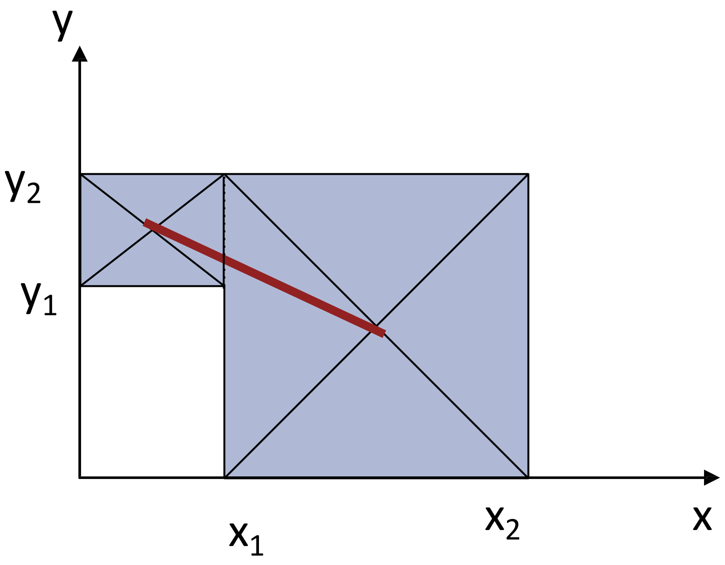


# Distance Calculations

- Rectilinear distance from centroid to centroid

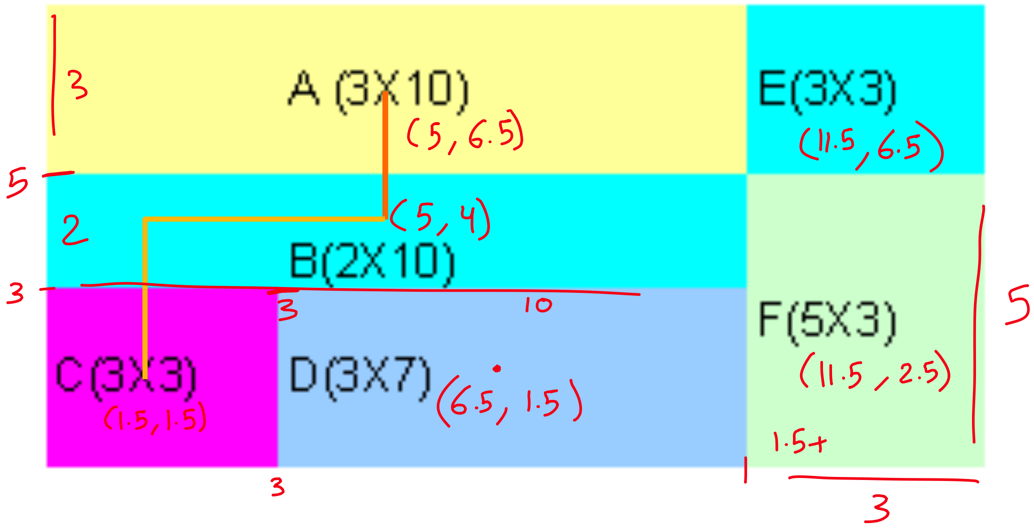


- Euclidean distance from centroid to centroid



# Distance Calculations

| | |
|---|---|
| C | (1.5, 1.5) |
| B | (5, 4) |
| A | ( ) |



Rectilinear distance from A to B:
D (AB) = 1.5 + 1 = 2.5

Rectilinear distance from B to C: 3.5 + 2.5
D (BC) = 1+1.5+2+1.5= 6

Start with initial Layout

from to chart

# CRAFT

impovement method (computerized)

## Computerized Relative Allocation of Facilities Technique

- For improvement of an existing facility
- Attempts to minimize transportation cost, where

Transportation cost = flow * unit cost * distance

$$Min \quad z = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij} c_{ij} d_{ij}$$

- Assumptions
  - Moving costs are linearly related to the length of the move.
- Distance metric used is the rectilinear distance between department centroids.
- Input is FT Chart (From-To chart)
- Department shapes are not restricted to the rectangular ones

# CRAFT

## Procedure

ليست دقيقة
لأنها تعتمد على الـ
initial Layout

1. Determine department centroids.
2. Calculate rectilinear distance between centroids.
3. Calculate transportation cost for the layout.
4. Consider department exchanges of either **equal area departments** or **departments sharing a common border**.

لأني ما راح اغير الـ centeroid
لـ Area
centroid Department A ⇄ centroid Department B

5. Determine the estimated change in transportation cost of each possible exchange.
6. Select and implement the departmental exchange that offers the greatest reduction in transportation cost.

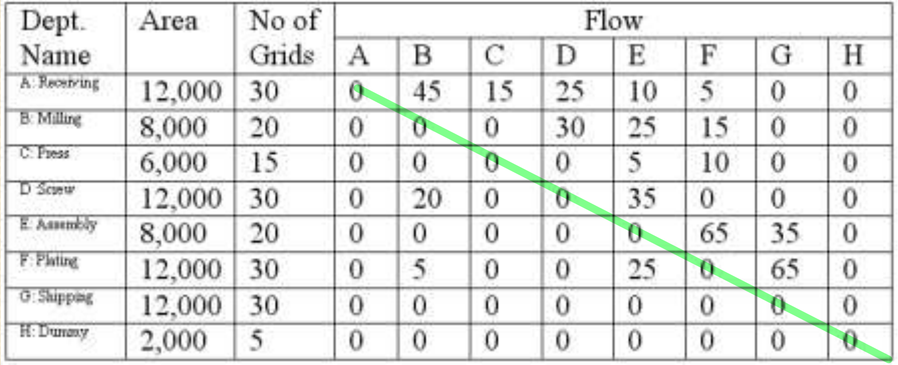
نختار اقل Transportation cost

7. Repeat the procedure for the new layout until no interchange is able to reduce the transportation cost.

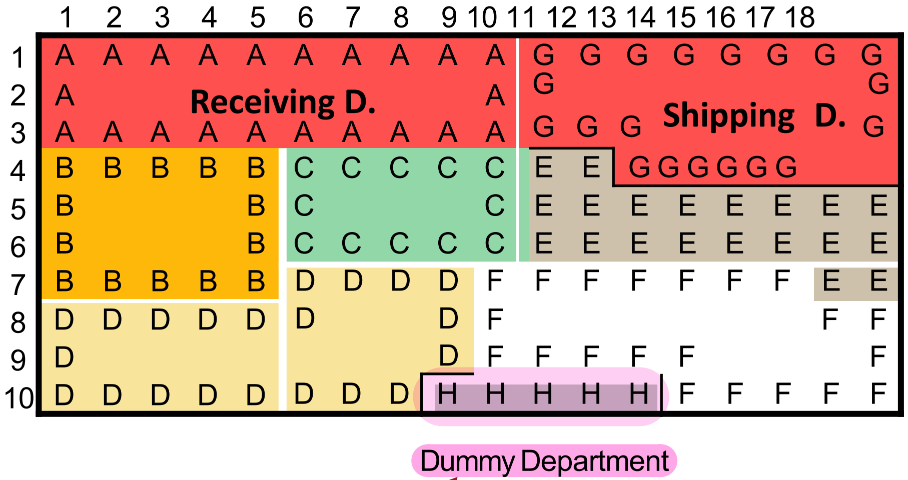
# CRAFT

## Example

- A facility with ~~7~~ 8 departments
- Cost of carrying any material $c_{ij} = 1$ for all $i$ and $j$ pairs.
- Each grid size is $20 \times 20$, = 400 m² total $72{,}000\ m^2$ is available
- Total requirement is $70{,}000$ m²
- Location of receiving (A) and shipping (G) departments are fixed



| Dept. Name | Area | No of Grids | Flow | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H |
| A: Receiving | 12,000 | 30 | 0 | 45 | 15 | 25 | 10 | 5 | 0 | 0 |
| B: Milling | 8,000 | 20 | 0 | 0 | 0 | 30 | 25 | 15 | 0 | 0 |
| C: Press | 6,000 | 15 | 0 | 0 | 0 | 0 | 5 | 10 | 0 | 0 |
| D: Screw | 12,000 | 30 | 0 | 20 | 0 | 0 | 35 | 0 | 0 | 0 |
| E: Assembly | 8,000 | 20 | 0 | 0 | 0 | 0 | 0 | 65 | 35 | 0 |
| F: Plating | 12,000 | 30 | 0 | 5 | 0 | 0 | 25 | 0 | 65 | 0 |
| G: Shipping | 12,000 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| H: Dummy | 2,000 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | | F | F |
| 9 | D | | | | | | | | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

➢ Improve the layout

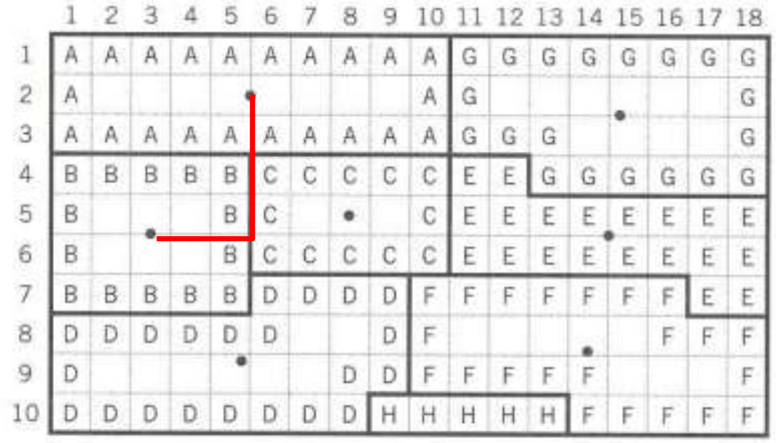
- Total available space > total required space:

  therefore we use a dummy department (H) with the size of 2,000 m²

72,000 − 70,000 = 2,000

# CRAFT Example

1. Determine department centroids.
2. Calculate rectilinear distance between centroids.
3. Calculate transportation cost for the layout.



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | F | F | F |
| 9 | D | | | | | | | D | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

Figure 6.15 Initial CRAFT layout and department centroids for Example 6.1 ($z = 2974 \times 20 = 59{,}480$ units).

Distance between A and B is 6 units (illustrated by the red line above)

$$z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} c_{ij} d_{ij}$$

8 Departments

Pairwise اذا كنا نعمل
(possible exchanges) $\frac{8 \times 7}{2}$ بكون

فهاد غلط بالـ craft

اما هنا يوجد شروط لا exchange
equal area
adjacent

| Dept. Name | Area | No of Grids | Flow | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H |
| A: Receiving | 12,000 | 30 | 0 | 45 | 15 | 25 | 10 | 5 | 0 | 0 |
| B: Milling | 8,000 | 20 | 0 | 0 | 0 | 30 | 25 | 15 | 0 | 0 |
| C: Press | 6,000 | 15 | 0 | 0 | 0 | 0 | 5 | 10 | 0 | 0 |
| D: Screw | 12,000 | 30 | 0 | 20 | 0 | 0 | 35 | 0 | 0 | 0 |
| E: Assembly | 8,000 | 20 | 0 | 0 | 0 | 0 | 0 | 65 | 35 | 0 |
| F: Plating | 12,000 | 30 | 0 | 5 | 0 | 0 | 25 | 0 | 65 | 0 |
| G: Shipping | 12,000 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| H: Dummy | 2,000 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

- **Distance Matrix**

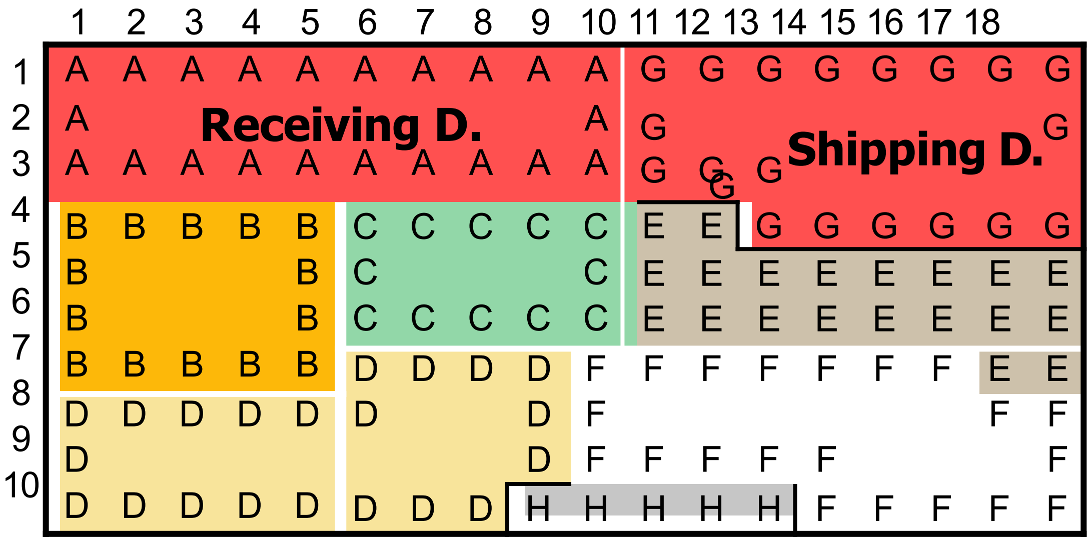
| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| A | | 6 | 5 | 6 | 13 | 16 | | |
| B | | | | 6 | 11 | 14 | | |
| C | | | | | 7 | 10 | | |
| D | | 6 | | | 12 | | | |
| E | | | | | | 3 | 4 | |
| F | | 14 | | | 3 | | 7 | |
| G | | | | | | | | |
| H | | | | | | | | |

- **Cost Matrix**

| | A | B | C | D | E | F | G | H | Total |
|---|---|---|---|---|---|---|---|---|---|
| A | | 270 | 75 | 150 | 130 | 80 | | | 705 |
| B | | | | 180 | 275 | 210 | | | 665 |
| C | | | | | 35 | 100 | | | 135 |
| D | | 120 | | | 420 | | | | 540 |
| E | | | | | | 195 | 140 | | 335 |
| F | | 70 | | | 75 | | 455 | | 600 |
| G | | | | | | | | | 0 |
| H | | | | | | | | | 0 |
| | | | | | | | | | 2980 |

2,990
Total cost of initial Layout

# CRAFT Example

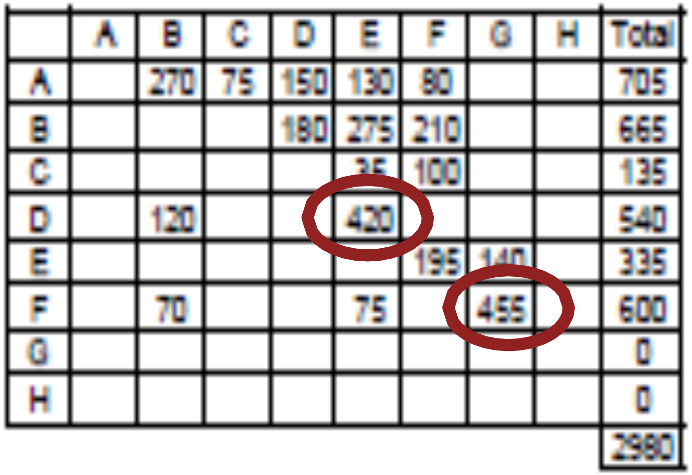


| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | Receiving D. | | | | | A | G | | | | Shipping D. | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G<br>G | G | | | | | |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | | F | F |
| 9 | D | | | | | | | | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

Dummy Department

Which departments to exchange?

- Cost Matrix



| | A | B | C | D | E | F | G | H | Total |
|---|---|---|---|---|---|---|---|---|---|
| A | | 270 | 75 | 150 | 130 | 80 | | | 705 |
| B | | | | 180 | 275 | 210 | | | 665 |
| C | | | | | 35 | 100 | | | 135 |
| D | | 120 | | | 420 | | | | 540 |
| E | | | | | | 195 | 140 | | 335 |
| F | | 70 | | | 75 | | 455 | | 600 |
| G | | | | | | | | | 0 |
| H | | | | | | | | | 0 |
| | | | | | | | | | 2980 |

1. Bringing the departments **E and D** closer might help to reduce total material flow
2. Bringing the departments **F and G** closer might help to reduce total material flow

**Exchange E and F**

Departments E and F can be reorganized only if they have **the same areas** **OR** they have **common border**

# CRAFT

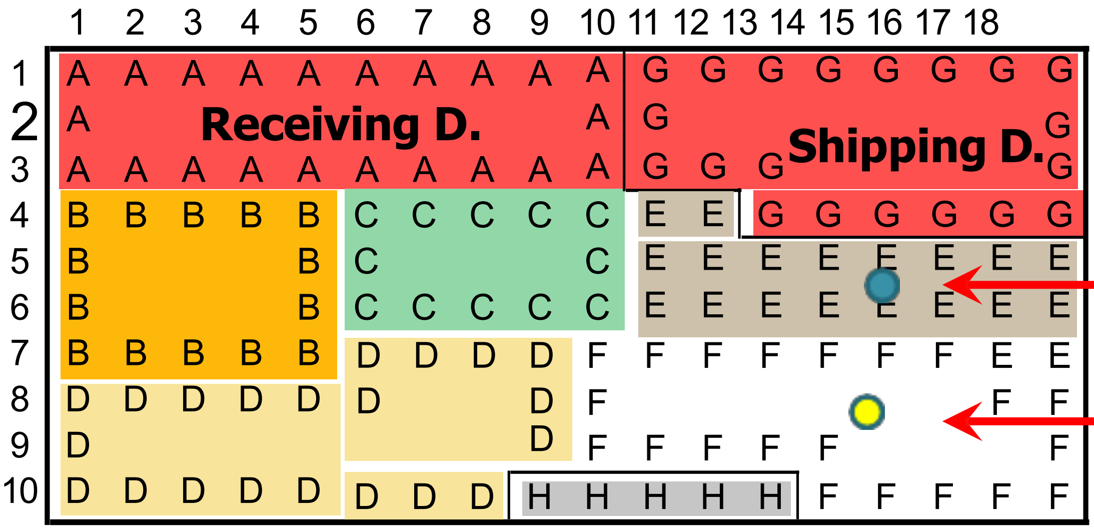
## Selection Criterion for Exchange

(Not Actual)

- Estimated change in the transportation cost:
  - Consider two departments ***i*** and ***j***:
    - Let the centroids of each location be $L_i$ and $L_j$
    - Assume that after the exchange, the new centroid of $i$ becomes $L_j$ and the centroid of $j$ becomes $L_i$.
    - Compute the change in the total transportation cost by using the new **estimated centroids**
      - Centroids of the two departments are temporarily swapped
      - The actual size of cost reduction can be 1 overestimated or 2 underestimated

# CRAFT

## Swapping the centroids

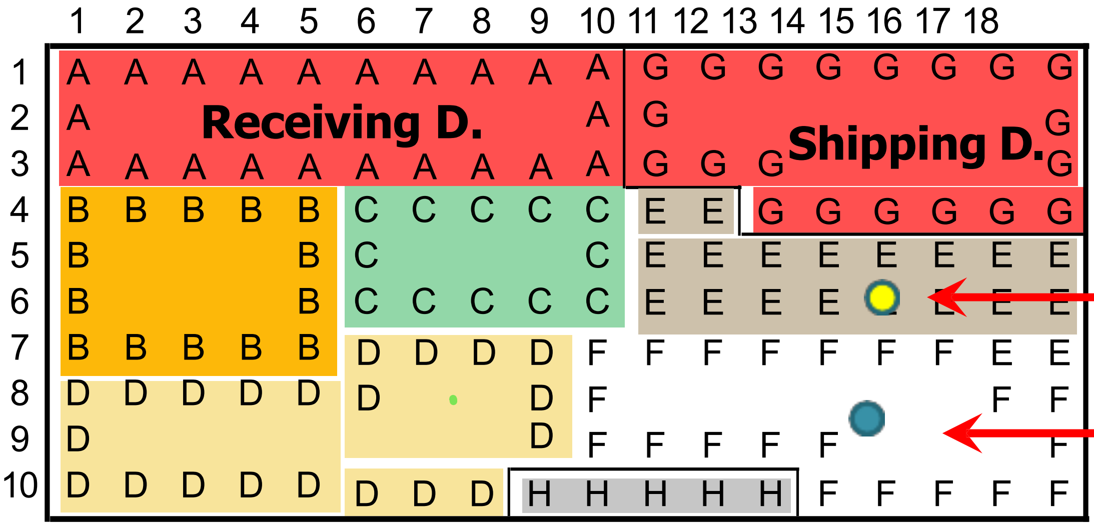


| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | Receiving D. | | | | | | A | G | | | | Shipping D. | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | | F | F |
| 9 | D | | | | | | | | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

Centroid of **E**

Centroid of **F**

Dummy Department



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | Receiving D. | | | | | | A | G | | | | Shipping D. | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | | F | F |
| 9 | D | | | | | | | | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

To calculate the estimated change in cost after the exchange:

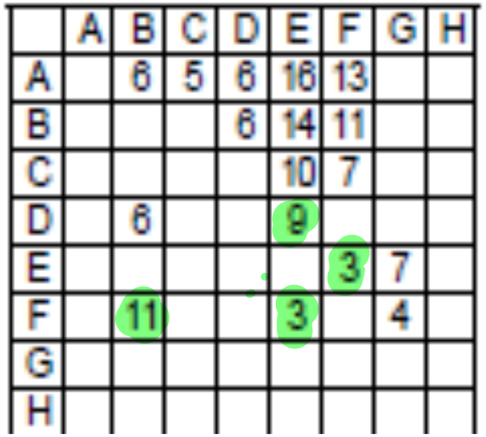
Centroid of **F**

Centroid of **E**

# CRAFT **Example**

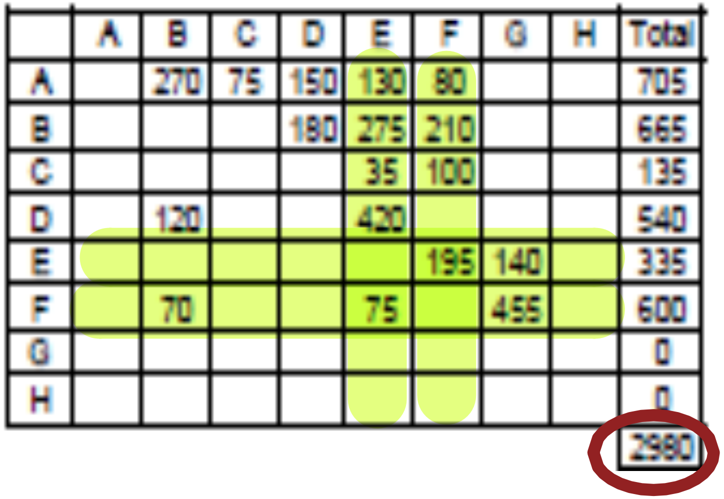
- **Estimation** of the change in transportation cost

## Trial distance matrix



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| A | | 6 | 5 | 6 | 16 | 13 | | |
| B | | | | 6 | 14 | 11 | | |
| C | | | | | 10 | 7 | | |
| D | | 6 | | | 9 | | | |
| E | | | | | | 3 | 7 | |
| F | | 11 | | | 3 | | 4 | |
| G | | | | | | | | |
| H | | | | | | | | |

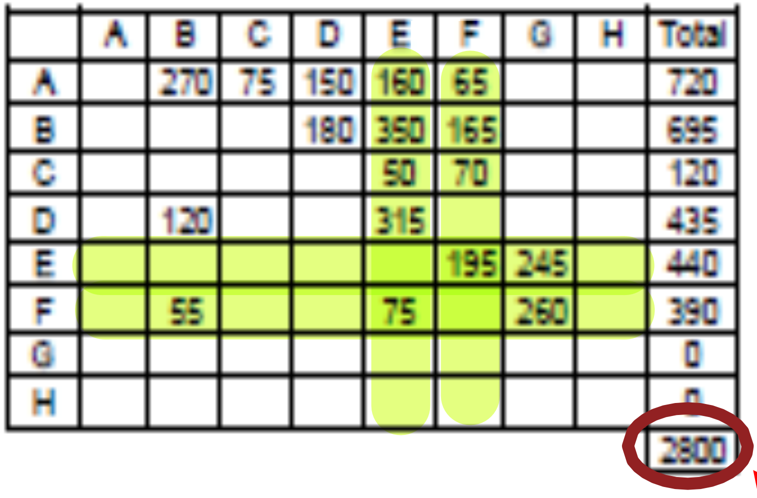
## Initial cost matrix



| | A | B | C | D | E | F | G | H | Total |
|---|---|---|---|---|---|---|---|---|---|
| A | | 270 | 75 | 150 | 130 | 80 | | | 705 |
| B | | | | 180 | 275 | 210 | | | 665 |
| C | | | | | 35 | 100 | | | 135 |
| D | | 120 | | | 420 | | | | 540 |
| E | | | | | | 195 | 140 | | 335 |
| F | | 70 | | | 75 | | 455 | | 600 |
| G | | | | | | | | | 0 |
| H | | | | | | | | | 0 |
| | | | | | | | | | 2980 |

2,990

## Trial cost matrix



| | A | B | C | D | E | F | G | H | Total |
|---|---|---|---|---|---|---|---|---|---|
| A | | 270 | 75 | 150 | 160 | 65 | | | 720 |
| B | | | | 180 | 350 | 165 | | | 695 |
| C | | | | | 50 | 70 | | | 120 |
| D | | 120 | | | 315 | | | | 435 |
| E | | | | | | 195 | 245 | | 440 |
| F | | 55 | | | 75 | | 260 | | 390 |
| G | | | | | | | | | 0 |
| H | | | | | | | | | 0 |
| | | | | | | | | | 2800 |

2,800

# CRAFT

## Exchanging two departments

- If the areas of the two departments are of **equal sizes** one department takes the shape of the other.

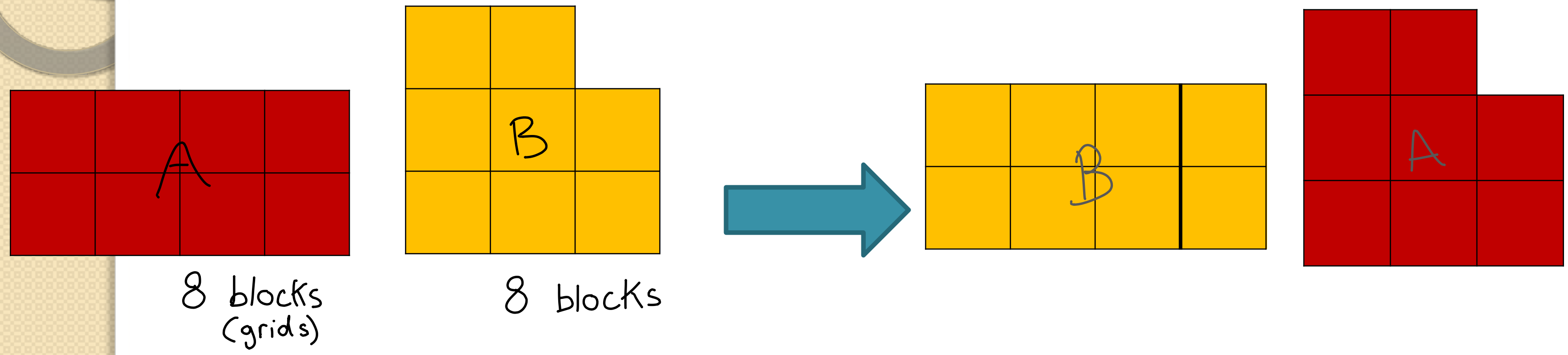
- If the areas **are not identical**:
    - Draw a box enclosing the two departments (this enclosed shaped includes the grids of the two departments only)

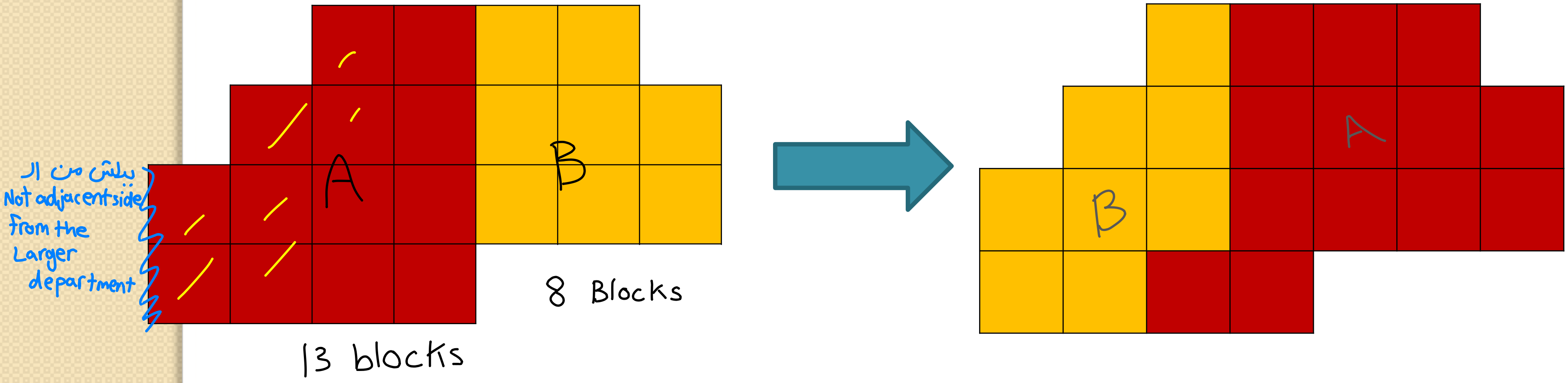
    - Count the number of grids of the smaller department. Let this count be *k*

    - Count *k* grids from the non-adjacent side of the larger department. These grids now become the new location of the smaller department. The space emptied by the smaller department now becomes part of the larger department's new territory

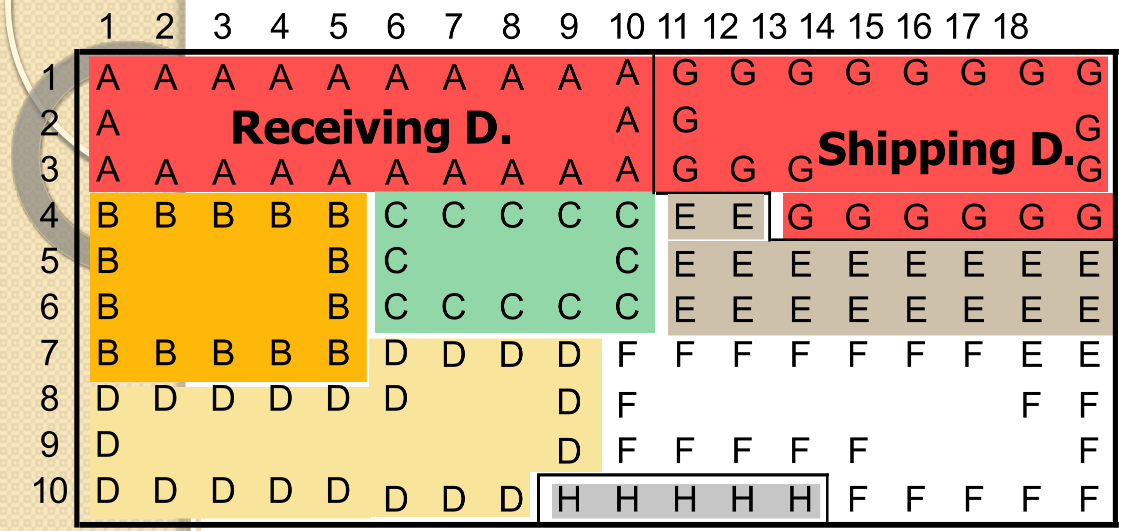
# CRAFT

# Exchanging two departments



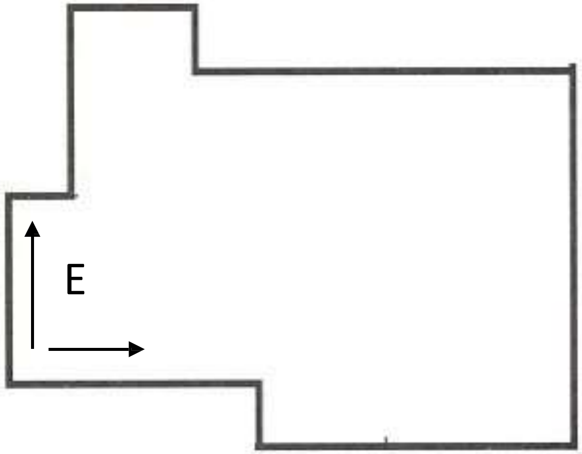


# CRAFT **Example** – exchanging E and F



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | **Receiving D.** | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | **Shipping D.** | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | E | E | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | E | E | E | E | E | E | E | E |
| 6 | B | | | | B | C | C | C | C | C | E | E | E | E | E | E | E | E |
| 7 | B | B | B | B | B | D | D | D | D | F | F | F | F | F | F | F | E | E |
| 8 | D | D | D | D | D | D | | | D | F | | | | | | | F | F |
| 9 | D | | | | | | | | D | F | F | F | F | F | | | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | F | F | F | F | F |

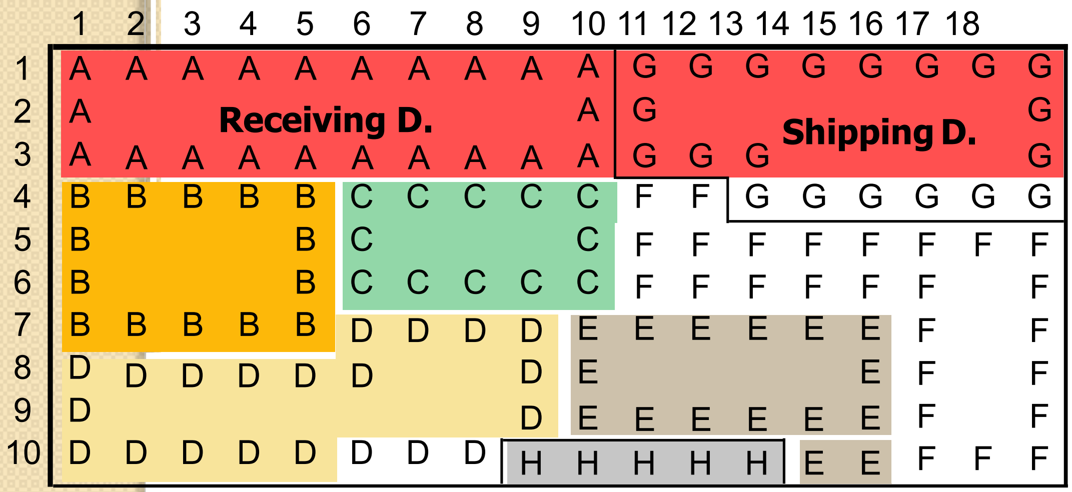
Dummy Department



Department E needs less space than department F. Then:

Starting from the non-adjacent side of department F, locate all the cells for department E

the Larger department

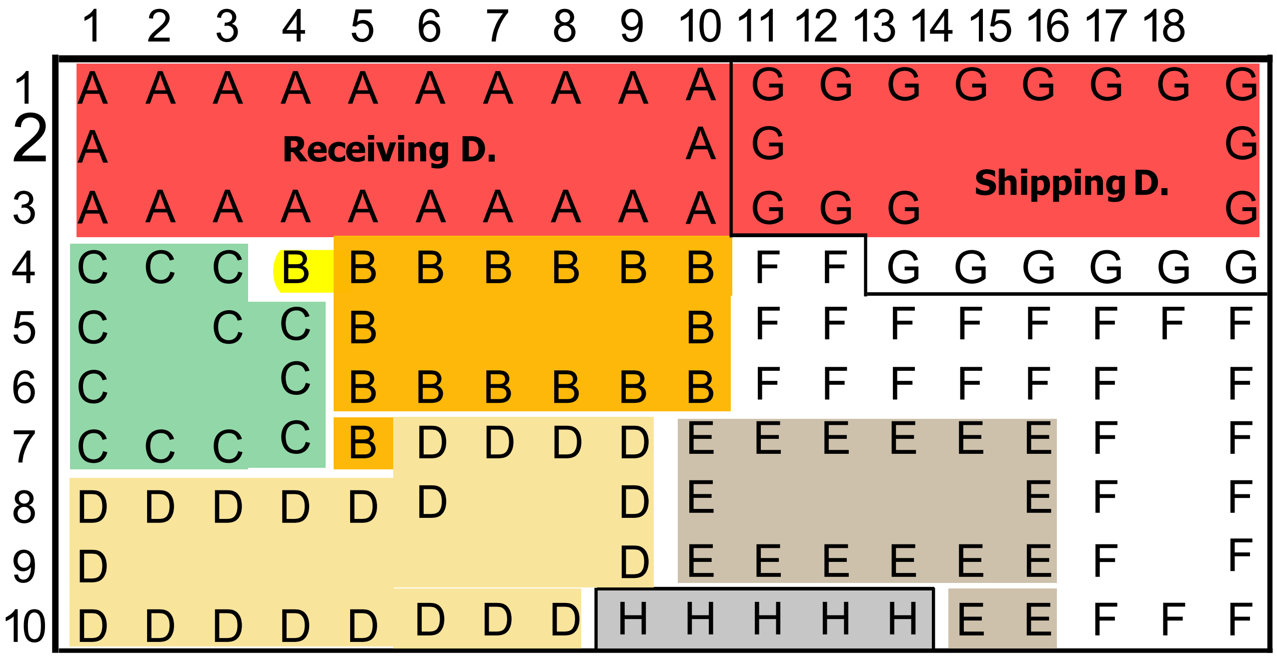


| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | **Receiving D.** | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | **Shipping D.** | | | G |
| 4 | B | B | B | B | B | C | C | C | C | C | F | F | G | G | G | G | G | G |
| 5 | B | | | | B | C | | | | C | F | F | F | F | F | F | F | F |
| 6 | B | | | | B | C | C | C | C | C | F | F | F | F | F | F | | F |
| 7 | B | B | B | B | B | D | D | D | D | E | E | E | E | E | E | F | | F |
| 8 | D | D | D | D | D | D | | | D | E | | | | | E | F | | F |
| 9 | D | | | | | | | | D | E | E | E | E | E | E | F | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | E | E | F | F | F |

**New Layout – after exchanging E and F**

# CRAFT **Example**

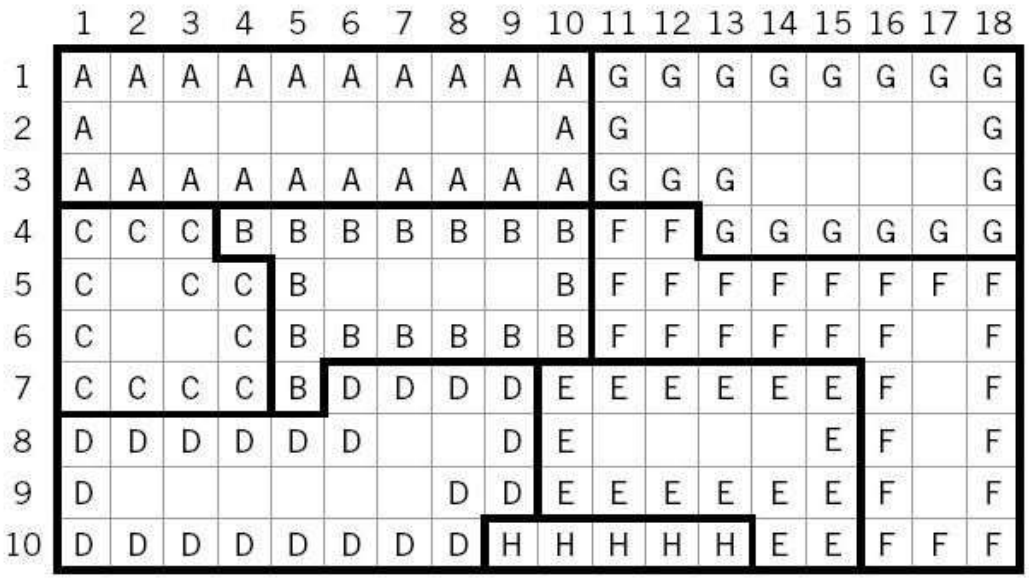
Final Layout – after exchanging B and C



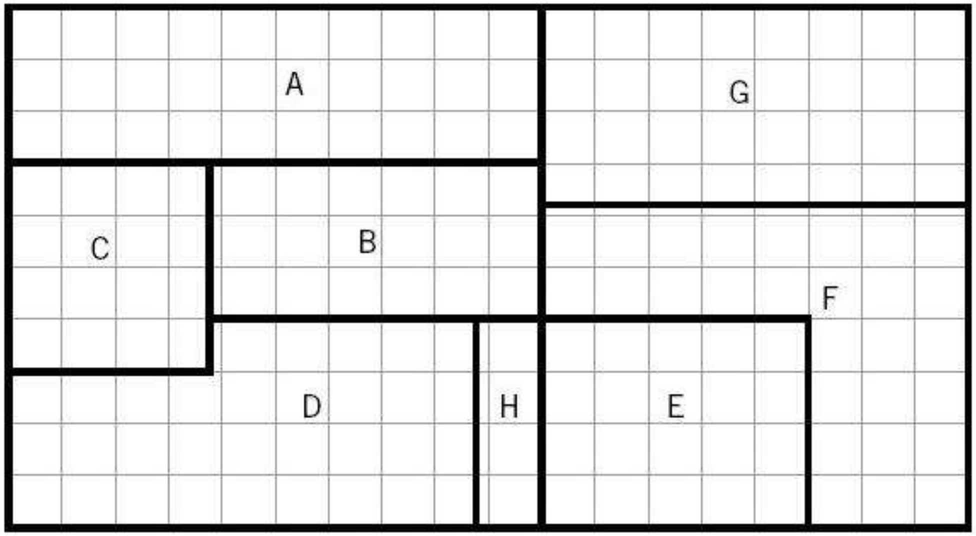
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | **Receiving D.** | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | **Shipping D.** | | | G |
| 4 | C | C | C | B | B | B | B | B | B | B | F | F | G | G | G | G | G | G |
| 5 | C | | C | C | B | | | | | B | F | F | F | F | F | F | F | F |
| 6 | C | | | C | B | B | B | B | B | B | F | F | F | F | F | F | | F |
| 7 | C | C | C | C | B | D | D | D | D | E | E | E | E | E | E | F | | F |
| 8 | D | D | D | D | D | D | | | D | E | | | | | E | F | | F |
| 9 | D | | | | | | | | D | E | E | E | E | E | E | F | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | E | E | F | F | F |

# CRAFT **Example**

## Manual Adjustment on CRAFT output



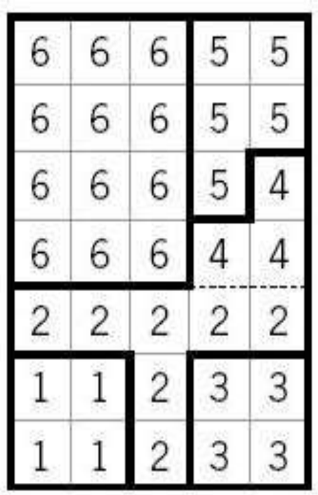
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | A | A | A | A | A | A | A | G | G | G | G | G | G | G | G |
| 2 | A | | | | | | | | | A | G | | | | | | | G |
| 3 | A | A | A | A | A | A | A | A | A | A | G | G | G | | | | | G |
| 4 | C | C | C | B | B | B | B | B | B | B | F | F | G | G | G | G | G | G |
| 5 | C | | C | C | B | | | | | B | F | F | F | F | F | F | F | F |
| 6 | C | | | C | B | B | B | B | B | B | F | F | F | F | F | F | | F |
| 7 | C | C | C | C | B | D | D | D | D | E | E | E | E | E | E | F | | F |
| 8 | D | D | D | D | D | D | | | D | E | | | | | E | F | | F |
| 9 | D | | | | | | | D | D | E | E | E | E | E | E | F | | F |
| 10 | D | D | D | D | D | D | D | D | H | H | H | H | H | E | E | F | F | F |



نقص

# CRAFT Insufficiency of Adjacency for Exchange

- If 2 departments are not equal in area, then adjacency is a necessary but not sufficient condition for an exchange



| | | | | |
|---|---|---|---|---|
| 6 | 6 | 6 | 5 | 5 |
| 6 | 6 | 6 | 5 | 5 |
| 6 | 6 | 6 | 5 | 4 |
| 6 | 6 | 6 | 4 | 4 |
| 2 | 2 | 2 | 2 | 2 |
| 1 | 1 | 2 | 3 | 3 |
| 1 | 1 | 2 | 3 | 3 |

CRAFT is unable to exchange departments 2 and 4 without splitting the department 2 or shifting other departments

لأنه بكل الطرق راح يصير (Spliting for deparment 2)

and I want to avoid spliting

# CRAFT - **Pros**

- CRAFT is flexible with respect to department shapes.
  - In theory, CRAFT is applicable only to rectangular facilities, yet using dummy extensions, we can still apply CRAFT algorithm to non-rectangular shapes.
- **Dummy departments**

Advantages

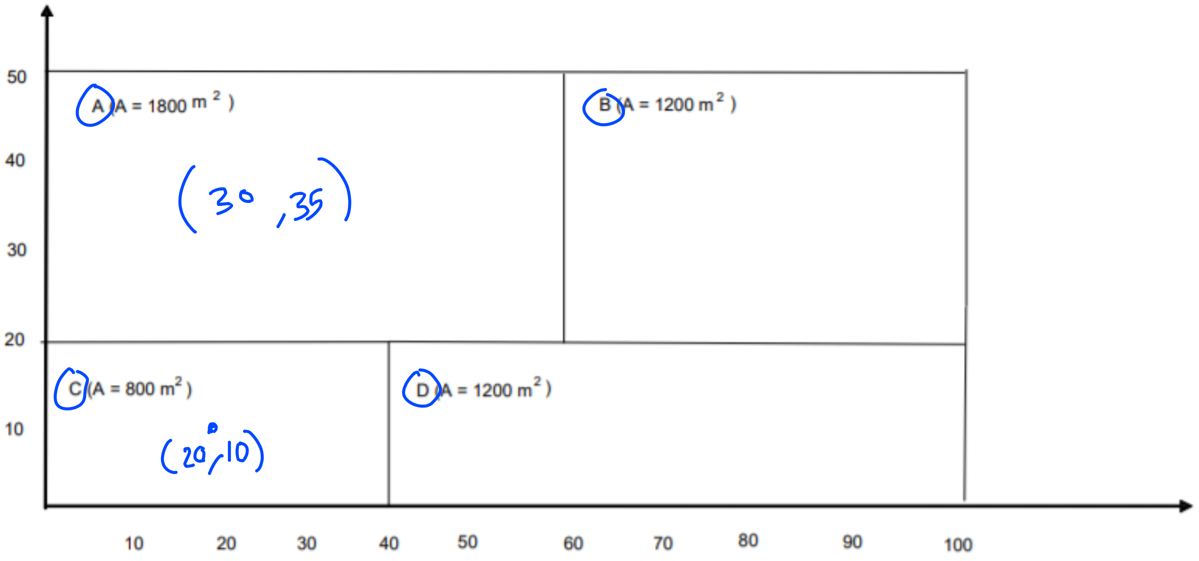
  - Have no flows or interaction with other departments
  - Require certain area
  - Can be fixed
  - Used for:
    - Non-rectangular facilities
    - Fixed areas in the layout (obstacles, unusable areas, etc.)
    - Aisle locations
    - Extra space
    - Building irregularities
- CRAFT captures the initial layout with reasonable accuracy

# CRAFT - **Cons**

- **Locally optimal solution** only
  - CRAFT is a path-oriented method so the final layout is dependent on the initial layout. Therefore, a number of different initial layouts should be used as input to the CRAFT procedure.
- CRAFT may lead to **irregular shapes** both for individual departments and the facility itself.
  - Most of the time, a manual "finishing" must be done before presenting the CRAFT output.
- It is not always possible to exchange two unequal size, adjacent departments without splitting the larger one.

Example:

A local manufacturing firm has recently completed construction of a new wing of an existing building to house four departments: A, B, C and D. The wing is 100 m by 50 m. The initial layout and flow matrix is given in below. **Assume unit cost matrix**. Using CRAFT algorithm do one iteration to obtain an improved layout.



معطى من السؤال →

| Material Flow | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 2 | 7 | 4 |
| B | 3 | 0 | 5 | 5 |
| C | 6 | 7 | 0 | 3 |
| D | 8 | 2 | 3 | 0 |

هنا يبدأ الحل

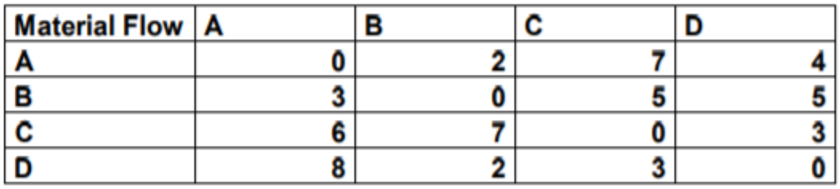
Step 1: Determine department centroids.

| Dept | centroid |
|---|---|
| A | (30,35) |
| B | (80,35) |
| C | (20,10) |
| D | (70,10) |

Step 2: Calculate rectilinear distance between centroids.

| | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 50 | 35 | 65 |
| B | 50 | ----- | 85 | 35 |
| C | 35 | 85 | ---- | 50 |
| D | 65 | 35 | 50 | ----- |

Step 3: Calculate transportation cost for the layout.



| Material Flow | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 2 | 7 | 4 |
| B | 3 | 0 | 5 | 5 |
| C | 6 | 7 | 0 | 3 |
| D | 8 | 2 | 3 | 0 |

Transportation cost matrix $z = \sum\sum f_{ij} d_{ij} c_{ij}$

| | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 100 | 245 | 260 |
| B | 150 | ----- | 425 | 175 |
| C | 210 | 595 | ---- | 150 |
| D | 520 | 70 | 150 | ----- |

Total cost of the initial layout (Distance based cost for the initial layout) is = $3,050

Step 4:

Possible exchange:
1. equal area departments

2. departments sharing a common border.

| Possible Exchange | Comments |
|---|---|
| A-B | sharing a common border |
| A-C | sharing a common border |
| A-D | sharing a common border |
| B-C | No exchange |
| B-D | sharing a common border and same area |
| C-D | sharing a common border |

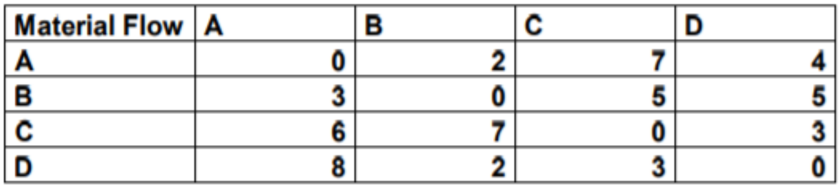
Step 5:

Exchange #1: (A and B)

| Dept | centroid |
|---|---|
| B | (30,35) |
| A | (80,35) |
| C | (20,10) |
| D | (70,10) |

Distance matrix after Exchanging A and B

|  | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 50 | 85 | 35 |
| B | 50 | ----- | 35 | 65 |
| C | 85 | 35 | ---- | 50 |
| D | 35 | 65 | 50 | ----- |



| Material Flow | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 2 | 7 | 4 |
| B | 3 | 0 | 5 | 5 |
| C | 6 | 7 | 0 | 3 |
| D | 8 | 2 | 3 | 0 |

Predicted transportation cost matrix after Exchanging A and B

|  | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 100 | 595 | 140 |
| B | 150 | ----- | 175 | 325 |
| C | 510 | 245 | ---- | 150 |
| D | 280 | 130 | 150 | ----- |

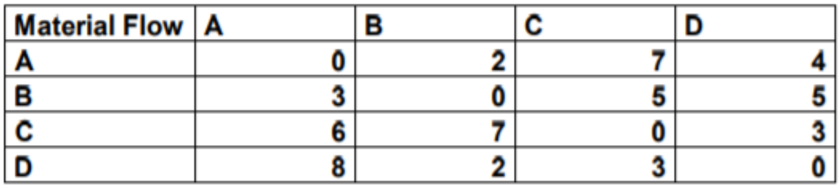
The predicted Transportation cost after exchanger dept A-B= $ 2,950

Exchange #1: (A and C)

| Dept | centroid |
|---|---|
| C | (30,35) |
| B | (80,35) |
| A | (20,10) |
| D | (70,10) |

Distance matrix after Exchanging A and C

| | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 85 | 35 | 50 |
| B | 85 | ----- | 50 | 35 |
| C | 35 | 50 | ---- | 65 |
| D | 50 | 35 | 65 | ----- |



| Material Flow | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 2 | 7 | 4 |
| B | 3 | 0 | 5 | 5 |
| C | 6 | 7 | 0 | 3 |
| D | 8 | 2 | 3 | 0 |

Predicted transportation cost matrix after Exchanging A and B

| | A | B | C | D |
|---|---|---|---|---|
| A | ----- | 170 | 245 | 200 |
| B | 255 | ----- | 250 | 175 |
| C | 210 | 350 | ---- | 195 |
| D | 400 | 70 | 195 | ----- |

**The cost after exchanger dept A-C= $ 2,715**

| Possible exchange | Predicated (estimated) total cost | Reduction in transportation cost = Initial cost – predicted cost of the layout after exchange |
|---|---|---|
| A-B | 2,950 | 100 |
| A-C | 2,715 | 335 |
| A-D | **3,185** | **-135** |
| B-C | No exchange | No exchange |
| B-D | **2,735** | **315** |
| C-D | **2,830** | **220** |

We choose to exchange A-C because it has the highest reduction in transportation cost.

C : (20,40)

A, A1(20,15)

A2(50,35)

| | Area | x | y | Ax = x*Area | Ay = y*Area |
|---|---|---|---|---|---|
| A1 | 40*30=1,200 | 20 | 15 | 24,000 | 18,000 |
| A2 | 20*30=600 | 50 | 35 | 30,000 | 21,000 |
| total | 1,800 | 70 | 50 | 54,000 | 39,000 |

$$x_c = \frac{A_x}{A} = \frac{54,000}{1,800} = 30$$

$$y_c = \frac{A_y}{A} = \frac{39,000}{1,800} = 21.67$$

Actual center for A after exchanging A and C is (30,21.67)

| Dept | centroid |
|---|---|
| A | (30,21.67) |
| B | (80,35) |
| C | (20,40) |
| D | (70,10) |

Actual Distance matrix after Exchanging A and C

| Dept | A | B | C | D |
|---|---|---|---|---|
| A | ------- | 63.333 | 28.33 | 51.67 |
| B | 63.333 | ------- | 65 | 35 |
| C | 28.333 | 65 | ------- | 80 |
| D | 51.667 | 35 | 80 | ------- |

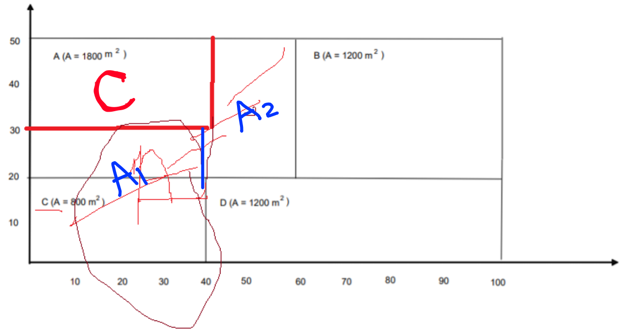
| Material Flow | A | B | C | D |
|---|---|---|---|---|
| A | 0 | 2 | 7 | 4 |
| B | 3 | 0 | 5 | 5 |
| C | 6 | 7 | 0 | 3 |
| D | 8 | 2 | 3 | 0 |

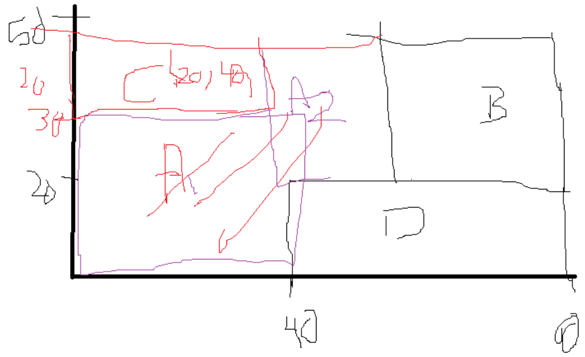
Actual cost matrix after exchanger dept A-C

| Dept | A | B | C | D |
|---|---|---|---|---|
| A | ------- | 126.67 | 198.31 | 206.68 |
| B | 189.9 | ------- | 325 | 175 |
| C | 169.99 | 455 | ------- | 240 |
| D | 413.33 | 70 | 240 | ------- |

Actual transportation cost after Exchanging A and C is 2809.9,

**Total costs of 2809.9, we do not achieve the estimated cost (2,715), but compared to the initial layout (3,050) we have cost reduction.**
**This layout (after exchanging A and C) will be considered as an initial for the second iteration.**





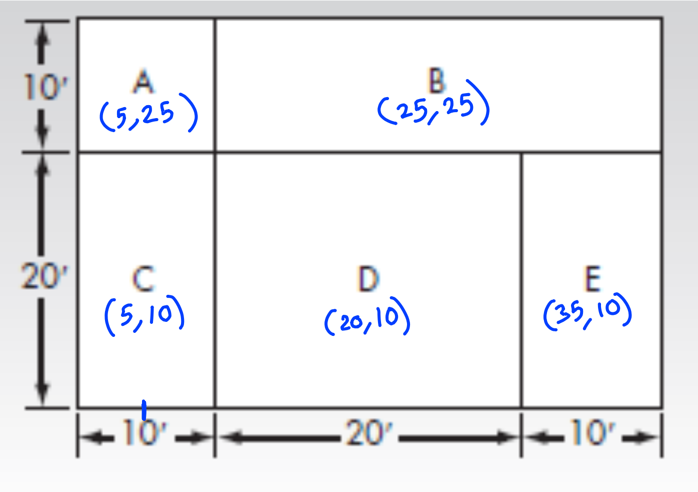
1. Determine department centroids.
2. Calculate rectilinear distance between centroids.
3. Calculate transportation cost for the layout.
4. Consider department exchanges of either **equal area departments** or **departments sharing a common border**.
5. Determine the estimated change in transportation cost of each possible exchange.
6. Select and implement the departmental exchange that offers the greatest reduction in transportation cost.
7. Repeat the procedure for the new layout until no interchange is able to reduce the transportation cost.

## Craft Example:

Suppose the following layout is provided as the initial layout for CRAFT. The flow-between matrix is given below. (All the $cij$ values are equal to $2) (unite load. unite distance).

**Flow-Between Matrix**

|  | A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | **----** | **8** | **2** | **8** | **14** |
| **B** |  | **----** | **12** | **8** | **16** |
| **C** |  |  | **----** | **6** | **10** |
| **D** |  |  |  | **----** | **4** |
| **E** |  |  |  |  | **----** |



1. Suppose the following layout is provided as the initial layout to CRAFT. Number of department pairs that will be considered for exchange that satisfy exchange requirements is:

   **Answer: 7**

2. The cost of the initial layout is:

   **Answer: 4980**

3. The estimated layout cost assuming that departments C and E are exchanged.

   **Answer: 4340**

4. The actual layout cost assuming that departments C and E are exchanged.

   **Answer: 4340**

5. The estimated layout cost assuming that departments C and D are exchanged.

   **Answer: 4500**

6. The actual layout cost assuming that departments C and D are exchanged.

   **Answer: 4260**

# Final Exam (Second semester)
## 2023/2024
by Nada Ababneh

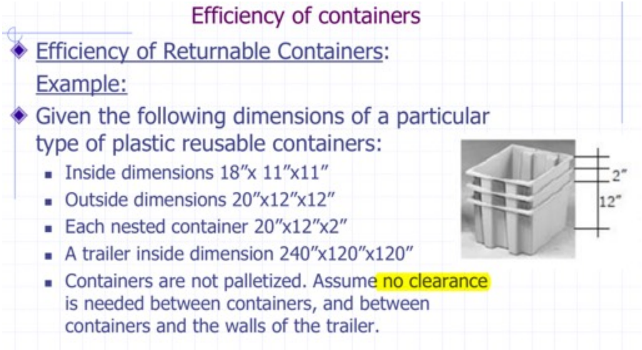
الامتحان
← دوائر ٣٠ علامة
← كتابة ← ٤ علامات
← صور ونكتب اسمهم ← ٦ علامات

① اجى على ال CRAFT ١٢ علامة

→ how many departments can be exchanged to satisfy...
→ initial cost for the Layout
→ exchange departments B and F and calculate
  → estimated cost
  → actual cost
→ exchange departments D and F and calculate
  → estimated cost
  → actual cost

② سؤالين دوائر حفظ 🤯

③



Efficiency of containers

- Efficiency of Returnable Containers:
  Example:
- Given the following dimensions of a particular type of plastic reusable containers:
  - Inside dimensions 18"x 11"x11"
  - Outside dimensions 20"x12"x12"
  - Each nested container 20"x12"x2"
  - A trailer inside dimension 240"x120"x120"
  - Containers are not palletized. Assume no clearance is needed between containers, and between containers and the walls of the trailer.

← مثل هذا السؤال
ونحسب اربع مطاليب ٩

④ فرعين على ال Adjacency based scoring
← نحسب ال Adjacency based score
← نحسب efficiency

$$Z = \frac{\Sigma\Sigma f x}{\Sigma f}$$

⑤ سؤال عن ال Health services

- 4 nusres
- 1 physician

و نحسب ال Total لل

- First aid room
- waiting room
- Examination room

إلى هنا الدوائر (٣٠ علامة)

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⑥ وسؤال نكتب اسماء الصور !! (٦ علامات)

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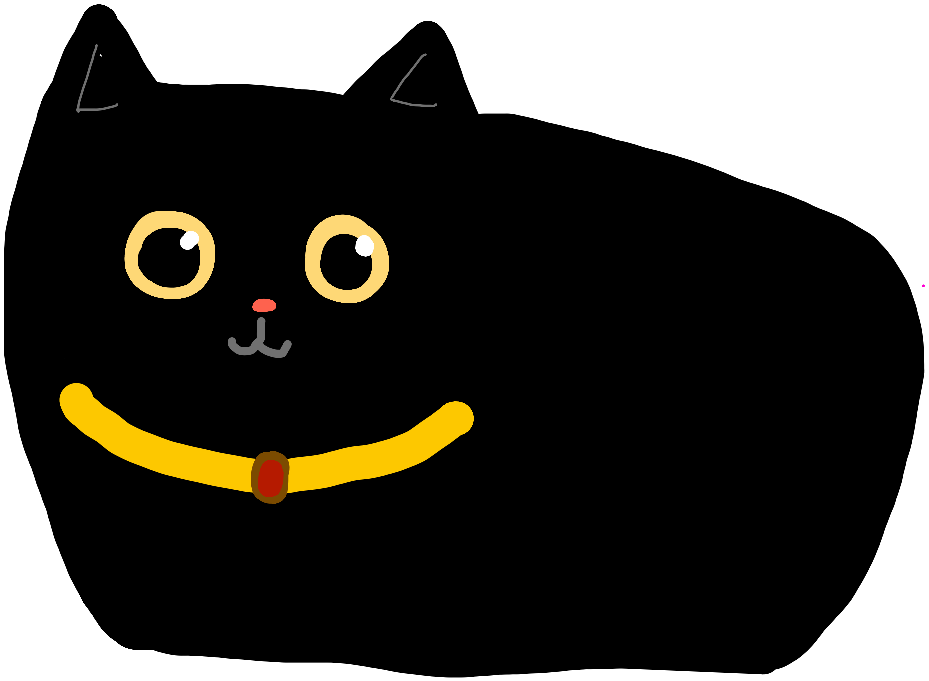
⑦ سؤال على ال machines (٤ علامات)



ملخص قوي للمادة

https://drive.google.com/file/d/1-N9oMDKC7fV3nTjCAk-Kv8pmiKQUEy2F/view?usp=drivesdk

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آخر صفحتين في الملف مكتوب فيهم اسئلة امتحان
الفاينل للفصل الثاني ٢٠٢٣/٢٠٢٤