OPEN UNIVERSITY MALAYSIA

EBIE3103

Introduction to Industrial Engineering

EBIE3103
INTRODUCTION TO INDUSTRIAL ENGINEERING

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OPEN UNIVERSITY MALAYSIA

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COURSE GUIDE

COURSE GUIDE DESCRIPTION

You must read this *Course Guide* carefully from the beginning to the end. It tells you briefly what the course is about and how you can work your way through the course material. It also suggests the amount of time you are likely to spend in order to complete the course successfully. Please refer to the *Course Guide* from time to time as you go through the course material as it will help you to clarify important study components or points that you might miss or overlook.

INTRODUCTION

EBIE3103 Introduction to Industrial Engineering is one of the courses offered at Open University Malaysia (OUM). This course is worth three credit hours and should be covered over 15 weeks.

COURSE AUDIENCE

This is a core course for learners taking the Bachelor of Manufacturing Management with Honours programme.

As an open and distance learner, you should be acquainted with learning independently and being able to optimise the learning modes and environment available to you. Before you begin this course, please ensure that you have the right course material and understand the course requirements as well as how the course is conducted.

STUDY SCHEDULE

It is a standard OUM practice that learners accumulate 40 study hours for every credit hour. As such, for a two-credit hour course, you are expected to spend 80 study hours. Table 1 gives an estimation of how the 80 study hours could be accumulated.

Table 1: Estimation of Time Accumulation of Study Hours

Study Activities	Study Hours
Briefly go through the course content and participate in initial discussions	3
Study the module	60
Attend 3 to 5 tutorial sessions	10
Online participation	12
Revision	15
Assignment(s), test(s) and examination(s)	20
TOTAL STUDY HOURS ACCUMULATED	**80**

COURSE LEARNING OUTCOMES

By the end of this course, you should be able to:

1. Explain the definition and history of industrial engineering;
2. Perform study method and work measurement in a manufacturing organisation; and
3. Apply plant layout, material handling and ergonomics at the workplace in a manufacturing organisation.

COURSE SYNOPSIS

This course is divided into eight topics. The synopsis for each topic is as follows:

Topic 1 gives an overall introduction to industrial engineering. It covers the basic concepts of industrial engineering, the people behind industrial engineering development and advancement as well as differences between various engineering disciplines. It also explains industrial and system engineering activities.

Topic 2 explains the importance of decision-making in manufacturing, compares between non-programmed and programmed decisions, describes alternative approaches to decision-making, explains scientific methods for business decision-making and elaborates on how to perform a break-even analysis.

Topic 3 covers productivity, basic definitions of productivity, how to compute productivity for a given data, the importance of productivity improvements, factors affecting productivity improvements and the fundamental techniques of productivity improvement.

Topic 4 introduces work study, objectives of work study, work study techniques, human factors in work study, definitions of method study and its objectives, method study procedures and the principles of motion economics.

Topic 5 covers work measurement, objectives of work measurement, common techniques used in work measurements, solving time study problems, calculating the sample size for work measurement and calculating the number of observations required in work sampling.

Topic 6 introduces the concepts of plant location and layout, choice of location and location selection, different plant layouts and their benefits, stages in location problems, location factors, how to apply location analysis techniques, objectives of plant layout and types of plant layouts.

Topic 7 covers material handling, objectives of material handling, the principles of material handling, types of material handling equipment, factors affecting the selection of material handling equipment and material handling costs. You will also learn the relationship between material handling, flow of materials, storage and packaging in material handling and organisation for effective materials handling.

Topic 8 introduces the concept of ergonomics, the goals of ergonomics, the objectives and benefits of ergonomics, the core of ergonomics knowledge, ergonomics application and its design principles.

TEXT ARRANGEMENT GUIDE

Before you go through this module, it is important that you note the text arrangement. Understanding the text arrangement will help you to organise your study of this course in a more objective and effective way. Generally, the text arrangement for each topic is as follows:

Learning Outcomes: This section refers to what you should achieve after you have completely covered a topic. As you go through each topic, you should frequently refer to these learning outcomes. By doing this, you can continuously gauge your understanding of the topic.

Self-Check: This component of the module is inserted at strategic locations throughout the module. It may be inserted after one subtopic or a few subtopics. It usually comes in the form of a question. When you come across this component, try to reflect on what you have already learnt thus far. By attempting to answer the question, you should be able to gauge how well you have understood the subtopic(s). Most of the time, the answers to the questions can be found directly from the module itself.

Activity: Like Self-Check, the Activity component is also placed at various locations or junctures throughout the module. This component may require you to solve questions, explore short case studies, or conduct an observation or research. It may even require you to evaluate a given scenario. When you come across an Activity, you should try to reflect on what you have gathered from the module and apply it to real situations. You should, at the same time, engage yourself in higher order thinking where you might be required to analyse, synthesise and evaluate instead of only having to recall and define.

Summary: You will find this component at the end of each topic. This component helps you to recap the whole topic. By going through the summary, you should be able to gauge your knowledge retention level. Should you find points in the summary that you do not fully understand, it would be a good idea for you to revisit the details in the module.

Key Terms: This component can be found at the end of each topic. You should go through this component to remind yourself of important terms or jargon used throughout the module. Should you find terms here that you are not able to explain, you should look for the terms in the module.

References: The References section is where a list of relevant and useful textbooks, journals, articles, electronic contents or sources can be found. The list can appear in a few locations such as in the *Course Guide* (at the References section), at the end of every topic or at the back of the module. You are encouraged to read or refer to the suggested sources to obtain the additional information needed and to enhance your overall understanding of the course.

PRIOR KNOWLEDGE

No prior knowledge required.

ASSESSMENT METHOD

Please refer to myINSPIRE.

REFERENCES

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TAN SRI DR ABDULLAH SANUSI (TSDAS) DIGITAL LIBRARY

The TSDAS Digital Library has a wide range of print and online resources for the use of its learners. This comprehensive digital library, which is accessible through the OUM portal, provides access to more than 30 online databases comprising e-journals, e-theses, e-books and more. Examples of databases available are EBSCOhost, ProQuest, SpringerLink, Books24×7, InfoSci Books, Emerald Management Plus and Ebrary Electronic Books. As an OUM learner, you are encouraged to make full use of the resources available through this library.

Topic 1 ▸ Introduction to Industrial Engineering

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Describe the history and development of industrial engineering;
2. Identify the six steps in an engineering process;
3. Explain industrial engineering and system; and
4. Classify industrial and system engineering activities.

▶ INTRODUCTION

What do you understand about the field of industrial engineering? Generally, industrial engineering is a branch of engineering that involves figuring out how to make or do things better. Industrial engineering is concerned with **design**, **improvement** and **installation** with integrated systems of **people**, **materials**, **information**, **equipment** and **energy**. The field of industrial engineering draws upon the knowledge and skills from several fields of science such as technical sciences, mathematical, economics and human sciences. These can also be supported with skills in information science. Industrial engineering includes knowledge of those sciences in an effort to increase process productivity, achieve product quality and ensure labour safety.

Therefore, in this first topic, we will look at the historical perspective of industrial engineering, the engineering process as well as industrial engineering and system. Finally, we will take a look at the formation and management of industrial and systems of engineering. Happy reading!

1.1 HISTORICAL PERSPECTIVE OF INDUSTRIAL ENGINEERING

Let us first look at the history that drives the existence of industrial engineering in order for us to fully understand the role of industrial engineering. Engineering and science have grown in parallel and complementary concept, although not always at the same rate. Basically, **science** is the **search for basic knowledge**, while **engineering** is about **using scientific knowledge to solve problems and seek a better life**.

Initially in its early days, engineering principles, especially regarding the construction of roads and bridges, were taught at military academies. If some of these principles are applied to fields other than military, they are linked to **civil engineering**.

Related advances in the field of **physics and mathematics** have enabled the practical use of mechanical principles. For example, the creation of a steam engine triggered **mechanical engineering** as a field of engineering in the early 1800s.

Other examples of progress such as basic work on **electric and magnetic** fields has allowed the use of electrical science, for example, in the invention of the telegraph by Samuel Morse.

Other than that, the creation of the carbon filament lamp by Thomas Edison resulted in the use of electricity for lighting purposes. This has led to the rapid growth in power generation, transmission and consumption. This work is associated with **electrical engineering**.

In addition to the developments in mechanical and electrical technology, there were also developments in the understanding of **materials and their properties**. This engineering field is known as **chemical engineering**.

These four key areas (**civil**, **mechanical**, **electrical** and **chemical**) are the branches of engineering that existed before the year 1900. Their existence is part of the Industrial Revolution and the initial technological revolution.

Emerging industrial organisations are exploiting technological advances. Science and complexity of manufacturing units have increased the need for better management systems, which resulted in the growth of what we call **industrial engineering**.

The developments after World War II resulted in the development of other engineering fields such as:

(a) Nuclear engineering;

(b) Electronics engineering;

(c) Aerospace engineering;

(d) Aeronautical engineering; and

(e) Computer engineering.

In addition, there are also:

(a) Environmental engineering; and

(b) Bioengineering.

SELF-CHECK 1.1

1. State the difference between science and engineering.

2. Briefly explain how the following fields of engineering began:

   (a) Civil engineering;

   (b) Mechanical engineering;

   (c) Electrical engineering; and

   (d) Chemical engineering.

ACTIVITY 1.1

Discuss with your coursemates in the myINSPIRE forum the following questions:

(a) Look around your workplace. Can you identify areas that relate to industrial engineering?

(b) How did mankind survived and progressed before the engineering era?

1.2 ENGINEERING PROCESS

The distinguishing feature of engineering is related to the **design of a system**. Design can be understood by discussing two other terms i.e. **synthesis** and **analysis**. What is the meaning of these two terms? Let us find out the answer in Table 1.1.

Table 1.1: Synthesis versus Analysis

Analysis	Synthesis
A process of scrutinising of something down to the basic elements.	A process of connecting elements into one.

Usually, **analysis** is for an **existing system** while **synthesis** is for a **new system**. An engineering process involves analysis and synthesis as shown in Figure 1.1.

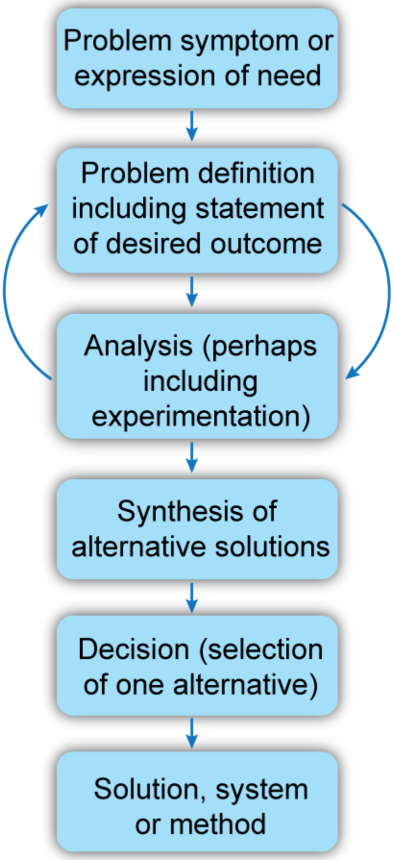

Figure 1.1: Six steps in an engineering process
Source: Turner, Mize, Case & Nazemtz (1993)

SELF-CHECK 1.2

Describe the difference between synthesis and analysis.

ACTIVITY 1.2

How do human needs lead to the development of new and innovative products? For example, in the context of the latest smartphone development. Discuss this matter in the myINSPIRE forum.

1.3 INDUSTRIAL ENGINEERING AND SYSTEM

Industrial engineering emerged as a profession as a result of the Industrial Revolution and the need for workers who are technically trained and can plan, manage and direct the operations of large complex systems. The need to improve efficiency and effectiveness of operations was the original impetus for the emergence of industrial engineering.

Now, let us look at the gurus who promoted industrial engineering:

(a) **Frederick W. Taylor (1856–1915)**

Did you know that Frederick W. Taylor (Figure 1.2) was the founder of **scientific management**? More accurately, he was the founder of the scientific method usage for the management of problems.

Figure 1.2: Frederick W. Taylor

What are the contributions of Taylor? Some of his contributions are:

(i) The separation between design and manufacturing.

(ii) Work research:

- Review the elements of a work by the use of a stopwatch; and
- Study movements to obtain a better way to make things work.

(iii) Incentive scheme.

(b) **Frank Gilbreth (1868–1924) and Lillian Gilbreth (1878–1972)**
Frank Gilbreth and Lillian Gilbreth are husband and wife who studied **time and motion** (see Figure 1.3).

Figure 1.3: Frank Gilbreth and Lillian Gilbreth

Some instances of important work done by the Gilbreths are:

(i) Developments in the field of motion of study;

(ii) Progress in the construction industry;

(iii) The creation of several new techniques, for example, micro-motion study;

(iv) Identify 17 basic movements used in the method study; and

(v) Study on fatigue.

(c) **Henry L. Gantt (1861–1919)**
Are you familiar with Gantt chart? This chart, which shows a work plan in relation to the passage of time is created by Henry L. Gantt (Figure 1.4).

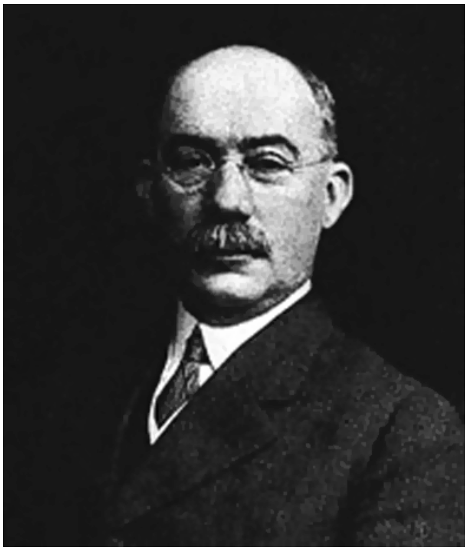

Figure 1.4: Henry L. Gantt

The most prominent contribution from Gantt is of course the **Gantt chart**, which is still an important tool in project management and programme management.

(d) **W. A. Shewhart (1891–1967)**

W. A. Shewhart (Figure 1.5) developed the basic principles of statistical quality control in 1924.

Figure 1.5: W. A. Shewhart

Shewhart is known as the father of statistical quality control. He created the Shewhart cycle, which consists of **plan**, **do**, **check** and **act**.

Now, let us look at Figure 1.6, which shows you the significant events and important developments that occurred in the evolution of industrial engineering. The position of an event relative to the time axis represents the estimated time it occurred or started.

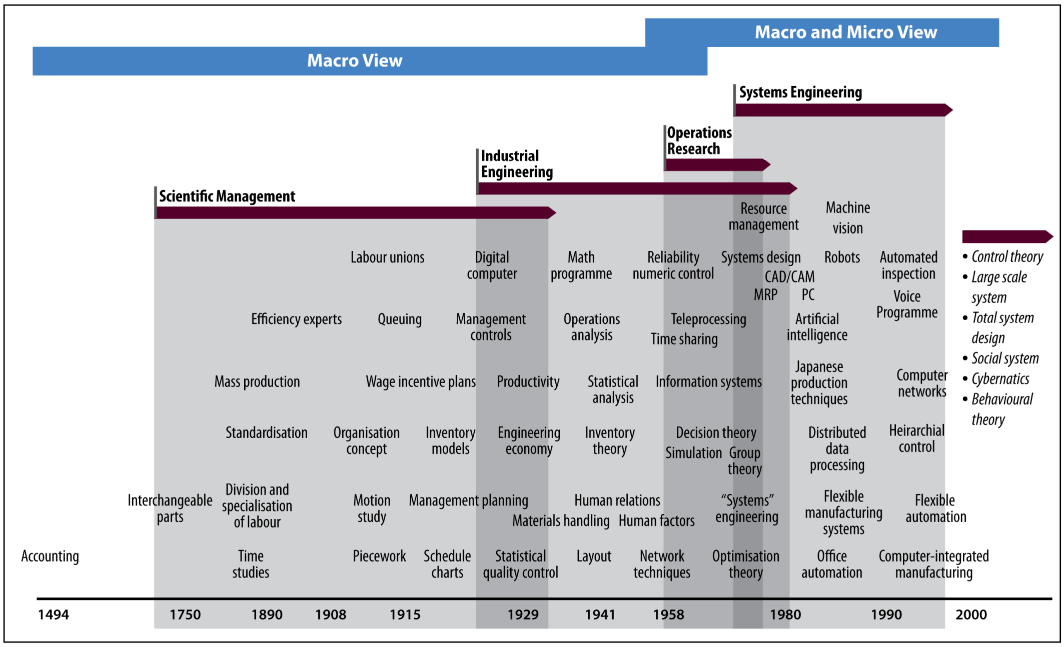

Figure 1.6: A chronology of significant events and developments in the evolution of industrial and systems engineering

Source: Turner, Mize, Case & Nazemtz (1993)

There are many engineering industry luminaries who have contributed to the development of this profession. In the years between 1920 and 1930, many of the basic works were carried out on the economic aspects, such as inventory problems, incentive plans, layout problems, transportation problems and the principles of the organisation.

As can be seen in Figure 1.6, the top of the chart emphasises a four-period overlap. The environment period from 1900 to the mid-1930s is usually associated with scientific management. The period associated with the engineering industry began at the end of the 1920s and continued to the present. The period that marked the operations research which influenced industrial engineering was from the mid-1940s to the mid-1970s.

Finally, the fourth period highlights the industrial and systems engineering, which started in the 1970s and continued to the present.

1.3.1 Definition of Industrial Engineering

What is industrial engineering? In 1955, the American Institute of Industrial Engineers (AIIE) took the following formal definition of industrial engineering:

> **Industrial engineering** is concerned with the **design**, **improvement** and **installation** of integrated systems of **men**, **materials** and **equipment**. It draws upon specialised **knowledge** and **skill** in the **mathematical**, **physical** and **social sciences** together with the **principles** and **methods of engineering analysis and design** to **specify**, **predict** and **evaluate** the results to be obtained from such systems.
>
> (Institute of Industrial and Systems Engineers, 2019)

The function of industrial engineers is to unite **people**, **machines**, **materials** and **information** for smoother operation. As for industrial engineering, it concerns not only **design**, **installation**, **evaluation** and **re-design** but also **human interaction** in and with the system. This involves not only the physical elements of the machinery but also the behavioural characteristics, stress-strain relations, carrying the load, the energy characteristics and motivational responses of people who are the vital links in a system.

Industrial engineering is a task for those designing and reforming, through studies, analysis and evaluation of the components in a human-machine system. It incorporates earlier components together with the latest components coupled with the whole-system design by integrating each individual component. Therefore, an industrial engineer must coordinate and cooperate with experts who are involved in the design of the system.

Since the birth of industrial engineering, it has been associated with the improvement of work that has been designed and/or evaluated:

(a) If the work was done by a human, industrial engineers will try to make the work more effective, with less fatigue and simple movements, more productive with less waste, energy and effort.

(b) If it is a series of works, industrial engineers will try to streamline and integrate the workflow better and with fewer stoppages.

(c) If it is transportation, industrial engineers will try to eliminate or reduce the amount of movements involved by rearranging the layout of the office or the plant's service area.

Each one involves reducing the cost and use of resources, regardless of whether they are human, material, facilities or financial.

1.3.2 How Industrial Engineering Changed and Developed

Before the mid-1950s, industrial engineers emphasised human interaction in manufacturing plant design, construction facilities, the means of controlling costs and quality control, production, processing and transportation of materials and manufacturing operations to produce goods or services. The design of certain subsystems, such as individual work centres or production centres, are also some of the important tasks of an industrial engineer. The design procedure that is used that time is more qualitative than quantitative; and is experience-based.

The 1950s era saw a reorientation in industrial engineering. With statistical and mathematical techniques as well as new equipment, setting priorities shifted from qualitative to **quantitative procedures**. At the same time, important changes also occurred in the types of projects carried out by industrial engineers.

Before 1950, almost all the work done in the field of industrial engineering were in the manufacturing phase of the mechanical goods industries. Expansion in this area can be seen by the creation of new titles to replace the industrial engineering.

Today, there are areas such as:

(a) Operations research;

(b) Manufacturing/production engineering;

(c) Automation; and

(d) Human engineering.

Engineers in these areas can be found in the fields of transportation, supply, finance, public health, services industry and manufacturing.

It is now clear that the scope of industrial engineering is changing. Originally, it emphasised on a relatively small system, now it is more focused on the study of a **macrosystem**.

1.3.3 Relationship with Other Branches of Engineering

As discussed earlier, the industrial engineering profession had emerged from the other branches of engineering. Figure 1.7 shows you the general evolution of industrial engineering, as well as additions of several branches in industrial engineering from non-engineering areas.

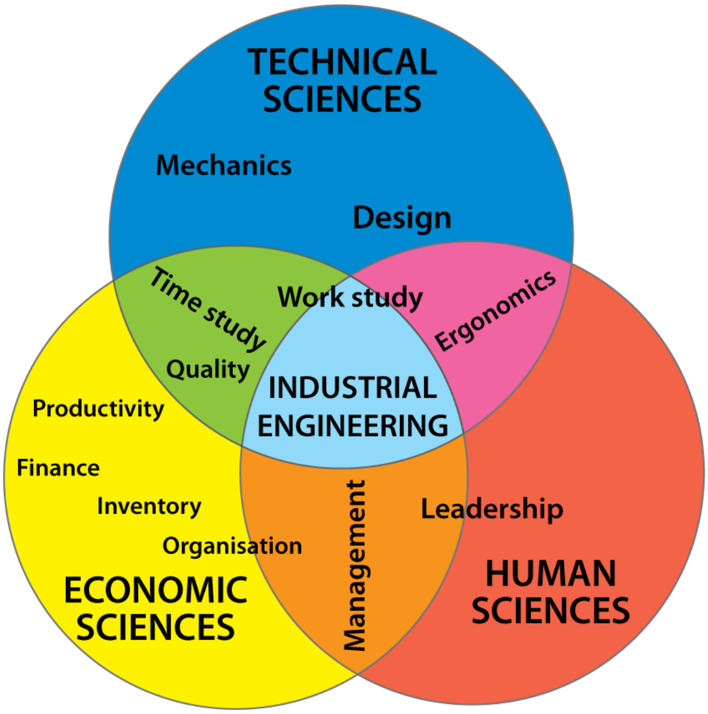

Figure 1.7: Other branches of engineering and their relationship to industrial engineering

1.3.4 Design of Industrial and Systems Engineering

Did you know that there are **two stages** in industrial and system engineering? The first stage is called **human system activities** and it refers to the **physical work**, which people carry out.

Meanwhile, the second stage is called the **management control system**, and it relates to the **planning procedures** for measuring and controlling all activities within an organisation. Let us look at Table 1.2, which lists the elements that are designed by industrial and system engineers for both systems.

Table 1.2: Elements of Human Activity System and Management Control System

System	Elements
Human activity system	(i) The manufacturing process itself; (ii) Materials and all other resources utilised in the production process; (iii) Machines and equipment; (iv) Methods by which workers perform tasks; (v) Workplace design; (vi) Data recording procedures for management reporting; and (vii) Safety procedures.
Management control system	(i) Management planning system; (ii) Forecasting procedures; (iii) Budgeting and economic analyses; (iv) Recruiting, training and placement of employees; (v) Materials requirement planning; (vi) Production scheduling; and (vii) Quality control system.

SELF-CHECK 1.3

1. When and how did industrial engineering emerge?
2. Describe some famous philosophers who promoted industrial engineering.
3. In your own words, provide a definition of industrial engineering.
4. With the aid of a chart, explain the relationship between industrial engineering and other branches of engineering.

ACTIVITY 1.3

Use the Internet to look for other gurus who promoted industrial engineering and list their contributions. Share your findings with your coursemates in the myINSPIRE forum.

1.4 FORMATION AND MANAGEMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING (ISE)

The activities to be carried out by the industrial and systems engineering (ISE) vary depending on the company itself. The activities that are expected to be done by industrial and systems engineers are listed in Table 1.3.

Table 1.3: The Activities Performed by Industrial and Systems Engineers

Activity	Description
Products or services	(i) Analyse a product or service to determine: • Whether it will be profitable; • Whether it is compatible with the existing products; • The best product design; and • The best materials. (ii) Always try to improve the products or services available; and (iii) Analyse the distribution of goods or delivery of services.
Process	(i) Determine the best process and method of production; (ii) Be involved in the selection of equipment; (iii) Determine the best operational rule, assembly line balancing; (iv) Determine the best layout of equipment; (v) Determine the flow of materials and the best material transportation procedures; (vi) Determine the best organisation for the supply of materials; (vii) Design the workplace; and (viii) Design the storage facilities.

Production or operations	(i) Anticipate the level of activity; (ii) Analyse the capacity and resource constraints; (iii) Conduct the operations planning, such as: • The composition of the amenities and transport materials; • Making or buying decisions; • Planning of production rate; • Developing a master production plan; and • Planning of material requirements. (iv) Conduct inventory analysis, such as: • Raw materials in the process; • Product completion; and • An analysis of multi-level inventory. (v) Running scheduling operations, such as: • Distribution of resources; • Scheduling assembly operations; and • Scheduling the production of components. (vi) Simultaneously smoothing production, inventory and labour; (vii) Design a system of quality control and inspection procedures; and (viii) Carry out research to facilitate and improve the methods of production.
Staffing	(i) Design a procedure to select, test and train workers; (ii) Design and implement an incentive pay system and job evaluation; (iii) Design safety procedures; (iv) Use of human engineering principles on work design; (v) Coordinate efforts and be wise with respect to individuals who have professional backgrounds and different skills; and (vi) Use of labour relations with employees.
Control	(i) Standards of conduct; (ii) Measure the effectiveness of the design for controlling operations; (iii) Design a method and system for analysing data and interpreting the results of operations; (iv) Determine the procedure for corrective actions, operations management and control; (v) Provide and show the results of actions to the superiors or top management; and (vi) Determine the best management information system (MIS).

Financial and cost	(i) Budget for system design; (ii) Assess alternative economic decisions; (iii) Carry out value engineering studies; (iv) Design and implement procedures of capital flows; and (v) Design a cost management programme.
Planning	(i) Take part in the study that involves: • Long-term planning; • The decision to deploy and load analysis; and • The location and relocation of plant. (ii) A new product line; and (iii) Take part in the study of organisational structure of firms.
Analysis	(i) An analysis of the system; (ii) Clarity of the problem which is being studied; (iii) Identify the appropriate methods for analysis; (iv) The need for experts in complex issues; (v) Identify all assumptions on the model and solution methods; (vi) Interpret the results of solutions in terms of the original problem statement and assumptions that have been made; and (vii) Quantitative decision-making as much as possible.
Design	(i) Processing and control; (ii) Planning and control operations; (iii) The activities of certain operations; (iv) Storage and distribution of goods; and (v) Transportation of people and goods.

Take note that the activities mentioned here cannot be done by one person and involves teamwork.

SELF-CHECK 1.4

State the activities performed by industrial and systems engineers.

1.4.1 Relationship with the Whole Organisation

Did you know that the activities listed earlier are not always implemented by the department of industrial engineering of a company? There is a big difference in the scope of the activities carried out by industrial engineers in different backgrounds. There are also large differences between the companies in which the industrial engineering functions fit into the overall organisational structure. Usually, the department of industrial engineering is a staff function reporting to the line managers in charge of operations.

However, it is not unusual for the department of industrial engineering to be located at the "managerial" level as shown in Figure 1.8.

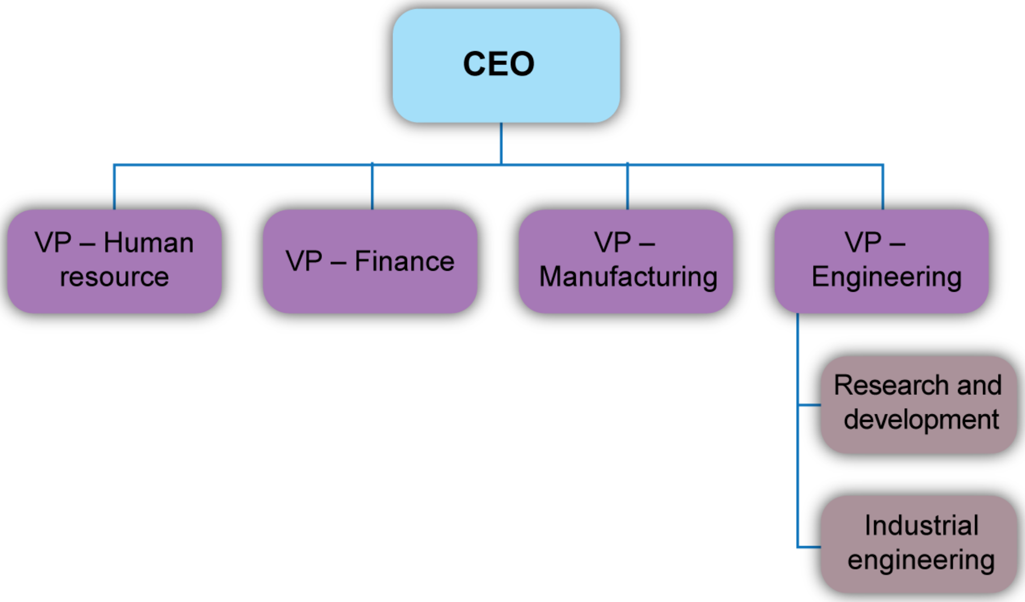

Figure 1.8: A typical organisational structure of a manufacturing operation
Source: Turner, Mize, Case & Nazemtz (1993)

ACTIVITY 1.4

Create an industrial engineering organisation chart based on your organisation. Share your answer for discussion in the myINSPIRE forum.

SUMMARY

- Engineering is about using scientific knowledge to solve problems and seek a better life.

- Initially in its early days, engineering principles, especially regarding the construction of roads and bridges, were taught at military academies. If some of these principles are applied to fields other than military, they are linked to civil engineering.

- Related advances in the field of physics and mathematics have enabled the practical use of mechanical principles, which then evolved to mechanical engineering.

- The works on electric and magnetic fields contributed to electrical engineering whereas the understanding of materials and their properties have contributed to chemical engineering.

- There are four branches of engineering that existed before 1900 namely civil, mechanical, electrical and chemical engineering. Their existence is part of the Industrial Revolution and the initial technological revolution.

- Science and complexity of manufacturing units have increased the need for better management systems, which resulted in the growth of what we call industrial engineering.

- Analysis is the description of something down to the basic elements.

- Synthesis is connecting elements into one.

- Usually, analysis is for the existing system while synthesis is for the new system.

- The six engineering processes are:
  - Problem symptom or expression of need;
  - Problem definition including statement of desired outcome;
  - Analysis (perhaps including experimentation);
  - Synthesis of alternative solutions;
  - Decision (selection of one alternative); and
  - Solution, system or methods.

- Industrial engineering emerged as a profession because of the Industrial Revolution and the need for workers who are technically trained and can plan, manage and direct the operations of large complex systems.

- Some gurus who promoted industrial engineering are Frederick W. Taylor, Frank Gilbreth and Lillian Gilbreth, Henry L. Gantt and W. A. Shewhart.

- Industrial engineering is concerned with the design, improvement and installation of integrated systems of people, materials and equipment. It draws upon specialised knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems.

- The function of industrial engineers is to unite people, machines, materials and information for smoother operations.

- Industrial and system engineers design systems in two stages. The first stage is called human system activities, while the second stage is called the management control system.

- The activities to be carried out by the industrial and systems engineering (ISE) vary depending on the company itself. The activities are products or services, process, production or operations, staffing, control, financial and cost, planning, analysis, and design.

KEY TERMS

Chemical engineering

Civil engineering

Electrical engineering

Industrial engineering

Inventory

Layout

Manufacturing

Mechanical engineering

Scientific management

Systems engineering

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Topic 2 ▸ Decision-making

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Compare between programmed and non-programmed decisions;
2. Identify alternative approaches to decision-making;
3. Explain scientific methods for business decision-making;
4. Discuss three management models in decision-making; and
5. Perform break-even analysis.

▸ INTRODUCTION

Let us start this topic with the following situation (see Figure 2.1).

Figure 2.1: Making a decision on which fruit to eat as a snack

We all make different decisions in our daily life, even for a simple thing such as deciding on what fruit to eat as a snack as shown in Figure 2.1. In a bigger picture, decision-making is an integral part of modern management. Decision-making can be sophisticated or complicated. Researches have shown that most people are weaker at making decisions than they think. This is why it is important for us to learn a few decision-making techniques. These techniques can help us to produce better decisions.

In this topic, we will learn about the two classes of decision-making in manufacturing. We will also learn the alternative approaches to decision-making, scientific methods for business decision-making, management models in decision-making and how to perform a break-even analysis. Let us continue with the lesson.

2.1 DECISION-MAKING IN MANUFACTURING

Making decisions can be divided into two classes (see Table 2.1).

Table 2.1: Two Classes of Decision-making

Class	Description
Programmed decisions	• These are commonly made decisions. • Managers will usually have a standard procedure for making decisions because they are repeated daily. • Some examples of the results of programmed decisions can be found in the areas of inventory control, cost control and production control.
Non-programmed decisions	• These decisions are not commonly made and are not repeated. • They are adjusted to suit the situation. • Managers will have to use judgement, experience, intuition, "rule of thumb" and special models for non-programmed decision-making.

The variables involved in non-programmed decisions are usually more complex than in programmed decisions. Besides **economic** factors, there are also **sociological**, **psychological** and **ethical** factors which are difficult to describe quantitatively.

Nevertheless, programmed decisions can be easily made because data can be easily found in a **quantitative form** and the factors that affect the decisions are controllable.

Now, let us look at Example 2.1 to fully understand a programmed decision.

Example 2.1:
Imagine that we are deciding on whether to buy raw materials using a cargo truck. To make a decision, we need to know our needs and the price differences. Assuming that the raw material purchased is less than a truckload, it is priced at RM1.10 per unit. If purchased at a truckload, it is priced at RM1.00 per unit. If a truckload is 1,000 units and our requirement is 2,000 units, the following alternatives may be available:

The weekly costs to buy less than a truckload would be RM2,200. Meanwhile, the weekly costs to buy at a truckload would be RM2,000. More savings on freight charges (if we have to pay) would be made if raw materials are delivered in a cargo truck. Therefore, it is better if we buy a lot of raw materials by the truckload. This kind of decision is classified as a **programmed decision**.

Meanwhile, here is an example of a non-programmed decision (see Example 2.2).

Example 2.2:
Assume that you are a purchasing agent faced with the decision to purchase goods from either supplier A or B. Supplier A's product quality is lower than that of Supplier B. It is also slightly below the specified requirements. Supplier A has stated that he can improve the product quality but is not sure how fast or how much could be improved. Prices of raw materials from Supplier A are lower than that of supplier B. If Supplier A were to increase the quality, the prices will also increase but he is not sure how high the prices will increase. Supplier B knows that the price difference favours Supplier A, but instead of reducing the price, he would rather give you a kickback. Which provider should you select?

Solution:
The previous situation has a lot of factors to consider and the decision is very difficult to make. This kind of decision can be classified as a **non-programmed decision**.

SELF-CHECK 2.1

1. Making decisions can be divided into two classes. Briefly describe them.
2. Explain the variables in programmed and non-programmed decision-making.

ACTIVITY 2.1

Discuss in the myINSPIRE forum the importance of decision-making in manufacturing.

2.2 ALTERNATIVE APPROACHES TO DECISION-MAKING

Programmed decisions have traditionally been made based on standard procedures, depending on the manager's behaviour, the use of quantitative techniques and through organisation channels. Development of procedures, habits, techniques and experience gained from trial-and-error are applied in decision-making. Because of this, some decisions, although effective, are rarely optimal.

New developments in this field have enabled managers to make optimal decisions. An example of this development is the use of computers in business. The use of computers has enabled managers to analyse data and consider the impact when an action is taken. A typical example is the use of the **simulation** technique. Simulation involves the manipulation of one or more variables. Associated constants of a problem are a major advantage of simulation in terms of decision-making. Therefore, actions can be determined before the actual implementation. With simulation, production managers can examine several alternatives and choose the one that gives the best results.

Another new direction involves the use of management techniques such as:

(a) Linear programming;

(b) Queuing theory;

(c) Dynamic programming;

(d) Game theory; and

(e) Markov analysis.

These techniques are designed to produce the best results. New developments do not occur at the same speed as non-programmed decisions. They cannot be solved satisfactorily by using quantitative techniques. Many of the variables that cannot be quantified (non-quantifiable) require subjective judgement. Such decisions need to use consideration, experience and intuition.

SELF-CHECK 2.2

State the alternative approaches in decision-making.

2.3 SCIENTIFIC METHODS FOR BUSINESS DECISION-MAKING

Now, let us look at scientific methods for business decision-making. There are seven steps in analysing business problems. These steps are important in order to make an effective decision. Let us look at the steps shown in Figure 2.2.

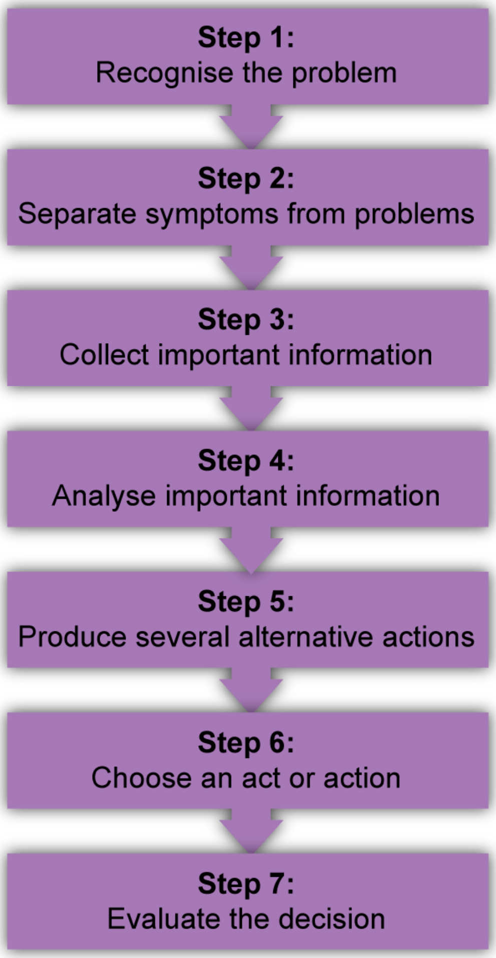

Figure 2.2: Seven steps in analysing business problems

Let us go through each step in detail as explained in Table 2.2.

Table 2.2: Seven Steps in Analysing Business Problems

Step	Description
Recognise the problem	In this step, we will identify the problem such as "production is not on schedule".
Separate symptoms from problems	We then make a decision to separate the symptoms from the problem. For the example given, the problems are real signs of trouble. Perhaps, because of the high priority orders entered into the production schedule, there may be a breakdown of machineries, or raw materials or components are not there when they are needed. These possibilities should be investigated to determine the real reason why production did not follow the schedule.

Collect important information	This step is where decision-makers' experiences play a role. They should know what information is important and have an idea about the analytical methods that they should use. In some cases, quantitative data can be obtained from studying statistics, account records, viewing and recording of quantitative data of a problem and running experiments on the variables involved. In this case, non-quantitative data should be collected. In such cases, interviews, questionnaires and written reports should also be applied.
Analyse important information	This step involves the analysis of vital information. At this stage, decision-makers have to consider the information collected. In many cases, they should use their experiences and discretion to make decisions. In addition to this, there are many analytical methods that can be used to solve the problem.
Produce several alternative actions	Alternative actions need to be generated due to the availability of many variables that change every time. By doing so, they will think out of the box.
Choose an act or action	The sixth step is to choose one of several alternative actions. The essence of the decision-making is the need to make decisions with sufficient information and then, take responsibility for the decisions made. One of the available techniques which can be used in decision-making is the analytical technique.
Evaluate the decision	This is the final step, which is to follow-up and review the decisions that have been made.

Bear in mind that a concept model is useful when making decisions and understanding many analytical methods.

SELF-CHECK 2.3

Explain the steps to be taken in analysing business problems.

ACTIVITY 2.2

Why are scientific methods for business decisions becoming popular? Discuss this matter with your coursemates in the myINSPIRE forum.

2.4 MANAGEMENT MODELS IN DECISION-MAKING

Models are an abstraction of the real world. They are useful in making decisions for two reasons:

(a) They can reduce complex problems into simpler forms; and

(b) They provide a way to apprehend the impact of a decision before it is made.

There are several types of models used in business, especially in manufacturing. These models are explained in Table 2.3.

Table 2.3: Three Management Models Used in Manufacturing

Model	Description
Physical model	A physical model represents a product, for example, cars, ships and aircrafts in a small form. It is a **scaling** of the actual products that are useful in the learning process. Each of these models should be modified and tested before production. Among the advantages of using a physical model are that modifications can be made inexpensively and testing to destruction will not involve high costs or loss of life. Use of production physical models normally involves **templates** to study the plan layout. What is a template? A template is a two-dimensional cut out, measured on a scale, which represents machines, desks and material transportation equipment.
Schematic model	A schematic model is more abstract than a physical model in explaining the real situation. It includes all types of graphs and charts. A **break-even chart** is a schematic model. It is the relationship of fixed costs, variable costs and revenues from different quantities of production and sales. Other examples include organisational charts, Gantt charts, PERT charts, process flow charts and others. Again, the schematic model is used as a scaling scheme, because it describes an important relationship. Another key area of the schematic model is that it can be handled in the process of decision-making analysis.

Mathematical model (deterministic and probability)	A mathematical model represents the maximum of "scaling" a real situation. This model is difficult to understand for those who are weak in mathematics. This is because abstract models (the **equation**) are used and they do not have a real situation. There are two types of mathematical model: (a) **Deterministic** – Yield a single solution describing the outcome such as area of a circle is r^2. (b) **Probability** – Making decisions in a common production in conditions of uncertainty. For example, it involves the prediction of tool wear to determine how many tools to be ordered. When making a decision using probability models, managers must determine the probability of an event. Probability can be determined from statistical distributions, based on experience from past records or by intuition and judgment. It should also discuss the limits of the model used. Since a model is a "scaling of the real world", it should not be considered as the real world. In addition, it rarely takes into account all the variables that exist in a complex business. Furthermore, the availability of the variables that cannot be quantified is not taken into account in the mathematical model.

The highlight of the test for a model, whether physical, schematic or mathematical, is that it is useful in understanding the actual situation. It would be better if the model had the potential to predict future decisions easily.

SELF-CHECK 2.4

Describe the three management models in decision-making.

2.5 BREAK-EVEN ANALYSIS

Firstly, what is a break-even analysis?

A **break-even analysis** is a way to create an understanding of **business revenues, costs and profit/loss**, and how it relates to the different **production quantities** and **sales**.

Why do we perform break-even analysis? The break-even analysis is used to provide answers to the following questions:

(a) What is the effect on profit when companies raise or lower prices?

(b) What is the impact on profit if there is an increase or decrease of costs such as tax, rent, salaries and others?

(c) How much profit will increase if there is an increase in production or sales?

2.5.1 Break-even Chart

Break-even analysis is usually done with the use of charts. Figure 2.3 represents a traditional break-even chart.

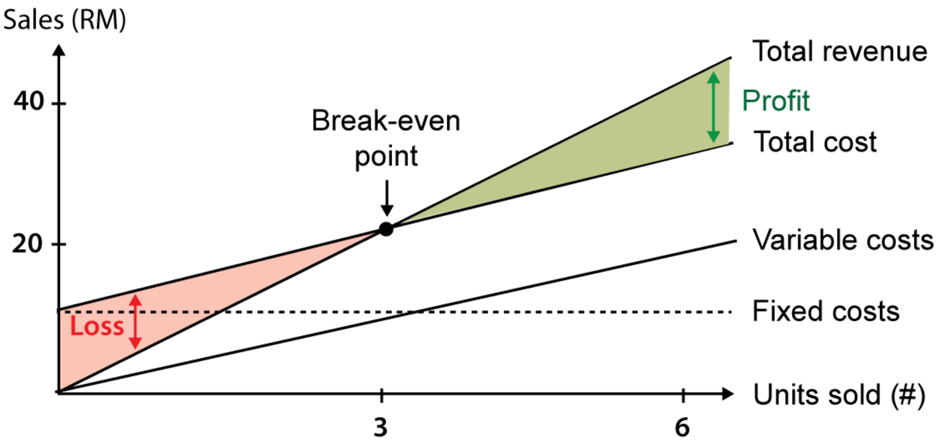

Figure 2.3: A traditional break-even chart
Source: Amrine, Ritchey, Moodie & Kmec (1993)

Based on Figure 2.3, the horizontal axis represents the total production unit, while the vertical axis represents the sales in Ringgit Malaysia or RM. The three other lines represent the relationship of amount and RM in terms of:

(a) Fixed costs;

(b) Variable costs; and

(c) Revenue from sales.

Fixed costs are usually represented by a horizontal line because for a certain range, fixed costs do not change with changes in the total. Examples of fixed costs are property taxes, depreciation, administrative salaries, rent, interest on long-term borrowing and others.

Variable costs are represented by a line starting from the point of intersection of the lines of fixed costs and vertical axis. It connects both of the points and to the right. The reason for leaning to the right and moving up is because variable costs increase when the production volume increases. Examples of variable costs include raw materials, direct labour and others.

2.5.2 Break-even Equation

Break-even analysis can also be made by using mathematical equation. For example, the level of profit or loss can be determined for different quantities of production by subtracting the fixed and variable costs from the revenues obtained for any quantities of production. It can be stated as follows:

$$\text{Profit or loss} = TR - (F + TVC)$$

where

TR = Total revenue is equal to the number of units produced and sold multiplied by the selling price per unit

F = Fixed cost

TVC = Total variable cost, equals to the number of units produced and sold multiplied by the variable cost per unit

Now, let us look at an example. With 6,000 units produced and sold,

$$\begin{aligned}\text{Profit or loss} &= \text{TR} - (\text{F} + \text{TVC}) \\ &= (6{,}000 \times \text{RM1}) - [\text{RM2,000} + (6{,}000 \times \text{RM0.50})] \\ &= 6{,}000 - (\text{RM2,000} + \text{RM3,000}) \\ &= \text{RM1,000 (profit)}\end{aligned}$$

If the break-even point is to be located using the equation, the sales and total cost lines should be identified, namely;

$$\text{Profit or loss} = \text{TR} - (\text{F} + \text{TVC})$$

where,

$$\text{TR} = \text{P}x \qquad \text{and} \qquad \text{TVC} = \text{V}x$$

The symbols used in break-even analysis:

P = Price per unit in Ringgit
x = Number of units produced
V = Variable cost per unit

Now, the break-even point occurs when there is no profit or loss, where the total revenue is equivalent to total cost.

$$\begin{aligned}\text{TR} &= \text{TC} \\ \text{P}x &= \text{F} + \text{V}x\end{aligned}$$

where,

TC = Total cost, equals to fixed cost plus variable cost of units produced

Solving for *x*, we get:

Break-even point in units,

$$\boxed{BEP_x = \frac{F}{P - V}}$$

and

Break-even point in Ringgit,

$$BEP_R = BEP_x \times P$$

$$= \frac{FP}{P - V} \times \frac{\frac{1}{P}}{\frac{1}{P}}$$

$$\boxed{BEP_R = \frac{F}{\left(1 - \frac{V}{P}\right)}}$$

Where,

BEP_x = Break-even point in units

BEP_R = Break-even point in Ringgit

For the example given earlier,

$$BEP_x = \frac{RM2,000}{RM1 - RM0.5} = 4,000 \text{ units}$$

$$BEP_R = \frac{RM2,000}{\left(1 - \frac{RM0.5}{RM1}\right)} = RM4,000.00$$

Now, let us look at another example (see Example 2.3).

Example 2.3:
Ace Company has a fixed cost of RM660 per week. The labour cost per unit production is RM1.75 and the material cost is RM2.25 per unit. The selling price is RM15.00. Calculate the break-even point for a week in units and Ringgit.

Solution:

$$\text{BEP}_x = \frac{\text{Total fixed cost}}{\text{Price per unit} - \text{Variable cost per unit}}$$

$$= \frac{\text{RM660}}{\text{RM15} - (\text{RM1.75} + \text{RM2.25})}$$

$$= 60 \text{ units}$$

$$\text{BEP}_R = \frac{\text{Total fixed cost}}{\left(1 - \dfrac{\text{Variable cost per unit}}{\text{Price per unit}}\right)}$$

$$= \frac{\text{RM660}}{1 - \dfrac{(\text{RM1.75} + \text{RM2.25})}{\text{RM15}}}$$

$$= \text{RM900}$$

SELF-CHECK 2.5

1. What is break-even analysis?

2. With the aid of a diagram, sketch and explain the traditional break-even chart.

3. Break-even analysis requires an estimation of costs. By giving appropriate examples, explain the following:

   (a) Fixed cost; and

   (b) Variable cost.

4. A manufacturing company must select a process for its new product from two different alternatives as shown in the table below. Assuming the selling price is RM5 per unit and zero variable cost:

   (a) Determine the break-even quantities for each process.

   (b) If the forecasted demand quantity for the new product is 2,500 units, which process is more desirable? Justify your answer.

Cost	Process X	Process Y
Fixed cost	RM5,000	RM10,000

SUMMARY

- The knowledge of decision-making can be a sophisticated or complicated art. Researchers have shown that most people are weaker at making decisions than they think.

- Making decisions can be divided into two classes. The first is called programmed decisions that are commonly made. The second class involves non-programmed decisions. These decisions are not commonly made and are not repeated but they are adjusted according to the situations.

- Other alternative approaches to decision-making are by using simulation, linear programming, queuing theory, dynamic programming, game theory and Markov analysis.

- There are seven steps to be taken in analysing business problems so that effective decisions are made. These steps are:
  - Recognise the problem;
  - Separate the signs from the problems;
  - Collect important information;
  - Produce several alternative actions;
  - Choose an act or action; and
  - Evaluate the decision.

- Models are abstractions of the real world. It is useful in making decisions for two reasons. Firstly, it can reduce complex problems into simpler forms. Secondly, it provides a way to apprehend the impact of a decision before it is made.

- There are several types of models used in business, especially in manufacturing. These include physical model, schematic model and mathematical model.

- A break-even analysis is a way to create an understanding of business revenues, costs and profit/loss and how it relates to the different production quantities and sales.

KEY TERMS

Analysing business problems
Break-even analysis
Decision-making
Deterministic model
Fixed cost
Mathematical model
Non-programmed decision
Physical model
Probability model
Programmed decision
Schematic model
Total revenue
Variable cost

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Topic 3 ▶ Productivity

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Define productivity;
2. Identify three types of productivity;
3. Describe the importance of productivity improvement;
4. Identify the factors that affect and improve productivity;
5. Explain productivity cycle and the benefits of high productivity in the organisation; and
6. Apply the techniques of productivity improvement.

▶ INTRODUCTION

Now, let us learn about productivity. How would you describe productivity? In this topic, we will look at the various definitions of productivity, the various types of productivity and the importance of productivity improvement. We will also review the factors that affect productivity improvement and productivity in manufacturing and services. After that, we will examine the productivity cycle and the benefits of high productivity for an organisation.

Finally, we will look at the techniques of productivity improvement in manufacturing. So are you ready to "master" the art of productivity? Let us continue with the lesson.

3.1 WHAT IS PRODUCTIVITY?

Did you know that the word "productivity" appeared for the first time in an article by Quesnay in 1766? What does it mean? Let us look at a more formal definition of productivity by the Organisation for European Economic Corporation (OEEC) in 1950 (Sumanth, 1998).

> "Production is the **quotient** obtained by dividing outputs by one of the factors of production. In this way, it is possible to speak of the productivity of the capital, investment or raw materials according to whether the output is being considered in relation to capital, investment or raw materials and others."

Let us look at Table 3.1 which elaborates the chronology of some key definitions of production.

Table 3.1: Chronology of Some Important Definitions of Productivity

Century	Source	Definition of Productivity
18th	Quesnay (1766)	The word "productivity" appears for the first time.
19th	Littre (1883)	"Faculty to produce".
20th	Early 1900s	Relationship between output and the means employed to produce this output.
	OEEC (1950)	Quotient obtained by dividing output by one of the factors of production.
	Davis (1955)	Change in product obtained for the resources expanded.
	Fabricant (1962)	Always a ratio of output to input.
	Kendrick & Creamer (1965)	Functional definition for partial, total factor and total productivity.
	Siegel (1976)	A family of ratios of output to input.
	Sumanth (1979)	Total productivity – The ratio of tangible output to tangible input.

Source: Sumanth (1998)

Are you aware that the term "productivity" is always confused with the term "production"? Many people think that by increasing production output, productivity will also be increased. However, this is not necessarily true.

Actually, **production** is the activity of **producing goods and services** while **productivity** is the **use of resources (input)** to produce goods and/or services (output) effectively.

In addition, from a quantitative point of view, **production** is the **total output**, while **productivity** is the **ratio of outputs to inputs**. Furthermore, productivity deals with:

(a) Design;

(b) Improvement; and

(c) Installation of integrated system (such as people, material and energy in industry).

Now, let us look at Example 3.1 to further understand productivity.

Example 3.1:
Suppose a manufacturing company produces 10,000 electronic calculators and hires 50 employees who work eight hours/day for 25 days. For this case,

Output: 10,000 calculators

$$\text{Productivity (labour)} = \frac{10{,}000\ \text{calculators}}{50 \times 8 \times 25\ \text{man-hours}}$$
$$= 1\ \text{calculator/man-hours}$$

Suppose the company increased its production to 12,000 machines and employed 10 more workers to work eight hours/day for 25 days, then,

Output: 12,000 calculators

$$\text{Productivity (labour)} = \frac{12{,}000\ \text{calculators}}{60 \times 8 \times 25\ \text{man-hours}}$$
$$= 1\ \text{calculator/man-hours}$$

What can we conclude from Example 3.1? Example 3.1 shows that the production has increased by 20 per cent (from 10,000 to 12,000), but its productivity (labour) did not increase.

Sometimes, confusion occurs when common terms such as **productivity**, **efficiency** and **effectiveness** are used. What do these terms mean? Let us find out the answer in Table 3.2.

Table 3.2: Definition of Efficiency, Effectiveness and Productivity

Term	Definition
Efficiency	It is the use of resources in systems, processes and activities to achieve the ratio of actual output achieved against standard output.
Effectiveness	It is the extent of objectives achieved. In other words, how well the results achieved effectiveness, while the usage of resources to achieve these results is related to efficiency.
Productivity	It is a combination of both effectiveness and efficiency as effectiveness can be linked to performance, while efficiency is associated with the use of resources.

SELF-CHECK 3.1

1. State the differences between production and productivity.
2. What is the difference between efficiency and effectiveness?

3.2 TYPES OF PRODUCTIVITY

Did you know that there are **three general types of productivity**? These three types of productivity are further explained in Table 3.3.

Table 3.3: Three Types of Productivity

Type	Description
Partial productivity	Productivity is the ratio of an output class to an input class. For example, labour productivity (the ratio of output to input labour) is a measure of partial productivity. In addition, capital productivity (the ratio of output to input capital) and material productivity (the ratio of output to input material) are examples of partial productivity.
Total-factor productivity	Total-factor productivity is the ratio of net output to the total input of labour and capital (factor). Net output is the total output minus goods and services purchased. The denominator of this ratio consists of the labour and capital factors.
Total productivity	Total productivity is the ratio of output to the sum of all input factors. This means that the measurements of total productivity illustrate joint effects of all inputs in producing the products.

Now, let us look at an example that demonstrates these three types of productivity.

Example 3.2:
The production data used for a specific period of time for ABC Company is shown in Table 3.4. Calculate total productivity.

Table 3.4: Production Data

Production Data	Malaysian Ringgit (RM)
Output	1,000
Labour input	300
Material input	200
Capital input	300
Energy input	100
Other expenses input	50

Solution:
Partial Productivity:

$$\text{Human productivity} = \frac{\text{Output}}{\text{Human input}} = \frac{1{,}000}{300} = 3.33$$

$$\text{Material productivity} = \frac{\text{Output}}{\text{Material input}} = \frac{1{,}000}{200} = 5.00$$

$$\text{Capital productivity} = \frac{\text{Output}}{\text{Capital input}} = \frac{1{,}000}{300} = 3.33$$

$$\text{Energy productivity} = \frac{\text{Output}}{\text{Energy input}} = \frac{1{,}000}{100} = 10.00$$

$$\text{Other expenses productivity} = \frac{\text{Output}}{\text{Other expenses input}} = \frac{1{,}000}{50} = 20.00$$

Then,

$$\text{Net output} = 1{,}000 - (200 + 300 + 100 + 50) = 1{,}000 - 650 = 350$$

$$\text{Total factor productivity} = \frac{350}{300 + 300} = 0.583$$

Total Productivity:

$$= \frac{\text{Total output}}{(\text{Human} + \text{Material} + \text{Capital} + \text{Energy} + \text{Other expenses})}$$

$$= \frac{1{,}000}{(300 + 200 + 300 + 100 + 50)} = 1.053$$

SELF-CHECK 3.2

Explain the three basic types of productivity.

3.3 IMPORTANCE OF PRODUCTIVITY IMPROVEMENT

Increased productivity occurs when the individuals involved **produce more goods or services in the same period**. Increasing productivity brings an enormous cumulative impact. For example, if we can improve the output of goods or services of each worker at a rate of two per cent per year, the cumulative effect of this two per cent increase will multiply the current output by 7.24 in the next 100 years. The calculation is as follows:

O future = O current (1+i)n
O current = Current output = RM100
O future = Future output
i = Growth rate = 2%
n = Number of periods = 100 years

Future value = RM100 × (1 + 0.02)100 = RM724

It is true that improvements in living standards in terms of goods and services rely heavily on our ability to increase productivity in producing the goods and services. Increased productivity is important in **reducing inflation pressures** on prices of these goods and services. This will result in a **high growth rate in output per man-hour and the prices of goods or services**. In addition, the efficient use of energy, raw materials and capital enables us to offset the increase in input price.

The increase in productivity helps industries to **compete** in the world market too. Therefore, the increase in productivity is an important factor in maintaining trade balance.

Furthermore, productivity gains offset any increase in salary. Assume that in one case, there are no productivity gains and in another case there is a three per cent increase in productivity. The difference in unit labour costs is three per cent as shown in Table 3.5.

Table 3.5: Productivity Improvement Comparison

Aspect	First Case	Second Case
Salary increase	8%	8%
Productivity improvement	0%	3%
Increased unit labour cost	**8%**	**5%**

The labour costs are a major component of the total business costs, as for the first case, the inflation is eight per cent and for the second case is five per cent.

SELF-CHECK 3.3

How does an increase in productivity offset an increase in employee salaries?

ACTIVITY 3.1

Discuss in the myINSPIRE forum, the importance of productivity improvement for a company and how it affects the living standards of people. Provide two examples to support your answer.

3.4 FACTORS AFFECTING PRODUCTIVITY

There are a variety of factors which can affect productivity, both positively and negatively. The most common factors include:

(a) Human resources;

(b) Investment of capital and technology; and

(c) Government rules.

Let us go through each factor in detail in the next subtopics.

3.4.1 Human Resource

Did you know that a **basic level of education** is an important factor in national productivity? This is because the use of computers, equipment and sophisticated system requires educated workers. Workers should be encouraged to be productive.

Apart from adequate salaries, they should have a good working environment as well as security and recognition as the most important people in a company. All employees should also be involved in the planning of how to do a job better and can contribute positively to an increase in productivity.

3.4.2 Investment of Capital and Technology

A key factor in long-term productivity increase is **technology**. New technology depends on research and development (R&D). The government can sponsor R&D efforts through programmes such as agriculture, electronics and other fields. They can also help the private sector in R&D efforts by providing tax relief for such activities. Providing direct support for research at local universities will help to develop new technologies too. Industrial and services sectors must invest in machinery, equipment and other new facilities if they intend to use new technologies.

3.4.3 Government Rules

Too many government regulations can affect productivity, for example, price controls, import/export quotas and quality standard controls. The government may review and abolish some of the regulations that are not needed, from time to time. **Cost-benefit analysis** can be done to determine the necessary rules for safety and health in the industry.

SELF-CHECK 3.4

Explain the factors that affect productivity.

3.5 PRODUCTIVITY IN MANUFACTURING AND SERVICES

A coordinated approach to increase the productivity of industries in the United States began with Frederick W. Taylor. In order to increase efficiency, he showed us how to manage the business by performance of a work, based on detailed knowledge of how a work should be carried out and separated them into basic elements. Henry L. Gantt, Frank and Lilian Gilbreth also played an important role in productivity increase (You have learnt about these pioneers in Topic 1. Can you still recall?).

The purpose of early scientific management and productivity continues until today, which is not to work very hard but to work smarter. The increased production derived from human effort is quite limited. If an employee has given his or her full effort, there is nothing more that could be asked of him or her. One way to continuously improve productivity is to make a **change** in the production system for industries and services. These changes will involve the following four factors:

(a) Design of products or systems;

(b) Machinery, tools and equipment;

(c) Skills and efficiency of workers; and

(d) Production capacity.

These four factors are further explained in the next subtopics.

3.5.1 Design of Products or Systems

Through better product design, a product can be simplified by eliminating several parts, which means certain materials used for the former product will no longer be required. Hence, the equipment and labour to make the former parts are also no longer required. **Value analysis** may lead to changes in product design that can improve productivity.

R&D can also contribute to the improvement of product design. Research may yield a new principle which allows new products to be produced at lower cost. Finally yet importantly, **standard products** and **technology** are the other design factors that enable increased productivity.

3.5.2 Machinery, Tools and Equipment

After a product is designed, an opportunity to increase productivity can be made through the arrangement of equipment used. The arrangement of equipment used such as **machines**, **conveyors**, **robots** and **fittings**, is very important. **Computers** are one of the important tools in today's manufacturing sector. This helps in the design of products, operation of complex equipment, materials and components inventory control. It has become an important blend of increased productivity. Every year, adding new equipment and repairing old equipment allow the cumulative effect of ongoing productivity improvement.

3.5.3 Worker Skills and Efficiency

The basis of the production or service industry is the skills and efficiency of **workers** who perform the work. Therefore, employees should be trained to carry out their work to the best of their ability and in an effective way. Employee participation in programmes such as **quality control training** provides them with ideas to enhance production efficiency.

3.5.4 Production Capacity

Let us assume that the output load is added twice. Therefore, the number of direct employees may be increased twofold and the number of indirect workers may be increased slightly. Nevertheless, the number of engineers, research scientists and other support staff may not be added.

Hence, if production is increased twofold, the productivity of support staff is also increased twofold.

SELF-CHECK 3.5

Explain the four factors that will improve productivity based on the changes in production in industries and services.

3.6 PRODUCTIVITY CYCLE

Now, let look at Figure 3.1 which shows you the productivity cycle.

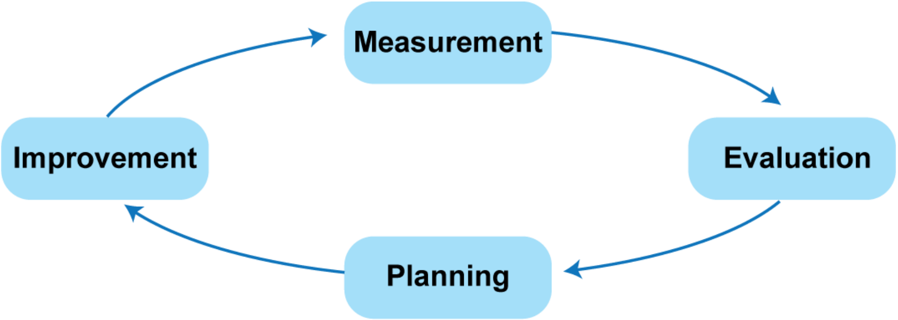

Figure 3.1: The productivity cycle
Source: Sumanth (1979)

An organisation that begins its production of a formal plan for the first time will start with the measurement of productivity. Once the level of productivity is measured, it needs to be assessed or compared with the planned values. Based on this assessment, the target productivity level is planned for both short and/or long term. To achieve the planned targets, the effort towards productivity increase should be done formally. Productivity should be measured again to evaluate the effectiveness of the efforts undertaken and to determine the degree of improvement for the new period. This cycle will continue as long as there are plans for productivity improvement.

The concept of productivity cycle, as can be seen in Figure 3.1, shows that increased productivity leads to measurement, evaluation and planning. All four phases of this cycle are equally important. The productivity issue is a "process" which means that productivity is not a one-time project but a continuous "process".

Let us look at Example 3.3 that demonstrates this cycle.

Example 3.3:
XYZ Company has a formal productivity plan for several years. Last year, the company's overall productivity was measured and valued at RM1.25 (for every Ringgit of input used, the company produces products worth RM1.25). Based on their record of accomplishment in overall productivity, the target level for overall productivity last year was RM1.30. The year before that, the overall level of productivity achieved was RM1.22.

The company's productivity manager can assess changes in productivity in two ways. First, by comparing the actual achievement with the agreed target and secondly, by comparing the actual productivity level for two consecutive years.

For the first case, there is a reduced achievement:

$$\text{Productivity change} = \frac{(1.30 - 1.25)}{1.25} \times 100\% = 4\%$$

While for the latter, increasing the overall productivity of the previous year to last year is:

$$\text{Productivity change} = \frac{(1.25 - 1.22)}{1.22} \times 100\% = 2.46\%$$

Both of these assessments help managers to set productivity targets that are reasonable for this year which is valued at, let us say RM1.31 (expected to increase by 4.8 per cent).

$$\text{Productivity change} = \frac{(1.31 - 1.25)}{1.25} \times 100\% = 4.8\%$$

In order to achieve this, the productivity manager needs to implement several techniques for productivity improvement, such as quality control team and statistical quality control.

At the end of the year, the productivity manager will once again measure the overall productivity to see whether the RM1.31 target is reached and the evaluation phase will start all over again.

SELF-CHECK 3.6

Explain the activities in the productivity cycle.

3.7 BENEFITS OF HIGH PRODUCTIVITY IN THE ORGANISATION

In improving the productivity of a company, the business will gain many benefits. What are the benefits of high productivity for an organisation? The benefits include:

(a) Increase in income/profitability;

(b) Lower running costs/operational costs;

(c) Maximise the use of all company resources such as land, equipment/machinery, factory, workers and others;

(d) Gain a greater share of the market; and

(e) More cash flow leading to more opportunities for the company to expand and grow.

SELF-CHECK 3.7

State the benefits of high productivity for an organisation.

3.8 TECHNIQUES OF PRODUCTIVITY IMPROVEMENT

Before we end this topic, let us learn about the techniques of productivity improvement which can be categorised into five basic types (see Table 3.6).

Table 3.6: Five Types of Productivity Improvement Techniques

Type	Example
Technology-based techniques	• Computer aided design (CAD); • Computer aided manufacturing (CAM); and • Robots and others.
Parts-based techniques	• Value engineering; • Parts standardisation; and • R&D and others.
Labour-based techniques	• Quality control teams; • Training and education; and • Work environment improvements and others.
Process-based techniques	• Engineering method; • Work measurement; and • Ergonomics and others.
Material-based techniques	• Industrial control; • Quality control; and • Material requirement planning and others.

ACTIVITY 3.2

ABC Manufacturing Company is a small metal parts company with 25 employees that was established in the year 2000 and has gradually grown to its present size. The financial figures for the past week shows the following data:

Sales : RM80,000 (over five weeks)

Input
Labour cost : RM20,000 (RM5.00 per piece)
Material cost : RM12,000 (RM20.00 per part)
Energy cost : RM4,000 (RM0.08 per unit)
Capital : RM16,000 (RM0.10 unit cost)
Others : RM8,000 (RM4.00 per unit)
Total : **RM60,000**

Productivity = 80,000/60,000 = 1.333

In the myINSPIRE forum, discuss these questions:

(a) If unit labour cost is RM10.00 per hour, is it possible to increase productivity to 1.4 if labour hours are reduced by 15 per cent, capital is increased by RM1,000 and the remaining items are unchanged?

(b) If energy costs are reduced by 50 per cent, what improvements in productivity can we expect? How about a 50 per cent reduction in the "others" category?

(c) What other considerations might be made to increase productivity?

SUMMARY

- The term "productivity" is always confused with the term "production". Many people think that by increasing production, productivity will also be increased. This is not necessarily true.

- From a quantitative point of view, production is the total output, while productivity is the ratio of outputs to inputs.

- Efficiency is the use of resources in systems, process and activities to achieve the ratio of actual output achieved against the standard output.

- Effectiveness is the extent of objectives achieved.

- Productivity is a combination of both effectiveness and efficiency as effectiveness can be linked to performance, while efficiency is associated with the use of resources.

- The three types of productivity are partial productivity, total-factor productivity and total productivity.

- Productivity improvement is important because it can increase productivity, reduce inflation pressures on prices and helps industries to compete in the world market.

- There are a variety of factors that can affect productivity, both positively and negatively. These include human resources, investment of capital and technology, and government rules.

- One way to continuously improve productivity is to make a change in the production system for industries and services. These changes will involve:

  - Design of products or systems;

  - Machinery, tools and equipment;

  - Skills and efficiency of workers; and

  - Production capacity.

- The concept of a productivity cycle shows that increased productivity leads to measurement, evaluation, planning and improvement.

- Some of the benefits of high productivity in the organisation are:
  - Increased profitability;
  - Lowered operational costs;
  - Maximised company resources; and
  - Increased market share and profitability, allowing the company to expand and grow.
- The techniques of productivity improvement can be categorised into five basic types: technology-, parts-, labour-, process- and materials-based techniques.

KEY TERMS

Effectiveness
Efficiency
Government rules
Human resources
Investment of capital
Labour-based techniques
Material-based techniques
Partial productivity
Parts-based techniques
Process-based techniques
Productivity
Productivity cycle
Technology-based techniques
Total productivity
Total-factor productivity

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Topic 4 ▶ Work Study

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Define work study and its objectives;
2. Identify the human factors in work study;
3. Describe method study procedures; and
4. Explain the principles of motion economics.

▶ INTRODUCTION

In this topic, you will be introduced to work study. Did you know that work study was the sequel to Taylor's famous scientific management? Work study is a major discipline under industrial engineering. It became the earliest effectiveness and efficiency technique; furthermore, it is the basic technique of all other techniques that developed later.

Therefore, you will first learn the definition and objectives of work study. Next, we will look at the human factors in work study and further review one of the branches of work study, which is the method study. At the end of this topic, you will learn the principles of motion economics. Happy reading!

4.1 DEFINITION OF WORK STUDY

Firstly, what does work study mean?

Work study can be defined as the **systematic inspection** of the methods of carrying out activities to improve the **effective use of resources**.

It is also to **set up standards of performance** for the activities carried out. Work study can be divided into two main branches:

(a) Method study; and

(b) Work measurements.

However, in this topic, we will focus on method study first. We will discuss work measurements in the next topic.

4.1.1 Direct Method

Now, look at Figure 4.1, which shows you the direct way to increase productivity, which is by using work study.

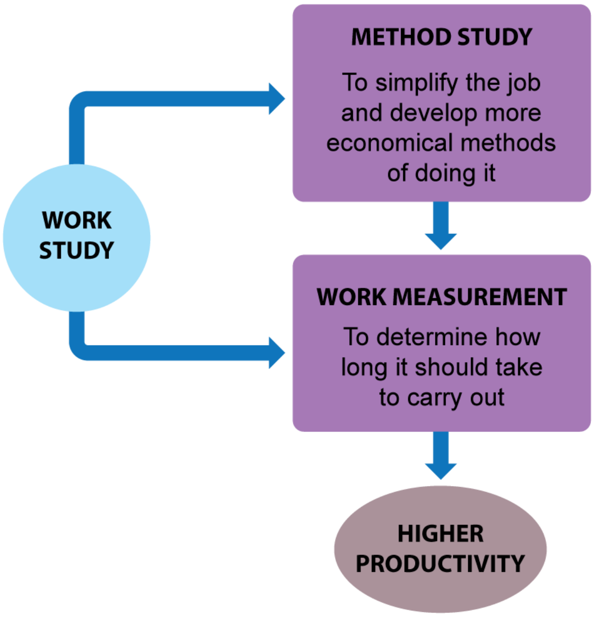


Figure 4.1: Work study

Work study intends to approach the problem of increasing productivity by making a systematic analysis of operations, processes and available work methods with a view to increase the efficiency. In addition, work study contributes to higher productivity with little or no capital expenditure. Research on work study is based on the following assumptions:

(a) Every job has one best way to implement it;

(b) The best way can be found by scientific method; and

(c) The time taken to do the work can be measured and can be considered as the standard time.

4.1.2 Objectives of Work Study

What are the objectives of work study? The objectives of work study are to:

(a) Standardise a job;

(b) Obtain the standard time to produce a work for the purpose of paying salary;

(c) Minimise production costs by making the best selection and suitable tools;

(d) Reduce the transfer of materials and movement of employees with the best plant layout; and

(e) Use manpower, tools and materials in the most effective way.

SELF-CHECK 4.1

Explain the meaning of work study and its objectives.

ACTIVITY 4.1

Discuss in the myINSPIRE forum:

(a) The importance of work study in a manufacturing and service organisation.

(b) You recently witnessed a job in which the person was obviously using a poor method. How would you suggest improving the method?

4.2 HUMAN FACTORS IN WORK STUDY

Human factors in work study involves the study of all aspects of the way people relate to the situation around them, with the aim of improving operational performance, safety, life, costs and adoption through improvement of end-user experience. When studying human factors, we have to observe two aspects as explained in Table 4.1.

Table 4.1: Two Aspects to Observe When Studying Human Factors

Aspect	Description
Workers' union reaction	There must be adequate consultation before the introduction of any scheme that will affect their members. There are two methods of consultation: (i) Through the productivity committee; and (ii) Through notice boards, information magazines and others. There should also be a permanent redundancy policy – aimed at removing the fear that their workers will be dismissed. However, the dismissal will not happen because: (i) Increased demand will absorb higher cost of production; (ii) The company has expansion plans; and (iii) Recruitment of workers can be adjusted. The procedure of work study programmes should be clearly explained with full consultation and description.
Management reaction	Any change is a nuisance to the complacent. Research work is seen as criticism and this affects the performance or opportunities for future managers. Officers should be given an explanation of work study as follows: (i) Work study is not to find problems but to train them to be more creative; (ii) Work study is a tool to help managers and not replace them; and (iii) Work study officers cannot overrule the supervisor's decision.

SELF-CHECK 4.2

Explain two aspects that we need to observe when studying human factors.

ACTIVITY 4.2

In the myINSPIRE forum:

(a) Name any two worker unions in Malaysia.

(b) Discuss what kind of reaction is expected by Malaysian workers' union when implementing work study.

4.3 METHOD STUDY

Now, let us learn about method study. What is method study?

Method study is a **systematic recording and critical examination of how existing work is done** and **suggestion of new methods** based on rules such as simplicity, effectiveness and cost reduction to maximise all utilities available.

4.3.1 Objectives of Method Study

What are the objectives of method study? Some objectives of method study are to:

(a) Improve processes and procedures;

(b) Improve factory and workplace layout and design of plant and equipment;

(c) Improve the use of materials, machines and manpower; and

(e) Produce better physical work environments.

4.3.2 Basic Procedures of Method Study

What are the basic procedures of method study? The basic procedures of method study are shown in Figure 4.2.

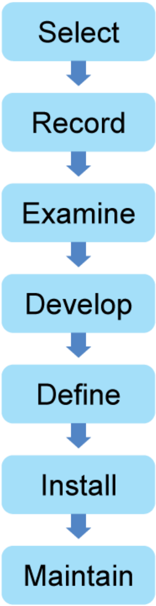


Figure 4.2: Seven procedures of method study

Let us go through each procedure in detail.

(a) **Select**

When considering a work to study, several factors should be considered. These factors are:

(i) Economic considerations, such as bottleneck, movement of materials and operations that involve repetitive work;

(ii) Technical considerations; and

(iii) Human reaction.

(b) **Record**

What do we need to record? We need to record the **facts**. The recording techniques commonly used are **charts** and **diagrams**. Why do we use charts and diagrams? We use charts and diagrams to record the:

(i) **Sequence of processes** but does not show the scale of events; and

(ii) **Events**, also in sequence, but in **time scale**.

There are three most commonly used charts and diagrams in method study. These are further explained in Table 4.2.

Table 4.2: Most Commonly Used Charts and Diagrams in Method Study

Type	Example
Charts indicating process sequence	• Outline process charts; • Flow process chart – Man type; • Flow process chart – Material type; • Flow process chart – Equipment type; and • Two-handed process chart.
Charts using time scale	• Multiple activity chart; and • SIMO (simultaneous-motion cycle) chart.
Diagrams indicating movement	• Flow diagram; • String diagram; • Cycle graph; • Chronocyclegraph; and • Travel chart.

Figure 4.3 shows you an example of cycle graph.

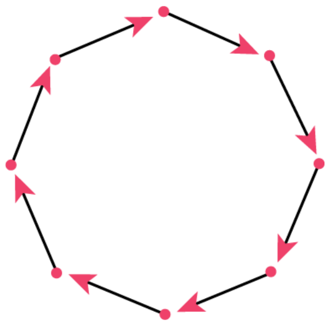


Figure 4.3: An example of a cycle graph

As for Table 4.3, it shows you typical industry problems and the appropriate method study techniques that you can use to solve the problems.

Table 4.3: Typical Industrial Problems and Appropriate Method Study Techniques

Type of Job	Example	Recording Technique
Complete sequence of manufacture	• Manufacturer of an electric motor from raw material to dispatch. • Transformation of thread into cloth from preparation to inspection. • Receipt, packing and dispatch of fruit.	• Outline process chart; • Flow process chart; and • Flow diagram.
Factory layout: Movement of materials	• Movements of a diesel engine cylinder head through all machining operations. • Movements of grain between milling operations.	• Outline process chart; • Flow process chart – Material type; • Flow diagram; • Travel chart; and • Models.
Factory layout: Movement of workers	• Labourers servicing spinning machinery with bobbins. • Cooks preparing meals in a restaurant kitchen.	• Flow process chart – Man type; • String diagram; and • Travel chart.
Workplace layout	• Light assembly work on a bench. • Typesetting by hand.	• Flow process chart – Man type; • Two-handed process chart; • Multiple activity chart; • SIMO chart; • Cycle graph; and • Chronocyclegraph.
Gang work or automatic machine operation	• Assembly line. • Operation looking after semi-automatic lathe.	• Multiple activity chart; and • Flow process chart – Equipment type.
Movements of operatives at work	• Females' operatives on short-cycle repetition work. • Operations demanding great manual dexterity.	• SIMO chart; • Films; • Film analysis; • Motion photography; and • Micromotion analysis.

Let us look at Figures 4.4 to 4.8 that show you an example of a typical outline process chart, flow process chart – material type, flow process chart – man type, string diagram and SIMO chart.

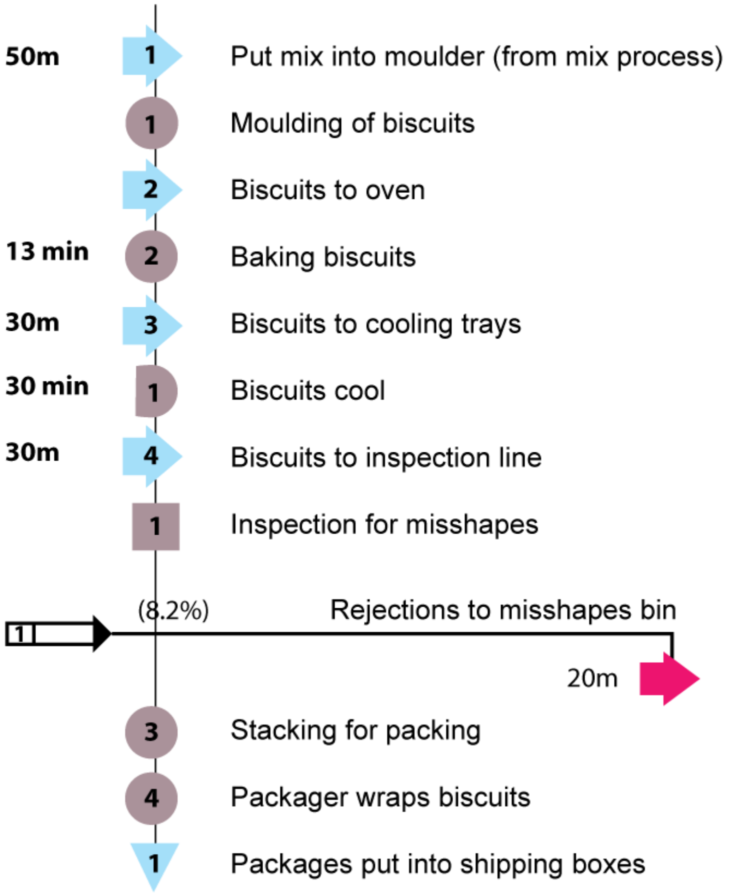
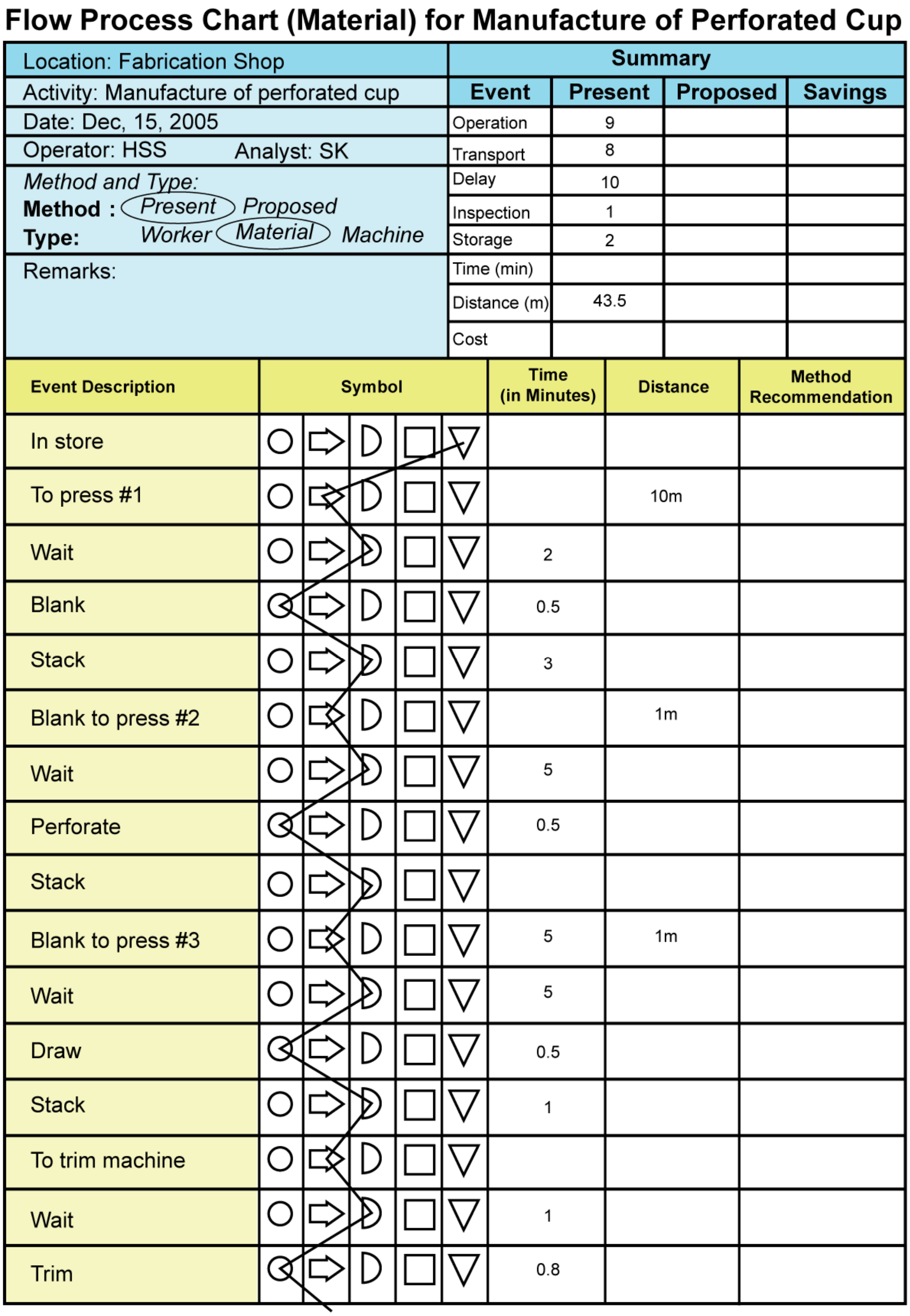


Figure 4.4: A typical outline process chart
Source: http://syque.com

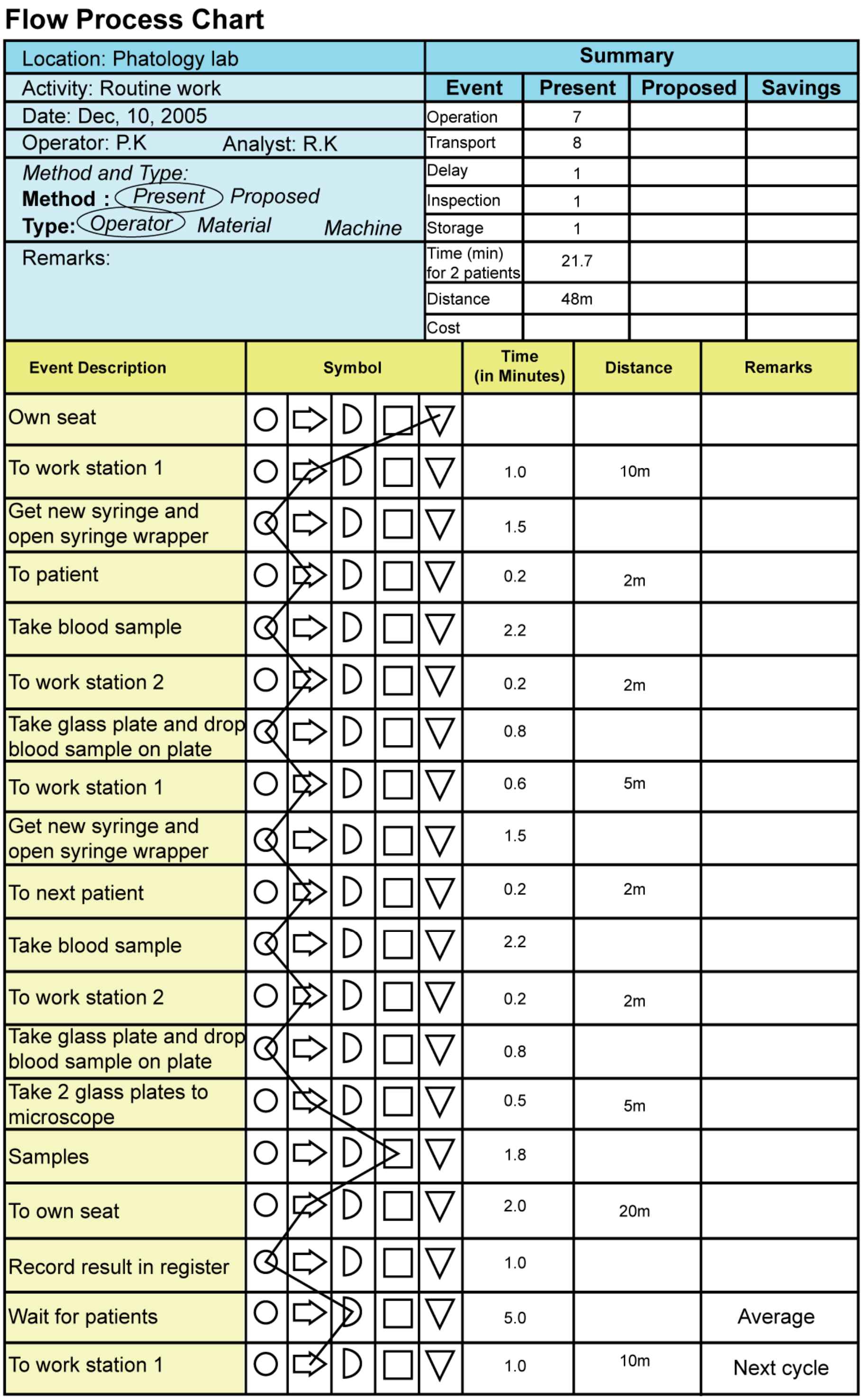


Flow Process Chart (Material) for Manufacture of Perforated Cup

Location: Fabrication Shop	**Summary**			
Activity: Manufacture of perforated cup	**Event**	**Present**	**Proposed**	**Savings**
Date: Dec, 15, 2005	Operation	9		
Operator: HSS Analyst: SK	Transport	8		
Method and Type: **Method :** [✓ *Present*] *Proposed* **Type:** *Worker* [✓ *Material*] *Machine*	Delay	10		
	Inspection	1		
	Storage	2		
Remarks:	Time (min)			
	Distance (m)	43.5		
	Cost			

Event Description	Symbol					Time (in Minutes)	Distance	Method Recommendation
In store	○	⇨	D	☐	▽			
To press #1	○	⇨	D	☐	▽		10m	
Wait	○	⇨	D	☐	▽	2		
Blank	○	⇨	D	☐	▽	0.5		
Stack	○	⇨	D	☐	▽	3		
Blank to press #2	○	⇨	D	☐	▽		1m	
Wait	○	⇨	D	☐	▽	5		
Perforate	○	⇨	D	☐	▽	0.5		
Stack	○	⇨	D	☐	▽			
Blank to press #3	○	⇨	D	☐	▽	5	1m	
Wait	○	⇨	D	☐	▽	5		
Draw	○	⇨	D	☐	▽	0.5		
Stack	○	⇨	D	☐	▽	1		
To trim machine	○	⇨	D	☐	▽			
Wait	○	⇨	D	☐	▽	1		
Trim	○	⇨	D	☐	▽	0.8		

Figure 4.5: Example of a flow process chart – material type
Source: http://nptel.iitm.ac.in



Flow Process Chart

Location: Phatology lab

Activity: Routine work

Date: Dec, 10, 2005

Operator: P.K Analyst: R.K

Method and Type:

Method : [✓ *Present*] *Proposed*

Type: [✓ *Operator*] *Material* *Machine*

Remarks:

Summary			
Event	**Present**	**Proposed**	**Savings**
Operation	7		
Transport	8		
Delay	1		
Inspection	1		
Storage	1		
Time (min) for 2 patients	21.7		
Distance	48m		
Cost			

Event Description	Symbol	Time (in Minutes)	Distance	Remarks
Own seat	○ ⇨ D □ ▽			
To work station 1	○ ⇨ D □ ▽	1.0	10m	
Get new syringe and open syringe wrapper	○ ⇨ D □ ▽	1.5		
To patient	○ ⇨ D □ ▽	0.2	2m	
Take blood sample	○ ⇨ D □ ▽	2.2		
To work station 2	○ ⇨ D □ ▽	0.2	2m	
Take glass plate and drop blood sample on plate	○ ⇨ D □ ▽	0.8		
To work station 1	○ ⇨ D □ ▽	0.6	5m	
Get new syringe and open syringe wrapper	○ ⇨ D □ ▽	1.5		
To next patient	○ ⇨ D □ ▽	0.2	2m	
Take blood sample	○ ⇨ D □ ▽	2.2		
To work station 2	○ ⇨ D □ ▽	0.2	2m	
Take glass plate and drop blood sample on plate	○ ⇨ D □ ▽	0.8		
Take 2 glass plates to microscope	○ ⇨ D □ ▽	0.5	5m	
Samples	○ ⇨ D □ ▽	1.8		
To own seat	○ ⇨ D □ ▽	2.0	20m	
Record result in register	○ ⇨ D □ ▽	1.0		
Wait for patients	○ ⇨ D □ ▽	5.0		Average
To work station 1	○ ⇨ D □ ▽	1.0	10m	Next cycle

Figure 4.6: Example of a flow process chart – man type
Source: http://nptel.iitm.ac.in

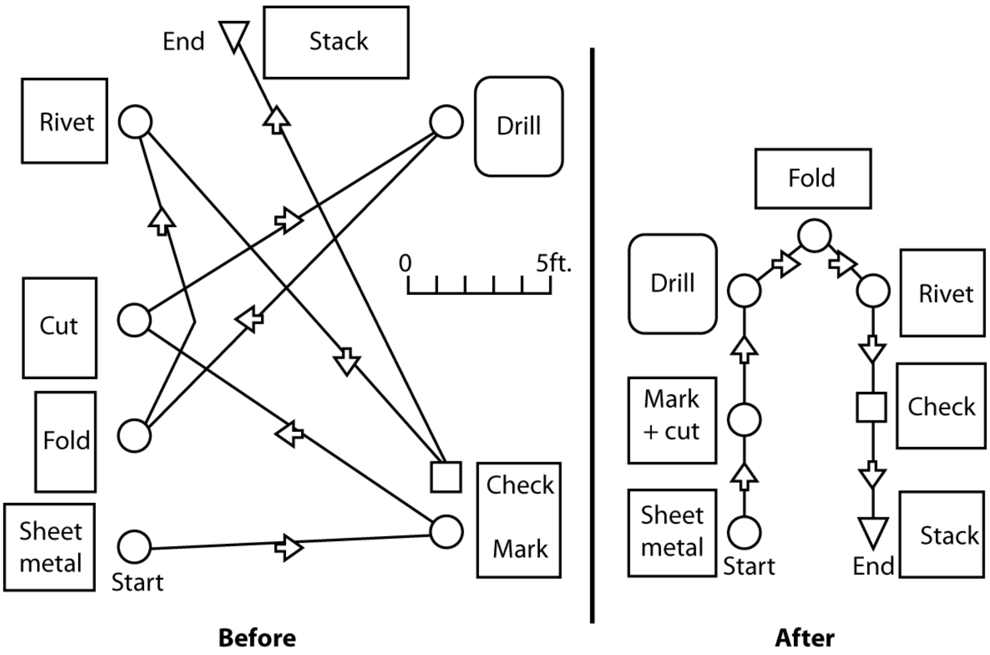
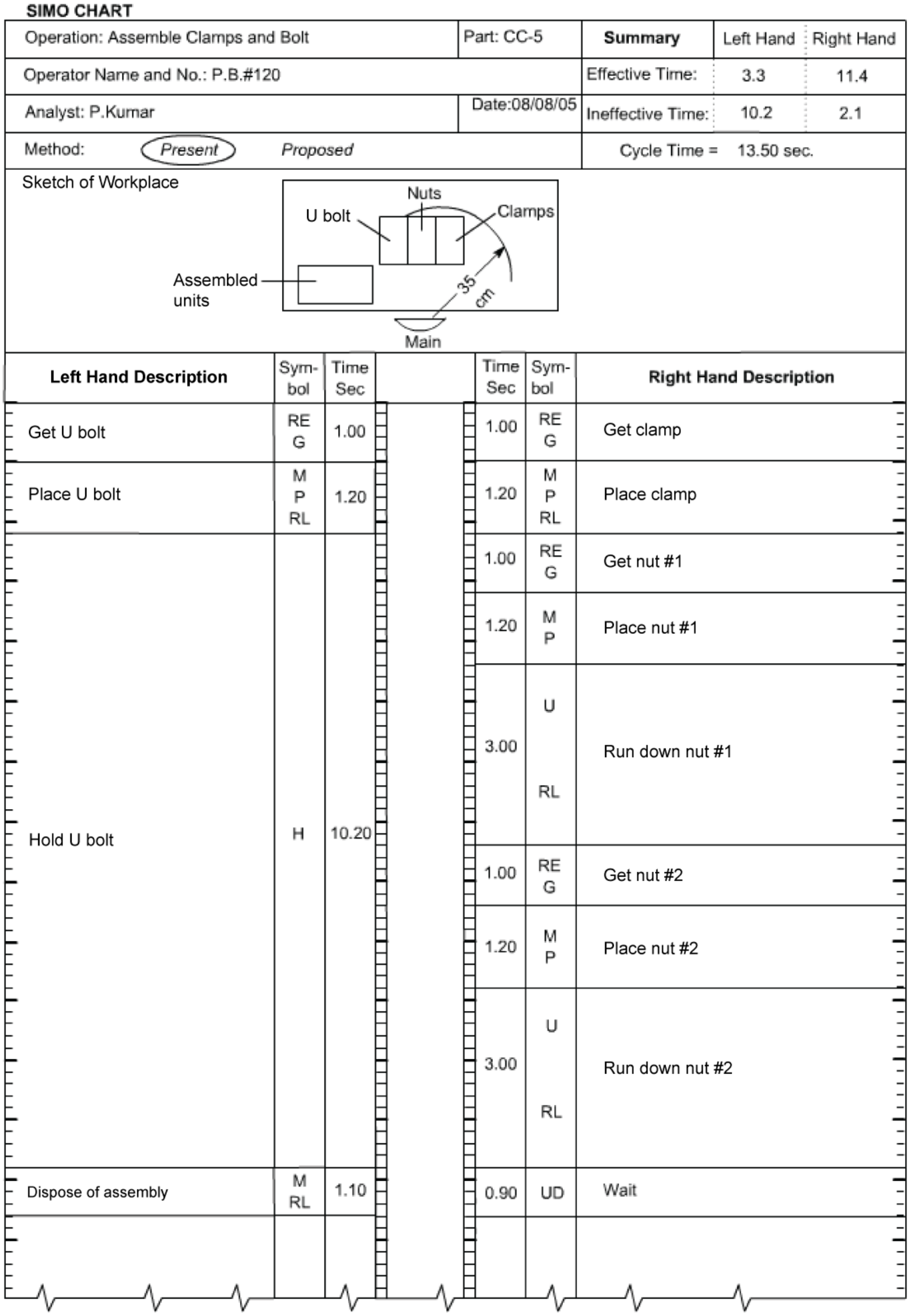


Figure 4.7: Example of a string diagram
Source: http://syque.com



SIMO CHART

Operation: Assemble Clamps and Bolt	Part: CC-5	**Summary**	Left Hand	Right Hand
Operator Name and No.: P.B.#120		Effective Time:	3.3	11.4
Analyst: P.Kumar	Date:08/08/05	Ineffective Time:	10.2	2.1
Method: [✓ *Present*] *Proposed*		Cycle Time =	13.50 sec.	

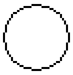
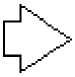
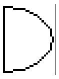
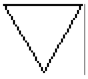
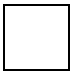
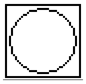
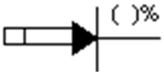
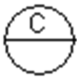
Sketch of Workplace

Left Hand Description	Symbol	Time Sec	Time Sec	Symbol	**Right Hand Description**
Get U bolt	RE G	1.00	1.00	RE G	Get clamp
Place U bolt	M P RL	1.20	1.20	M P RL	Place clamp
Hold U bolt	H	10.20	1.00	RE G	Get nut #1
			1.20	M P	Place nut #1
			3.00	U RL	Run down nut #1
			1.00	RE G	Get nut #2
			1.20	M P	Place nut #2
			3.00	U RL	Run down nut #2
Dispose of assembly	M RL	1.10	0.90	UD	Wait

Figure 4.8: Example of a SIMO chart
Source: http://nptel.iitm.ac.in

Now, let us take a look at the symbols used in a process chart. Various symbols are used in process charts to depict the nature and flow of the steps in a process. The following Table 4.4 shows you several typical symbols that are used in those charts.

Table 4.4: Typical Symbols Used in Process Charts

Symbol	Signify	Description
	Operation	A complex action or process (possibly described elsewhere), often changing something.
	Transport	Movement of people or things. May be accompanied by a distance measurement.
	Delay	Idle time of people or machines, or temporary storage of materials.
	Storage	Permanent storage of materials or other items.
	Inspection	Checking of items to ensure correct quality or quantity.
	Combined operation	Overlay symbols for actions which combine types. Put the main activity outside.
	Reject	Rejection of item. Parentheses show percentage of items rejected. Line to right lead to consequent action.
	Differentiated operation	Letter shows type of operation, such as C = Clerical and M = Machine.
	State change	Description indicates change in state, for example a liquid cooling into a solid.

Source: http://syque.com

(c) **Examine**

The next step in method study is to examine all the facts. **Questioning** is a technique of carrying out a critical analysis, whereby for every activity, a series of questions is presented systematically and progressively. There are two types of questions:

(i) **Primary Question**

Primary questions investigate **aim**, **place**, **sequence**, **people** and **method** of every activity. The findings are recorded systematically and the reason for each answer is required. Let us look at Table 4.5 which gives some examples of primary questions.

Table 4.5: Examples of Primary Questions

Aim	What	What is really made?
	Why	Why is this activity needed?
Place	Where	Where is it made?
	Why	Why is it made in that place?
Sequence	When	When is it made?
	Why	Why is it made at that time?
People	Who	Who made it?
	Why	Why is it made by that person?
Method	How	How is it made?
	Why	Why is it done that way?

(ii) **Secondary Question**

These questions include the second stage of secondary questioning technique where the answers to primary questions are presented for further questioning to determine whether alternatives to the place, order, people and/or other means, can be practised and preferred as a means to improve existing conditions. Table 4.6 describes an example of secondary questions.

Table 4.6: Examples of Secondary Questions

<table>
<tr><th colspan="3">Primary Question</th></tr>
<tr><td rowspan="2">Aim</td><td>What</td><td>What is really made?</td></tr>
<tr><td>Why</td><td>Why is this activity needed?</td></tr>
<tr><th colspan="3">Secondary Question</th></tr>
<tr><td colspan="2">What else</td><td>What else can we do?</td></tr>
<tr><td colspan="2">What should</td><td>What to do?</td></tr>
</table>

(d) **Develop**

This is the stage where you need to develop better methods. As learnt previously, the following questions need to be answered:

(i) What should we do?

(ii) Where should it be done?

(iii) When should it be made?

(iv) Who should make it?

(v) How should it be made?

When these questions are answered, it is the duty of the method study officer to ensure whatever planned is put in practice.

The first step of the implementation is to record the proposed method on a process flow chart so that it can be compared with the original method to ensure nothing is missed. This also allows for a summary of the total activity for both methods, movement distance savings and expected time as a result of the change and also financial savings that might be gained.

When the study is completed, a new method is developed. Usually, the approval of the management must be obtained prior to the implementation. Therefore, the method study officer must provide a report containing information on existing and new methods and should give reasons for the change to be made.

(e) **Define**

This is the stage where a new method is defined. The following are some of the information required:

(i) Tools and equipment used and operating conditions;

(ii) Description of the method – The details required depends on the nature of work and the expected production; and

(iii) Workplace layout and special tools, jigs or fixtures sketch that may be required.

(f) **Install**

This is the stage where the **new methods** are implemented. At this point, we will need support from the management and unions. Implementation can be divided into five stages as follows:

  (i) Obtain change approval from the department supervisor;

  (ii) Obtain change agreement from the management;

  (iii) Obtain change approval from affected workers and representatives;

  (iv) Train the employees who will practise the new method; and

  (v) Maintain a close relationship until work performance is satisfactory and expected results are achieved.

(g) **Maintain**

This is the stage of **observation** and **sustainability**. Work habits, other than those required by the method study officer, may become worse if the new methods are not practised. Continuous visits by the officer may be required in order to maintain the new methods.

SELF-CHECK 4.3

1. Explain the objectives of method study.
2. What are the basic procedures of method study?

ACTIVITY 4.3

1. Use the Internet or any other resources to search/look for:
    (a) Flow process chart – Equipment type;
    (b) Multiple activity chart;
    (c) Chronocyclegraph; and
    (d) Travel chart.
2. Based on your experience, how extensively do you think method study has been applied to the industry and household?
3. What are the secondary questions? List them.
4. Identify factors that cause workers not to follow new methods implemented by method study officers.

Post your answers on the myINSPIRE forum for discussion.

4.4 THE PRINCIPLES OF MOTION ECONOMICS

There are several principles of motion economics that have been developed as a result of experience and have become a good basis for developing better methods in the workplace. These principles can be grouped into three categories as explained in Table 4.7.

Table 4.7: Three Categories of Motion Economics Principles

Category	Description
The use of human body	The motion of both hands should begin and end at the same time. Both hands should not be silent except during rest. Meanwhile, motion of the arms should be symmetric and the opposite direction should be done simultaneously.
Workplace layout	Tools and materials are required to be "pre-positioned" to reduce the search. Equipment, materials and controls should be placed in a maximum work area and the closest possible to the workers. These should also be arranged to enable the best order of movements.
The design of tools and equipment	Hands should be released from holding a work piece when it can be done with jigs or fixtures. Other than that, two or more tools or equipment should be integrated when conditions permit.

4.4.1 Motion Explanation

Use of motion economy rules calls for the use of the lowest possible (Class 1 is the lowest and Class 5 is the highest) classified human body movements. Now, let us refer to Table 4.8 which shows the classification of movements.

Table 4.8: Classification of Movements

Class	Pivot	Body Member(s) Moved
1	Knuckle	Finger
2	Wrist	Hand and fingers
3	Elbow	Forearm, hand and fingers
4	Shoulder	Upper arm, forearm, hand and fingers
5	Trunk	Torso, upper arm, forearm, hand and fingers

As can be seen in Table 4.8, Class 2 includes Class 1 item; Class 3 includes Class 1 and 2 and so on.

Now, let us look at Figures 4.9 and 4.10 that show you the different working areas for these classes.

Average Physical Data for Man	
Weight: 69kg	Length of forearm: 45.73cm
Height: 172.7cm	Length of hand: 17.78cm
Length of arm => 30°	

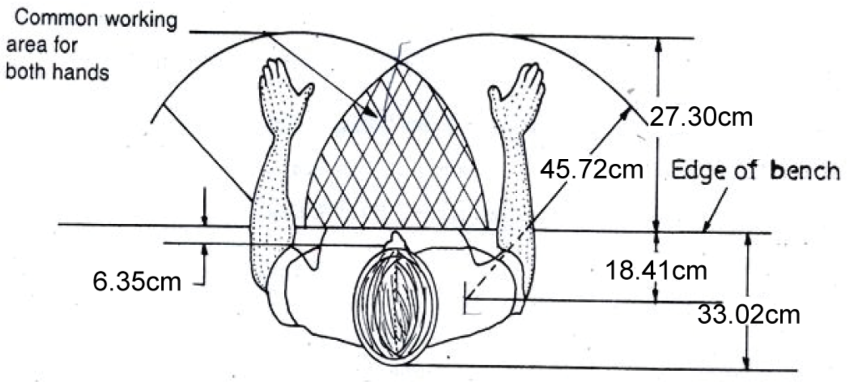


Figure 4.9: Normal working area using finger, wrist and elbow movements
Source: http://www.transtutors.com

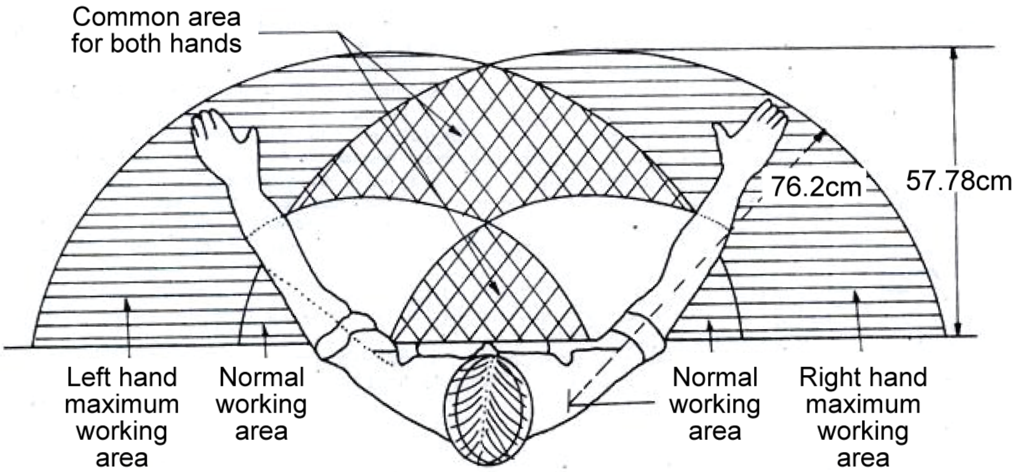


Figure 4.10: Maximum working area using shoulder movements
Source: http://www.transtutors.com

Take note that tools, materials and workplace should be placed in the working area. Priority must be given to lower class body elements.

On the other hand, field of vision is important for seeing objects, control panels and others. In addition, field of vision is an important consideration in locating items for tasks such as inspection, examination and others.

SELF-CHECK 4.4

Describe the three categories of principles of motion economics.

ACTIVITY 4.4

Although the human body can endure much discomfort and stress, prolonged exposure to unnatural motions may eventually cause physical problems. Discuss in the myINSPIRE forum an example in which operators were adversely affected and what was done to alleviate the problem.

SUMMARY

- Work study can be defined as the systematic inspection of the methods of carrying out activities to improve the effective use of resources.

- Work study is a major discipline under industrial engineering and has become the earliest effectiveness and efficiency technique. It can be divided into two main branches namely method study and work measurements.

- Some of the objectives of work study are to standardise a job and effectively use manpower, tools and materials.

- When studying human factors, we have to observe two aspects namely the workers union reaction and management reaction.

- Method study is the systematic recording and critical examination of how the existing work is done and suggestion of new ways based on the rules of simplicity, effectiveness and costs reduction.

- Questioning is a technique of carrying out critical analysis, where for every activity, a series of questions is presented systematically and progressively.

- There are several principles of motion economics that have been developed as a result of experience and is a good basis for developing better methods in the workplace.

- The principles of motion economics can be grouped into three categories namely the use of human body, workplace layout and the design of tools and equipment.

KEY TERMS

Charts

Design of tools and equipment

Diagrams

Human body

Management reaction

Method study

Work measurements

Work study

Workers union reaction

Workplace layout

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Topic 5 ▶ Work Measurement

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Define work measurement;
2. Identify the common techniques used in work measurement;
3. Solve time study problems;
4. Calculate the sample size for work measurement; and
5. Determine the number of observations required in work sampling.

▶ INTRODUCTION

In Topic 4, you have learnt about one of the branches of work study which is method study. Can you still recall?

Now in this topic, you will be introduced to work measurement. Did you know that there are many techniques that can be used in work measurement? Nevertheless, this topic will focus on only two techniques in work measurement, which are time study and work sampling. So are you ready to discover more? Let us continue with the lesson.

5.1 INTRODUCTION TO WORK MEASUREMENT

Did you know that work measurement is a terminology covering several different ways to find out how long a work or part of a work should take to complete? What does it stand for?

Work measurement can be defined as a **systematic determination** (through the use of various methods) of the amount of **effective work units** in terms of **physical** and **mental requirements** of a specified work.

In other words, work measurement can be defined as the **use of techniques** designed to **set the time** for a **qualified person** to carry out a **specific work** at a **defined behaviour level**. Work units are usually given in standard **hours** or **minutes**.

Now, let us look at the other terms related to work measurement in Table 5.1.

Table 5.1: Terms in Work Measurement

Term	Definition
Trained employee	A person who has agreed to have the physical characteristics required, with the necessary education and intelligence. This trained employee also has to possess the skills and knowledge required to carry out the work given in accordance to the safety standards and be able to achieve satisfactory quality of work.
Regular employment rate	The rate of employment for any employee under the supervision of competent supervisors without an incentive pay plan encouragement. A value of 100 (according to the British Standard) is given to the concept.
Normal behaviour	Any work will lead to fatigue. Hence, **time off**, also known as **fatigue relief**, is given to recover from fatigue. Normal behaviour is a situation when work is done at a normal rate of work and fatigue relief is given.

What are the objectives of work measurement? The objectives of work measurement are:

(a) As a basis for the comparison of alternative methods;

(b) Early workforce planning and appropriate distribution;

(c) Reasonable labour costing; and

(d) As a basis for a good incentive scheme.

SELF-CHECK 5.1

1. In your own words, define work measurement.
2. State the objectives of work measurement.

ACTIVITY 5.1

Based on your experience, how does work measurement contribute to the operation of a modern manufacturing concern? Share your experience with your coursemates in the myINSPIRE forum.

5.2 WORK MEASUREMENT TECHNIQUES

What are the common techniques used in work measurement? Some common techniques used in work measurement are:

(a) Time study;

(b) Work sampling;

(c) Pre-determined motion time systems;

(d) Synthesis;

(e) Production research;

(f) Analytical estimating; and

(g) Comparative estimating.

However in this topic, we will focus on time study and work sampling only. These two will be discussed further in Subtopic 5.3 and Subtopic 5.5.

5.3 TIME STUDY

What is time study?

Time study is a technique that involves **recording the time** and **rate of work** for certain elements of the work undertaken in certain circumstances.

Time study is also used to analyse the data to determine the **time required to carry out any work within a defined behaviour or standard behaviour**.

(a) **Concept of Standard Work Rate**
What is standard behaviour? Standard behaviour is the result of **ideal work efficiency** and **appropriate relaxation**, which means that it can be practised throughout the year without overexertion.

(b) **Reasons for Conducting Time Study**
Why do we need to conduct time study? There can be numerous reasons for conducting time study. Some of the relevant reasons are:

(i) The work is a new product, component or group of new activities;

(ii) Changes in manufacturing methods and new standard time are needed;

(iii) Complaints received from an employee or representative of workers regarding an operation; and

(iv) Certain operations show a "bottleneck".

(c) **Time Study Tools**
What are the basic tools that are normally used in a time study? The basic tools normally used in a time study are:

(i) Stop watch (see Figure 5.1).

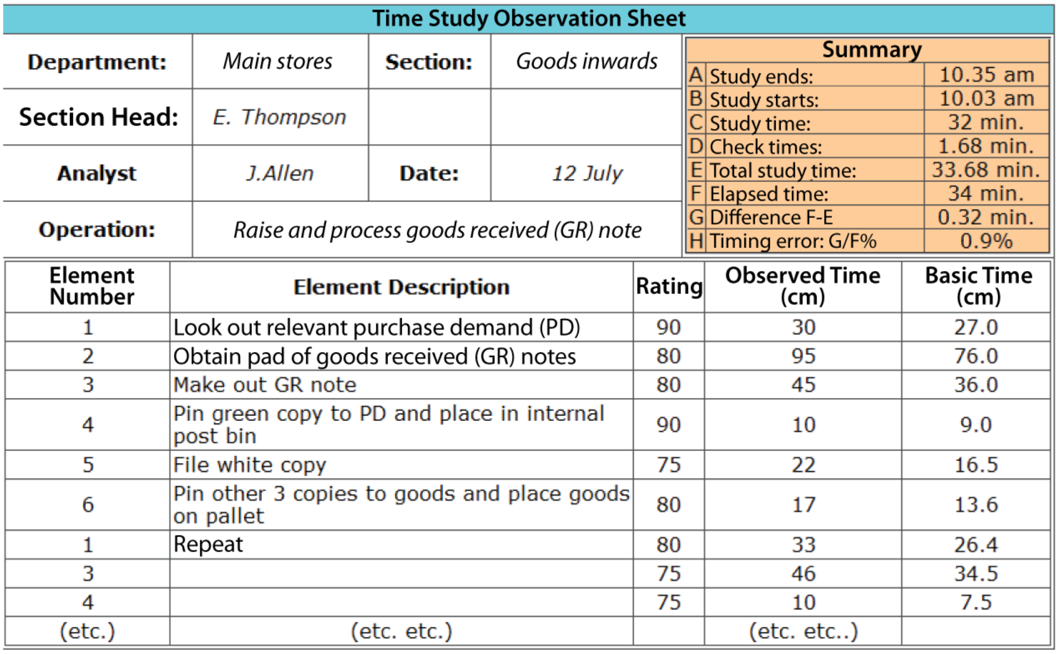
Figure 5.1: Stop watches (analogue and digital)
Source: http://www.gilliswatches.com

(ii) Study board.

(iii) Pencil.

(iv) Calculator.

(v) Time study forms (see Figure 5.2).



Time Study Observation Sheet

Department:	*Main stores*	**Section:**	*Goods inwards*
Section Head:	*E. Thompson*		
Analyst	*J.Allen*	**Date:**	*12 July*
Operation:	*Raise and process goods received (GR) note*		

Summary

A	Study ends:	10.35 am
B	Study starts:	10.03 am
C	Study time:	32 min.
D	Check times:	1.68 min.
E	Total study time:	33.68 min.
F	Elapsed time:	34 min.
G	Difference F-E	0.32 min.
H	Timing error: G/F%	0.9%

Element Number	Element Description	Rating	Observed Time (cm)	Basic Time (cm)
1	Look out relevant purchase demand (PD)	90	30	27.0
2	Obtain pad of goods received (GR) notes	80	95	76.0
3	Make out GR note	80	45	36.0
4	Pin green copy to PD and place in internal post bin	90	10	9.0
5	File white copy	75	22	16.5
6	Pin other 3 copies to goods and place goods on pallet	80	17	13.6
1	Repeat	80	33	26.4
3		75	46	34.5
4		75	10	7.5
(etc.)	(etc. etc.)		(etc. etc..)	

Figure 5.2: A sample of time study sheet/form
Source: http://www.managers-net.com

Did you know that there are three ways to use a stop watch during a time study? Let us see Table 5.2 that explains these ways further.

Table 5.2: Three Ways of Using a Stop Watch in a Time Study

Method	Description
Flyback	A watch is used where the hand having recorded the length of the element, can be made to return immediately to zero and begin with the next element.
Cumulative timing	The hands of the watch are continuously moving throughout the study. The element times are read and taken as they occur; the time for each subsequent element is obtained by subtraction.
Differential timing	Time for very small elements are obtained using this method. First, elements are timed in groups by including and then excluding the small element. The time is subsequently obtained by subtraction.

(d) **Time Scales**

The following time scales are adopted in a time study:

(i) Decimal – Minutes;

(ii) Seconds; and

(iii) Decimal – Hours.

(e) **Elements Period**

The elements period used in a time study are:

(i) Better between 10 and 50 centi-minutes;

(ii) Repetitive work, long cycle – The proportion recorded every 0.5 minutes; and

(iii) Repetitive work, short cycle – Total time taken for a number of cycles and an overall rate is made.

(f) **Steps in Conducting Time Study**

Did you know that there are nine basic steps in conducting a time study? These steps are:

Step 1: Select the task to be studied.

Step 2: Record all relevant information.

Step 3: Divide the tasks or operations into elements.

Step 4: Decide how many times to measure the task.

Step 5: Time and record element times and rating of performance.

Step 6: Calculate the average observed time.

Step 7: Determine the performance rating and normal time.

$$\text{Normal time} = [\text{Average observed time}] \times [\text{Performance rating factor}]$$

Step 8: Add the normal times for each element to develop the total normal time for the task.

Step 9: Calculate the standard time.

$$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$$

(g) **Relaxation Allowances**

Generally, the following relaxation allowances are recommended when conducting a time study:

(i) Personal time allowance – Four per cent to seven per cent of total time (use of restroom, water fountain and others);

(ii) Delay allowance – Based on actual delays that occur;

(iii) Fatigue allowance – To compensate for physical or mental strain, noise level, tediousness, heat and humidity, assumption of an abnormal position and others; and

(iv) Rest allowances (in percentage) for various classes of work as shown in Table 5.3.

Table 5.3: Rest Allowances (%) for Various Classes of Work

No.	Type	Details	%
1	Constant allowance	Personal allowance	5
		Basic fatigue allowance	4
2	Variable allowances	Standing allowance	2
		Abnormal position (i) Awkward (bending) …………….. (ii) Very awkward (lying, stretching)	 2 7
		Use of force or muscular energy in lifting, pulling, pushing Weight lifted (pounds) 20…………………………………… 40…………………………………… 60……………………………………	 3 9 17
		Bad light (i) Well below recommended …….. (ii) Quite inadequate ………………	 2 5
		Atmospheric conditions (heat and humidity) Variable……………………………..	 1–10
		Close attention (i) Fine or exacting ………………… (ii) Very fine or very exacting ……….	 2 5
		Noise level (i) Intermittent – Loud …………… (ii) Intermittent – Very loud or high-pitched	 2 5
		Mental Strain (i) Complex or wide span of attention (ii) Very complex…………………..	 4 8
		Tediousness: (i) Tedious…………..………………. (ii) Very tedious……………………	 2 5

Now, let us look at Example 5.1 and Example 5.2 that show you how to conduct time study.

Example 5.1:
The following information is given for a production operation:

Average observed time = 4.0 minutes
Worker rating = 85%
Allowance factor = 13%

Calculate the following:

(a) Normal time; and

(b) Standard time.

Solution:

(a) Normal time = (Average observed time) × (Rating factor)
= 4.0×0.85
= 3.4 minutes

(b) Standard time $= \dfrac{\text{Total normal time}}{1 - \text{Allowance factor}} = \dfrac{3.4}{1-0.13} = 3.9$ minutes

Example 5.2:
The following information is given for an operation with an allowance factor of 15 per cent:

Job Element	Cycle Observed (in Minutes)					Performance Rating
	1	2	3	4	5	
(a) Compose and type letter	8	10	9	21*	11	120%
(b) Type envelope address	2	3	2	1	3	105%
(c) Stuff, stamp, seal and sort envelopes	2	1	5*	2	1	110%

Calculate:

(a) The average times for each element;

(b) The normal time for each element;

(c) The total normal time; and

(d) The standard time for the job.

Solution:
Delete unusual or non–recurring observations (marked with *)

(a) Average times for each element:

$$\text{Average time for A} = \frac{(8+10+9+11)}{4} = 9.5 \text{ minutes}$$

$$\text{Average time for B} = \frac{(2+3+2+1+3)}{5} = 2.2 \text{ minutes}$$

$$\text{Average time for C} = \frac{(2+1+2+1)}{4} = 1.5 \text{ minutes}$$

(b) Normal time = (Average observed time) × (Rating)
Normal time for A = (9.5) (1.2) = 11.4 minutes
Normal time for B = (2.2) (1.05) = 2.31 minutes
Normal time for C = (1.5) (1.10) = 1.65 minutes

(c) Add the normal times to find the total normal time
Total normal time = 11.40 + 2.31 + 1.65 = 15.36 minutes

(d) Compute the standard time for the job

$$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$$

$$= \frac{(15.36)}{(1-0.15)}$$

$$= 18.07 \text{ minutes}$$

SELF-CHECK 5.2

1. State the four reasons for conducting a time study.
2. List the basic tools that are normally used in a time study.

5.4 DETERMINING THE SAMPLE SIZE

Why do we need to determine sample size? The sample size needs to be determine so that we can verify:

(a) How accurate we want to be;

(b) The desired level of confidence; and

(c) How much variation exists within the job elements.

How do we determine the sample size? We can determine the sample size by using this formula:

$$\text{Required sample size, } n = \left[\frac{zs}{hx}\right]^2$$

where

h = Accuracy level desired in percentage of the job element expressed as a decimal.
z = Number of standard deviations required for the desired level of confidence (see Table 5.4).
s = Standard deviation of the initial sample.
x = Mean of the initial sample.
n = Required sample size.

Table 5.4: Common z Values

Desired Confidence (%)	z Value (Standard Deviation Required for the Desired Level of Confidence)
90.0	1.65
95.0	1.96
95.45	2.00
99.0	2.58
99.73	3.00

Let us look at Example 5.3 to understand more about this matter.

Example 5.3:
Data for an operation is given as follows:

Desired accuracy = 5%
Confidence level = 95%
Sample standard deviation = 1.0
Sample mean = 3.00

Determine the sample size required.

Solution:
$h = 0.05$ $x = 3.00$ $s = 1.0$ $z = 1.96$ (from Table 5.4)

$$\text{Required sample size, } n = \left[\frac{zs}{hx}\right]^2 = \left[\frac{1.96 \times 1.0}{0.05 \times 3}\right]^2 = 170.74 \approx 171$$

SELF-CHECK 5.3

Why do we need a sample size for work measurement?

ACTIVITY 5.2

1. Harris takes three hours and 25 minutes to write an end-of-month report. Tom is rated at 95 per cent (work pace is 95 per cent) and the office has a personal time allowance of eight per cent. There is no delay time or fatigue time.
    (a) What is the normal time for writing an end-of-month report?
    (b) What is the standard time for writing an end-of-month report?
2. Sam, a marketing surveyor, takes an average of 10 minutes to complete a particular questionnaire. Sam's performance rating (pace) is 110 per cent and there is an allowance of 15 per cent.
    (a) What is the normal time for completing this questionnaire?
    (b) What is the standard time for completing this questionnaire?

Post your answers for discussion on the myINSPIRE forum.

5.5 WORK SAMPLING

Before we end this topic, let us learn more about work sampling. It is a well-known fact that sampling is a technique based on **statistics** that can be used as a basis for work measurement. Without work sampling, it will be difficult to obtain a complete and accurate record of the productive and idle time of people and machines. This will take many observers and will be very expensive.

Nevertheless, if you are in a factory and can see most of these people and machines, you will be able to get a rough estimate of each activity percentage by simply glancing through the plant every few minutes. This is because work sampling applies some structures and rigours of this process of "glancing through".

What is work sampling? Let us look at its definition given by BS 3138:41008.

> "A technique in which a large number of observations are made over a period of time of one group of machines, processes or workers. Each observation records what is happening at that instance and the percentage of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs."
>
> (BS 3138:41008)

What we are trying to say here is that:

"We are very confident that for 95% of the time, our observation is correct within $\pm x$, where x is the error rate we are pleased with. To do this, we need to know how many observations to take."

What are advantages of activity sampling? Two advantages of activity sampling are it allows:

(a) Long activities or groups of activities that will be examined economically and in a way that produces statistically accurate data; and

(b) An observer to record data from a number of activities, processes or people.

The formula for the number of observations is as follows:

$$N = \frac{z^2 p(1-p)}{h^2}$$

where

N = Required number of observations.

z = Standard normal deviation for the desired confidence level.

p = Estimated value of sample proportion.

h = Acceptable error level in percentage.

Now, look at Example 5.4 that demonstrates this matter.

Example 5.4:
An operation wants employees to be idle 25 per cent of the time. The sample should be accurate within three per cent and have 95.45 per cent confidence level in the results. Calculate the number of observations.

Solution:

z = Two for a 95.45 per cent confidence level
p = Estimate of idle proportion = 25 per cent = 0.25
h = An acceptable error of three per cent = 0.03

$$N = \frac{z^2 p(1-p)}{h^2}$$

$$= \frac{(2)^2 (0.25)(0.75)}{(0.03)^2}$$

$$= 833 \text{ observations}$$

SELF-CHECK 5.4

1. What is work sampling?
2. State the advantages of work sampling.

ACTIVITY 5.3

1. Sam and Peter recently time-studied a janitorial task. From a sample of 75 observations, they computed an average cycle time of 15 minutes with a standard deviation of two minutes. Was their sample large enough that one can be 99 per cent confident that the standard time is within five per cent of the true value? Discuss this matter with your coursemates in the myINSPIRE forum.

2. It is estimated that an operator in an assembly line has 20 per cent idle time. The expected accuracy in work sampling is ± four per cent. For a 95 per cent confidence level, how many observations are needed? Share your answer with your coursemates in the myINSPIRE forum.

SUMMARY

- Work measurement is defined as the use of techniques designed to set the time for a qualified person to carry out a specific work at a defined behaviour level.

- Work measurement techniques provide a quantitative assessment of specific human work and to set an appropriate time to ensure the effective conduct of a job/task. Some of the common techniques are time study and work sampling.

- Time study is a technique that involves recording the time and rate of work for certain elements of the work undertaken in certain circumstances and to analyse the data to determine the time required to carry out any work within a defined behaviour or standard behaviour.

- Sample size is conducted to determine how accurate we want to be, the desired level of confidence and how much variation exists within the job elements.

- According to BS 3138:41008, work sampling is "a technique in which a large number of observations are made over a period of time of one group of machines, processes or workers."

KEY TERMS

Allowance	Standard time
Normal behaviour	Standard work rate
Normal time	Time scales
Observations	Time study
Regular employment rate	Trained employee
Relaxation allowances	Work measurement
Sample size	Work sampling

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Topic 6 ▶ Plant Location and Layout

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Describe the concepts of plant location;
2. Identify the stages in plant location selection;
3. Explain the influence of location of plant layout;
4. Apply the location analysis techniques;
5. Explain the concepts and the importance of plant layout; and
6. Compare the different types of plant layout.

▶ INTRODUCTION

In this topic, you will learn about plant location and layout. Did you know that a good plant location plays an important role in the production of goods and services? This is because a good location and layout will reduce costs and make the production process more efficient and effective. Area location is simply a process of dividing the building space or allocating space among the departments.

What else do you need to know about plant location? Let us "survey" the best location!

6.1 CONCEPTS OF PLANT LOCATION

As stated earlier, a good location for manufacturing or services facilities will result in a cost advantage. This is because it can reduce the cost of raw materials and distribution. In fact, the location factor is very beneficial to small business enterprises and service units.

Location leads to competitive advantages and better profits. Usually, the question of location arises when:

(a) A new plant facility or new services facility is being planned;

(b) An existing business is expanding and/or capacity is being added in other areas or regions;

(c) The current facilities are to be relocated or modified; and

(d) There is an opportunity to take advantage of better infrastructure or tax incentives from government agencies.

Information of the total plant size and the shape of the facility is required very early in the project in order to design the building. This is because the location of the plant or services facility is a permanent fixture which incurs considerable expenditure.

Due to this reason, the final selection has to be done after considering all the relevant aspects. Bear in mind that making any mistake in choosing the location of a plant or facility will result in losses incurred due to wasteful expenditure on in site development, construction, machinery installation and other infrastructure expenses.

There are **three main issues** that need to be observed in choosing a location. These issues are explained in Table 6.1.

Table 6.1: Three Main Issues in Choosing a Location

Issue	Description
Selection of the region	It is essential to produce near the base of raw materials or customers to meet the competitive set, trade agreements and transportation costs.
Selection of the place	The choice usually boils down to industrial areas that have been developed or have government-sponsored advantage.
Selection of the site	Low labour cost advantages, low-cost land, good infrastructure or transport selected.

SELF-CHECK 6.1

1. Describe the concepts of plant location.
2. Explain the three main issues in choosing a location.

6.2 STAGES IN PLANT LOCATION SELECTION

What are the stages in plant location selection? There are **two stages** in plant location selection:

(a) **Selection of General Area**

This stage requires the selection of a plant location (general in nature) which may be obtained from federal, state economic development corporations, chambers of commerce and others.

(b) **Selection of Communities and Plant Site**

When the region of location has been selected, the selection of the site for communities will have to be made. Preliminary results are needed on the size of the community where the plant will be located. Alternative options can be classified into three categories (see Table 6.2).

Table 6.2: Three Categories of Alternative Options

Categories	Description
Urban	The circumstances which suggest urban locations include: • Skilled labour force; • Availability of city facilities; • Multi-level buildings; • Close relationships with suppliers; and • Availability of rapid transportation.
Suburban (suburb)	The circumstances which suggest suburb locations include: • Semi-skilled or female labour force; • Avoidance of taxes and high insurance in the city; • Expansion of the plant is easier than in the city; and • People close to, but not in, the large population centres.

Rural	The circumstances which suggest rural locations include: • A large site is required for present or future demand; • Lower property tax; • Unskilled labour force; • Lower salaries to enable competitiveness; and • Producing dangerous chemicals or unpleasant products.

A "rule of thumb" about the size of the site is that it **should not be less than five times the actual size of the plant**.

SELF-CHECK 6.2

Explain the circumstances which suggest an urban location.

6.3 THE INFLUENCE OF LOCATION ON THE LAYOUT OF PLANT

The location of plants will determine the closeness of a plant to the source of raw materials and markets. This is because the distance between the plant and the area (source of raw materials and markets) will determine the means of transportation to be used.

Furthermore, the transportation type will determine whether the layout should provide facilities for highways, railways and trucks. Ordering, shipping and receiving will vary according to the types of transportation used.

In addition, the need to determine the total space and building size for better arrangement during the receiving and delivery process of parts should be considered too. Location of plants will also be affected by fuel needs. Plant layout should provide a safe fuel storage. Last but not least, the plant layout must consider the needs for power generation and the future expansion of the plant layout.

Let us look at Table 6.3 which summarises the location factors that should be considered when selecting a region, community and site.

Table 6.3: Some Key Factors Commonly Considered in Locating a Plant

Factor	Region	Community	Site
Proximity to good highways	×	×	×
Access to a major airport	×		
Labour supply	×	×	
Nearness to market	×		
Nearness to raw materials	×		
Nearness to an existing plant	×	×	
Suitable land and land costs		×	
Transportation	×	×	
Water supply	×	×	
Power supply	×	×	
Pollution control		×	
Taxes		×	
Climate			
National defence	×		
Community administration and attitude	×	×	
Schools, churches and residential areas		×	
Zoning restrictions		×	×
Space for expansion			×

Source: Amrine, Ritchey, Moodie & Kmec (1993)

Take note that several key factors have a bearing on both the region and the community in which the plant is to be located, while other factors need to be considered either at the regional or community level only.

SELF-CHECK 6.3

1. List several key factors that have a bearing on both the region and the community in which the plant is to be located.
2. State the importance of transportation and proximity to an airport as factors in a plant location analysis.

ACTIVITY 6.1

Discuss in the myINSPIRE forum the location factors that can attract foreign investors to Malaysia.

6.4 LOCATION ANALYSIS TECHNIQUES

Did you know that we can employ a few quantitative techniques for solving location problems? Some of them are:

(a) Factor rating technique;

(b) Centre-of-gravity technique; and

(c) Load-distance technique.

Let us take a look at each technique further in the next subtopics.

6.4.1 Factor Rating Technique

Did you know that **factor rating** is one of the most common techniques used to select location? This is because it analyses a variety of factors that can be easily understood. This rating system consists of **ratings** and the **weights** of various factors as shown in Table 6.4.

Table 6.4: Factor Rating Technique

Factor	Rating (1–100)	Weight	Factor Rating
Energy availability	60	0.3	18
Labour availability	80	0.2	16
Transportation	40	0.2	8
Supplies	90	0.1	9
Taxes and regulations	70	0.1	7
Infrastructure	70	0.1	7
Overall factor rating	–	–	65

A firm can evaluate each site based on the value of various costs and benefits offered by the alternative locations, and multiply this value with the appropriate weight. This number is then added together to get the overall rating factor. Then, the firm can compare it with the alternatives.

ACTIVITY 6.2

A manufacturing organisation has narrowed the possible location for a new plant to three sites. Using experts in real estate, plant operations, marketing and construction, they selected the location factors that would be important for the successful operation of the plant. Then, they scored each site for the factors chosen. The results of their meeting are shown in Table 6.5. Rate each site to compare the location choices. Share your answer for discussion in the myINSPIRE forum.

Table 6.5: Location Factors

Location Factor	Weight	Scores (1–100)		
		Site 1	Site 2	Site 3
Labour pool and climate	0.30	80	65	90
Proximity to suppliers	0.20	100	91	75
Wage rates	0.15	60	95	72
Community environment	0.15	75	80	80
Proximity to customers	0.10	65	90	95
Shipping modes	0.05	85	92	65
Air service	0.05	50	65	90

6.4.2 Centre-of-Gravity Technique

This method is useful for identifying individual location in view of:

(a) The existing location;

(b) The distance between them; and

(c) The number of products that will be shipped.

Normally, firms use this method mainly to locate **distribution warehouses**. To use this technique, companies plot their existing location on the grid with a coordinate system (it does not matter which coordinate system is used). The idea behind this technique is to identify the relative distance between locations. After the current location is placed on the grid, the centre of gravity is determined by calculating the x and y coordinates that have the lowest transportation costs. The following formula is used in this calculation:

The coordinate of the centre of gravity at x

$$C_x = \frac{\sum_i x_i W_i}{\sum_i W_i}$$

The coordinate of the centre of gravity at y

$$C_y = \frac{\sum_i y_i W_i}{\sum_i W_i}$$

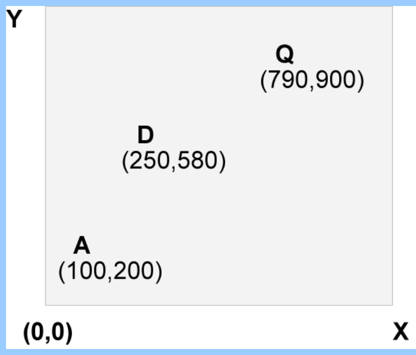
where x_i = x-coordinate of location i

y_i = y-coordinate of location i

W_i = Quantity of goods moved to or from location i

Let us look at Example 6.1 that demonstrates this calculation.

Example 6.1:
Several car showrooms are located according to the following grid as shown in Figure 6.1 which represents coordinate locations for each showroom.



Showroom	No of Z-Mobiles sold per month
A	1,250
D	1,900
Q	2,300

Figure 6.1: Coordinate locations for each showroom

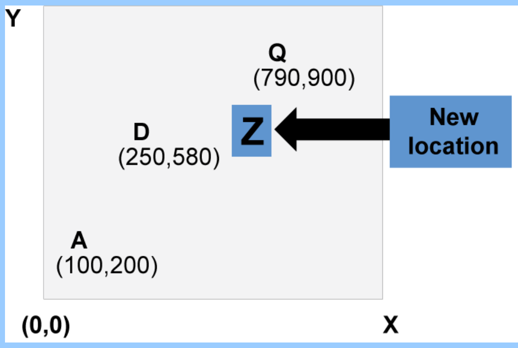
What is the best location for a new Z-Mobile warehouse storage facility considering only distances and quantities sold per month?

Solution:
Compute the new coordinates using the formula.

$$C_x = \frac{100(1{,}250) + 250(1{,}900) + 790(2{,}300)}{1{,}250 + 1{,}900 + 2{,}300} = \frac{2{,}417{,}000}{5{,}450} = 443.49$$

$$C_y = \frac{200(1{,}250) + 580(1{,}900) + 900(2{,}300)}{1{,}250 + 1{,}900 + 2{,}300} = \frac{3{,}422{,}000}{5{,}450} = 627.89$$

New coordinate location for Z-Mobile is shown in Figure 6.2.



Showroom	No of Z-Mobiles sold per month
A	1,250
D	1,900
Q	2,300

Figure 6.2: New coordinate location for Z-Mobile warehouse

ACTIVITY 6.3

An automobile dealership in a large city has four locations spread around the standard metropolitan area where some are as far as 60km apart. Each location has a dealership showroom, maintenance and repair service with parts stockroom, and used and new vehicle lots. The coordinates in kilometres on an x-y grid of each city location are shown below with the number of major parts sold each month as the third coordinate that is, P (10, 20, 30) is x-axis = 10km, y-axis = 20km, and 30 parts are sold per month. What is the best location for a new centralised warehouse?

Site A (20,50,34); Site B (60,40,36); Site C (70,55,56); Site D (90,30,28)

Share your answer for discussion in the myINSPIRE forum.

6.4.3 Load-distance Technique

Did you know that this method is a variation of the centre-of-gravity technique to locate the coordinates of a facility? In this method, a single central site location is not found. However, several different site locations are evaluated for distance and load.

For example, three different locations can be evaluated as possible locations for the optimal location among four different suppliers. A summary of the load-distance method is:

For a single potential location, a load-distance value (LD) is computed as follows:

$$\mathrm{LD} = \sum_{i=1}^{n} l_i d_i$$

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2}$$

where

x, y = Coordinates of the new or proposed facility
x_i, y_i = Coordinates of existing facility
LD = Load-distance value
l_i = Load expressed as weight, number of trips or unit
d_i = Distance between the new and existing facility

Let us look at Example 6.2 that demonstrates this matter.

Example 6.2:
Given the following data, what is the best location based on the load-distance technique?

Proposed sites:

Site 1: $x_1 = 360$, $y_1 = 180$
Site 2: $x_2 = 420$, $y_2 = 450$
Site 3: $x_3 = 250$, $y_3 = 400$

Existing sites:
Site A (200,200); Site B (100,500); Site C (250,600); Site D (500,300)
The total quantity of product to be delivered to Site A is 75, Site B is 105, Site C is 135 and Site D is 60.

Solution:
First, the distances between the proposed sites (1, 2 and 3) and each existing facility (A, B, C and D) are computed using the straight-line formula for d_i:

Site 1:

$$\begin{aligned} d_A &= \sqrt{(x_A - x_1)^2 + (y_A - y_1)^2} \\ &= \sqrt{(200-360)^2 + (200-180)^2} \\ &= 161.2 \end{aligned}$$

$$\begin{aligned} d_B &= \sqrt{(x_B - x_1)^2 + (y_B - y_1)^2} \\ &= \sqrt{(100-360)^2 + (500-180)^2} \\ &= 412.3 \end{aligned}$$

$$\begin{aligned} d_C &= \sqrt{(x_C - x_1)^2 + (y_C - y_1)^2} \\ &= \sqrt{(250-360)^2 + (600-180)^2} \\ &= 434.2 \end{aligned}$$

$$\begin{aligned} d_D &= \sqrt{(x_D - x_1)^2 + (y_D - y_1)^2} \\ &= \sqrt{(500-360)^2 + (300-180)^2} \\ &= 184.4 \end{aligned}$$

Site 2: $d_A = 333,\ d_B = 323.9,\ d_C = 226.7,\ d_D = 170$

Site 3: $d_A = 206.2,\ d_B = 180.3,\ d_C = 200,\ d_D = 269.3$

Next, the formula for load distance is computed for each proposed site:

$$\text{LD}(\text{site}\,1) = \sum_{i=1}^{n} l_i d_i$$

$$= (75)(161.2) + (105)(412.3) + (135)(434.2) + (60)(184.4) = 125{,}063$$

$$\text{LD}(\text{site}\,2) = (75)(333) + (105)(323.9) + (135)(226.7) + (60)(170) = 99{,}789$$

$$\text{LD}(\text{site}\,3) = (75)(206.2) + (105)(180.3) + (135)(200) + (60)(269.3) = 77{,}555$$

Since Site 3 has the lowest load-distance value, it would be assumed that this location would also minimise transportation costs.

SELF-CHECK 6.4

Explain briefly the three quantitative techniques used for solving location problems.

ACTIVITY 6.4

1. XYZ Co. has just signed a contract to deliver products to three locations and they are trying to decide where to put their new warehouse. The three delivery locations are Chicago, Kansas City and Memphis. The two potential sites for the warehouse are Peoria and St Louis. The x, y coordinates for the delivery locations and warehouses are as follows (see Table 6.6).

   Table 6.6: Delivery Locations and Potential Sites for the Warehouse Coordinates

Location		x-coordinate	y-coordinate
Delivery	Chicago	92	42
	Kansas City	85	39
	Memphis	90	35
Potential site	Peoria	90	41
	St. Louis	90	39

   The total quantity to be delivered to each destination is 400 to Chicago, 150 to Kansas City and 100 to Memphis. Calculate the total load-distance value from each potential warehouse location.

2. Analyse the type of industry that is preferred in your community area.

Share your answers for discussion in the myINSPIRE forum.

6.5 CONCEPTS OF PLANT LAYOUT

Production facilities and employees are placed within the plant facilities. Therefore, a good layout plant can ensure smooth and rapid material movement, from the raw materials to the final product stage. The plant layout includes new layout as well as improving the existing layout. What is a layout?

> A **layout** can be described as a **documentation of the complex results** of many months of **data collection** and **analysis**.

In other words, the layout is the **visual presentation** of the data collection and analysis and a combination of both factors that can lead to less than desirable outcomes. How about plant layout? What does it stand for?

> **Plant layout** can be defined as a method for **locating equipment, processes and plant services** in the factory to achieve the **right quantity and quality of the product** at the **lowest possible cost of manufacturing**.

Plant layout involves innovative arrangement of production facilities that has a direct workflow.

6.6 IMPORTANCE OF PLANT LAYOUT

Firstly, plant layout is an important activity because it has a **long-term commitment**. An ideal plant layout should demonstrate an optimum relationship between output, floor area and manufacturing processes. It also allows operation flexibility and smooth flow of production by using the building economically and promoting effective utilisation of work force to provide work comfort for workers, optimum exposure to natural ventilation and sunlight.

In general, a good plant layout:

(a) Facilitates the production process, minimising time, cost and material handling; and

(b) Reduces costs of operation and can play an important role in achieving plant objectives.

Specifically, a good plant layout will:

(a) Ensure proper and efficient use of floor space;

(b) Ensure that the work from one point to another proceeds without any delay;

(c) Provide sufficient production capacity;

(d) Reduce the cost of material handling;

(e) Reduce hazards to employees;

(f) Ensure the efficient use of workers;

(g) Improve staff morale;

(h) Reduce accidents;

(i) Provide product and volume flexibility;

(j) Provide good supervision and control;

(k) Provide safety and health to workers;

(l) Allow easy maintenance;

(m) Allow high equipment utilisation;

(n) Increase productivity; and

(o) Reduce the number of workers.

ACTIVITY 6.5

Go to a hypermarket in your location and observe the building both inside and outside. Do you think plant layout went into the design of the building? Discuss in the myINSPIRE forum this matter as well as the functionality of the building for the purpose intended.

6.7 TYPES OF PLANT LAYOUT

There are many types of layout available. Some of the most popular layouts are shown in Figure 6.3.

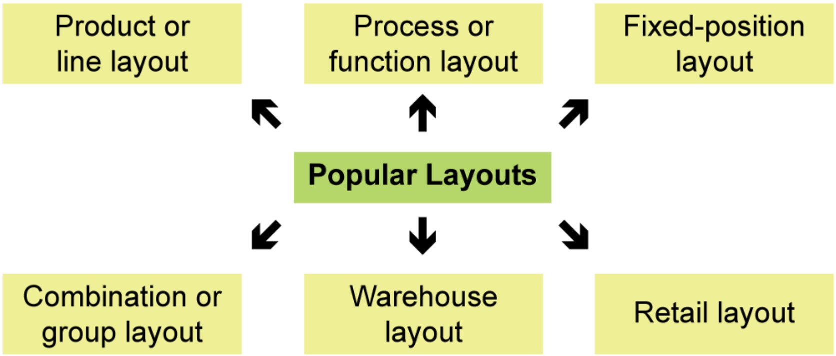


Figure 6.3: Six most popular layouts

These six layouts are further explained in the next subtopics.

6.7.1 Product or Line Layout

In this layout, machines are arranged in a **row** depending on the sequence of operations required. Materials are moved sequentially from one workstation to another without any backtracking. Machines are gathered in a sequence where materials are fed into the first machine and finished goods are produced at the end of production line.

For example, in paper mills, bamboos are inserted into the machine at one end and paper comes out at the other end. The raw material moves very quickly from one workstation to another workstation with minimum work-in-progress (WIP) storage and material handling.

A product or line layout for two products is given in Figure 6.4.

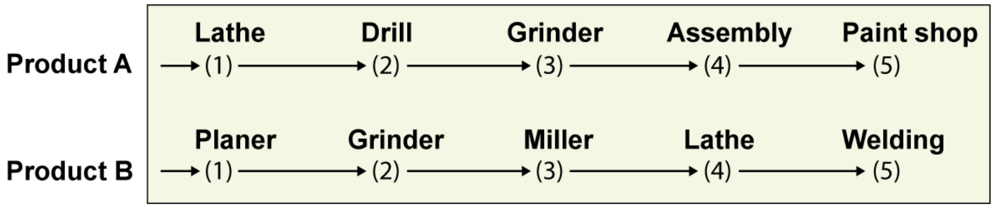


Figure 6.4: A product or line layout

6.7.2 Process or Function Layout

In this layout, similar machines are **arranged or grouped together** in one place. For example, machines performing milling are arranged in the milling section and machines performing drilling are arranged in the drilling section.

Therefore, the machines are installed in plants following its **functionality**. Move material through the plant as far as possible to reduce inventory carrying cost. Such a layout often has a milling section, drilling section, casting section, welding section, painting section and so on.

In fact, if we examine process layout from the historical perspective, it has evolved from the handicraft methods. The work is allocated to each section to ensure that no machine is selected to do a different job. The work that has to be done is allocated to the machine as per the loading schedule to ensure that each machine is fully loaded. A typical process layout is shown in Figure 6.5.

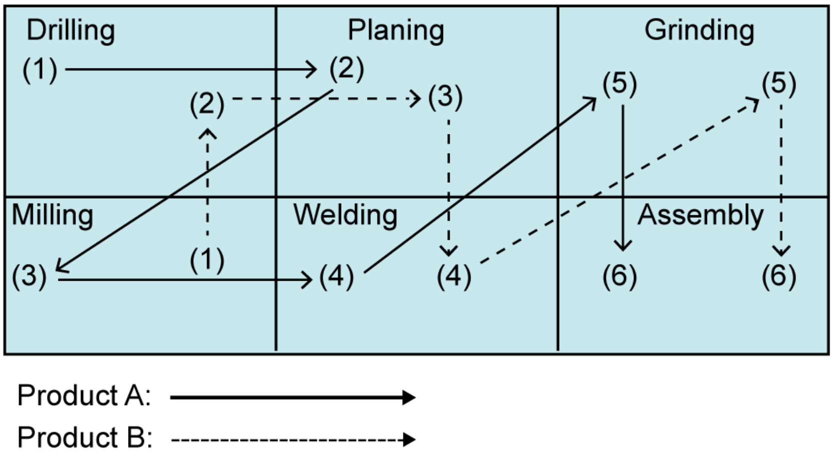


Figure 6.5: A typical process or function layout

6.7.3 Fixed-position Layout

In this layout, the product or item being worked on remains stationary while workers, materials and equipment are moved about as needed. For example, ships are not produced on an assembly line. In this strategy, the attention is focused on **timing of material and equipment deliveries** to not clog up the work site and to avoid having to relocate materials and equipment around the work site. Lack of storage space can present a significant problem in this strategy.

How do we handle this issue? In order to handle this issue, an alternative approach is to complete as much of the project as possible off-site. Figure 6.6 shows the fixed-position layout.

Figure 6.6: Fixed-position layout

6.7.4 Combination or Group Layout

Some production units may require a combination of three major layouts namely:

(a) Product;

(b) Process; and

(c) Fixed-position.

This solution is commonly called a **combination or group layout**. For example, a firm can use the layout for most processes along with an assembly in one area.

Alternatively, a firm can use a fixed-position layout for the assembly of its final product but use product or function layout to produce components and sub-assemblies that make the final product (such as an automobile and an aircraft).

6.7.5 Warehouse Layout

Did you know that the main objective of warehouse layout is to find the optimal trade-off between material handling costs and costs associated with space of the warehouse? In other words, this means to **maximise the utilisation of the total warehouse "cube" space**, that had fully utilised the warehouse volume and at the same time maintain lower material handling costs. In fact, a good warehouse layout reduces damage and pilferage of materials.

Another important factor in warehouse layout is **order frequency**. Items often ordered are placed next to each other near the entrance facilities, while those ordered less often are placed in the rear part of the facility.

Pareto analysis is a very good method to determine which items to place near the entrance. According to the Pareto principle, 20 per cent of the items typically represent 80 per cent of the items ordered and it is easy to determine the 20 per cent items to place in the most convenient location. With this arrangement, picking an order is made more efficient.

6.7.6 Retail Layout

Lastly, let us look at the retail layout. A retail layout provides **shelf space** and responds to **customers' behaviour**. Sales and profitability vary directly with customer exposure to the product range. Studies show that greater exposure rates result in higher sales and greater return-on-investment (ROI). A complete arrangement of a retail store and the allocation of space to various products within the arrangement are called **retail layout strategies**.

What is the main objective of retail layout? The main objective of retail layout is to **maximise profit per square feet of floor space**.

SELF-CHECK 6.5

State the six most popular plant layouts.

ACTIVITY 6.6

Based on your experience, have you ever come across plant location and layout activities? If yes, discuss the benefits of these activities in the myINSPIRE forum.

SUMMARY

- A good plant location plays an important role in the production of goods and services.
- The location of plant facilities or services is a permanent fixture and involves a considerable expenditure.
- The three main issues in choosing a location are selection of the region, selection of places and selection of sites.
- The placement of plants should be completed in two stages – selection of general area and selection of communities and plant site.
- A "rule of thumb" about the size of the site is that it must not be less than five times the actual size of the plant.

- The location of plants determines the closeness of the plants to the source of raw materials and markets.

- Several key factors have a bearing on both the region and the community in which the plant is to be located. Some of the key factors are labour supply, water supply, power supply, taxes and climate.

- A few quantitative techniques for solving location problems are the factor rating, centre-of-gravity and load-distance techniques.

- A plant with a good layout can ensure a smooth and rapid material movement, from the stage of raw materials to the final product.

- Plant layout can be defined as a method for locating equipment, processes and plant services in the factory to achieve the right quantity and quality of the product at the lowest possible cost of manufacturing.

- An ideal plant layout should demonstrate an optimum relationship between output, floor area and manufacturing processes. It also allows operation flexibility and the smooth flow of production by using the building economically and promoting effective utilisation of workforce to provide work comfort for workers, optimum exposure to natural ventilation and sunlight.

- The most popular layouts are product or line layout, process or function layout, fixed-position layout, combination or group layout, warehouse layout and retail layout.

KEY TERMS

Centre-of-gravity technique

Combination or group layout

Factor rating technique

Fixed position layout

Load-distance technique

Location analysis

Plant layout

Plant location

Process or function layout

Product or line layout

Retail layout

Warehouse layout

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Topic 7 ▶ Material Handling

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. State the meaning, objectives and principles of material handling;
2. Identify the types of material handling equipment as well as the factors affecting the selection of material handling equipment;
3. Describe material handling costs;
4. Identify the relationship between material handling, flow of material and plant layout;
5. Explain storage and packaging in material handling; and
6. Discuss the organisation for effective material handling.

▶ INTRODUCTION

It is necessary for materials to move from one station to another in a typical manufacturing environment. The movement of materials from other areas of processing and from one department to another requires the use of many personnel and equipment and the handling of a large amount of materials. Improvements in material handling have positive effects on workers in terms of work design and ergonomics.

Therefore in this topic, we will discuss material handling in the context of manufacturing. We will start by looking at the definitions and objectives of material handling. Next, we will learn the principles of handling materials, types of material handling equipment and factors affecting the selection of material handling equipment. We will also learn accounting for material handling costs and the relation of material handling to the flow of material and plant layout.

Finally, we will discuss storage and packaging in material handling as well as organisation for effective material handling. Happy reading!

7.1 WHAT IS MATERIAL HANDLING?

Before we go further, let us learn the definitions, objectives and principles of material handling in manufacturing as the introduction to material handling.

7.1.1 Definitions of Material Handling

Generally, material handling is about **loading**, **moving** and **unloading materials**. In order to perform this process safely and economically, various types of gadgets and equipment are used. This is also referred to as the **mechanical handling** of materials. In fact, we have been moving materials mechanically since primitive men discovered the use of wheels and levers. All activities that involve humans and materials require material handling.

Now, the term "material handling" is used with reference to industrial activities in the fields of engineering and technology. In any industry, when it involves manufacturing or any type of work, materials should be treated as **raw materials**, **intermediate goods** or **finished products**, regardless of their size. Material handling started from the stage of receiving and storage of raw materials through production processes until the stage of finished goods storage and delivering.

Based on the optimum design requirements and specific application to the type of industry, material handling can be as varied as the industry itself. Due to these factors, there is no universally accepted definition for material handling. One definition by the American Society of Material Handling is (Stephens, 2019):

Material handling is the art and science involving the **moving, packaging** and **storing** of **substances in any form**.

According to Ray (2007), these are some of the other definitions of material handling such as:

(a) Material handling is the movement and storage of materials at the lowest cost possible through the use of effective methods and equipment.

(b) Material handling is the moving of materials or product by any way, which includes storage and all movements except processing operations and inspection.

(c) Material handling is the art and science of elevating, conveying, positioning, transporting and storing of materials.

7.1.2 Objectives of Material Handling

Did you know that the main objective of material handling systems is to **reduce the unit cost of production**? Other objectives of material handling are to:

(a) Reduce the manufacturing cycle time;

(b) Promote better control of the flow of goods;

(c) Reduce delays and damage;

(d) Promote safety and improved working conditions;

(e) Maintain or improve product quality;

(f) Promote productivity;

(g) Encourage the increased use of facilities;

(h) Reduce the tare weight;

(i) Ensure inventory control;

(j) Reduce warehousing and inventory costs; and

(k) Reduce processing costs.

7.1.3 Principles of Material Handling

Generally, the principles of material handling involve implementing movement of materials safely and economically. In reviewing the principles, we will find that almost all apply to some aspects of material handling and assist in achieving one or more objectives. Now, let us observe the specific principles of material handling in Table 7.1.

Table 7.1: The Principles of Material Handling

Principle	Description
Planning principle	Material handling projects on a large scale usually require a team approach. Planning considers material handling in every step, every storage requirement and any delay to reduce production costs. This plan should reflect the organisation's strategic objectives and immediate needs.
Systems principle	Material handling and storage activities should be fully integrated to form a streamlined operating system that spans receiving, inspection, storage, production, assembly, shipping and handling returns. Furthermore, the flow of information and physical material should be integrated and treated as simultaneous activities. Finally yet importantly, methods should be provided for easy identification of materials and products, to determine the location and status in the facility and the supply chain.
Simplification principle	This principle focuses on the simplification of handling by reducing, eliminating or combining unnecessary movements and/or equipment. The following are four questions to be asked to simplify the work: (i) Can this job be eliminated? (ii) If it cannot be eliminated, can the movements be combined to reduce cost? (Concept of unit load) (iii) If the movements cannot be eliminated or merged, can these be restructured to reduce the distance travelled? (iv) If none of these can be done, can the movements be simplified?
Gravity principle	Uses the concept of gravity to move materials whenever possible.
Space utilisation principle	Utilises the building in "cube" form, so that less space is needed to purchase or lease/rent. The use of racks, mezzanines and overhead conveyors are a few examples.

Unit load principle	At each stage of the supply chain, unit loads should be properly sized and configured. A common unit load is the use of pallets, such as: (i) Cardboard pallets; (ii) Plastic pallets; (iii) Wooden pallets; and (iv) Steel skids.
Automation principle	Material handling operations should be automated wherever and whenever possible to improve efficiency, responsiveness, consistency and predictability while reducing costs, that is auxiliary and automated storage/retrievable systems (ASRS).
Equipment selection principle	Applies the 5W1H technique (Why? What? Where? When? Who? How?). For each move, if we ask and answer these questions, the solution will become apparent.
Standardisation principle	Promotes the selection of standardised handling methods as well as handling equipment types and sizes. If there are too many sizes and types of equipment. This will result in higher operational cost. To simplify the storage, fewer sizes of cartons will do.
Dead-weight principle	Reduces the ratio of equipment weight with respect to product weight. Do not acquire equipment that is bigger than required. Reduce tare weight and save costs.
Maintenance principle	Has a systematic preventive and scheduled maintenance plan for all handling equipment. Do not be surprised that pallets and storage facilities need repair too.
Life cycle cost (LCC) principle	Analyses the cost of equipment or systems over its life span. A detailed economic analysis should be planned for the entire life cycle of all material handling equipment and systems.
Capacity principle	Achieves the targeted production capacity by using handling equipment. For example, material handling equipment can be employed to maximise production equipment utilisation.

SELF-CHECK 7.1

1. Give two definitions of material handling.
2. State the main objective of material handling.
3. Describe any five principles of material handling.

ACTIVITY 7.1

Discuss in the myINSPIRE forum:

(a) Look around your workplace. Can you see any material handling gadgets or equipment? If yes, then briefly describe their usefulness.

(b) Let us say you are a manufacturing manager in a manufacturing industry. Identify what are the material handling objectives you would think of? Which are the most important/critical principles of material handling?

7.2 TYPES OF MATERIAL HANDLING EQUIPMENT

According to Tompkins, White, Bozer and Tanchoco (2010), there are five major classifications of material handling equipment (see Figure 7.1).

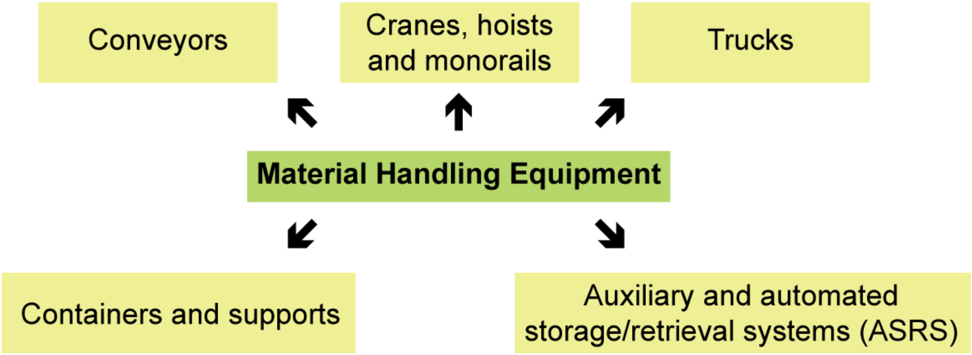

Figure 7.1: Five major types of material handling equipment
Source: Tompkins, White, Bozer & Tanchoco (2010)

Let us look at Table 7.2, which shows you some examples of material handling equipment used in the industry.

Table 7.2: Examples of Material Handling Equipment

Type	Example
Conveyor	 **Source:** http://www.hoj.net/
Crane	 **Source:** http://www.agcranes.com

Hoist	 **Source:** http://www.directindustry.com
Monorail	 **Source:** http://www.eisenmann.com

Truck	 **Source:** www3.allaroundphilly.com
Auxiliary and automated storage/ retrieval systems (ASRS)	 **Source:** http://www.mjoshua.com

7.2.1 Factors Affecting the Selection of Material Handling Equipment

Material handling equipment selection is needed to achieve a balance between the problems of production, existing equipment capabilities and human elements that are involved. As stated before, the main objective of material handling is to reach the **lowest cost per unit**.

Therefore, we may consider the following factors in the selection of material handling equipment (see Table 7.3).

Table 7.3: Factors in the Selection of Material Handling Equipment

Factor	Description
Adaptability	Load carried and the characteristics of the equipment movement must fit the material handling problem.
Flexibility	The equipment should have the flexibility to handle more than one material; either the class or size.
Load capacity	The selected equipment should have substantial load-carrying characteristics to perform the duties effectively but need not be too large and incur excessive operating costs.
Power	Power is sufficient to do the job.
Speed	Movement speed of materials rapidity, within the limits of the production process or plant safety should be considered.
Space requirement	During the selection process, the space required to install or operate the material handling equipment is an important factor.
Supervision required	This refers to the degree of automaticity planned into the equipment.
Ease of maintenance	The selected equipment should be easily maintained at a reasonable cost.
Environment	The selected equipment should comply with environmental regulations.
Cost	The cost of equipment is an important factor in the selection.

SELF-CHECK 7.2

1. List the types of material handling equipment used in the manufacturing industry.
2. Explain any four factors affecting the selection of material handling equipment.

ACTIVITY 7.2

Based on Question (b) in Activity 7.1, list the types of material handling equipment that can be found in your plant. What are the factors affecting the selection of material handling equipment in your plant? Discuss your answer in the myINSPIRE forum.

7.3 ACCOUNTING FOR MATERIAL HANDLING COSTS

There are two sources of material handling costs. These two sources are:

(a) Cost of equipment; and

(b) Maintenance and operational costs of the system.

Normal accounting practice classifies material handling costs either as **indirect costs** or **overheads**. This classification is based on the movement of materials that does not contribute to their physical changes or adds value to them as a product or as a component part.

In some manufacturing situations, such as in a carbon black plant in which materials are constantly moving during the production process, this cost argument may be challenged. However, the problem of classification of unit handling costs in most situations is more academic than practical in nature.

SELF-CHECK 7.3

What are the two sources of material handling costs?

ACTIVITY 7.3

Discuss in the myINSPIRE forum the importance of cost factor in material handling.

7.4 RELATIONSHIP OF MATERIAL HANDLING TO FLOW OF MATERIAL AND PLANT LAYOUT

Material flow patterns in plants will have a material impact on operating costs. The production process must be designed such that machines and benches are organised to reduce material handling to a minimum with as little backtracking of goods as possible. In this respect, the **types of manufacturing or operations** are an important factor to consider.

Therefore, the flow of pattern needs to be planned in advance for a continuous manufacturing process. The reasons of this are to:

(a) Ensure a well-balanced machine and assembly line;

(b) Ensure a well-planned flow of component parts, sub-assemblies and assemblies;

(c) Obtain and install the best equipment for work if it is possible to grow the operation in advance; and

(d) Design for a minimum material handling cost.

However, after installation, this plan does not have much flexibility and costs a lot for any changes to be made.

SELF-CHECK 7.4

Why do we need to plan in advance the material flow patterns in a plant?

ACTIVITY 7.4

Based on your experience, can you relate how material handling system or equipment will affect the overall plant layout? Post your answer for discussion on the myINSPIRE forum.

7.5 STORAGE

Materials are to be considered in stationary or idle form in the storage area. On the other hand, using **conveyors** as a storage area is becoming very popular. This form of storage device (conveyor or crane) may be located overhead and continuously move, utilising the ceiling-space storage. An example of such a system is shown in Figure 7.2.

Figure 7.2: An overhead conveyor system
Source: http://www.amber-industries.ltd.uk

7.6 PACKAGING

The phase of packaging operation of materials is to some degree an academic question. Furthermore, the unit load itself can be considered as a "package". However, the term "packaging" generally refers to the **final product packaging for shipment**, especially if the product involved is consumer goods.

Incoming material packaging as well as outgoing material or product packaging will directly affect the material handling systems/methods and the related material handling costs. The package design of a product is closely inter-related with:

(a) Material-handling systems;

(b) Production methods; and

(c) Marketing.

In addition, well-packaged goods on store shelves and counters as well as identification of shipments via trucks and railroad cars are effective advertisements and sales promotion of the product.

ACTIVITY 7.5

Discuss in the myINSPIRE forum the importance of storage and packaging in the final selection of material handling equipment.

7.7 ORGANISATION FOR EFFECTIVE MATERIAL HANDLING

The manufacturing team members (from the top management down to the ordinary workers) are responsible to ensure that good material handling is practised at the manufacturing area, storage and warehouse area and others. This can be achieved if every member of the organisation plays his or her role in the material handling procedure effectively. A good **education** and **training** on material handling is a must for related personnel to work effectively and keep the material handling costs as low as possible. Figure 7.3 shows you a typical layout where various elements of the manufacturing, storage and material handling systems interact.

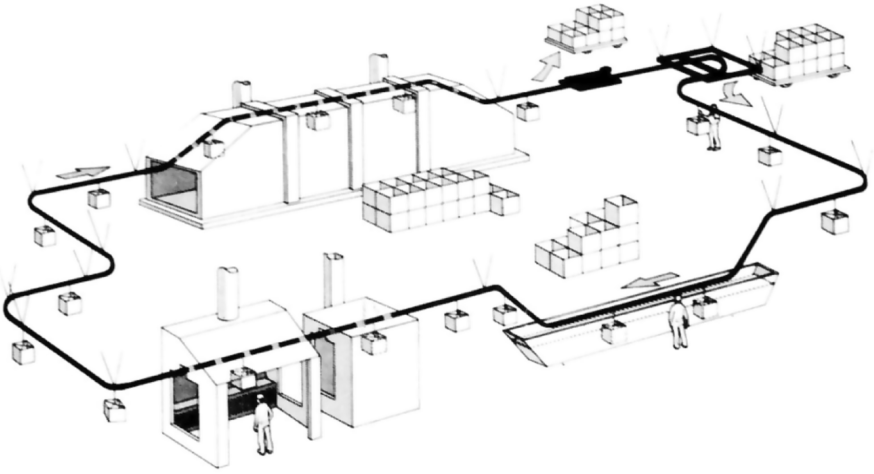

Figure 7.3: Interaction of various elements in a manufacturing environment
Source: http://www.castorandladder.co.za

Therefore, staff responsibilities for effective material handling might include the following:

(a) Ensure all new methods for handling new materials or products are used and select the appropriate or best equipment and tools;

(b) Research on material handling methods, systems, tools and equipment;

(c) Plan and implement relevant education and training programmes for all employees involved in material handling;

(d) Set up cost control of current material handling by cost analysis and compare it with the budget;

(e) Plan and implement continuous material handling cost reduction/improvement using Deming's PDCA (plan, do, check and act) concept;

(f) Establish a good measurement system for material handling effectiveness using the annual performance appraisal of the key performance indicators or KPI as a yardstick; and

(g) Establish a good preventive and predictive maintenance programme for all material handling systems and equipment.

SELF-CHECK 7.5

Explain the responsibilities of manufacturing team members in ensuring good material handling is practised at the workplace.

SUMMARY

- It is necessary for materials to move from one station to another in a typical manufacturing environment.

- Material handling is the art and science involved in the moving, packaging and storing of substances in any form. In other words, it is about loading, moving and unloading materials.

- The main objective of material handling systems is to reduce the unit cost of production.

- The principles of material handling focus on moving materials economically and safely.

- There are five types of material handling equipment namely conveyors, cranes, hoists and monorails, trucks, containers and supports, and auxiliary and automated storage/retrieval systems (ASRS).

- The selection of material handling equipment needs to achieve a proper balance between the problems of production and existing equipment capabilities and human elements. Some factors in the selection of material handling equipment are adaptability, flexibility, speed and cost.

- Material handling costs arise from two sources – the cost of owning the equipment as well as the maintenance and operational costs of the system.

- Material flow patterns in plants have a material impact on operating costs. The production process must be designed whereby machines and benches are organised in order to reduce material handling to a minimum with as little backtracking of goods as possible.

- Using conveyors as a storage area is becoming very popular. This form of storage devices (conveyors or cranes) may be overhead and continuously move, utilising the ceiling-space storage.

- Incoming and outgoing material or product packaging directly affect the material handling systems and the related material handling costs.

- The manufacturing team members (from the top management down to the ordinary workers) are responsible for ensuring that good material handling is practised at the manufacturing area, storage and warehouse areas and other areas. Therefore, the manufacturing team needs to ensure that good material handling is practised in the plant.

KEY TERMS

Automated storage/retrieval systems (ASRS)

Containers and supports

Conveyors

Costs

Cranes

Flow of material

Hoists

Material handling

Mechanical handling

Monorails

Packaging

Plant layout

Storage

Trucks

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Topic 8 ▶ Ergonomics

LEARNING OUTCOMES

By the end of the topic, you should be able to:

1. Define ergonomics;
2. Describe the goals, objectives and benefits of ergonomics;
3. Discuss the core of ergonomics knowledge; and
4. Apply the design principles of ergonomics in your workplace.

INTRODUCTION

Did you know that ergonomics is a rapidly growing field? Much of ergonomics is basic common sense and we practise ergonomics daily without even thinking or knowing about it. For example, when we get into the driver seat of a car, we usually adjust the rear and side mirrors, the seat and steering wheel to our comfort (see Figure 8.1).

Figure 8.1: Adjusting rear mirror is basic common sense that reflects ergonomics

Using the same principles, our workplace must be adjustable to meet our individual needs. Generally, **ergonomics** is considered a multidisciplinary field of science that examines **human physical** and **psychological capabilities and limitations**.

Therefore in this last topic, we will learn the definition of ergonomics, the goals, objectives and benefits of ergonomics and the core of ergonomics knowledge. Finally, at the end of this topic, we will look at the application of ergonomics and its design principles. So are you ready to discover more? Let us continue with the lesson!

8.1 DEFINITION OF ERGONOMICS

What is ergonomics? The term "ergonomics" is derived from the following two Greek words:

(a) *Ergon* – Means work; and

(b) *Nomos* – Means natural laws or the science of work and a person's relationship to that work.

Next is the technical definition of ergonomics by the International Ergonomics Association (IEA) (2020):

> "**Ergonomics (or human factors)** is the scientific discipline concerned with the understanding of **interactions** among **humans** and **other elements of a system**, and the profession that applies **theory**, **principles**, **data** and **methods to design** in order to **optimise human well-being** and **overall system performance**."

In plain terms, ergonomics make things **comfortable** and **efficient**.

SELF-CHECK 8.1

Define ergonomics.

ACTIVITY 8.1

Look around you and identify various systems and elements that are ergonomics in our daily life. Post your answer for discussion on the myINSPIRE forum.

8.2 THE GOALS OF ERGONOMICS

Generally, ergonomics is be used to design and modify the workplace, equipment, products or work procedures so that these can improve human performance and reduce the likelihood of injuries and illnesses.

In the industry, the goal of ergonomics is to create a safe, efficient, satisfying and even enjoyable working environment.

Specifically, there are three fundamental goals of ergonomics as explained in Table 8.1.

Table 8.1: Three Fundamental Goals of Ergonomics

Goal	Description
Tolerable working conditions	Working conditions must not be hazardous to human health.
Acceptable working conditions	Working conditions in which the people involved agree on, according to the current scientific knowledge and given sociological, technological and organisational circumstances.
Optimal working conditions	Working conditions that are designed to be well-adapted to human characteristics. Capabilities and desires of physical, mental and social well-being are achievable by the majority of people.

SELF-CHECK 8.2

Explain the following goals of ergonomics:

(a) Tolerable working conditions;

(b) Acceptable working conditions; and

(c) Optimal working conditions.

ACTIVITY 8.2

In your working place, which of these three goals in Table 8.1 has the highest priority? Justify your answer with relevant examples. Discuss your answer in the myINSPIRE forum.

8.3 OBJECTIVES AND BENEFITS OF ERGONOMICS

What are the objectives and benefits of ergonomics? Generally, the following are the objectives and benefits of ergonomics:

(a) Reducing occupational injuries and illnesses;

(b) Decreasing disability costs for workers;

(c) Increasing productivity;

(d) Improving the quality of work;

(e) Lowering absenteeism;

(f) Applying existing rules; and

(g) Decreasing the loss of raw material.

Now, what are the methods of obtaining the objectives and benefits of ergonomics? The methods of obtaining the objectives and benefits of ergonomics are:

(a) Analysis and appreciation of risks in the workplace;

(b) Identification and quantification of risk conditions in the workplace;

(c) Recommendation of engineering and administrative controls to reduce risk conditions that are identified; and

(d) Awareness and education to supervisors and workers about the hazardous conditions at the workplace and implement workplace safety.

SELF-CHECK 8.3

1. Describe the objectives and benefits of ergonomics.
2. Explain the methods to obtain the objectives and benefits of ergonomics.

ACTIVITY 8.3

Can you relate the objectives and benefits of ergonomics to your own experience? Focus your answer on safety, health, job satisfaction and personal development. Share your answer for discussion in the myINSPIRE forum.

8.4 CORE OF ERGONOMICS KNOWLEDGE

Did you know that ergonomics knowledge covers four areas of applied sciences? What are they? Let us find out the answer in Figure 8.2.

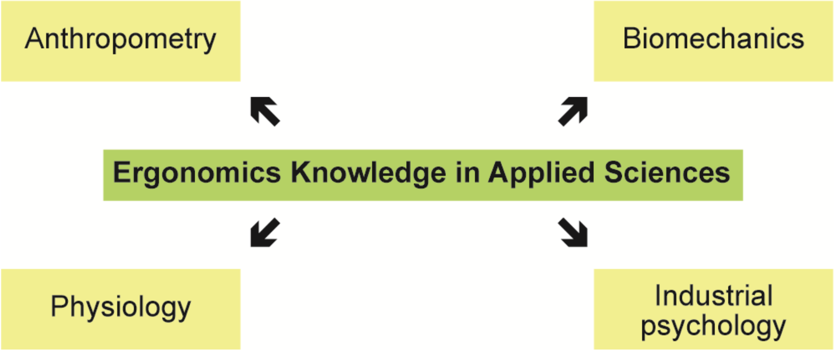


Figure 8.2: Four areas of applied sciences in ergonomics knowledge

These four areas are further explained as follows:

(a) **Anthropometry**

What is anthropometry?

> **Anthropometry** is the study of the **dimensions** and **abilities** of the **human body**.

When designing systems for people, we have to consider their **measurements** and **use averages** since everyone is different. For instance, males have different overall measurements than females. Due to this, we need two sets of data. This science of measurement is called **anthropometry**.

There are three types of data measurement for anthropometry namely:

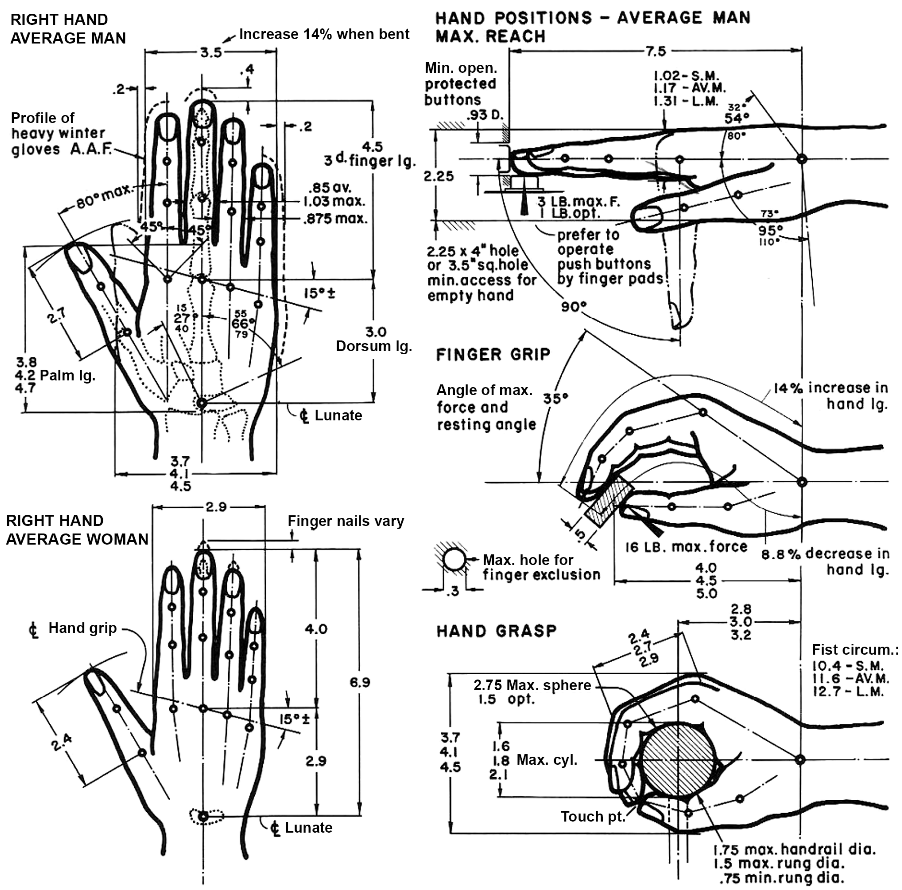
(a) Design for average;

(b) Design for extreme; and

(c) Design for range.

Figure 8.3 shows a typical example measurement data in anthropometry.

HAND MEASUREMENTS OF MEN, WOMEN AND CHILDREN



HAND DATA	MEN			WOMEN			CHILDREN			
	2.5%tile	50.%tile	97.5%tile	2.5%tile	50.%tile	97.5%tile	6 yr.	8 yr.	11 yr.	14 yr.
Hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
Hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.3	2.5	2.8	—
$3^{d.}$ finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
Dorsum lg.	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
Thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

Figure 8.3: Anthropometry measurement data
Source: http://soni2006.hubpages.com

(b) **Biomechanics**

What is biomechanics?

Biomechanics is the science concerned with **internal and external forces** acting on the **human body** and the **effects** produced by these forces.

Another branch of biomechanics is called **kinematics**. What does it stand for?

Kinematics is about the **study of movement** with reference to the amount of **time taken to carry out the activity**.

Can you think of examples of biomechanics? The examples of biomechanics are walking, running and stepping.

(c) **Physiology**

Let us imagine the human body as an automobile in order to understand human physiology. In this respect, muscles are comparable to cylinders and pistons, while bones and joints correspond to gears and drive shafts. The muscles oxidise nutrients (fuel) to produce energy and generate metabolic by-products (waste). Physiology studies this **energy conversion process**. In addition, it can reduce fatigue and improve worker's stamina.

(d) **Industrial Psychology**

What is industrial psychology?

Industrial psychology is a branch of applied psychology that studies the **attitudes of employees and employers**, **organisational behaviour**, **workplace environment** and their **effects**.

SELF-CHECK 8.4

Define the following:

(a) Anthropometry;

(b) Biomechanics;

(c) Physiology; and

(d) Industrial psychology.

ACTIVITY 8.4

Do you think the study of anthropometry is important in a manufacturing environment? Discuss this matter in the myINSPIRE forum.

8.5 ERGONOMICS APPLICATION AND DESIGN PRINCIPLES

Finally yet importantly, let us learn about the application of ergonomics and its design principles. We have learnt that the field of ergonomics focuses on the interaction between job demands and employee capabilities. The goal is to optimise productivity and ensure the safety and health of workers.

What are the applications of ergonomics? Ergonomics is applied in the following situations:

(a) Design of workstation;

(b) Works that involve repetitive hand-and-wrist movements;

(c) Selection of hand tools and their use; and

(d) Materials lifting, lowering and carrying.

Ergonomics design principles can assist employers in reducing the risk of **work-related musculoskeletal disorders (MSD)**. In addition, these principles also offer innovative ideas for correcting existing problems and preventing other problems when new production processes or operations are planned.

Proactive ergonomics emphasises on these principles in the early design stage to develop work processes and job tasks, thereby preventing difficulties in finding retrofit solutions and any economics and human costs associated with the after-the-fact approach. Figure 8.4 shows an example of an ideal set-up for workstation ergonomics.

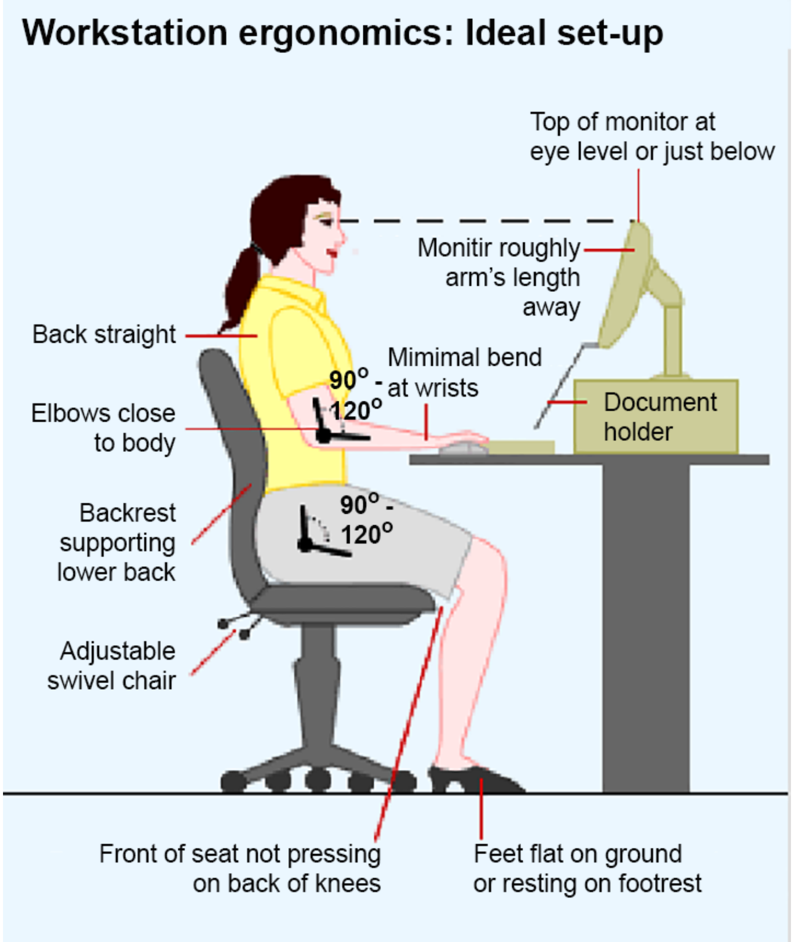


Figure 8.4: Workstation ergonomics: An ideal set-up
Source: http://soni2006.hubpages.com

The following subtopics will discuss the application of the design principles in various situations.

8.5.1 General Workstation Design Principles

The goal of human factors is to design systems that reduce human error, increase productivity and comfort. Therefore, workstation design can help improve the fit between humans, machine and environment. The following are general workstation design principles adapted from the design checklists developed by Dave Ridyard (Cohen, Gjessing, Fine, Bernard & McGlothlin, 1997).

1. Make the workstation adjustable, enabling both large and small persons to fit comfortably and reach materials easily.

2. Locate all materials and tools in front of the worker to reduce twisting motions. Provide sufficient workspace for the whole body to turn.

3. Avoid static loads, fixed work postures and job requirements in which operators must use frequently or for long periods:

   (a) Lean to the front or the side;

   (b) Hold a limb in a bent or extended position;

   (c) Tilt the head forward more than 15 degrees; or

   (d) Support the bodyweight with one leg.

4. Set the work surface above elbow height for tasks involving fine visual details and below elbow height for tasks requiring downward forces and heavy physical effort.

5. Provide adjustable, properly designed chairs with the following features:

   (a) Adjustable seat height;

   (b) Adjustable up-and-down backrest, including a lumbar (lower back) support;

   (c) Padding that will not compress more than an inch (about 2.5cm) under the weight of a seated individual; and a

   (d) A chair that is stable on the floor at all times (five-leg base).

6. Allow the workers, at their discretion, to alternate between sitting and standing. Provide floor mats or padded surfaces for prolonged standing.

7. Support the limbs. Provide elbow, wrist, arm, foot and backrest as needed and where feasible.

8. Use gravity to move materials.

9. Design the workstation so that arm movements are continuous and curved. Avoid straight-line and jerking arm motions.

10. Design so that arm movements pivot about the elbow rather than around the shoulder to avoid stress on shoulder, neck and upper back.

11. Design the primary work area so that arm movements or extensions of more than 38cm or 15 inches are minimised.

12. Provide dials and displays that are simple, logical and easy to read, reach and operate.

13. Eliminate or minimise the effects of undesirable environmental conditions such as excessive noise, heat, humidity, cold and poor illumination.

*Adapted from design checklists developed by Dave Ridyard, CPE, CIH, CSP. Applied Ergonomics Technology, 270 Mather Road, Jenkintown, PA 19046–3129.

8.5.2 Hand Tool Use and Selection Principles

Now, let us look at the hand tool use and selection principles adapted from the design checklists developed by Dave Ridyard (Cohen, Gjessing, Fine, Bernard & McGlothlin, 1997).

1. Reduce the number of repetitions per shift. Where possible, substitute full or semi-automated systems.

2. Maintain neutral (handshake) wrist positions:

   (a) Design jobs and select tools to reduce extreme flexion or deviation of the wrist;

   (b) Avoid inward and outward rotation of the forearm when the wrist is bent to minimise elbow disorder (i.e. tennis elbow).

3. Reduce the force or pressure on the wrists and hands:
    (a) Wherever possible, reduce the weight and size of objects that must be handled repeatedly;
    (b) Avoid tools that create pressure on the base of the palm which can obstruct blood flow and nerve function;
    (c) Avoid repeated pounding with the base of the palm; and
    (d) Avoid repetitive, forceful pressing with fingertips.

4. Design tasks so that a power rather than a finger pinch grip can be used to grasp materials. Note that a pinch grip is five times more stressful than a power grip.

5. Avoid reaching more than 38cm or 15 inches in front of the body for materials:
    (a) Avoid reaching above shoulder height, below waist level or behind the body to minimise shoulder disorders; and
    (b) Avoid repetitive work that requires full arm extension (i.e. the elbow held straight and the arm extended).

6. Provide support devices where awkward body postures (elevated hands or elbows and extended arms) must be maintained. Use fixtures to relieve stressful hand/arm positions.

7. Select power tools and equipment with features designed to control or limit vibration transmissions to the hands, or alternatively design work methods to reduce time or need to hold vibrating tools.

8. Provide for the protection of the hands if working in a cold environment. Furnish a selection of glove sizes and sensitise users to problems of forceful over gripping when worn.

9. Select and use properly designed hand tools (e.g., grip size of tool handles should accommodate the majority of workers).

*Adapted from design checklists developed by Dave Ridyard, CPE, CIH, CSP. Applied Ergonomics Technology, 270 Mather Road, Jenkintown, PA 19046–3129.

8.5.3 Design Principles for Lifting and Lowering Tasks

Next is the design principles for lifting and lowering tasks adapted from the design checklists developed by Dave Ridyard (Cohen, Gjessing, Fine, Bernard & McGlothlin, 1997).

1. Optimise material flow through the workplace by:
    - (a) Reducing manual lifting of materials to a minimum;
    - (b) Establishing adequate receiving, storage and shipping facilities; and
    - (c) Maintaining adequate clearances in aisle and access areas.
2. Eliminate the need to lift or lower manually by:
    - (a) Increasing the weight to a point where it must be mechanically handled;
    - (b) Palletising handling of raw materials and products; and
    - (c) Using unit load concept (bulk handling in large bins or containers).
3. Reduce the weight of the object by:
    - (a) Reducing the weight and capacity of the container;
    - (b) Reducing the load in the container; and
    - (c) Limiting the quantity per container to suppliers.
4. Reduce the hand distance from the body by:
    - (a) Changing the shape of the object or container so that it can be held closer to the body; and
    - (b) Providing grips or handles for enabling the load to be held closer to the body.

5. Convert load lifting, carrying and lowering movements to a push or pull by providing:
    (a) Conveyors;
    (b) Ball caster tables;
    (c) Hand trucks; and
    (d) Four-wheel carts.

*Adapted from design checklists developed by Dave Ridyard, CPE, CIH, CSP. Applied Ergonomics Technology, 270 Mather Road, Jenkintown, PA 19046–3129

8.5.4 Design Principles for Pushing and Pulling Tasks

The following are design principles for pushing and pulling tasks adapted from the design checklists developed by Dave Ridyard (Cohen, Gjessing, Fine, Bernard & McGlothlin, 1997).

1. Eliminate the need to push or pull by using the following mechanical aids, when applicable:
    (a) Conveyors (powered and non-powered);
    (b) Powered trucks;
    (c) Lift tables; and
    (d) Slides or chutes.
2. Reduce the force required to push or pull by:
    (a) Reducing the side and/or weight of the load;
    (b) Using four-wheel trucks or dollies;
    (c) Using non-powered conveyors;

(d) Requiring that wheels and casters on hand-trucks or dollies have:

  (i) Periodic lubrication of bearings;

  (ii) Adequate maintenance; and

  (iii) Proper sizing (provide larger diameter wheels and casters).

(e) Maintaining the floors to eliminate holes and bumps; and

(f) Requiring surface treatment of floors to reduce friction.

3. Reduce the distance of the push or pull by:

   (a) Moving receiving, storage, production, or shipping areas closer to work production areas; and

   (b) Improving the production process to eliminate unnecessary material- handling steps.

4. Optimise the technique of the push or pull by:

   (a) Providing variable-height handles so that both short and tall employees can maintain an elbow bend of 80 to 100 degrees;

   (b) Replacing a pull with a push whenever possible; and

   (c) Using ramps with a slope of less than 10 per cent.

*Adapted from design checklists developed by Dave Ridyard, CPE, CIH, CSP. Applied Ergonomics Technology, 270 Mather Road, Jenkintown, PA 19046–3129.

8.5.5 Design Principles for Carrying Tasks

Lastly, here is the design principles for carrying tasks adapted from the design checklists developed by Dave Ridyard (Cohen, Gjessing, Fine, Bernard & McGlothlin, 1997).

1. Eliminate the need to carry by rearranging the workplace to eliminate unnecessary materials movement and using the following mechanical handling aids, when applicable:
   (a) Conveyors (all kinds);
   (b) Lift trucks and hand trucks;
   (c) Tables or slides between workstations;
   (d) Four-wheel carts or dollies; and
   (e) Air or gravity press ejection systems.
2. Reduce the weight that is carried by:
   (a) Reducing the weight of the object;
   (b) Reducing the weight of the container;
   (c) Reducing the load in the container; and
   (d) Reducing the quantity per container to suppliers.
3. Reduce the bulk of the materials that are carried by:
   (a) Reducing the size or shape of the object or container;
   (b) Providing handles or hand-grips that allow materials to be held close to the body; and
   (c) Assigning the job to two or more persons.
4. Reduce the carrying distance by:
   (a) Moving receiving, storage or shipping areas closer to production areas; and
   (b) Using powered and non-powered conveyors.

5. Convert carry to push or pull by:
   - (a) Using non-powered conveyors; and
   - (b) Using hand trucks and push carts.

*Adapted from design checklists developed by Dave Ridyard, CPE, CIH, CSP. Applied Ergonomics Technology, 270 Mather Road, Jenkintown, PA 19046–3129.

ACTIVITY 8.5

Discuss in the myINSPIRE forum some principles of ergonomics that are applied in your workplace design.

SUMMARY

- Ergonomics is a multidisciplinary field of science that examines human physical and psychological capabilities and limitations.
- The term "ergonomics" is derived from two Greek words: "ergon" (work) and "nomos" (natural laws).
- There are three fundamental goals of ergonomics, namely tolerable working conditions, acceptable working conditions and optimal working conditions.
- Among the objectives and benefits of ergonomics are to increase productivity, improve the quality of work, lower absenteeism and apply existing rules.
- The core of ergonomics knowledge covers four areas of applied sciences, which are anthropometry, biomechanics, physiology and industrial physiology.
- Anthropometry is the study of the dimensions and abilities of the human body.
- Biomechanics is the science concerned with internal and external forces acting on the human body and the effects produced by these forces.
- Physiology studies the energy conversion process that happens in the human body.

- Industrial psychology is a branch of applied psychology that studies the attitudes of employees and employers, organisational behaviour, workplace environment and its effects.

- Ergonomics focuses on interaction between job demands and employee capabilities. The goal is to reach interaction between the job and the worker that will optimise productivity and at the same time, ensure the safety and health of the workers.

- Some design principles are design of workstation, selection of hand tools and their usage as well as materials lifting, lowering and carrying.

- These principles can assist employers in reducing the risk of work-related musculoskeletal disorders (MSD).

KEY TERMS

Anthropometry
Biomechanics
Design principles
Ergonomics
Hand tools
Industrial psychology
Kinematics
Lifting
Lowering
Musculoskeletal disorders (MSD)
Physiology
Working conditions
Workstation

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