# Chapter 1

# PRODUCT DESIGN AND DEVELOPMENT IN THE INDUSTRIAL ENTERPRIZE

# Chapter 1 Goals and Objectives

The overall goal is to introduce the spectrum of activities that are normally involved in the different product development phases. The main objectives are to:

- Review the main activities of performing a feasibility study and selecting an optimum concept.
- Discuss the main stages of designing and manufacturing a product.
- Discuss the main activities involved in testing and refining a new product and then launching and selling it.
- Analyze the environmental issues that are involved in making a product and in retiring it.
- Explain the concepts of life cycle costing and the product life cycle.

# Stages of product development

A product usually starts as a concept which, if feasible, develops into a design, then a finished product. The following seven phases can be identified in a variety of product design and development projects.

1. identification of needs, feasibility study and concept selection,
2. system-level design, detail design and selection of materials and processes,
3. testing and refinement,
4. manufacturing the product
5. launching the product,
6. selling the product, and
7. planning for its retirement.

# Feasibility study

Elements of feasibility study include:

1. Market research
2. Product specifications
3. Concept generation, screening and selection
4. Economic analysis
5. Selecting optimum solution

# Market research I

1. The range of features and the technical advantages and disadvantages of existing products, the mechanism of their operation, and the materials and processes used in making them.
2. Past and anticipated market growth rate and expected market share by value and volume.
3. The number of companies entering and leaving the market over the past few years, and reasons for those movements.
4. The reasons for any modifications which have been carried out recently and the effect of new technology on the product.
5. Patent or license coverage and what improvements can be introduced over existing products.

# Market research II

6. Profile of prospective customers (income, age, sex, etc.) and their needs in the area covered by the product under consideration.
7. Ranking of customer needs in order of their importance.
8. Product price that will secure the intended volume of sales.
9. How long will it take the competition to produce a competitive product?
10. What is the optimum packaging, distribution, and marketing method?

# Product specifications

Product specifications give precise and measurable description of the expected product performance based on the qualitative descriptions of the customer needs.

For example, a specification of “the total weight of the product must be less than 5 kg” can be based on the customer need of a “light weight product” and the observation that the lightest competing product is 5 kg.

Similarly, a specification of “average time to unpack and assemble the product is less than 22 min.” can be based on a customer need of “the product is easy to assemble” and the observation that the competing product needs 24 minutes to unpack and assemble.

# Concept generation and screening

Product specifications are then used to develop different product concepts that satisfy customer needs.

Some of the concepts may be generated by the development team as novel solutions but others may be based on existing solutions or patents.

The different concepts are then compared in order to select the most promising option.

The Pugh method is useful as an initial concept screening tool.

# The Pugh methods of concept selection

Table (1.1) Concept Screening Matrix

| Selection criteria | Reference Concept | Concept A | Concept B | Concept C | Concept D |
|---|---|---|---|---|---|
| Criterion 1 | 0 | - | + | + | 0 |
| Criterion 2 | 0 | + | + | 0 | 0 |
| Criterion 3 | 0 | + | + | + | - |
| Criterion 4 | 0 | 0 | 0 | + | - |
| Criterion 5 | 0 | 0 | - | - | + |
| Total (+) | 0 | 2 | 3 | 3 | 1 |
| Total (-) | 0 | 1 | 1 | 1 | 2 |
| Total (0) | 5 | 2 | 1 | 1 | 2 |
| Net Score | 0 | 1 | 2 | 2 | -1 |
| Decision | No | Consider | Consider | Consider | No |

# Economic analysis

The economic analysis section of the feasibility study normally provides an economic model that estimates:

- the development costs,
- the initial investment that will be needed,
- the manufacturing costs, and
- the income that will result for each of the selected concepts.

The economic analysis also estimates sources and cost of financing based on the rate of interest and schedule of payment.

# Selecting an optimum solution

Factors involved in selecting an optimum solution:

- customer needs,
- physical characteristics of size and weight,
- expected life and reliability under service conditions,
- energy needs,
- maintenance requirements and operating costs,
- availability and cost of materials and manufacturing processes,
- environmental impact,
- quantity of production,
- expected delivery date.

# Quantitative methods of selecting an optimum solution

Table (1.2) Concept Selection

| Product specifications/ Selection Criteria | Weight | Concept A | | Concept B | | Concept C | |
|---|---|---|---|---|---|---|---|
| | | Rating | Weighted rating | Rating | Weighted rating | Rating | Weighted rating |
| Criterion 1 | 0.1 | 2 | 0.2 | 4 | 0.4 | 4 | 0.4 |
| Criterion 2 | 0.2 | 4 | 0.8 | 4 | 0.8 | 3 | 0.6 |
| Criterion 3 | 0.2 | 4 | 0.8 | 4 | 0.8 | 4 | 0.8 |
| Criterion 4 | 0.3 | 3 | 0.9 | 3 | 0.9 | 5 | 1.5 |
| Criterion 5 | 0.2 | 3 | 0.6 | 1 | 0.2 | 2 | 0.4 |
| Total score | | | 3.3 | | 3.1 | | 3.7 |
| Rank | | Second | | Last | | First (optimum) | |

(Rating: 5 = excellent, 4 = very good, 3 = good, 2= fair, 1 = poor)

# Case study: Developing the Greenobile I

Market Research

The questions discussed include:

1. frequency of driving the car, how far is each journey on average and expected distance traveled per year, and expected life of the car,
2. aesthetic qualities: main preferences for body styling and look, number of doors, number of wheels, etc.,
3. level of comfort on a bumpy road,
4. ease of handling and parking,
5. safety issues including stability on the road especially when turning round sharp corners,
6. expected cost

# Case study: Developing the Greenobile II

Specifications

- Product Description: A two-seater, inexpensive, environmentally friendly car
- Primary use: Driving in the city to get to work or go shopping
- Main customers: Middle class families who may already own a family car
- Technical specifications: Mass up to 500 kg, Maximum speed 90 km/hr, Speed maintained on 5% gradient 60 km/hr, Acceleration time from 0 – 90 km/hr average 20 sec
- Cost Up to $6,000,
- Safety requirements: Same as a normal sedan car
- Engine emission: Environmental Protection Agency (EPA) test limits or less
- Main features: Seating for two passengers, Small boot/trunk accessible from the back
- Main business goals: Production starts in three years from approval of final concept, Units produced in the first year 20,000 to increase by 10% each subsequent year

# Case study: Developing the Greenobile III

Concept generation:

- Concept A: is a sedan with a hard roof, 4 wheels, two seats side-by-side, internal combustion engine, expected life 5 years, expected weight 500 kg, acceleration from 0 – 90 km/hr is 15 sec, higher level of comfort, expected cost $6,000
- Concept B: is a sedan with a hard roof, 3 wheels (one in front and two in the back), two seats side-by-side, rechargeable battery operated engine, expected life 4 years, expected weight 450 kg, acceleration from 0 – 90 km/hr is 25 sec, medium level of comfort, expected cost $5,000
- Concept C: is a sedan with a movable roof, 3 wheels (one in front and two in the back), two seats one behind the other, rechargeable battery operated engine, expected life 4 years, expected weight 400 kg, acceleration from 0 – 90 km/hr is 20 sec, lower level of comfort, expected cost $4,000

# Case study: Developing the Greenobile IV

Table 1.4 Concept selection for Greenobile

| Selection Criteria | Weight | Concept A | | Concept B | | Concept C | |
|---|---|---|---|---|---|---|---|
| | | Rating | Weighted rating | Rating | Weighted rating | Rating | Weighted rating |
| 1. Life | 0.1 | 5 | 0.5 | 4 | 0.4 | 4 | 0.4 |
| 2. Aesthetic qualities | 0.2 | 5 | 1.0 | 4 | 0.8 | 3 | 0.6 |
| 3. Level of comfort | 0.1 | 5 | 0.5 | 4 | 0.4 | 3 | 0.3 |
| 4. Ease of handling and parking | 0.1 | 4 | 0.4 | 5 | 0.5 | 3 | 0.3 |
| 5. Safety | 0.2 | 5 | 1.0 | 4 | 0.8 | 4 | 0.8 |
| 6. cost | 0.3 | 3 | 0.9 | 4 | 1.2 | 5 | 1.5 |
| Total score | | | 4.3 | | 4.1 | | 3.9 |
| Rank | | First | | Second | | Third | |

(Rating: 5 = excellent, 4 = very good, 3 = good, 2 = fair, 1 = poor)

# System-level design

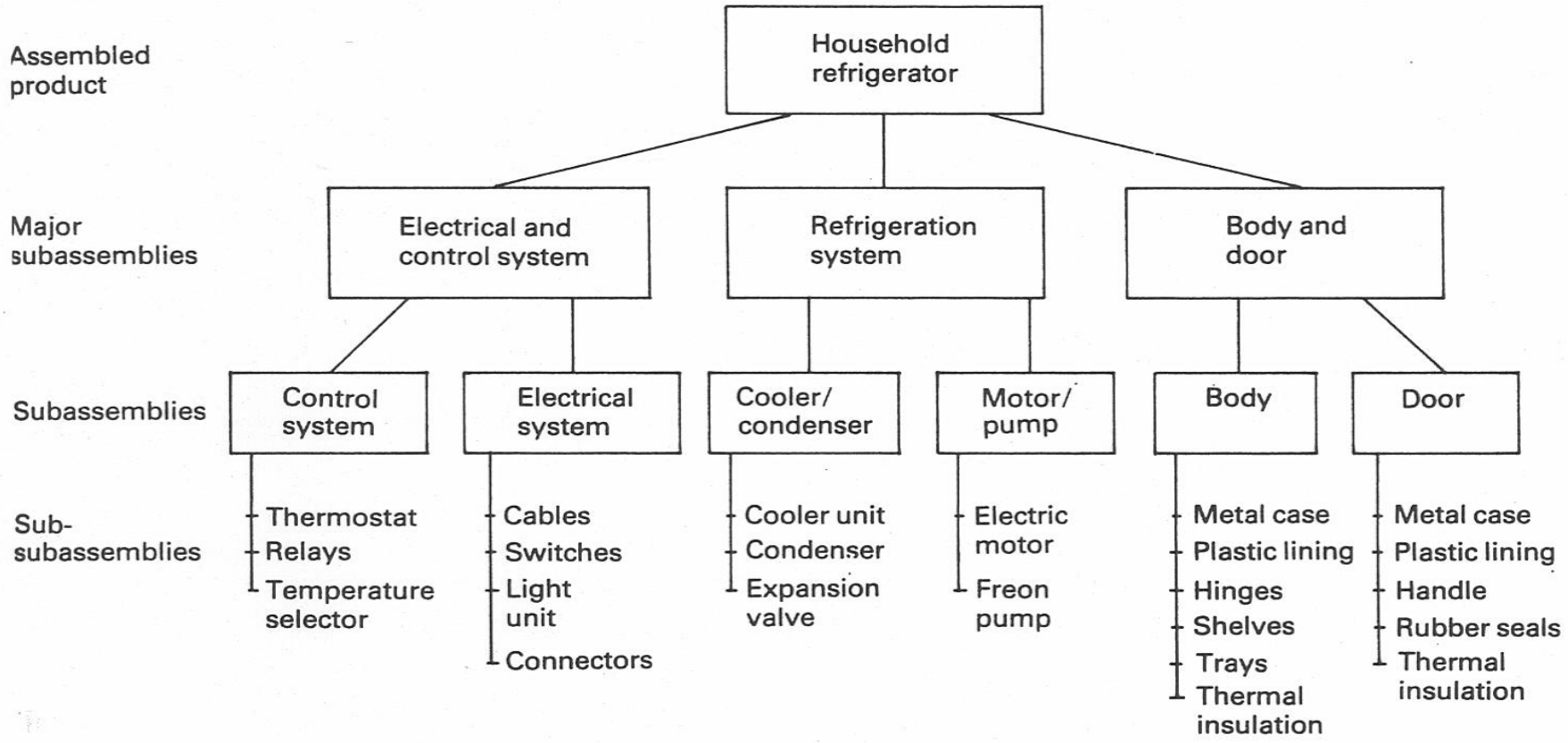


**Figure 1.2** Breakdown of a household refrigerator into major subassemblies, subassemblies and sub-subassemblies.

# Launching and selling the product

Launching the product:

- Project planning and scheduling
- Manufacturing
- Quality control
- Packaging
- Marketing

Selling the product:

- Cost of product engineering
- Actual manufacturing cost
- Sales expense and administrative cost
- Selling price

# Case study: Planning for installation of an injection molding machine I

Table 1.5 Installing and preparing for operation an injection molding machine

| Major task | Activity | Description | Immediate predecessor | Time (h) |
|---|---|---|---|---|
| I | a | Excavate foundations | - | 5 |
| | b | Pour concrete in foundation | a | 2 |
| | c | Unpack parts | - | 3 |
| II | d | Place machine body on foundations | b, c | 2 |
| | e | Level machine body | d | 1 |
| | f | Assemble rest of the machine parts | c, e | 3 |
| | g | Connect electrical wiring | f | 1 |
| | h | Connect cooling water and drainage | f | 2 |
| III | i | Install injection molding die | g, h | 3 |
| | j | Calibrate temperature controller | i | 2 |
| | k | Place plastic pellets in hopper | f | 1 |
| | l | Adjust plastic metering device | k | 1 |
| | m | Perform experimental runs | j, l | 2 |

# Case study: Planning for installation of an injection molding machine II

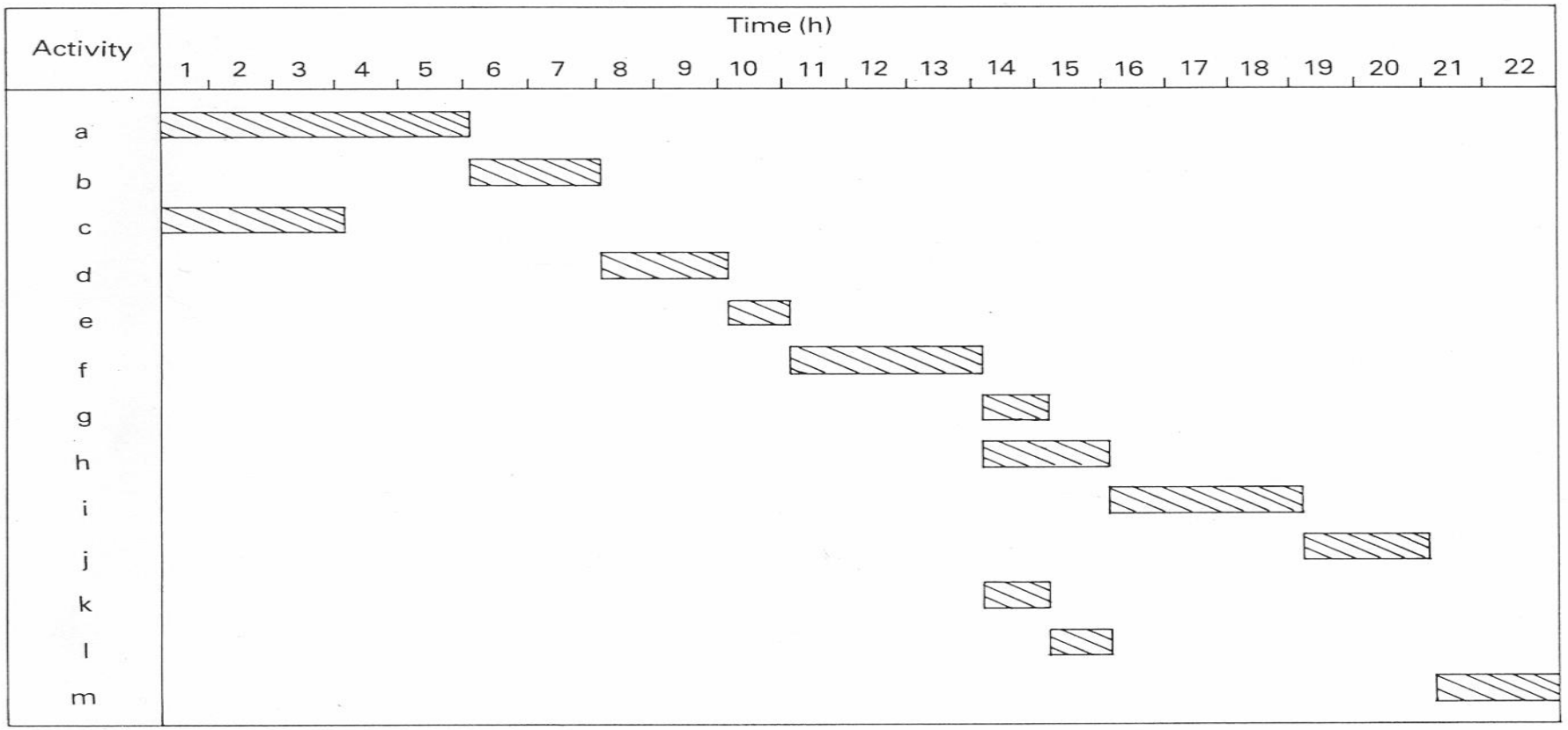


**Figure 1.3** Bar chart describing the activities of installing and preparing an injection molding machine for operation. See Table 1.5 for a description of the activities.

# Manufacturing the product

| PROCESS SHEET | | Page 1 of 3 pages |
|---|---|---|
| *Written by* M.M.F.<br>*Date* 1/3/88 | *Order no.* 1844<br>*Date* 1/1/88 *Pcs req'd* 30 | *Dwg no.* 12<br>*Patt. no.* 5 |
| *Enters assembly at stage* x-23 Loader 6 | *Part name* 250 mm Pulley | |
| *Material condition*<br>Gray CI, ASTM A48-74 35, 245 BHN | *Rough weight*<br>15 kg | *Finish weight*<br>12 kg |

| *Oper. no.* | *Description* | *Set-up time (h)* | *Cycle time (h)* | *Mach. no.* |
|---|---|---|---|---|
| 10 | Turn O.D. of body and flanges, face hub<br>Speed 200 rpm, feed 0.25 mm per rev<br>tool no. TT-25 | 0.5 | 0.5 | L-2 |
| 20 | Turn bore and face other side of hub<br>Speed 200 rpm, feed 0.25 mm per rev<br>tool no. TT-25 | 0.6 | 0.3 | L-2 |
| 30 | Drill and tap 2 holes, 10 and 12 mm diameter<br>standard metric thread M10 and M12 | 0.3 | 0.2 | D-1 |

**Figure 1.4** Example of a simple process sheet.

# Selling the product I

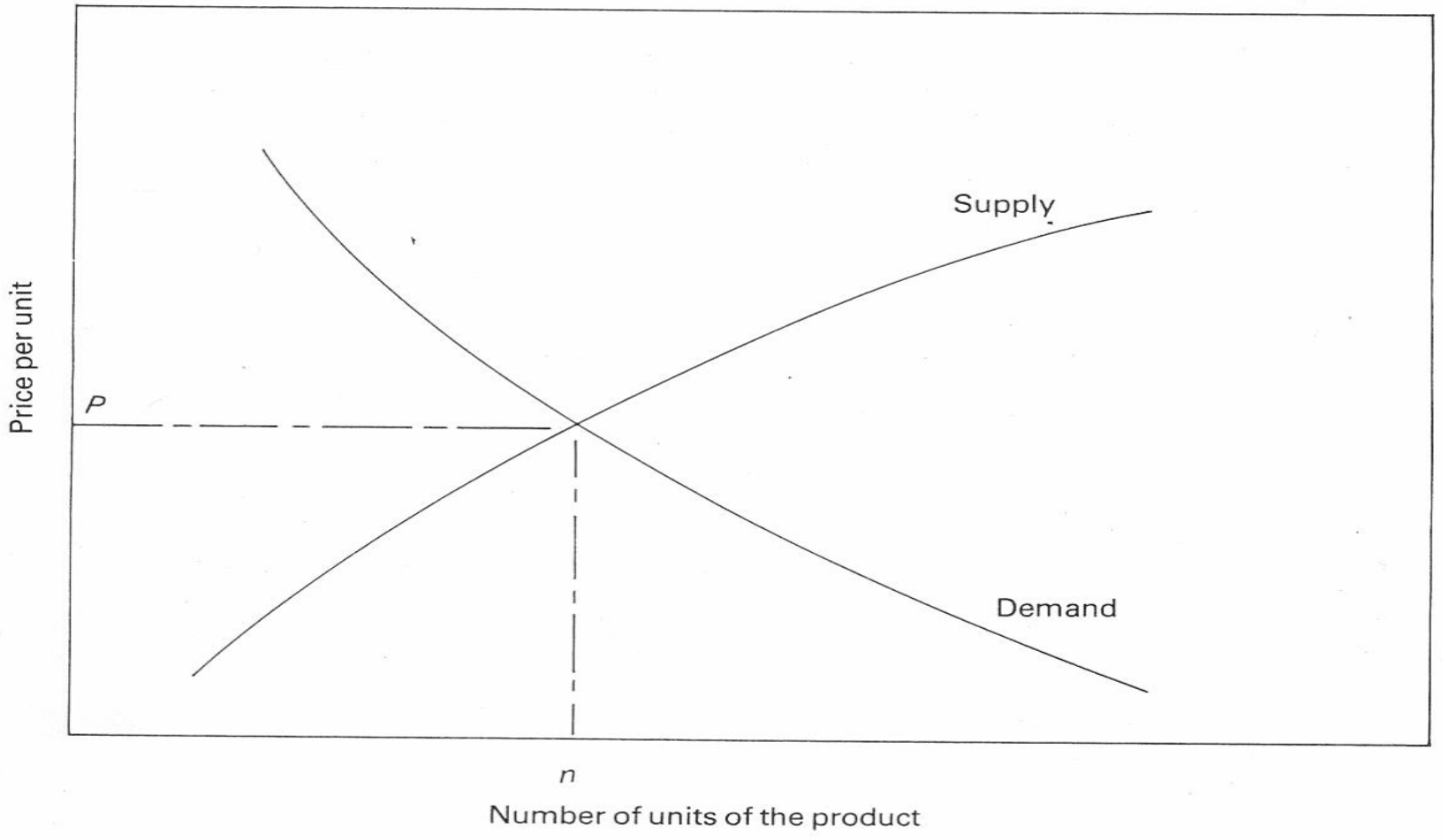


**Figure 1.5** Schematic representation of typical supply and demand curves.

# Selling the product II

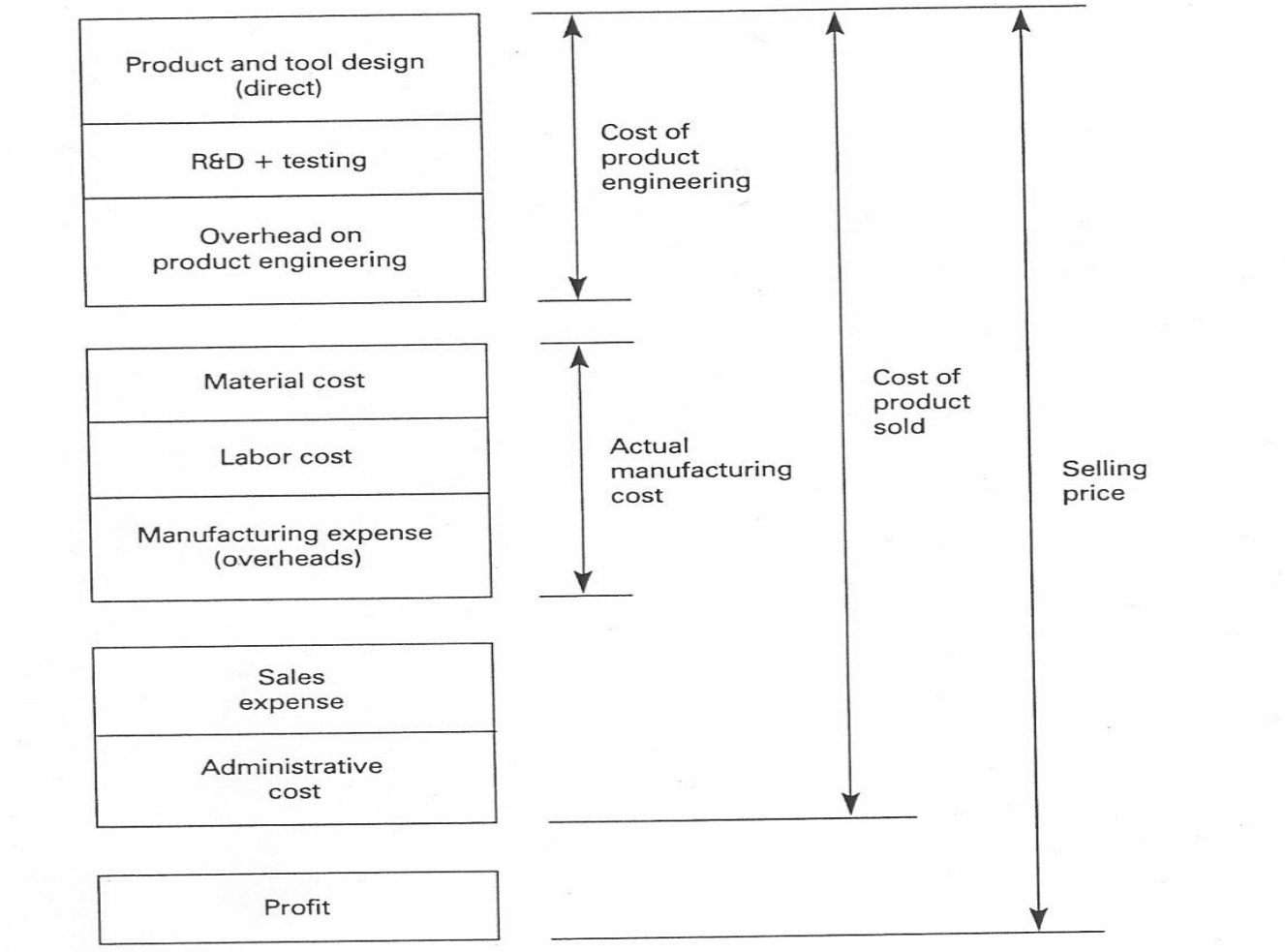


**Figure 1.6** Factors involved in determining the selling price of a product.

# Recycling of materials

Table 1.6 Energy used for production of some engineering materials

| Metal | Primary metal | | Secondary metal | |
|---|---|---|---|---|
| | GJ/ton | % | GJ/ton | % of primary metal |
| Mg | 370 | 100 | 10 | 2.7 |
| Al | 350 | 100 | 15 | 4.3 |
| Ni | 150 | 100 | 15 | 10 |
| Cu | 120 | 100 | 20 | 17 |
| Zn | 70 | 100 | 20 | 29 |
| Pb | 30 | 100 | 10 | 33 |
| Steel | 35 | 100 | 15 | 43 |

Figures based on: Metals Handbook, Desk Edition, ASM, Metals Park, Ohio, 1985,p 31.5

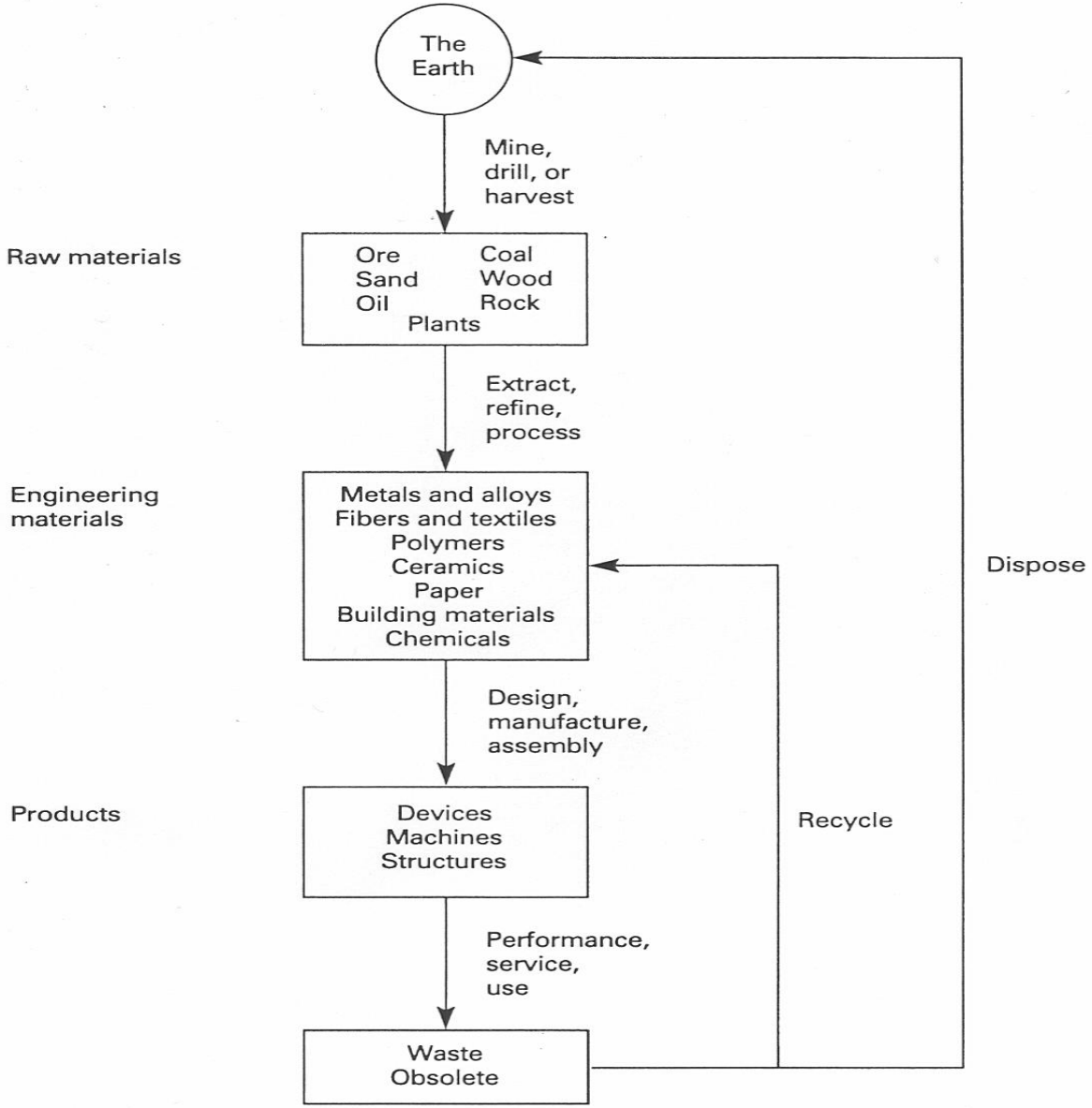


**Figure 1.7** The place of recycling in the total material cycle.

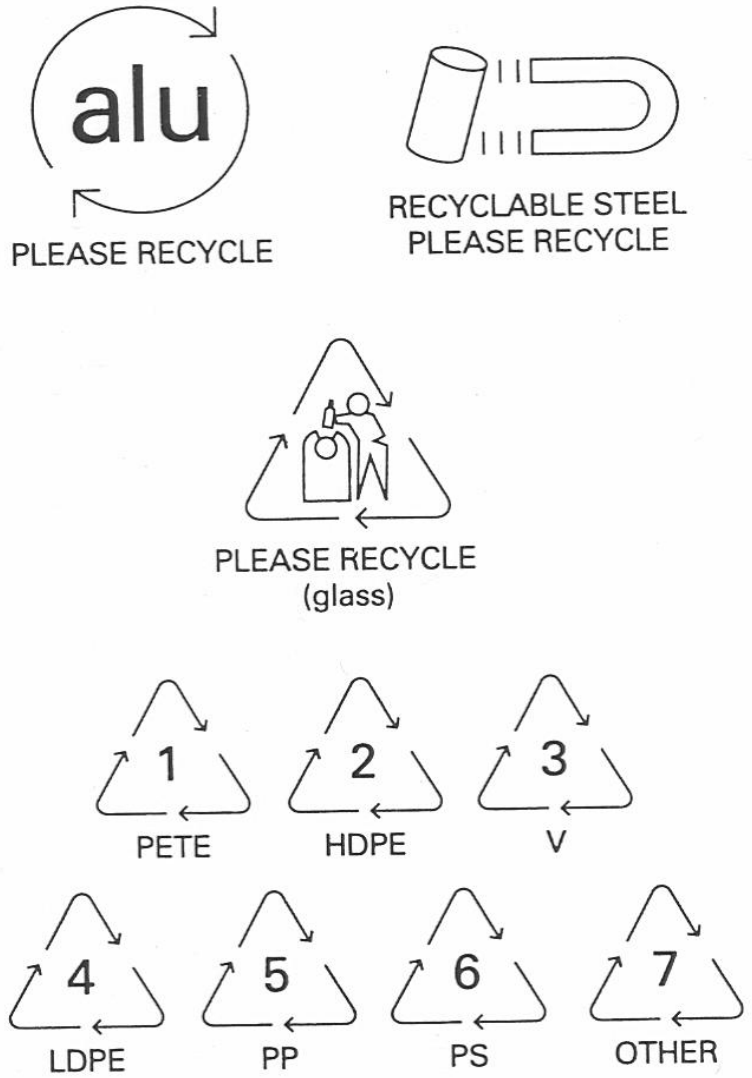


**Figure 1.8** Examples of the symbols used to help in sorting materials for recycling.

# The product life cycle

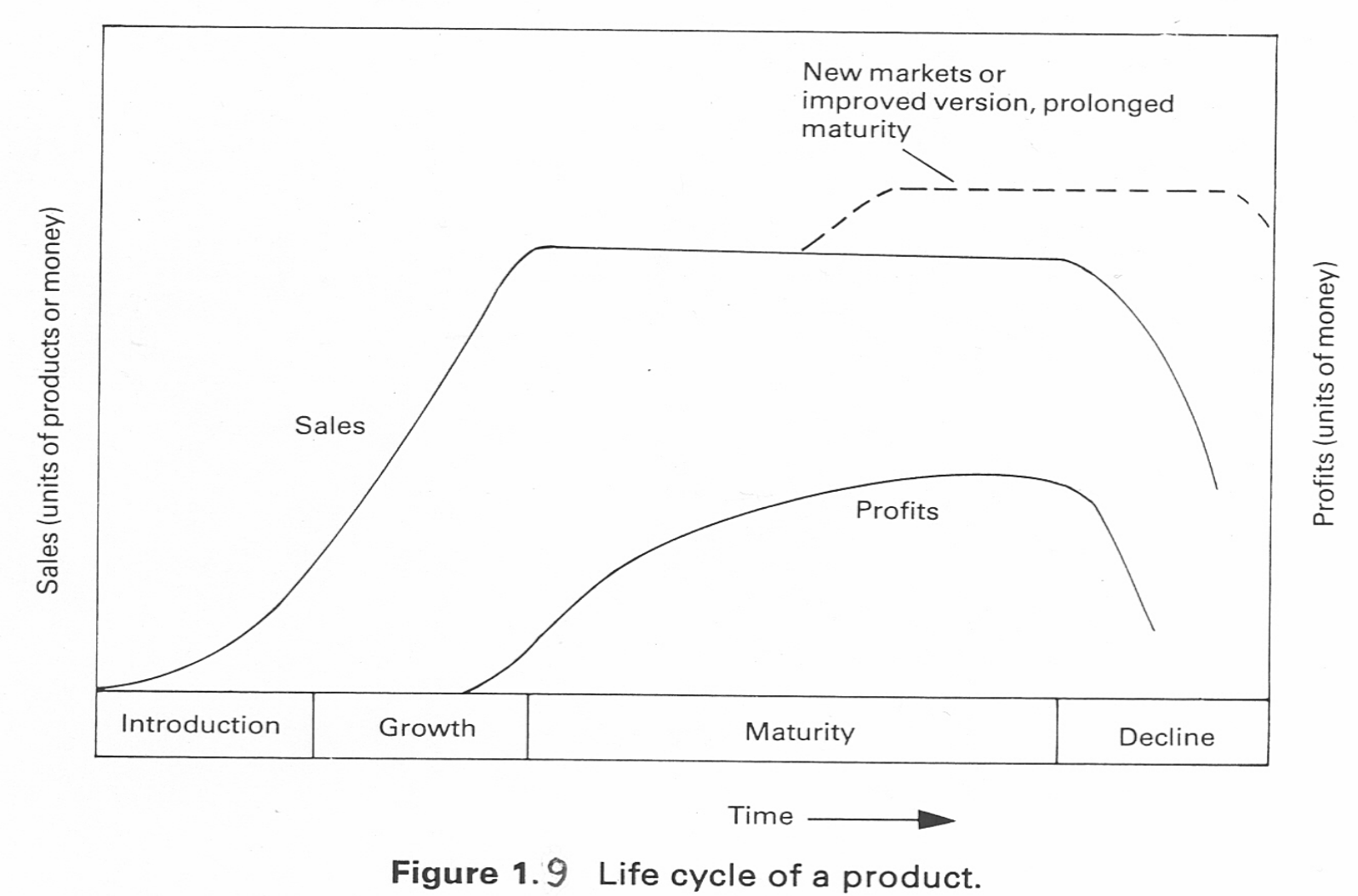


**Figure 1.9** Life cycle of a product.

# Chapter 1 Summary 1

1. Ideally, product development is performed by an interdisciplinary team with representatives from different segments of an industrial enterprise including engineering design, materials and manufacturing, finance, legal, sales, and marketing. This is because in addition to satisfying the technical requirements, a successful product should also be aesthetically pleasing, safe to use, economically competitive, and compliant with legal and environmental constraints.
2. The activities involved in product development include: concept development and feasibility study, system-level design, detail design and selection of materials and processes, testing and refinement, launching the product, and selling the product.

# Chapter 1 Summary 2

3. The selling price of a product is determined by the cost of product engineering (design, R&D, testing & refinement), manufacturing cost (material and labor costs), sales expense and administrative cost, income taxes, and net profit.
4. Because materials industry consumes a considerable amount of energy in making its products, it is no longer acceptable that engineering materials are used and then discarded in landfills. Better alternatives include waste reduction and recycling. Efficient recycling needs an infrastructure for sorting and scrap processing.

# Chapter 1 Summary 3

5. The life cycle of a product consists of introduction stage, growth stage, maturity where the production rates and sales volume reach the design value, decline where sales decrease leading to the end of the life cycle of the product. Because most profits are made during the maturity stage, it should be prolonged by developing new markets and introducing design modifications.