INDMEET

Funded by NORHED II-NORAD

Module of Product Design and Development

This Module supported by
NORHED-II NORAD INDMEET Project (grant nr. 62862)
INDMEET project is a six year partnership between three Universities

Module developed by
Jimma University Team

Thus, team acknowledge the fund provided by NORAD

October, 2022
Jimma, Ethiopia

Objectives of Module on Product Design and Development

To impart knowledge on product development process and learn the challenges in product development, product planning, product specifications, concept selection and product architecture. On the other hand, the module is intended to provide the following benefits to the learns:

1. This module provides the catalyst for dramatic improvements in new product design and development capability
2. Reinforcement of specific knowledge from other courses through practice and reflection in an action-oriented setting.
3. Understand how to build products with sustainable competitive advantage
4. Learn to prioritise new product ideas based on business strategic alignment, return on investments and ability to execute.
5. Develop an understanding and enthusiasm for engineering activities involved with bringing a product to market, etc...

Module outcomes

Engineering design is the process of creating products and systems that satisfy the needs of a customer. This module covers design philosophy, methodology, and design process techniques. Students can practice engineering design methodology by participating in different mechanisms. At the end of this module each student should be able to:

1. Use the product design and development process, as a means to manage the development of an idea from concept to production.
2. Competence with a set of tools and methods for product design and development.
3. Confidence in your own abilities to create a new product.
4. Awareness of the role of multiple functions in creating a new product (e.g. marketing, finance, industrial design, engineering, production).
5. Ability to coordinate multiple, interdisciplinary tasks in order to achieve a common objective.

Contents

Contents **II**

List of Figures **IV**

1 Introduction to Product Design **1**
1.1 Product Life Cycle . . . 3
1.1.1 Identifying user need . . . 3
1.2 Role of product designer . . . 6
1.3 Skills and Training . . . 7
1.4 Review questions . . . 9

2 Product Design Process **16**
2.1 Idea Development . . . 16
2.2 Product Design Consideration . . . 17
2.2.1 Design Requirements . . . 17
2.2.2 Total Life Cycle . . . 18
2.2.3 Regulatory and Social Issues . . . 18
2.3 Product Design Phases . . . 19
2.3.1 Design Initiation . . . 19
2.3.2 Conceptual Design . . . 19
2.3.3 Preliminary design . . . 28
2.3.4 Prototype design . . . 28
2.3.5 Prototype manufacture . . . 29
2.3.6 Prototype testing . . . 29
2.4 Review questions . . . 30

3 Product Planning **41**
3.0.1 Elements of product planning . . . 41
3.0.2 Characteristics of product planning . . . 42
3.0.3 Major factors for successful product planning: . . . 43

3.1 Product Planning Process 44
3.1.1 Objective of product planning process 44
3.2 Product development 46
3.3 Review questions 49

4 Product Design Specification **55**
4.1 Elements of PDS 57
4.2 How to Write a Product Specification 60
4.3 Example of PDS 61
4.4 Review questions 66

5 Design for Manufacturing and Assembly **70**
5.1 What is Design for Manufacturing and Assembling (DfMA) 70
5.1.1 The process of DFMA 70
5.2 DfMA principles 70
5.3 Design for Manufacture (DFM) 72
5.3.1 Principles of DFM 73
5.4 How to implement DFM 75
5.4.1 Steps in DFM 77
5.4.2 Assembly methods 79
5.4.3 Guidelines for different assembly methods 80
5.4.4 Functional analysis 83
5.4.5 Assembly analysis 83
5.4.6 Fitting analysis 84
5.5 Review questions 84

6 Product Life Cycle **87**
6.1 Stages of Product Life Cycle 88
6.2 Applying Product Life Cycle 90
6.3 PLC–As a Guideline for Marketing Strategy 91

List of Figures

1.1 Product life cycle . . . 3
1.2 Product design approach . . . 3
1.3 Diagram of the Kano model . . . 6

2.1 Product Design Process . . . 19
2.2 Steps of conceptual design . . . 20
2.3 An example of a classification tree . . . 34
2.4 An example of concept combination table for handheld nailer . . . 34
2.5 The concept development funnel . . . 35

3.1 Product Planning activities . . . 41
3.2 Product Planning process . . . 46
3.3 Product development process . . . 46

4.1 A product design sub-system . . . 56
4.2 A spiral design model of PDS development . . . 56
5.1 Common steps taken in DFMA . . . 70

5.2 DFM Impact vs cost . . . 76
5.3 Steps of DFM . . . 77
5.4 Components of manufacturing cost . . . 77
5.5 Assembly volume vs production cost of different assembly methods . . . 80
5.6 DFA sequence flow chart . . . 82

CHAPTER

1 Introduction to Product Design

Before beginning to discuss the definition of product design and let try to answer the question "what is product design?", it is important to reevaluate the definition of a 'product'. Up to nowadays, the term was used only in relation to something material and often found in stores as a product. However, 'product' and the product design process now also applies to digital products; modern product examples include websites and phone apps. There are even product designers called UX designers that specifically focus on usability of the digital product. Keeping this information in mind, building great products consists of many elements, with the design features being one of the most important qualities from seamless digital applications to the functionality of an executive office chair, every successful product starts with a useful design.

Whether it is designing state-of-the-art machinery or developing complex medical diagnostic systems, the field of product design spans over numerous industries, including agriculture, health-care, lifestyle, interior design, automotive, and many more. In this section, we'll explore the definition of product design, as well as the role of a Product Designer, including job outlook, skills needed and industry statistics. So what is product design? Product design as a verb is to create a new product to be sold by a business to its customers. Designing a product is a very broad concept, it is essentially the efficient and effective generation and development of ideas through a design process that leads to new products. Thus, it is a major aspect of new product development. However, many business experts will agree that product design is the process of identifying a market opportunity, clearly defining the user's needs and problem, developing a proper solution for that problem, and validating the solution with real users. When considering high-quality products or features, designers must understand business objectives, know the elements of a good design, and be able to answer the following questions:

1. What problem are we solving?
2. Who has this problem?

3. What do we want to achieve?

Answering these questions allows design engineers to understand the user experience of a product as a whole, and not simply the interaction (feel) or visual (look) part of a design. These design principles apply to both physical products and digital product design. Finding a solution to a problem includes the following five basic phases:

1. **Research:** In order to get a deeper understanding of your consumer, you must conduct and gather research for whom you are designing your product for.
2. **Define:** Create a point of view that is based on user needs and insights.
3. **Brainstorm:** In order to generate a wide range of potential solutions, design thinking and brainstorming sessions are required during this phase of product development.
4. **Prototype:** After narrowing down design concepts, build a prototype (or series of prototypes) to test your hypothesis. Creating a prototype allows the designer to discover if they're on the right track, and it often sparks different ideas that you wouldn't have come up with otherwise to further streamline product development. However, depending on the product, physical prototyping tools can be very expensive so digital design can be significantly more cost-effective in the beginning stages of product design and problem-solving pain points within the design.
5. **Test:** Return to your users for feedback.

As discussed, creating and building great products (and great brands) is contingent upon forward-thinking design implementation. Today's businesses essentially rely upon their product design team to give their products or services an aesthetic and functional edge over their competitors while maintaining relevance in a world where technological advancement never sleeps.

Did You Know...

Q: What is the difference between UX Design and UI Design?

A: While User Experience (UX design) is a conglomeration of tasks focused on human-centered design aka the optimization of a product for effective and enjoyable use, User Interface Design (UI) is its complement, addressing the look and feel (visual design) as well as the presentation and interactivity of a product.

What is the role of a product designer? Due to the vast (and ever-changing) demands of the Product Designer, it is by definition a rather elusive job role to describe: because the design process of product development keeps changing, the roles of people (and consequent skills sets) continue to evolve, thus encompassing a wider scope of responsibilities. Because of this, it is important that anyone entering the field have the proper hands-on training with a respectable design program. While Visual Designers address the look and feel of a product, UX or UI Designers deal with wireframes and user flows. However, the Product Designer is an individual who can take a high-level concept and see it all the way through, from inception to completion. Responsible for designing nearly everything we use in our daily lives, Product Designers utilize their

creativity, technical knowledge and keen eye for detail to design and implement new and innovative products and services, as well as streamlining existing products by improving their aesthetic appeal and functionality. In order to succeed in product design, you must understand the relationship between art, technology, and science. As a Product Designer, your responsibilities will include planning, designing, and modeling products, creating prototypes and conducting research, as well as rigorous product testing.

1.1 Product Life Cycle

The time period between conceiving a product and the point at which manufacturing it no longer is profitable is defined as the product life cycle. As shown in Figure 1.1, the sales volume for a new product rises after its introduction. Once the customers recognize and accept the product, sales increase rapidly (growth). This is followed by a maturity period, when sales increase further. Eventually, competitive products appear on the market and sales decline. As the market saturates and the product no longer is fresh, sales and profits decline further and it no longer is profitable to produce the product. During this period, the profits should be maintained by making minor modifications to the product and relaunching it as new and improved. Businesses (designers and manufacturers) must understand this cycle to maximize profits: The efforts should focus on extending the maturity period as much as possible. Also, for businesses to grow, they must launch new products in such a way that a new product approaches sales maturity just when the ones launched earlier are in decline. Figure 1.2 shows a considerably more detailed

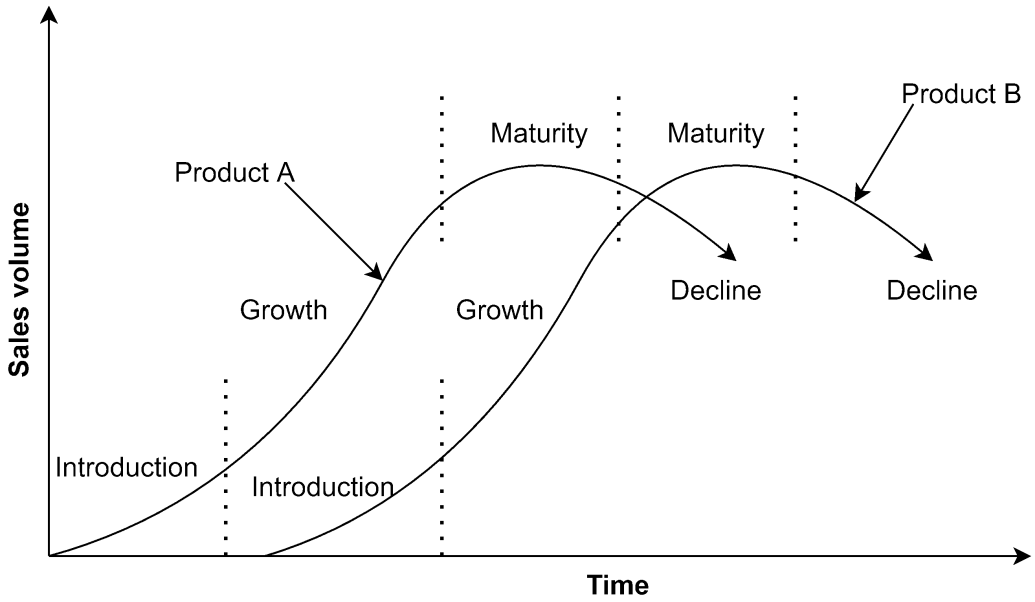

Fig. 1.1: Product life cycle

and integrated approach to product design and reflects more accurately the design for manufacturing philosophy.

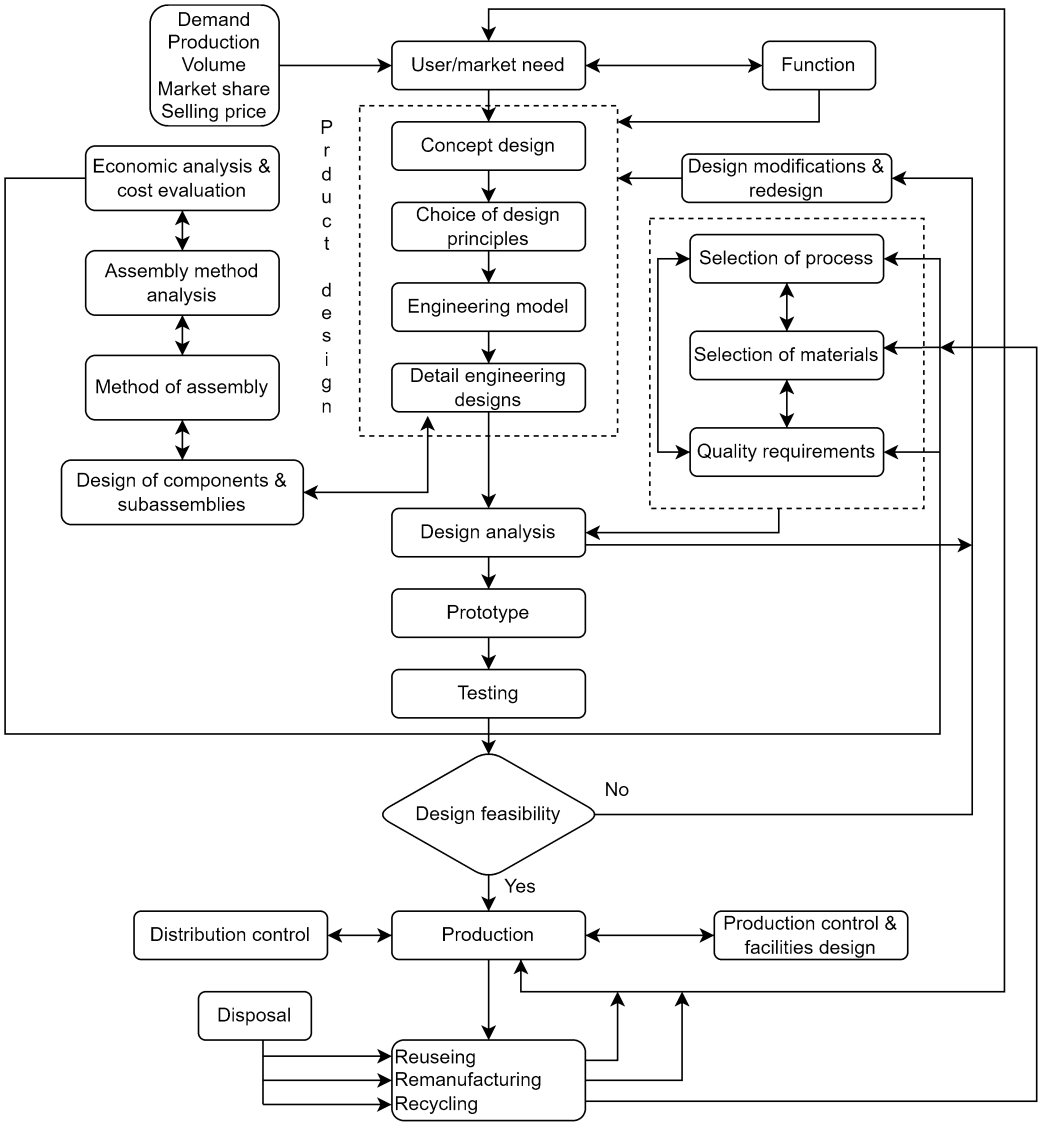

Fig. 1.2: Product design approach

1.1.1 Identifying user need

User needs are defined as the influential factors that trigger them to buy your product or service. In order to identify customer needs, it is important to understand the reasons behind their decision making. Needs are essentially independent of any specific product we could build; they are not limited to the notion we ultimately choose to pursue. A team should be able to identify client needs without knowing whether or not those needs will be addressed in the future. Customer needs identification is a process in itself, for which we provide a five-step strategy. The five steps are:

1. Gather raw data from customers.
2. Interpret the raw data in terms of customer needs.
3. Organize the needs.

4. Establish the relative importance of the needs.

5. Reflect on the results and the process.

1. **Gather raw data from customers:** Intuitively, the first step must be to gather data from the customers. Without their input, it would be impossible to identify their needs. Gathering needs data is very different than a sales call, the goal is to elicit an honest expression of needs, not to convince a customer of what he or she needs. Try to learn as much as possible about the customers; the data are there to serve as guidelines for product development. There are three recommended ways to gather data,this are:

   a) **Interviews:** Interviews are one-on-one meetings with potential customers, usually 1-2 hours in length. Frequently they take place in the customer's own environment, as they are more comfortable there and there is a chance to see a problem in action.

   b) **Focus groups:** Focus groups are like expanded interviews. They are about 2 hours long, and they involve about 8 to 12 customers. The group is lead in a discussion by an interviewer. It is very common for the group to be watched by some number of unseen observers who take notes on the proceedings.

   c) **Observation:** Seeing someone struggle with a problem is an easy way to get a general understanding of the issue. And frequently you are not the first person to identify that problem, so "watching customers use an existing product or perform a task for which a new product is intended" is a perfectly reasonable way to identify customer needs, as well as ways in which successful companies are attempting to solve them. Observation can either be passive, where one simply watches a customer work in their natural environment, or observation can be active, where one works side-by-side with the customer and gain and understanding of their problems from their perspective.

   All three of these options are excellent ways to get information from customers. If there is one pitfall of data collection, though, it would have to be written surveys. Surveys are extremely popular, but they are extremely limited. Surveys generally have very little data on the environment in which the problem is occurring, and they are fairly terrible at picking up on unanticipated needs. It's rather difficult to write a question about a need that hasn't been thought of yet. These interviews and focus groups are the primary means of learning about customers, so make sure to conduct interviews as effectively as possible. Here are a few suggestions that will lead to successful interviews:

   - Prepare questions, but don't be afraid to deviate if appropriate
   - Use visual stimuli and props
   - Suppress preconceived hypothesis about the product technology
   - Have the customer demonstrate the product and/or typical related tasks

- Be alert for surprises and the expression of latent needs: pursue surprising answers with follow-up questions
- Watch for non-verbal information

2. **Interpreting Data:**

   After the interviews it is usually necessary to translate the vague statements of the customers into a useful list of needs. As this is a relatively subjective process, multiple analysts may translate the same interview notes into different needs. For that exact reason, it is beneficial to have multiple people work on the interpretations. So how, exactly, does one transform what the customer says into something you can work with? Here is a useful process with several helpful constraints and suggestions for expressing the data.

   - Write the needs in terms of what the product has to do, not how it might do it.
   - Express the needs as specifically as the raw data
   - Use positive phrasing
   - Express the needs as an attribute of the product
   - Avoid the words must and should

3. **Organizing the needs:** After interpreting the data, organize them. Group similar needs together, prioritize them, etc. Decide what is truly important to the customer. Define the "critical needs," those needs which absolutely must be met before the product can be considered successful.

   The "Kano method" developed by Professor Noriaki Kano is a categorization system which is the most widely method to organize needs.The essence of the Kano Method is the five Qualities that product features can have (Figure 1.3).

   a) **Exciting quality**: when these product qualities are met they provide satisfaction, but when they are not met they do not cause dissatisfaction. For example, when a backpack has a separate compartment for a laptop.

   b) **Normal quality:** when these qualities are met they provide satisfaction, and when they are not met they create dissatisfaction. For example, when the shoulder straps on a backpack are padded, they provide comfort, but when not padded they are painful.

   c) **Expected quality:** these product qualities are assumed to be met, and they cause dissatisfaction when they are not met. Backpacks are expected to be able to hold books.

   d) **Indifferent quality:** these qualities are neither good nor bad, and they do not increase nor decrease customer satisfaction when met or not met.

   e) **Reverse quality:** The qualities cause either satisfaction or dissatisfaction when met, but it is customer dependent. For example, backpacks with a lot of compartments and pouches. Some customers really like the wealth of storage options these spaces provide, and other customers actively dislike how excessive or unmanageable those same spaces are.

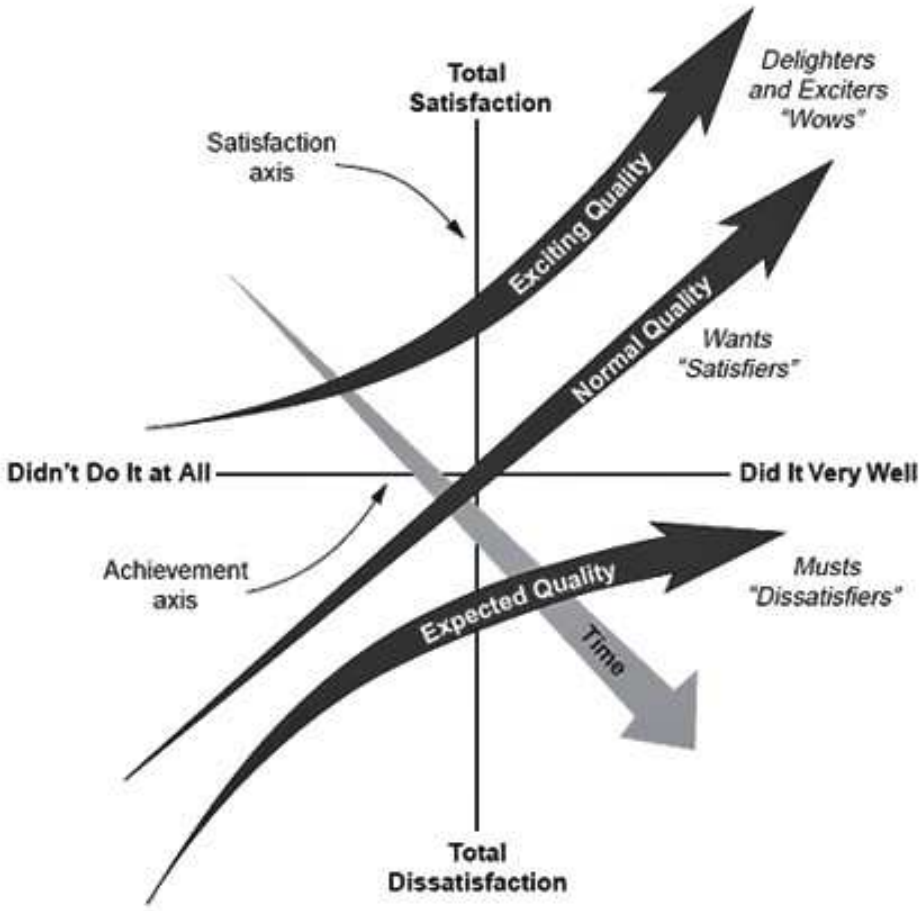

Fig. 1.3: Diagram of the Kano model

These five qualities describe the set of customer needs and expectations that a product can meet. This set of classifications also makes it apparent why surveys can't identify all of the customers' needs. Customers identify needs based on dissatisfaction with a current setup or problem; a survey only contains questions about predicted or perceived problems. It can certainly find all of the one-dimensional and must-be qualities, but it will be difficult, if not impossible, to identify all of the other needs just with surveys.

4. **Establish the relative importance of the needs:** The hierarchical list alone does not reveal the relative value that customers assign to various demands.This stage yields a numerical relevance weighting for a subset of the demands. The job can be approached in two ways: **(1)** depending on team members' consensus based on their customer experience, or **(2)** basing the importance judgment on further consumer surveys. The apparent trade-off between the two techniques is cost and time against accuracy: in one meeting, the team can make an educated judgment of the relative significance of the demands, but a consumer survey typically takes at least two weeks. Most of the time, we feel the customer survey is essential

and worth the time it takes to complete. Other development processes, such as concept formulation and competitive product analysis, might start before the relative significance surveys are finished.

5. **Reflect on the results and the process**

   The final step in the customer needs identification process is to reflect on what's been done. Consider the statements that have been gathered and study the interpretations. Try to evaluate how the process was executed. Have all types of customers been interviewed? Do any customers require follow-up interviews? Are any of the needs surprising? Look for ways to improve or refine the Customer Needs Identification process. Would more interviews help? Less? How about focus groups? Could the process have been done faster? Every project will have different answers to these questions, but taking the time to consider this particular process will help to prepare for the next one. Remember, as of now there are no product specifications! This entire process is about identifying needs, not designing solutions. That comes later.

1.2 Role of product designer

A product designer role may include:

- Wire-framing and 3D designing
- Coding/Prototyping
- Creating style guides and patterns
- Conceptualizing product definitions and naming conventions
- Building requirements documentation with other engineers and designers
- Manning support and helping fill tickets to better understand customers from the front-lines
- Any number of other things to help tie up loose ends on the design side

1.3 Skills and Training

If you are considering a career in Product Design, possessing the following skills is essential to your success:

- **Analytical skills:** Industrial designers use logic or reasoning skills to study consumers and recognize the need for new products.
- **Artistic ability:** Industrial designers sketch their initial design ideas, which are used later to create prototypes. As such, designers must be able to express their design through illustration.
- **Commercial and entrepreneurial expertise**

- **Communication skills:** Possessing effective communication skills is essential in this role
- **Computer skills:** Industrial designers use computer-aided design software to develop their designs and create prototypes.
- **Creativity:** Industrial designers must be innovative in their designs and how they integrate existing technologies into their new product. General & Specialized IT Skills, such as computer-aided design (CAD) and other computer software programs
- **Interpersonal skills:** Industrial designers must develop cooperative working relationships with clients and colleagues who specialize in related disciplines.
- **Mechanical skills:** Industrial designers must understand how products are engineered, at least for the types of products that they design.
- **Presentation skills:** One of the core phases of product development entails detailed presentations to clients; therefore, possessing strong presentation skills is crucial to this role.
- **Problem-solving skills:** Industrial designers determine the need, size, and cost of a product; anticipate production issues; develop alternatives; evaluate options; and implement solutions.
- **Teamwork mentality:** As a Product Designer, you will be collaborating with a variety of staff and clients; therefore, you must be comfortable working within a team dynamic.
- **Time management skills:** In addition to adhering to stringent deadlines, designers must also have the ability to take initiative and work independently.
- **Visual** & **Spatial Awareness:** In addition to creative/artistic abilities, having a keen sense of visual/spatial awareness is crucial to your success in this career path.

Understandably, you will need to be confident using complex computer software, such as computer-aided design (CAD) tools. You will do most of your training "on-the-job", developing your CAD skills and technical knowledge under the supervision of an experienced product designer. However, you may occasionally be required to attend in-house training courses. As you progress in your career and move into project management, your company may even sponsor you to complete a relevant professional qualification, such as an MBA. You may also wish to take part in workshops offered by external organizations, colleges or universities. Many product designers eventually progress into project management roles. Another option is to work as a freelance product designer, where you will work for different companies on a variety of projects.

Career Possibilities

Jobs where your degree would be useful include:

- Automotive Engineer

- Industrial/Product Designer
- Graphic Designer
- Materials Engineer
- Product Manager
- Production Designer
- Purchasing Manager

Studying product design gives you broad theoretical knowledge and practical skill set you'll need to use production methods and materials creatively.

1.4 Review questions

1. The most important criteria for the economic success of a company depends on its:
   a) ability to hire many employees
   b) access to up to date technological resources
   c) ability to identify customer needs and quickly create products at low cost to meet those needs
   d) none of the above.
2. Which of the following factors is holistically responsible for the economic success of a business?
   a) marketing
   b) design
   c) manufacturing
   d) product development
3. Product quality is ultimately reflected in the _____ and the price that customers are willing to pay.
   a) development cost
   b) development time
   c) market share
   d) development capability
4. The performance of a product development process can be assessed by:
   a) product quality and cost
   b) development time, cost and capability
   c) both a and b
   d) none of the above
5. The success of the product development process of a company primarily depends on:
   a) product quality and cost
   b) development time and cost
   c) development capabilities
   d) all of the above
6. Sustainable product development demands:
   a) that the products should be made using cheapest labor
   b) ecologically sound use of resources and reduction of hazardous waste byproducts

c) that the business organizations should be not-for-profit

d) larger development costs and time

7. Product development is an interdisciplinary activity with three central functions. These are:

a) Design, Marketing, and Manufacturing

b) Design, Sales, and Marketing

c) Marketing, Manufacturing and Sales

d) Design, Finance, and Manufacturing

8. The core team of product development includes all of the following areas of expertise except:

a) Finance

b) Manufacturing

c) Design

d) Marketing

9. Which of the following factors is/are responsible for a productâ€™s development cost?

a) Duration of the project

b) Number of people on the project team

c) Both a and b

d) none of the above

10. The product development team members usually gain satisfaction from:

a) creation of the product

b) a dynamic environment

c) budget enhancements

d) none of the above

11. Which of the following is not a challenge for product development?

a) the presence of high team spirit

b) to earn reasonable return on investment on the product.

c) the need to make product development decisions quickly and without complete information

d) managing trade-offs to maximize the success of a product

12. Characteristics of a dysfunctional product development team includes

a) a lack of empowerment of the team

b) inadequate resources

c) a lack of cross-functional representation on the project team

d) all of the above

13. Which is the final phase of product development process?

a) System level design

b) Detail design

c) Testing and refinement

d) Production ramp-up

14. In the context of product development, identifying customer need is primarily necessary for:

a) hiring project managers for the company

b) deciding prices for the company products

c) selling company products to them

d) creating products which meet customer needs

15. Identifying customer need helps the project team to proceed to the next phase of product development, that is

a) selecting project concept

b) establishing target specification

c) testing product concept

d) setting final specification

16. A precedes the identifying customer needs phase.

a) mission statement

b) vision statement

c) budget statement

d) financial statement

17. The needs are the ones that the customers expect to be met, whereas needs would surprise the customers.

a) critical, latent

b) latent, critical

c) critical, verbal

d) hidden, critica

18. The dormant customer needs are the those which

a) customers are unaware off and not fulfilled by existing products.

b) customers are fully aware off and fulfilled by existing products.

c) product developers recognize as critical customer needs.

d) are widely recognized by the consumers and retailers.

19. Raw data can be gathered from consumers commonly by:

    a) interviewing
    b) facilitating focus groups
    c) observing the products in use
    d) all of the above

20. Establishing the relative importance of customer need can be done only after:

    a) organizing data into a hierarchy of customer needs
    b) collecting raw data from customers
    c) reflecting on the results and the process of identifying customer need
    d) none of the above

21. Focus groups are one of the methods for:

    a) interpreting raw data collected from customers
    b) organizing data into a hierarchy of customer needs
    c) gathering raw data from customers
    d) reflecting on the results and the process of identifying customer need

22. An Interview with a customer to gather data usually takes:

    a) one to two hours
    b) four to five hours
    c) whole day
    d) many days

23. Which of the following is a technique to gather data by watching customers to use the product in their natural environment?

    a) Interview
    b) Focus groups
    c) Observation
    d) All of the above

24. For a single-market segment, the guideline for choosing the number of customers to Interview is between .

    a) 10 and 50
    b) 20 and 100
    c) 30 and 100
    d) 50 and 150

25. Customers can be contacted for gathering data by:

a) making phone call using online directories

b) sending e-mail using online directories

c) attending social networking events

d) all of the above

26. Which of the following is not an effective way to interact with customers to collect data?

a) disregard non-verbal information

b) to be alert for surprises and the expression of latent need

c) use visual stimuli and props

d) suppress preconceived hypotheses about the product technology

27. Interactions with customers during the data collection process are commonly documented by:

a) audio and/or video recording

b) taking notes

c) taking photography

d) all of the above

28. The final task in gathering data from customers is:

a) preparing customer data template

b) interpreting need from customer statement

c) writing "thank-you" notes to the customers involved in the process

d) none of the above

29. One of the fundamental guidelines to interpret raw customer data is:

a) Expressing the need in terms of "What" the product has to do, not in terms of "How" it might do it

b) Expressing the need as an attribute of the product

c) use of positive, not negative phrasing

d) Avoiding the words "must" and "should"

30. Customer data can be organized into a hierarchy based on their need(s), such as

a) primary

b) secondary

c) tertiary

d) all of the above

31. The step-by-step process to create a hierarchical list for customer needs include:

a) printing or writing each need statement on a separate card or self-stick note

b) grouping the cards according to the similarity of the needs they express

c) choosing a label for each group

d) all of the above

32. Use of customer survey to establish relative importance of customer needs is than using consensus among experienced team members.

a) less reliable

b) more reliable

c) less costly

d) quicker

Long answer questions

1. What Is Product Design ? How Product Design Could Be Evaluated Discuss With Examples.
2. Why is product design important and what factors affect a good design? Give some examples of good product design?
3. Explain the importance of the product design process. Which phase of the product design process are the most and least important in your views? why?
4. Briefly describe the levels of product design. What criteria should marketers consider when making product design decisions? Use an example to support your answer.
5. Product design is one of the basic activity in the production cycle. a) Explain the main objective of Product design and bring out its threats and control.b) Explore about PLM and what are the components of PLM software that helps in improving the efficiency and effectiveness of product design?

Multiple choice answers

1. c
2. d
3. d
4. c
5. d
6. b
7. a
8. a
9. c
10. b
11. a
12. d
13. d
14. d
15. b

16. a
17. a
18. a
19. d
20. a
21. c
22. a
23. c
24. a
25. d
26. a
27. d
28. c
29. a
30. d
31. d
32. b

CHAPTER

2 Product Design Process

Product design has two aspects: technical design and aesthetic design. Technical design is process of defining all the performance and physical characteristics of a product. Technical design specifies the materials, dimensions and tolerances, and performance standards of a product. Aesthetic design is the process of establishing the sensual and psychological characteristics and benefits of a product. This involves deciding on what the product will look like and feel like, deciding on the color and texture, and the exterior shape or appearance of the product. A company's product design must match the needs and preferences of the customer group targeted by the company's business strategy. Otherwise, the company will lose its customer base and erode its market position.

A product design process is series of coordinated activities that results in the creation of a product. A product may be conceived as a system which is a combination of interrelated components that serve a useful purpose. Hence the design of a product is an instance of system design. System design is the conception of a system in its totality. It envisions the whole system and defines its interconnected substructures and components. The critical units of the system are the primary focus at the beginning of the design. Through a process decomposition and refinement, the system is eventually conceived and documented.

2.1 Idea Development

All product designs begin with an idea. The idea might come from a product manager who spends time with customers and has a sense of what customers want, from an engineer with a flare for inventions, or from anyone else in the company. To remain competitive, companies must be innovative and bring out new products regularly. In some industries, the cycle of new product development is predictable. We see this in the auto industry, where new car models come out every year, or the retail industry, where new fashion is designed for every season. In other industries, new product releases are less predictable but just as important. The first source of ideas is the customers, the

driving force in the design of products and services. Marketing is a vital link between customers and product design. Market researchers collect customer information by studying customer buying patterns and using tools such as customer surveys and focus groups. Management may love an idea, but if market analysis shows that customers do not like it, the idea is not viable. Analyzing customer preferences is an ongoing process. Customer preferences next year may be quite different from what they are today. For this reason, the related process of forecasting future consumer preferences is important, though difficult. Competitors are another source of ideas. A company learns by observing its competitors products and services and the success rate of these products and services.

2.2 Product Design Consideration

Design is a multifaceted process. The various considerations in a good design can be grouped into three categories: (1) design requirements, (2) life-cycle issues, and (3) regulatory and social issues.

2.2.1 Design Requirements

It is obvious that to be satisfactory the design must demonstrate the required performance. Performance measures both function and behavior of the design, i.e., how well the device does what it is designed to do.

1. ***Performance Requirements***

   - ***Functional Performance Requirements***: They address capacity measures such as forces, strength, energy, material flows, power, deflection, and efficiency of design, its accuracy, sensitivity etc.
   - ***Complementary performance requirements:*** They are concerned with the useful life of design, its robustness to factors in the service environment, its reliability, and ease, economy, and safety of maintenance. Issues such as built-in safety features, noise level in operation, all legal requirements, and design codes must be considered.

2. ***Physical requirements:*** These pertain to such issues as size, weight, shape, and surface finish.

3. ***Environmental requirements:*** There are two separate aspects. The first concerns the service conditions under which the product must operate. The extremes of temperature, humidity, corrosive conditions, dirt, vibration, noise, etc., must be predicted and allowed for in the design. The second aspect of environmental requirements pertains to how the product will behave with regard to maintaining a safe and clean environment, i.e., green design. Among these issues is the disposal of the product when it reaches its useful life.

4. ***Aesthetic requirements:*** They are concerned with how the product is perceived by a customer because of its shape, colour, surface texture, and also such factors as balance, unity, and interest.
5. ***Manufacturing technology:*** This must be intimately connected with product design. There may be restrictions on the manufacturing processes that can be used, because of either selection of material or availability of equipment within the company.
6. ***Cost:*** The final major design requirement is cost. Every design has requirements of an economic nature. These include such issues as product development cost, initial product cost, life cycle product cost, tooling cost, and return on investment.

2.2.2 Total Life Cycle

The total life cycle of a part starts with the conception of a need and ends with the retirement and disposal of the product.There are three important parameters to consider for the life cycle of the products.

- ***Material selection:*** Material selection is a key element in the total life cycle of a product. In selecting material for a given application, the first step is evaluation of the service conditions. Next, the properties of materials that relate most directly to the service requirements must be determined.
- ***Producibility:*** Material selection can not be separated from Producibility. There is an intimate connection between design and material selection and the production processes. The objective in this area is a trade-off between the opposing factors of minimum cost and maximum durability.
- ***Durability:*** It is concerned with the number of cycles of possible operation, i.e., the useful life of the product.

2.2.3 Regulatory and Social Issues

Specifications and standards have an important influence on design practice. The standards produced by such societies represent voluntary agreement among many elements (users and producers) of industry. As such, they often represent minimum standards. When good design requires more than that, it may be necessary to develop company or agency standards. The code of ethics of all professional engineering societies requires the engineer to protect public health and safety. Increasingly, legislation has been passed to require government agencies to regulate many aspects of safety and health. The designer has to develop the design in such a way to prevent hazardous use of the product in an unintended but foreseeable manner. When unintended use cannot be prevented by functional design, then clear, complete, unambiguous warnings must be permanently attached to the product.An important design consideration is adequate attention to human factors engineering, which uses the sciences of bio-mechanics, ergonomics, and engineering psychology to assure that the design can be operated efficiently by humans.

2.3 Product Design Phases

Figure 2.1 shows a simplified design process model informed by the critical stages in a product development cycle. The process of designing a product is an iterative one involving a review stage that leads to feedback and modifications. Graphic modeling is at the heart of the design process and design drafters will be called upon to help create them. Drawing details and complexity grow as the design progresses from the conceptual phase to the prototype phase.

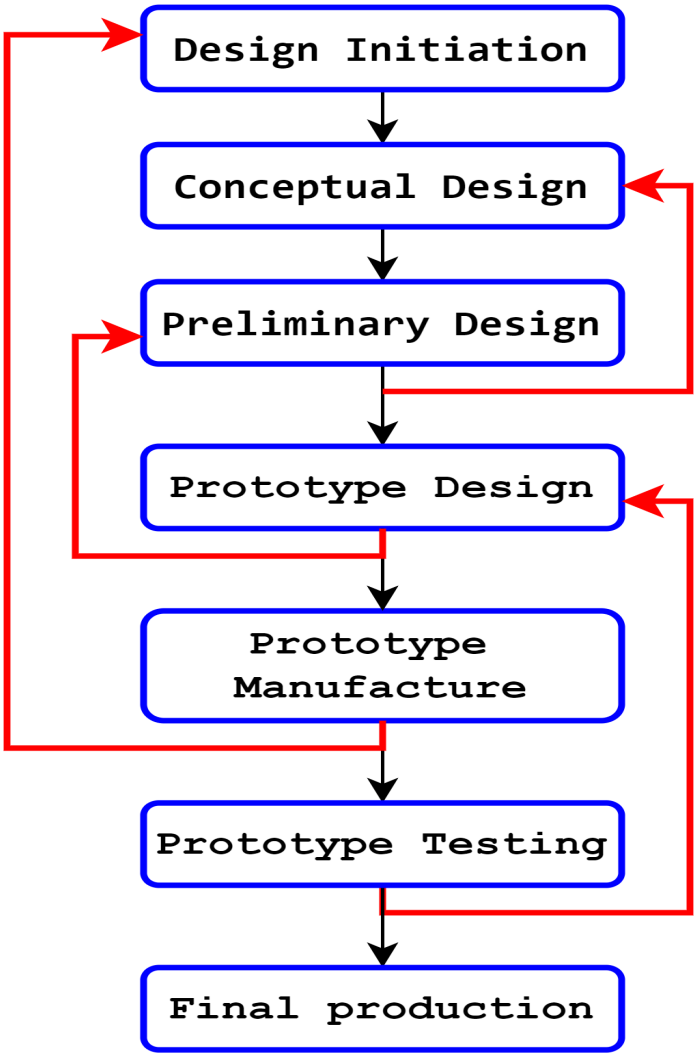

Fig. 2.1: Product Design Process

2.3.1 Design Initiation

Design project is initiated when a product need is identified. Product need may arise from:

- New idea, customer request, market research

- Inadequate/improved technology
- Manufacturing process; materials; machine tools
- Production cost reduction
- Mass production capability
- Safety and reliability
- Deliverable: Design Brief
- Statement of design problem.
- Tells what product should do not how it is done

2.3.2 Conceptual Design

In the concept design phase, alternative product concepts are generated and evaluated, and one or more concepts are selected for further development and testing.A concept is a description of the form, function, and features of a product and is usually accompanied by a set of specifications, an analysis of competitive products, and an economic justification of the project. The conceptual design must focus on the following key points:

- Investigate feasibility of product concepts such as Functional requirements, Aesthetic Requirements
- Develop a comprehensive System design (identify critical units)
- Ideation drawings (Isometric Sketches, Block Diagrams, Schematic and kinematic diagrams)
- Concepts and ideas refined
- Computer models

Conceptual design is the part of the design process where by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure, the basic solution path is laid down through the elaboration of a solution principle. The conceptual design is mainly preceded by a decision.The purpose of this decision is to answer the following questions based on the requirements list agreed upon during task clarification:

- Has the task been clarified sufficiently to allow the development of a solution in the form of a design?
- Is a conceptual elaboration really needed, or do known solutions permit direct progress to the embodiment and detail design phases?
- If the conceptual stage is indispensable, how and to what extent should it be developed systematically?

Steps of conceptual design

Figure 3.3 shows the steps involved, correlated in such a way as to satisfy the principles of the general problem solving process.

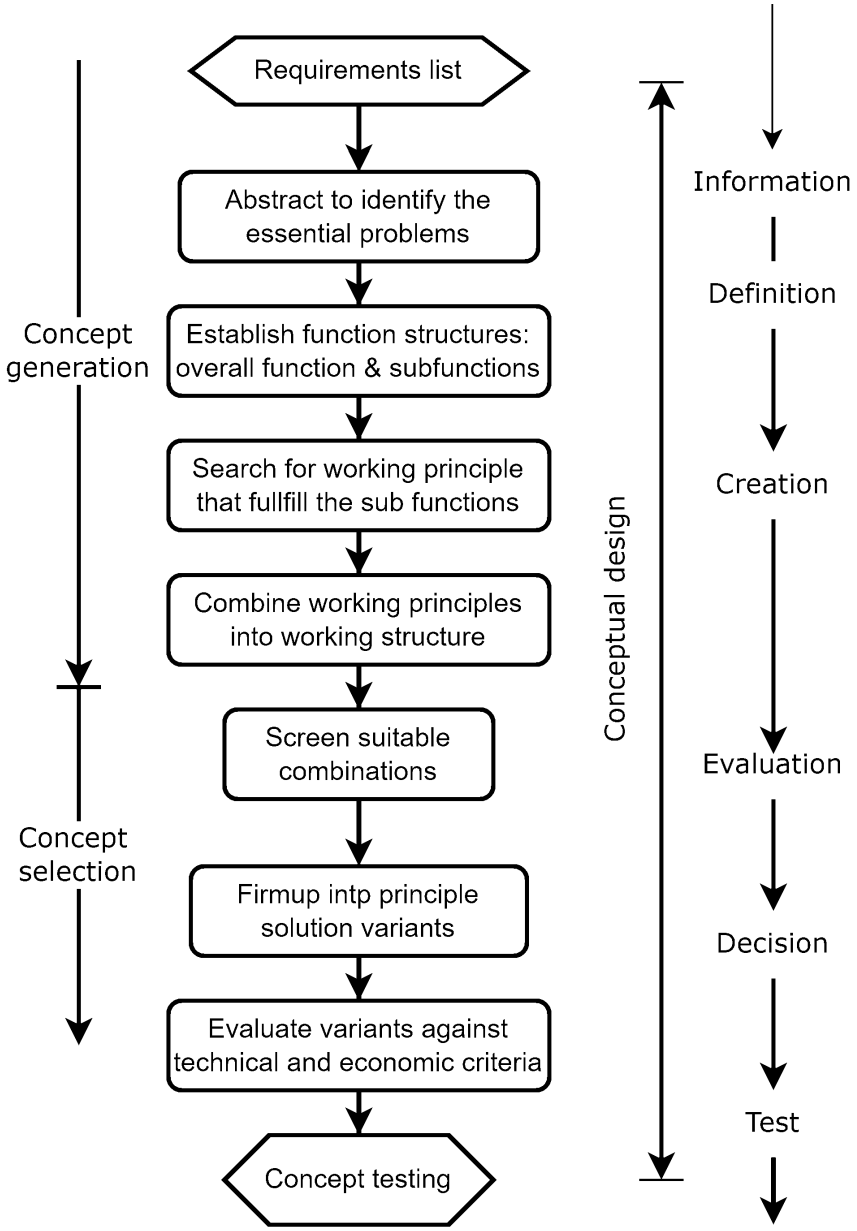

Fig. 2.2: Steps of conceptual design

1. **Identifying the Essential Problems from the Requirements List:**

   The clarification of the task with the help of a requirements list will have helped to focus attention on the problems involved and will have greatly increased the particular level of information. Elaborating the requirements list may thus be

said to have prepared the way for following steps. Here the task is to analyze the requirements list with respect to the required function and essential constraints in order to confirm and refine the crux of the problem. The functional relationships contained in the requirements list should be formulated explicitly and arranged in order of their importance.In order to formulate the problems from the requirement list, one must follow the following steps:

Step 1. Eliminate personal preferences.
Step 2. Omit requirements that have no direct bearing on the function and the essential constraints.
Step 3. Transform quantitative into qualitative data and reduce them to essential statements.
Step 4. As far as it is purposeful, generalize the results of the previous step.
Step 5. Formulate the problem in solution-neutral terms. This analysis thus leads to a definition of the objective on an abstract plane without laying down any particular solution.

Take the following points in mind when formulating a solution from the problems.

- Do not design a garage door, but look for means of securing a garage in such a way that a car is protected from thieves and the weather.
- Do not design a keyed shaft, but look for the best way of connecting a gear wheel and shaft.

- Do not design a packing machine, but look for the best way of despatching a product safely or, if specific constraints really exist, of packing a product safely, compactly and automatically.
- Do not design a clamping device, but look for a means of keeping a workpiece firmly fixed.

  From the above formulations, and this is very helpful for the next step, the final formulation can be derived in a way that does not prejudice the solution, i.e. solution-neutral, and at the same time turns it into a function.

2. **Establishing Function Structures**

   a) **Overall Function** The requirements determine the function that represents the intended overall relationship between the inputs and the outputs of a plant, machine or assembly.once the crux of the overall problem has been formulated, it is possible to indicate an overall function that, based on the flow of energy,material and signals can, with the use of a block diagram, express the solution-neutral relationship between inputs and outputs.That relationship must be specified as precisely as possible.

   b) **Breaking a function down into sub-functions** Depending on the complexity of the problem, the resulting overall function will in turn be more or less complex. By complexity we mean that the transparency of the relationships between

inputs and outputs is relatively poor, that the required physical processes are relatively intricate, and that the number of assemblies and components involved is relatively large. Just as a technical system can be divided into subsystems and elements , so a complex or overall function can be broken down into sub-functions of lower complexity. The combination of individual sub-functions results in a function structure representing the overall function. The aims of breaking down complex functions are to:

- Determine sub-functions that facilitate the subsequent search for solutions.
- Combine these sub-functions into a simple and unambiguous function structure.

It is useful to start by determining the main flow in a technical system, if this is clear. The auxiliary flows should only be considered later. When a basic function structure, including the most important links, has been found, it is easier to undertake the next step; that is, to consider the auxiliary flows with their sub-functions and to achieve a further subdivision of complex sub-functions. For this step it is helpful to create a temporary working structure or a solution for the basic function structure, without, however, prejudicing the final solution. The optimum method of breaking down an overall function that is,the number of sub-function levels and also the number of sub-functions per level is determined by the relative novelty of the problem and also by the method used to search for solutions. In the case of original designs, neither the individual sub-functions nor their relationships are generally known. In that case, the search for and establishment of an optimum function structure constitute some of the most important steps of the conceptual design phase. In the case of adaptive designs, on the other hand, the general structure with its assemblies and components is much more well known, so that a function structure can be obtained by analyzing the existing product.

3. **Searching for working principles** Working principles need to be found for the various sub-functions, and these principles must eventually be combined into a working structure. A working principle must reflect the physical effect needed for the fulfillment of a given function and also its geometric and material characteristics. Designers usually search for working principles that include the physical process along with the necessary geometric and material characteristics, and combine these into a working structure.Theoretical ideas about the nature and form of function carriers are usually presented by way of diagrams or freehand sketches.

   The search for working principles for sub-functions should be based on the following guidelines:

   - Preference should be given to the main sub-functions that determine the principle of the overall solution and for which no solution principle has yet been discovered.

- Classifying criteria and associated parameters (characteristics) should be derived from identifiable relationships between the energy, material and signal flows, or from associated systems.
- If the working principle is unknown, it should be derived from the physical effects and, for instance, from the type of energy. If the physical effect has been determined, appropriate form design features (working geometry, working motions and materials) should be chosen and varied. Checklists should be used to stimulate new ideas.
- Designers should also enter solutions found intuitively and analyze which key classifying criteria influence particular working principles.These criteria should then be subdivided, limited or generalized using further headings.
- To prepare for the selection process, the important properties of the working principles should be noted.

4. **Combining working principles** To fulfill the overall function, it is then necessary to generate overall solutions by combining the working principles into a working structure.The classification scheme of Zwicky (morphological matrix) is particularly suitable for systematically combining solutions.In order to apply morphological analysis to product design, we simply identify the critical functions in our function structure diagram and then identify many different solutions for each function. The results of this research are compiled and presented in morphological chart. A morphological chart has the critical sub functions listed across the 1st row and then each column contains the different solutions for each critical function.Critical functions are the functions in your function structure diagram that are hard to accomplish and/or have many inputs and outputs. As a guideline: Only combine compatible sub-functions, Only pursue solutions that meet the demands of the requirements list and look like falling within the proposed budget, Concentrate on promising combinations and establish why these should be preferred above the rest.

5. **Screening suitable combinations**

   Because working structures are generally not very concrete and the properties are only known qualitatively, the most suitable screening procedure is characterized by the activities of selecting and indicating preferences, and it makes use of a schematic selection chart that provides a clear overview.The purposes of this stage are to narrow the number of concepts quickly and to improve the concepts.The team makes a go/no-go decisions by answering this simple questions.

   - Is the idea feasible?
   - Is the idea desirable?
   - Does the technology exist, or does it need to be developed?
   - **If it needs to be developed does the team have the resources (skill, time, money) to do the development?**

The screening process can be summarized using the following 4 steps.

Step 1: prepare the selection matrix
The team chooses a physical media suited for the challenge at hand to construct the matrix. Individuals and small groups with a limited set of criteria might utilize paper matrices for selection.The inputs (concepts and criteria) are then inserted into the matrix. Although thoughts may have been produced by different people, they should be presented at the same degree of detail for meaningful comparison and fair selection. A textual description plus a pictorial illustration of the principles work well. A basic one-page drawing of each concept considerably simplifies communication of the concept's major aspects. The concepts are added using graphical or textual labels at the top of the matrix.The team selects a concept to serve as the benchmark, or reference concept, against which all other concepts are evaluated. The reference is usually an industry standard or a simple notion that the team members are quite familiar with.

Step 2: rate the concepts
Each column in the matrix is assigned a relative score of "better than" (+), "same as" (0), or "worse than" (-) to signify how each idea compares to the reference concept in relation to the specific criterion. It is normally recommended to assess each notion on one criterion before going on to the next. With a large number of concepts, however, it is faster to use the opposite strategy and rate each notion entirely before going on to the next.

Step 3: rank the concepts
After grading all of the concepts, the team adds the number of "better than," "same as," and "worse than" ratings for each category and inserts the total in the matrix's lower rows.The team ranks the notions when the summation is done. Those conceptions with more pluses and fewer minuses are obviously ranked higher. Often, the team may find one or two characteristics that appear to truly separate the concepts at this phase.

Step 4: Combine and improve the concepts
Having rated and ranked the concepts, the team should verify that the results make sense and then consider if there are ways to combine and improve certain concepts. Two issues to consider are:

- Is there a generally good concept that is degraded by one bad feature? Can a minor modification improve the overall concept and yet preserve a distinction from the other concepts?
- Are there two concepts that can be combined to preserve the "better than" qualities while annulling the "worse than" qualities?

Combined and improved concepts are then added to the matrix, rated by the team, and ranked along with the original concepts.

Step 5: select one or more concepts Once the members of the team are pleased with their awareness of each thought and its relative quality, they determine which

concepts will be refined and analyzed further. The team will most likely have a clear sense of which concepts are the most promising based on the previous processes. Team resources will restrict the number of concepts chosen for further examination (personnel, money, and time).Concept variants that are some 60% below the target are not worth further development. Variants with ratings above 80% and a balanced value profile those without extremely bad individual characteristics can generally be moved on to the embodiment design phase without further improvement.

6. **Firming up into principle solution variants**

   The principles elaborated in the above sections are usually not concrete enough to lead to the adoption of a definite concept. This is because the search for a solution is based on the function structure, and so it is aimed, first and foremost, at the fulfillment of a technical function.Before concept variants can he evaluated they must be firmed up, and experience has shown that this almost invariably involves considerable effort.

   To firm up the most promising combinations we must follow the following methods:

   - rough calculations based on simplified assumptions.
   - rough sketches or rough scale-drawings of possible layouts, forms, space requirements, compatibility, etc.
   - preliminary experiments or model tests used to determine the main properties or to obtain approximate quantitative statements about the performance and scope for optimization.
   - construction of models in order to aid analysis and visualization (for example, kinematic models).
   - analogue modeling and systems simulation, often with the help of computers; for example stability and loss analyses of hydraulic systems using electrical analogies.
   - further searches of patents and the literature with narrower objectives.
   - market research of proposed technologies, materials, bought-out parts, etc.

7. **Evaluating principle solution variants**

   When evaluating principle solution variants, the following steps are recommended.

   a) **Identifying evaluation criteria** Evaluation criteria are accordingly derived from:

      i. The requirements list:
         - Probability of satisfying the demands (how probable, despite which difficulties?)
         - Desirability of exceeding minimum requirements (exceed by how much?)
         - Wishes (satisfied, not satisfied, how well are they satisfied?)

ii. General technical and economic characteristics from the checklist (to what extent are they present, how well are they satisfied?).

During the conceptual phase, the total number of evaluation criteria should not be too high: 15-30 criteria are usually enough.

b) **Weighting the evaluation criteria**

The evaluation criteria adopted may differ markedly in importance. During the conceptual phase, in which the level of information is fairly low because of the relative lack of embodiment, weighting is not generally advisable. It is much more advantageous in the selection of evaluation criteria to strive for an approximate balance, ignoring low-weighted characteristics for the time being. As a result, evaluation will be concentrated on the main characteristics and hence provide a clear picture at a glance. Extremely important requirements, however, which cannot be ignored until later, must be introduced with the help of weighting factors.

c) **Searching for weak spots**

During the conceptual phase, the value profile plays an important role. Variants with a high rating but definite weak spots (unbalanced value profile) may prove extremely troublesome during subsequent development. If, because of an unidentified evaluation uncertainty, which is more likely to occur in the conceptual than in the embodiment phase, a weak spot should make itself felt later, then the whole concept may be put in doubt and all the development work may prove to have been n vain. In such cases it is very much less risky to select a variant with a slightly lower rating but a more balanced value profile Weak spots in favorite variants can often be eliminated by the transfer of better sub-solutions from other variants.

8. **Concept testing**

Concept testing is defined as a research method that involves asking customers questions about your concepts and ideas for a product or service before actually launching it. Thus, you can gauge your customers' acceptance and their willingness to buy and therefore make critical decisions before the launch.
Over the years, researchers have designed and applied many different methods of concept testing. These methods are categorized based on how the concepts are displayed. Each of these methods is suitable for different types of research. Concept testing is easily achieved with the help of a research platform. Here are the four primary methods of concept testing:

a) **Comparison testing**

In comparison testing, two or more concepts are presented to the respondents. The respondents compare these concepts by using rating or ranking questions or merely asking to select the best concept displayed. Comparison tests give clear and easily understandable results. It's easy to determine which concept is the winner. However, the results lack context. There is no way to tell why

the respondents choose one concept over others. It is essential to understand these details before successfully launching a product.

b) **Monadic testing**

In a monadic test, the target audience is broken down into multiple groups. Each group gets shown only one concept. These tests focus on analyzing a single concept in-depth. A monadic test survey is usually short and highly targeted. Since each group of respondents sees a single concept, it is possible to go in-depth without making the survey lengthy. Researchers can ask follow-up questions about the various attributes of a concept, such as what they liked about the concept, it's look and feel, price point, etc. Though each group of respondents sees different concepts in isolation, each concept's follow-up questions will be the same.

Monadic test surveys are short and give researchers the flexibility to ask multiple follow-up questions. Thus the results provide more context around why a specific concept is better than the others. However, since the target audience is split into multiple groups, the sample size required to conduct a monadic test is extensive. Since various concepts need testing, more significant is the sample size. The increase in sample size considerably increases the cost of research.

c) **Sequential monadic testing** Like the monadic test, in sequential monadic tests, the target audience is split into multiple groups. However, instead of showing one concept in isolation, each group is presented with all the concepts. The order in the concepts is randomized to avoid bias. The respondents are asked the same set of follow-up questions for each of the concepts to get further insights. Since each group of respondents sees all concepts, the target audience's size required to perform a sequential monadic test is relatively small. Multiple concepts can be tested in a single round. Thus sequential monadic tests are more cost-effective and easy to field. This concept testing method makes it ideal for research with budget constraints or when only a small target audience is available. However, since all the concepts are presented to each group of respondents, the questionnaire's length is fairly long. This affects the completion rate and might introduce nonresponse bias. Researchers can reduce the length of the questionnaire by limiting the number of questions. However, this affects the depth of the collected insights.

d) **Proto-monadic testing**

A protomonadic test includes a sequential monadic test followed by a comparison test. Here, respondents first evaluate multiple concepts and then ask to choose the concept they prefer. This design is useful to validate the results from the sequential monadic test. Researchers can verify if the concept selected in the comparison test is compatible with the insights collected about each concept.

Concept testing survey design

Once you have finalized the method you will be using; you must design a survey for conducting your test. Here are a few tips to help you design a useful concept testing survey.

a) **Set an objective for your survey** Once you set an overall objective for your survey, it becomes easy to come up with questions that will collect pertinent insights about your concept. It helps to think about the actual motive of the test and the particular details that you want to learn from your customers. Thus you can design a survey with relevant questions and gather meaningful information about your customers' viewpoint.

b) **Consistent survey design**

It's always a good practice to group related questions using survey blocks. Survey blocks help create a well-ordered flow for your surveys and make it easier for the respondents to answer them. Respondents can easily focus on one area of your concept without any distractions and provide accurate and insightful feedback.

c) **Likert scales**

Likert scales are rating scales with an odd-numbered series of answer choices, usually between five to seven. You can include Likert scale questions in your survey to ask the respondents to rate their opinion on a five- or seven-point scale from "strongly agree" to "strongly disagree." Using Likert scale questions creates a consistent design for your survey, making it easier for respondents to answer them. Moreover, it's easier to analyze the data collected using Likert scales.

d) **Include images**

"A picture is worth a thousand words." This idiom is true when you want respondents to provide feedback about a visual concept. Logo testing is a good example where it makes sense to use images instead of text. You can display different concepts of your logo design to your respondents and select the one they like best. This negates any bias and provides easily digestible results.

e) **Demographic questions**

It's essential to include demographic questions in your survey to ensure that the respondents are part of your target audience. You may receive negative feedback about your concept. However, it may not be a reflection on the concept itself. Rather the respondent may not be part of your customer base and isn't interested in your product. It's essential to have demographic survey questions to ensure your concept will be successful with your ideal customers.

2.3.3 Preliminary design

The system-level design phase includes the definition of the product architecture, decomposition of the product into subsystems and components, and preliminary design of key components. Initial plans for the production system and final assembly are usually

defined during this phase as well. The output of this phase usually includes a geometric layout of the product, a functional specification of each of the product's subsystems, and a preliminary process flow diagram for the final assembly process.The Preliminary Design must focus on the following key points:

- Exploration of few viable solutions
- Choice of candidate solution(s)
- Refine units/system
- Component sketches
- Preliminary drawings
- Computer Models

2.3.4 Prototype design

The detail design phase includes the complete specification of the geometry, materials, and tolerances of all of the unique parts in the product and the identification of all of the standard parts to be purchased from suppliers. A process plan is established and tooling is designed for each part to be fabricated within the production system. The output of this phase is the control documentation for the product, the drawings or computer files describing the geometry of each part and its production tooling, the specifications of the purchased parts, and the process plans for the fabrication and assembly of the product. The Prototype Design must focus on the following key points:

- Choose most promising design
- Refine preliminary units/system
- Refine preliminary components
- Detail design analysis and calculations
- Analysis and optimization
- Simulations
- Final drawings

Activities

1. Perform detail analysis on most promising design
2. Prepare working drawings
3. Prepare a detail Design

2.3.5 Prototype manufacture

In this phase, the early prototype is made using the intended manufacturing system mainly for the testing phase to refine the product for the final distributed product.The Prototype Manufacture must focus on the following key points:

- Design and build tooling
- Process design
- Build full scale prototype
- Record manufacturing problems and solutions
- Record results

2.3.6 Prototype testing

The testing phase involves the construction and evaluation of multiple preproduction versions of the product.Early prototypes are usually built with production-intent parts, parts with the same geometry and material properties as intended for the production version of the product but not necessarily fabricated with the actual processes to be used in production. This prototypes are tested to determine whether the product will work as designed and whether the product satisfies the key customer needs.Later secondary prototypes are usually built with parts supplied by the intended production processes but may not be assembled using the intended final assembly process. The secondary prototypes are extensively evaluated internally and are also typically tested by customers in their own use environment. The goal for this prototypes is usually to answer questions about performance and reliability in order to identify necessary engineering changes for the final product.The Prototype Testing must focus on the following key points like: perform experimentation, Ffnctionality, operability, reliability, safety, etc.

Final production

2.4 Review questions

1. After establishing target specification, the product development team proceeds to the _____phase.

   a) identifying customer needs

   b) concept generation

   c) test product concept

   d) production ramp-up

2. Concept generation is a _____ process which can be done _____ in comparison to the rest of the development process.

   a) relatively expensive, relatively quickly

   b) relatively inexpensive, relatively quickly

c) relatively inexpensive, relatively slowly

d) relatively expensive, externally

3. An effective development team usually generates:

a) only one excellent concept.

b) a few mediocre concepts to choose from.

c) a few excellent concepts to choose from.

d) hundreds of concepts of which very few will merit serious consideration.

4. Which of the following is not one of the common reasons for the development team to be dysfunctional during concept generation?

a) Involvement of all the team members in the concept generation process.

b) Ineffective integration of promising partial solutions.

c) Failure to consider entire categories of solutions.

d) Consideration of only a few alternatives proposed by the most assertive members of the team

5. The first step of the five-step concept generation process is:

a) rank the concepts

b) clarify the problem

c) select one or more concepts

d) collect competitive benchmark information

6. The five steps of concept generation process does not include:

a) clarifying the problem

b) translating customer needs in product specifications

c) searching externally and internally for the solutions

d) reflecting on the solutions and the process

7. Decomposition of a complex problem into a simpler subproblems can be done by:

a) functional decomposition

b) using sequence of user actions

c) identifying key customer needs

d) all of the above

8. According to the textbook, focusing initial efforts on the critical subproblems is a part of:

a) clarifying the problem at step 1

b) search externally at step 2

c) search internally at step 3

d) explore systematically at step 4

9. Interviewing lead users is one of the options a development team uses for finding solutions to the subproblems as a part of:

   a) internal search
   b) external search
   c) explore systematically
   d) clarify the problem

10. A development team may use the option of consulting experts for finding solutions to the subproblems as a part of:

   a) external search
   b) internal search
   c) systematic exploration
   d) clarification of the problem

11. External search for finding solutions to the subproblems involves:

   a) interviewing lead users and consulting experts
   b) searching patents and published literatures
   c) benchmarking related products
   d) all of the above

12. External search for finding solutions to the subproblems does not involve:

   a) interviewing lead users and consulting experts
   b) searching patents and published literatures
   c) individual and group sessions of team members
   d) benchmarking related products

13. To find solutions to the subproblems, the development team may search patents and published literatures as a part of:

   a) internal search
   b) external search
   c) exploring systematically
   d) clarifying the problem

14. The internal search process can be useful in _____ session(s).

   a) individual
   b) group
   c) individual and/or group
   d) none of the above

15. Suspension of judgment is one the guidelines for the _____ process for both individual and group sessions.

    a) internal search
    b) external search
    c) exploring systematically
    d) reflect on the solutions and the process

16. Welcoming ideas that may seem infeasible is one the guidelines for the _____ process for both individual and group sessions.

    a) internal search
    b) external search
    c) exploring systematically
    d) reflect on the solutions and the process

17. The guidelines for finding solutions by the internal search process does not include:

    a) generating a lot of ideas
    b) benchmarking related products
    c) welcoming ideas that may seem infeasible
    d) building sketch models

18. One of the ways to generate concepts by searching internally in Individual and group sessions is:

    a) by making analogies
    b) interviewing lead users
    c) searching patents
    d) benchmarking related products

19. One of the ways to generate concepts by searching internally in Individual and group sessions is:

    a) interviewing consulting experts
    b) using "wish and wonder" approach
    c) searching published literatures
    d) searching patents

20. One of the ways to generate concepts by searching internally in Individual and group sessions is:

    a) interviewing lead users
    b) searching published literatures
    c) using gallery method

d) benchmarking related products

21. Which of the following is not one of the helpful for generating solution concepts using internal search method?

    a) By setting quantitative goals

    b) Using related and unrelated stimuli

    c) By searching patents

    d) Using gallery method

22. In order to explore systematically in the concept generation process, the development team uses the:

    a) gallery method

    b) concept classification tree

    c) unrelated stimuli

    d) sketch model

23. The classification tree does not provide the following benefit:

    a) pruning of less promising branch and refinement of the problem decomposition for a particular branch

    b) potential solution by combining fragments from each column

    c) refinement of the problem decomposition for a particular branch

    d) exposure of inappropriate emphasis on certain branch

    Figure 2.3 an example of a classification tree

24. Figure7- 1 shows different options considered by the development team for providing energy sources for the handheld nailer. Which of the following options does not fall under the electrical energy source for the nailer?

    a) wall outlet

    b) battery

    c) explosive system

    d) fuel cell

25. The Figure 2.4 shows that _____ option is used to convert electrical energy to translational energy, followed by _____ option for accumulating energy, and finally _____option to apply translational energy to nail.

    a) rail gun; moving mass; multiple impact

    b) solenoid; spring; single impact

    c) rotary motor w/ transmission; spring; push nail

    d) rotary motor w/ transmission, spring; multiple impact

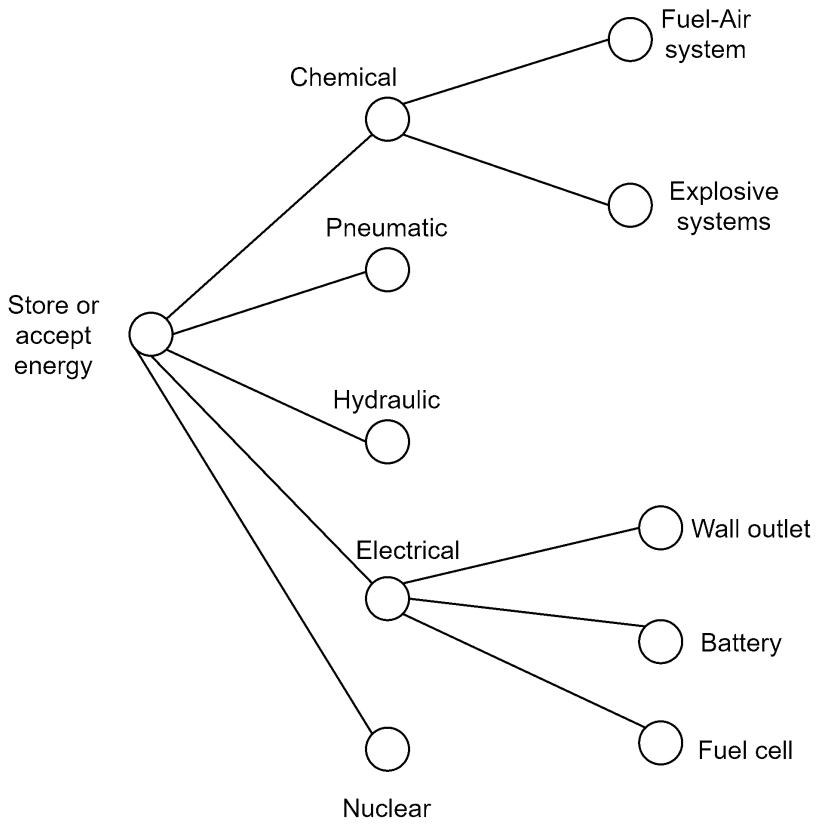

Fig. 2.3: An example of a classification tree

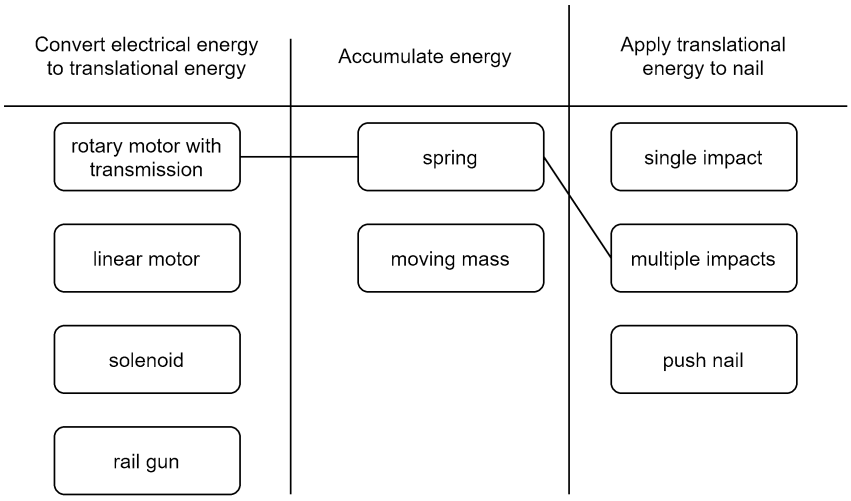

Fig. 2.4: An example of concept combination table for handheld nailer

26. As shown in Figure 7-2 , which of the following is not one of the concept solution fragments for applying translational energy to nail:

    a) single impact

    b) rail gun

c) multiple impact

d) push nail

27. While reflecting on the solutions and the process of concept generation, the development team takes a look at some critical questions such as:

a) Is the team developing confidence that the solution space has been fully explored?

b) Are there alternative diagrams and alternative ways to decompose the problem?

c) Have external sources been thoroughly pursued, and everyone's ideas been accepted and integrated in the process?

d) All of the above

28. The concept selection phase comes right after the _____ phase.

a) identifying customer need

b) concept generation

c) concepts testing

d) establishing target specification

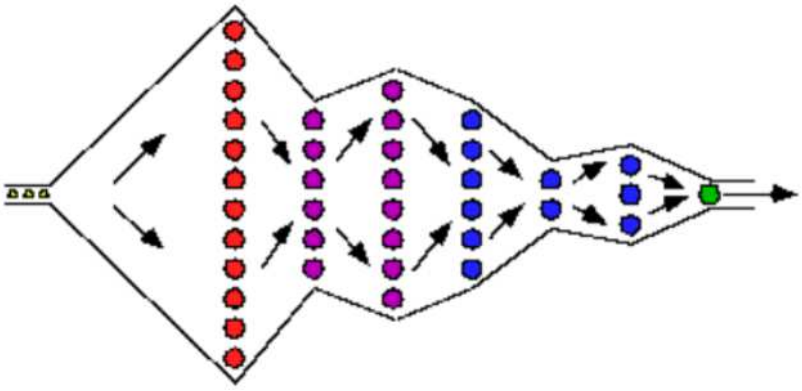

Fig. 2.5: The concept development funnel

29. Figure 2.5 shows a typical concept development funnel. It signifies that the concept selection is an iterative process which is refined and improved by concept _____, and _____ in order to select a few promising concepts for further development.

a) generation; testing

b) screening; scoring

c) development; testing

d) planning; generation

30. Choosing a concept on the basis of "Product Champion" method means that:

a) an influential member of the development team chooses a concept based on personal preference

b) customers or clients help to choose the concepts.

c) the development team rates each concept against pre-specified selection criteria

d) the team makes a choice based on the group opinion on the strengths and weaknesses of each concept.

31. Choosing a concept on the basis of "Pros and cons" method means that the:

a) development team rates each concept against pre-specified selection criteria

b) team lists the strength and weaknesses of each concept and makes a choice based upon group opinion

c) organization builds and tests prototypes of each concept, making a selection based upon test data

d) selection of concepts are based on the test results of prototypes built by the organizations.

32. Choosing a concept on the basis of "intuition" method means that the:

a) development team rates each concept against pre-specified selection criteria

b) team lists the strength and weaknesses of each concept and makes a choice based upon group opinion

c) concept is chosen by its feel. Explicit criteria or trade-offs are not used.

d) Concept is selected based on the personal preference of an influential member of the product development team

33. The potential benefit(s) for using a structured concept selection method include(s):

a) a customer-focused product and a competitive design

b) better product-process coordination and reduced time to product introduction

c) effective group decision making and documentation of the decision process

d) all of the above

34. One of the potential benefits for using a structured concept selection method includes:

a) a customer-focused product

b) ineffective group decision making

c) useless product-process coordination

d) increased time to product introduction

35. The following is not one of the potential benefits of a structured methods of concept selection:

a) A competitive design

b) Increased time to product introduction

c) Better product-process coordination

d) Documentation of the decision process

36. According to the text book, each part of the concept selection phase can be divided into a _____ process.

a) Four- step

b) Five-step

c) Six-step

d) Seven-step

37. As per text book, the first step of concept selection phase is to:

a) rank the concepts

b) prepare the selection matrix

c) rate the concepts

d) select one or more concepts

38. As described in the text book, both of the concept _____ and _____ stages follow a six-step process.

a) generation, selection

b) screening, scoring

c) generation, screening

d) selection, scoring

39. While preparing the concept-screening matrix, the development team chooses:

a) a benchmark or reference concept which is either an industry standard, or a straightforward concept which is very familiar to the team members

b) a benchmark or reference concept which is neither an industry standard, nor familiar to the team members

c) several concepts which team members are not familiar with.

d) none of the above

40. As described in the text book, the selection criteria chosen by the development team for the reusable syringe example was:

a) ease of handling

b) readability of dose setting

c) dose meter accuracy

d) all of the above

41. One of the selection criteria chosen by the development team for the reusable syringe example in the text book was _____ of the syringe.

a) size

b) shape

c) ease of use

d) price

42. The selection criteria chosen by the development team for the reusable syringe example in the text book did not include

a) price

b) dose meter accuracy

c) ease of use

d) ease of manufacture

43. At the concept scoring phase, scale compression can be avoided by using _____ reference point(s) for various selection criteria.

a) a single

b) two

c) different

d) same

44. The goal of the concept selection is to:

a) develop the best concept by combining and refining the available concepts

b) select the best concept

c) develop an average concept

d) test the best concept

45. Upon reflecting on the results and the process of the concept scoring phase, a development team may enquires:

a) If both the group and individual sessions were effective in generating many good concepts.

b) How the concept selection method can be modified to improve team performance?

c) Whether the results make sense to everyone

d) If any important criteria is missing from the screening matrix

46. One of the few caveats on concept selection process is:

a) ranking the concepts correctly

b) where to include cost

c) preparing the selection matrix

d) selecting one or more concepts

47. The following is not one of the few caveats on concept selection process:
    a) decomposition of concept quality
    b) to facilitate improvement of concepts
    c) selecting concept(s) that are most promising and would be likely to result in successful product(s).
    d) subjective criteria
48. The concept selection process is applied
    a) only during concept development phase
    b) throughout the subsequent design and development process
    c) during the planning process
    d) production ramp-up phase
49. Concept selection is a group process that facilitates
    a) the selection of a winning concept
    b) helps build team consensus
    c) creates a record of the decision-making process
    d) all of the above
50. According to the text book, the concept selection process is followed by:
    a) setting final specification
    b) setting target specification
    c) testing of product concepts
    d) planning for manufacturing

Answer

1. b
2. b
3. d
4. a
5. b
6. b
7. a
8. a
9. b
10. a
11. d
12. c
13. b
14. c
15. a
16. a
17. b

18. a
19. b
20. c
21. c
22. b
23. b
24. c
25. d
26. b
27. d
28. b
29. b
30. a
31. b
32. c
33. d
34. a
35. b
36. c
37. b
38. b
39. a
40. d
41. c
42. a
43. c
44. a
45. b
46. b
47. c
48. b
49. d
50. c

CHAPTER

3 Product Planning

Product planning is a technique of planning all the aspects of a product in its relationship with the market. It answers several basic questions related to the product such as what type of product, How much, when, where, at how much, for whom etc. In answering all these questions, a designer tries to match the products of the company with the market expectations. The aim of product planning is to avoid designing of unsuitable products and all the related expenses. The present day customer will not accept any product which does not suit his requirements in any way-price, style, designing, features, distribution etc. Product planning is always done keeping in mind the market or consumer expectations (see Figure 3.1). Product planning is an activity that considers the portfolio of projects that an organization might pursue and determines what subset of these projects will be pursued over what time period. The product planning activity ensures that product development support the broader business strategy of the company and addresses these questions:

- What product development projects will be undertaken?
- What mix of fundamentally new products, platforms, and derivative products should be pursued?
- How do the various projects relate to each other as a portfolio?
- What will be the timing and sequence of the projects?

3.0.1 Elements of product planning

Here are the essential elements of product planning process must consider before the product is envisioned:

Before taking a decision to produce a new item, market research should be carried out extensively. The company must know beforehand what should be produced and for whom. It should decide the characteristics of the product that can meet the requirements of the people.

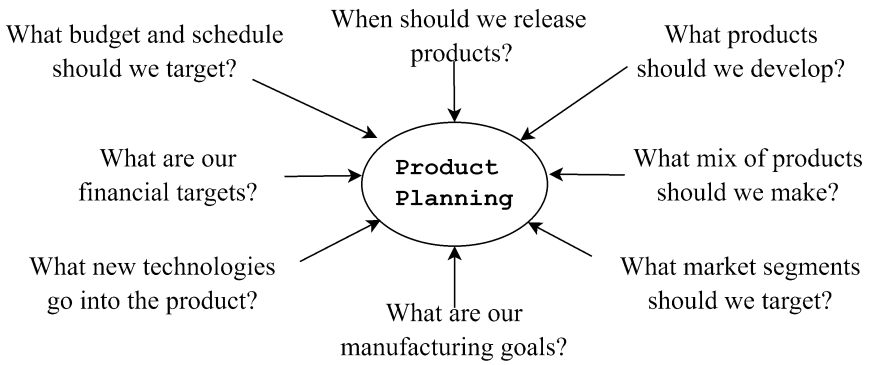

Fig. 3.1: Product Planning activities

Element 1: Possibility of production method: What production method would be followed and is practicable to develop a product exactly the way the customer wants? This possibility should also be examined before taking a decision of producing a new product.
Element 2: Modification in existing lines: The existing production lines should also be diagnosed whether they can be improved to meet the new requirements of the consumer or a new product is to be developed. If it is possible to modify the existing line, then, to what extent.
Element 3: Elimination of the product: Product planning involves the decision regarding the elimination of the unprofitable product lines so that the resources may be used to some other product profitably.
Element 4: Improvement in the product: Product planning includes decision regarding the improvement of the existing product in terms of quality, packing etc., taking in view the competitors strategies in the market.
Element 5: Price determination: Determining the price of the product is the main element of the planning. Would the prices be fixed on the basis of the prices fixed by the competitors for their products or on the basis of its cost of production or on the basis of the forces of its demand and supply in the market?
Element 6: Commercialization of product: Product planning includes products commercialization and sale of the product which can earn a good profit to the company on the one hand and may satisfy the needs of the consumers on the other hand. It also involves attractive introduction of the product in the market.
Element 7: Coordination: Product planning also attempts to coordinate the various products and their efforts so that the company can maintain or rather improve its competitive position. It can be done by taking timely decisions for marketing conditions from time to time.

3.0.2 Characteristics of product planning

The following are the main characteristics of Product Planning:

Characteristic 1: Product Investigation: Before preparing the product for marketing, marketing research is carried out to know the desired need of the consumers so that

product's size, colour, design, features, package, price etc. are according to their requirements and only then the product satisfying all these choices is to be produced.
Characteristic 2: Change in Commodity According to Demand: If the existing product needs certain modifications according to the demand, then collection of necessary facts and making changes in the product accordingly are also part of product planning.
Characteristic 3: To Know the Practical Aspect of the Product: After knowing the product features desired by the consumers, it is important to know whether it is practicable to develop a product exactly what the consumers want.
Characteristic 4: Discontinuance of Product: Product Planning involves the decision regarding the elimination of the unprofitable product or product lines so that the resources may be used to some other product profitably.

3.0.3 Major factors for successful product planning:

A product plan or strategy is a company's plan for marketing its products.The success of product plan depends on the following factors:

1. **Product line**

   A product line is a group of products within a product class that are closely related, either because they function in a similar manner, are sold to the same customer groups, are marketed through the same types of outlets or fall within a given price range.Product lines are created by companies as a marketing strategy to capture the sales of consumers who are already buying the brand. The operating principle is that consumers are more likely to respond positively to brands they know and love and will be willing to buy the new products based on their positive experiences with the brand in the past.For example, a heavy machinery equipment manufacturing company that's already selling a high-priced product line of earth-moving machinaries (that might include excavators, Backhoe Loaders, Bulldozers, and Dump Trucks) under one of its well-known brands might launch a product line under the same brand name but at a lower price point. Product lines can vary in quality, price, and target market. Companies use product lines to gauge trends, which helps them to determine which markets to target.

2. **Product Mix** Product mix, also known as product assortment, refers to the total number of product lines that a company offers to its customers. For example, a company might sell multiple lines of products, with the product lines being fairly similar, such as toothpaste, toothbrush, or mouthwash, and also other such toiletries. All these are under the same brand umbrella. The product lines may range from one to many and the company may have many products under the same product line as well. All of these product lines when grouped together forming the product mix of the company. The product mix is a subset of the marketing mix and is an important part of the business model of a company. The product mix has the following dimensions or components:

   Width: The width of the mix refers to the number of product lines the company has to offer.For example: if a company produces only soft drinks and juices, this means

its mix is two products wide. Coca-Cola deals in juices, soft drinks, and mineral water, and hence the product mix of Coca-Cola is three products wide. **Length**: The length of the product mix refers to the total number of products in the mix. That is if a company has 5 product lines and 10 products each under those product lines, the length of the mix will be 50 [5 x 10].

Depth: The depth of the product mix refers to the total number of products within a product line. There can be variations in the products of the same product line. For example-Colgate has different variants under the same product line like Colgate advanced, Colgate active salt, etc.

Consistency: Product mix consistency refers to how closely products are linked to each other. Less the variation among products, more the consistency. For example, a company dealing in just dairy products has more consistency than a company dealing in all types of electronics.

3. **Packaging**: A package is a wrapper or container in which a product is enclosed, encased or sealed. Packaging can be defined as "an act of designing and producing the package for a product". Now packaging is done according to consumer convenience.

4. **Labeling**: Labeling is the right of consumers in the free market economy, to be informed with accurate and up-to-date information about the content and necessary guidance regarding the use of the product.

5. **Branding**: Branding is the practice of giving a specified name to a product or group of products from one seller. The brand names of Mercedes Benz, Pepsi, Sony, etc., are examples of branding, which help distinguish their product in the market and create individuality. A well promoted brand name has an earned reputation in the market.

6. **Service after sale**

   Marketing focuses on the idea of satisfying the needs of the customer, as the customer is considered king in marketing terminology. Marketing approach is a customer oriented approach and in this context, service after sales is very important.

7. **Product research and improvements** The success of product planning and development depends on product research and improvement. In other words, product analysis and research is the study of consumer preference, habits and dealer preferences, habits relating to a given product, the market potentiality for a new product, etc. This analysis will help the firm redesign, improve or modify the product mix, as per the expectations and requirements of customers.

3.1 Product Planning Process

The product planning process takes place before a product development project is formally approved, before substantial resources are applied, and before the larger

development team is formed.

3.1.1 Objective of product planning process

The main objective of product planning process is to address the following 8 main points:

1. ***To meet the customer needs*** - Successful marketing lies in identifying and meeting customer needs. Product planning is a technique which enables identification and meeting of customer needs through working with the customers and securing their feedback. This makes possible delivering customer satisfaction.

2. ***To increase the sales*** - Product planning enables a company to manufacture appropriate products which satisfy customer expectations and thereby increase sales.

3. ***To optimally utilize resources*** - Every company has limited resources in terms of money, material and human resources. Product planning enables the company to make the best use of such limited resources by channeling them towards the most appropriate products.

4. ***To analyze the company's strengths and weaknesses*** - Product planning analyzes the strengths and weaknesses of the company in the light of the market requirements. This enables the company to consolidate on its strengths and overcome its weaknesses.

5. ***Survival of the firm*** - Product planning enables a company to survive in a highly competitive market through its components such as product innovation, renovation and elimination.

6. ***Commercial success*** - Product planning enables a company to achieve commercial success by coordinating the activities of all the specialists in the company who contribute to the product's performance in the marketplace. This is done through product development teams, marketing executives, quality managers and sales representatives.

7. ***Achieving the goals of marketing management*** â€“ Product management and marketing management share similar objectives, which are to maximize revenue and profit by meeting customer needs. Product managers work closely with marketing managers, using research from the marketplace to plan and prioritize product development programs, and briefing marketing teams on the benefits of new products so that they can develop effective customer communications.

8. ***To plan effectively***-A key objective for product management is planning and developing the specifications for a range of products or a product portfolio that meets the long-term strategic plan. The strategic plan may require development of new products to meet the needs of new market sectors or improvements and extensions to the current product range to increase share in the existing sectors.

The product planning process starts either with a recognized customer need or with a basic product idea established through market research or other sources. Regardless of the origin of the product idea, (it may originate from a salesman, a customer, the company's advertising agents, the technical research and development department), market research should be used at some stage, to determine whether it meets a known or as yet unrealized need. Marketing research will help to establish **(a)** The existence or otherwise of a real or latent need, **(b)** The dimensions and trend of the market (the number of potentials customers, their desires and preferences, where they are located, their purchasing power and buying habits, whether the market is expanding, static or shrinking in size and so on), **(c)** The competitive state of the market, and **(d)** The standing, with the customer, of competitors and the company's own products.

The major advantages of proper product planning processes are as follows,

1. The quality of the product is the key to successful development. Therefore proper planning will allow the team to focus on making the right product as expected by the end-user.
2. Proper planning will prevent rework and hence saves cost.
3. The satisfied customer becomes the brand ambassador and will fetch more business. Hence plan to deliver the right product at the planned time.
4. It will be easy to market the product that is developed after proper planning which enhances its market value.
5. Prioritizing the product backlog will become easy for a PO once they understand an effective planning process.
6. The overall time consumed in development can be predicted with proper planning in place.

In short, the product planning process will enhance the product features and will give a clear idea about the time box and increment. Precise planning will help the team align with the timeliness and deliver an expected outcome. Customers can review the development and provide suggestions to improvise the planning process. Having a clear road map will allow feature enhancement and thus even in a dynamic environment lot of time is saved.

Figure 3.2 illustrates the steps in the product planning process.

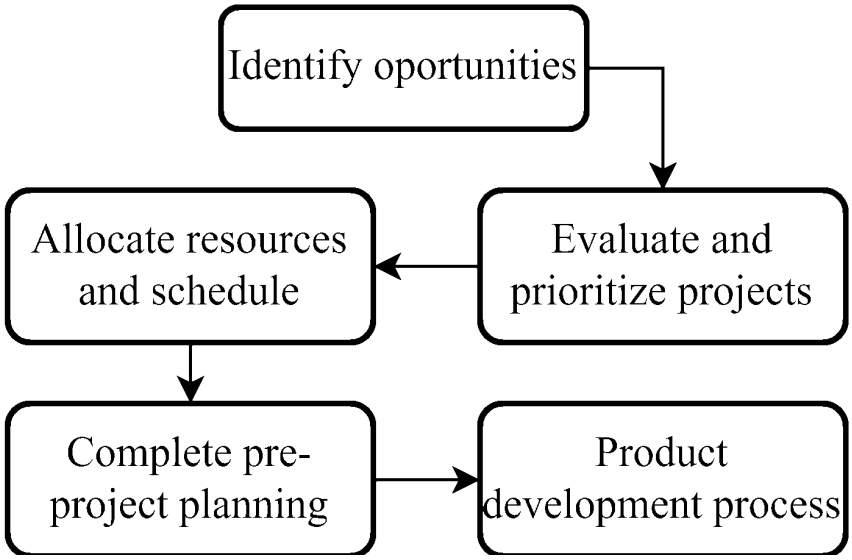

Fig. 3.2: Product Planning process

3.2 Product development

Figure 3.3 illustrates the steps in the product development process.Some of the major process of product development are as follows: 1. Exploration 2. Screening 3. Detailed Business Analysis 4. Development 5. Test Marketing 6. Commercialization.

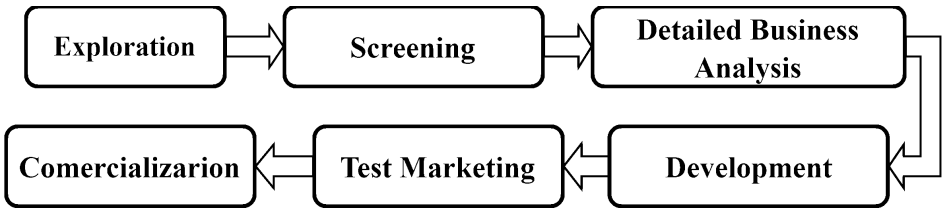

Fig. 3.3: Product development process

1. **Exploration** Product planning begins with the generation and formulation, of ideas or concepts for new products. The product ideas may come from sales persons or the designer who are in constant touch with the needs and desires of consumers. Middlemen, research and development department, trade and technical journals, consumers, trade associations, chambers of commerce, government agencies, research laboratories and executives can be other fruitful sources of product ideas. New ideas may also emerge from individual innovators, suggestion schemes, marketing research, cost studies, service organizations, etc. At this stage, the products of competitors, institutes and allied products should also be considered.

2. **Screening:** This stage involves a preliminary comparison and evaluation of product ideas to select the most promising idea which warrants further consideration. A large number of ideas may be available. It is necessary to eliminate the ideas which have no potential. Careful screening helps to avoid wastage of time and resources

in impracticable or uneconomical ideas. A clear understanding of the company's objectives and facilities is essential for successful screening. This will help to reject the ideas which are inconsistent with the strategy and resources of the enterprise. In recent years, leading companies have developed specific criteria for screening. Such criteria consist of:

- Profitability requirements over a period of time;
- Annual value of production;
- Unit profit margin;
- New capital required;
- Use of existing distribution network, etc.

3. **Detailed business analysis:** Those ideas and concepts which survive the screening stage are put to rigorous economic evaluation. The technical and economic factors involved in the ideas are analyzed in sufficient detail to judge the commercial viability and technical feasibility. A statement of expected costs, sales and profits over a period of time is prepared. Business analysis may also involve some preliminary testing and analytically studies which is known as concept testing.

   Business analysis is made to answer the following questions:

   - Is the product idea technically feasible?
   - Is there an adequate market demand?
   - Is it necessary to obtain patent right?
   - What is the raw material position?
   - Will machinery be imported?
   - Are the production facilities suitable?
   - How much will it cost to produce and sell?

4. **Development:** At this stage, a design or specification of the product is prepared. The product idea is given a practical shape in the form of a working model or prototype. The idea on paper is converted into a physical product. The prototype is tested in the laboratory to ensure that it meets all technical specifications.

5. **Test Marketing:** A sample of the product is then tested in a selected market to find but the reactions or responses of consumers. The working model or prototype is produced in a limited quantity and it is tested in the market before starting full scale production.

   On the basis of the feedback from consumers, necessary improvements (re-designing) arc made in the product. Test marketing is a vital phase of product development as it helps to "tie up the loose ends" before launching the product in the market.

6. **Commercialization:** In this final stage, the product is actually introduced in the market on a full scale. The pricing, channels and promotional methods are finalized.

The product is fully integrated into the company's normal operations and it no longer remains a new product.

3.3 Review questions

1. Without careful product planning, organizations may face:
   a) inadequate coverage of target markets with competitive products
   b) poor distribution of resources
   c) initiation and subsequent cancellation of ill-conceived projects
   d) all of the above
2. Product development projects can be classified into _____ types.
   a) two
   b) three
   c) four
   d) five
3. New product platform projects are based on:
   a) the extension of an existing product platform
   b) a new, common platform
   c) radically different production technology
   d) addition or modification of some features of existing product
4. Derivatives of existing product platform projects are based on:
   a) the extension of an existing product platform
   b) a new common platform
   c) radically different production technology
   d) addition or modification of some features of existing product
5. Some projects may only involve adding or modifying some features of existing products. These projects are classified as:
   a) new product platforms
   b) derivatives of existing product platforms
   c) fundamentally new product platforms
   d) incremental improvements to existing product platforms
6. Fundamentally new products are based on:
   a) a major development effort to extend a family of existing products
   b) derivatives of existing product platforms
   c) radically different products or production technology
   d) addition or modification of some features of existing product
7. An Ipad is an example of:

a) a new product platform

b) a derivative of an existing product

c) an incremental improvement to an existing product

d) a fundamentally new product

8. To develop a product plan and project mission statements, a _____ process is suggested.

a) Five-step

b) Six-step

c) Seven-step

d) Eight-step

9. The outcome of a product planning process is:

a) a vision statement

b) a new product

c) a mission statement

d) a new opportunity

10. The first step of developing product planning process starts with:

a) identifying opportunities

b) allocating resources and plan timing

c) evaluating and prioritizing projects

d) complete pre-project planning

11. The second step of product planning process is to:

a) allocating resources and plan timing

b) select most promising projects to pursue

c) complete pre-project planning

d) identifying opportunities

12. An organizationâ€™s competitive strategy includes:

a) technology and cost leaderships

b) customer focus

c) following market trends

d) all of the above

13. A product segment map shows:

a) products that are used in different market segments, as well as those of the competitors

b) product performance over the years

c) product life cycles

d) perceptual map of products used by the company.

14. Which of the following is not a basis for segmenting a market within a company?

a) Personal

b) Workgroup

c) Department

d) Industry

15. A key product planning decision making tool in technology-intensive business is a:

a) U curve

b) S curve

c) Y curve

d) Straight line plot

16. A product-technology roadmap shows:

a) relative cost of development project

b) architecture of a family of products

c) product performance

d) life cycles of available technologies

17. Managers may use the _____ to balance an organizationâ€™s portfolio of the development projects.

a) S curve

b) Technology roadmap

c) Product-process change matrix mapping

d) Product segment map

18. Aggregate planning process helps to:

a) plan introduction of new products in the market

b) allocate resources efficiently by pursuing only those projects that can be completed with budgeted resources

c) acquire and implement new technologies

d) none of the above

19. Aggregate resource planning can be achieved by:

a) estimating resource demands over time

b) tracking product performance over time

c) identifying products for each market segments

d) evaluating new product opportunities

20. A Product Plan includes the _____, approved by the planning process, and _____.

    a) final project; sequenced in time
    b) set of projects; the allocated budget
    c) final project; the allocated budget
    d) set of projects; sequenced in time

21. A mission statement includes:

    a) Brief description of the product
    b) Benefit proposition and key Business goals
    c) Target market, assumptions and constraints
    d) All of the above.

22. The Product Planning process is immediately followed by the:

    a) System-level design phase
    b) Detail design phase
    c) Concept development phase
    d) Testing and refinement phase

23. The outcome of a product planning process is:

    a) a vision statement
    b) a new product
    c) a mission statement
    d) a new opportunity

24. The Product Planning process is immediately followed by the:

    a) System-level design phase
    b) Detail design phase
    c) Concept development phase
    d) Testing and refinement phase

Long answer questions

1. Explain product planning.
2. Discuss The Process Of The Product Planning Process
3. How do product planning strategies affect product viability?
4. List and describe the five steps in the product planning process.
5. What factors may affect the length of the new-product planning process?

6. The five stages of Product Planning and Development Process are idea stage, concept stage, product development stage, test marketing stage, and commercialization. Using a business example explain the five stages (in flow order) of the Product Planning and Development Process?

7. You are required to select a product category of a XYZ firm (you can use any company name) and develop a new-product-planning process for it. Considering the nature of the product and product category that youâ€™ll select, devise a new product planning process and discuss relevant (not necessarily all) steps youâ€™ll consider while designing and implementing the new product planning process. Discuss in detail and validate your choices with justifications and arguments.

8. Assume that you are the product planning manager of Johnson and Johnson company, Discuss individual product decisions : line extension, brand extension, multibrand and new brand (If there is no individual product decisions in which one you as a product planning manager can develop on your own).

9. Using Solerable shoe manufacturing company as an example, discuss how do they implement their Global Product Planning with various strategic alternatives to suite variety of conditions. In your discussion, besides critically discussing the implementation of their Global Product Planning, you also need to suggest better marketing solutions in order for this company to stay competitive and relevant in the near future.

10. In product planning process, what are the main factors must be consider for resources distribution among projects and timing planning?

11. Have an Introduction and conclusion on New product planning and development process with an examples of a product ?

Answer

1. d
2. c
3. b
4. a
5. d
6. c
7. a
8. a
9. c
10. a
11. b
12. d
13. a
14. d
15. b
16. d
17. c
18. b
19. a

20. d
21. d
22. c
23. c
24. c

CHAPTER

4 Product Design Specification

A product design specification (PDS) is a document that contains all the requirements, constraints and specifications that a new product must adhere to. It should be a clear list with detailed information outlining every aspect of the design brief and fulfill SMART criteria (specific, measurable, achievable, realistic and testable). The PDS document describes the intended function of the device being designed, and the environment in which it will be used. It also specifies certain high-level requirements related to global constraints such as safety, shipping, and manufacturing. A properly written PDS document is solution neutral and does not specify design details; i.e., it describes what the product should do and not how it does it. This is crucial to ensure that the creative control of the designers is not stifled, and that changes to the design details will not necessarily require a change to the PDS. Furthermore, with regard to communication within large design teams, the PDS serves to ensure that every member of the team is working towards the same overall goals PDS will be referred to throughout the design process to ensure that any changes comply with the original specification and remain in scope for that specific project.

The PDS is a single document that details what the product needs to do, look like and deliver for the end user. Having this document will guarantee that design teams have clear expectations for the finished product and ensure that all parties are working with the same understanding of exactly what the product will be saving time and money. Using a PDS effectively will provide transparency and direction throughout the development process. By completing the specification, abstract elements of the initial design can be turned into a tangible list of requirements that must be met to ensure the product is successful. This includes detailing each problem and its proposed solutions. While this may sound like a lengthy process, clearly defining these parameters ensures that any adjustments, improvements or solutions are feasible within the project's limitations. While many of these aspects will be universally included in product design specifications, each different project will demand its own, specific considerations. Preparing this information before writing will help you to create an effective and understandable product design specification document. We can model the

production of the PDS for a given product using a process flow diagram. One example of such a diagram is given in Figure 4.1. This diagram assumes that a conceptual design

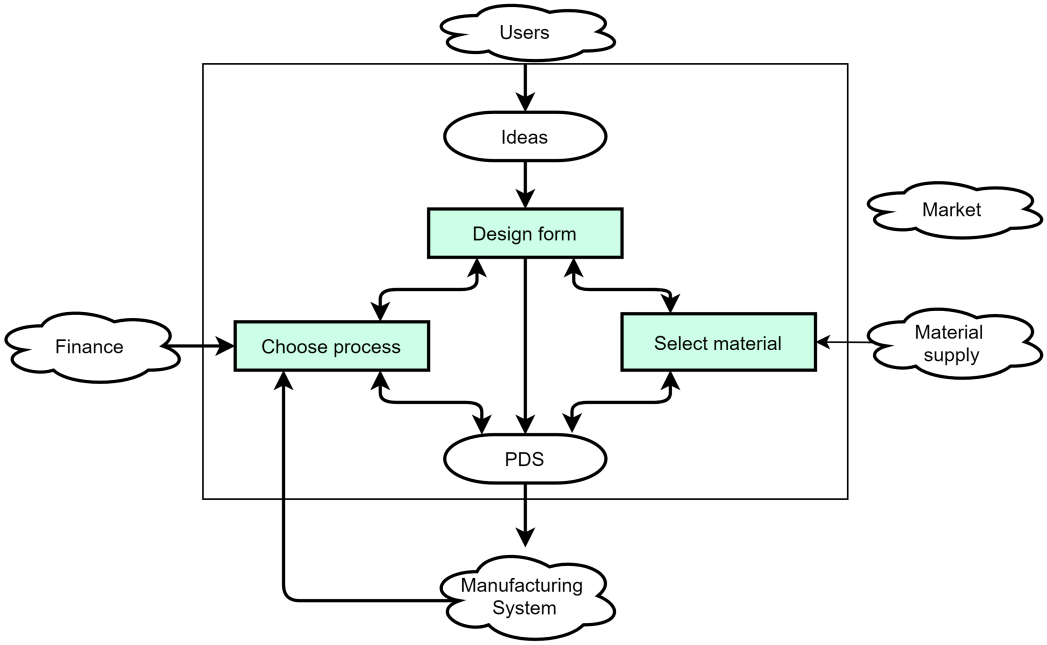

Fig. 4.1: A product design sub-system

for a product already exists and so concentrates on how we resolve the conflict between the shape of a product, the choice of material and the selection of a process to make it. It is clear that the output of any useful design system should be a specification detailing the way in which the product is to be made, and the standard to which it is to be manufactured. Such a specification will take into account the company's manufacturing capability, the relative performance of candidate materials, the behavior of the market and many other technical and commercial factors. The design activity is triggered by an idea for a product. However, there is not usually much point making a product if you can't sell it so the idea is usually coupled with information concerning the market and expressed in terms of a market need. The market need is defined by the PDS which evolves with the product, starting out as the expression of often only a vague idea but gradually increasing in complexity and detail as the product design takes shape. One approach to ensuring a comprehensive PDS is the use of a PDS checklist.

It would be a mistake to think that this checklist is a prescription to design solutions. The PDS is a specification of what is required but not the specification of the product itself. Describing the actual product is done in the technical specification, once the product has been designed. The difference is important since describing the product itself at the stage of creating a PDS, effectively constraints the range of alternatives that are considered during the design process.The distinction can be seen as the difference between "What is the product to do?" and "How will the product do it?". The important thing to realize is that the PDS increases in detail as the design becomes progressively refined and each of the questions in the list will have to be asked on a number of

occasions, the answers becoming more comprehensive on each iteration. One attempt to describe this iterative development of the PDS uses the spiral design model, as shown in Figure 4.2. Here the idea of needing to reconsider the three areas of product shape,

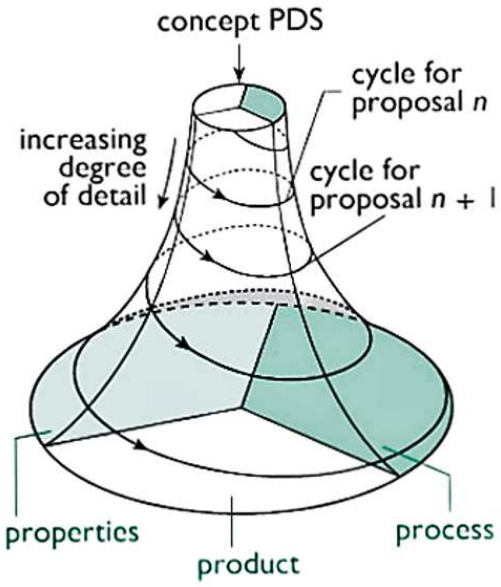

Fig. 4.2: A spiral design model of PDS development

material properties and process capability is repeated. The increasing size of the spiral represents the fact that the amount of detailed information on the PDS grows with each iteration.

Inevitably, the parts of the PDS you consider important depend on your viewpoint and purpose. Consider, for example, the contrasting viewpoints of an engineer who works for a foundry and is trying to use up spare manufacturing capacity profitably, and an aeronautical engineer working on a new form of anti-stall flap for an airliner. Product teams with expertise in engineering design, marketing and production are required if a balance is to be maintained through the design activity. The leader of this team, often known as the product champion, will be chosen for his or her particular skills depending on the nature of the product. The one skill, however, which is always needed by such a person is leadership.

4.1 Elements of PDS

Although the PDS has to be a written document, its not set in stone. it can be changed. in fact it is likely to change. As a rule, the design follows the PDS. But if the design that develops from the PDS departs from it for a good reason the PDS can be reviewed and revised to accommodate the necessary changes. The most important thing to note is that the PDS needs to always work with the design process itself. The product design specification, or PDS, should contain all the facts relating to the product. It should not lead the design by presupposing the outcome, but it must contain the realistic

constraints on the design. This list is one attempt to cover the principal questions that need to be answered in formulating a PDS. Inevitably, it isn't comprehensive; specific products will require their own additional items.Here are the primary elements of PDS

- An overview explaining the products' place in the market and intentions behind its creation
- **Performance considerations:** Here the performance demanded of any product should always be fully and precisely defined.It should answer the following questions: how easy is it to operate?, How durable is it?, Operating conditions (see environment)
- **Environment:** All aspects of the environmental conditions that the product is likely to come into contact with, and have an effect on, need to be considered and investigated at the outset of the project. Environmental hazards may occur during a number of stages in the design and development.It should answer the following requirements: how does it handle in weather conditions?, temperature performance ranges, Corrosion and break down resistance, How much load does it need to withstand?, Dust and dirt should be easily cleaned from the product.
- **Life in Service:** The service life of the product and how this is to be measured needs to be stated.
- **Maintenance:** You should be aware of the maintenance issues surrounding the product at all stages of its life, including the need for spare parts or special tools.You must focus on the following questions:
  - What standards does this product and its parts need to comply with
  - What parts must be accessible
  - How easy should it be to replace a part
- **Target product cost:**Establish targets for production, supplier, contractor, and retail costs as early as possible. By checking competitor or similar products.The product is aimed at the (low/mid/high) price range. Retail cost is _____ and target cost for manufacture is between _____ and _____.
- **Competition** You will need to conduct a comprehensive analysis of competing and similar products; this will typically involve literature searches, patent, and product searches.
- **Packing:** It is likely that the product being designed will need some form of packaging even if this is merely to protect the product while it is being transported from one place to another. The cost of packaging can have a significant impact on the final cost to the customer. The packaging size, cost and, weight must be kept to a minimum, must be waterproof, Must be easily unpacked by the customer? Company logo must be clearly shown on package?.
- **Shipping/Transport:** Is your product delivered by land, sea, or air? Consider the type of truck, pallet container, or aircraft.

- **Performance/Quality/Reliability:** Consider how many products you wish to manufacture, which will affect quantity, costs and schedule.How many produced initially, short/medium/Long production run expected.Performance is important in a sense that the assistive device actually benefits the user. If the design does implement a handle but hinders the drinking feasibility compared to the original can or water bottle by itself, it is not a good design. Reliability in our case can be things like the assistive device actually holding the can or water bottle well. Quality mostly relates to aesthetics of the product in our case.
- **Manufacturing Facility** Where is the product to be made and what facilities and expertise will be available?There are no constraints on the manufacturing facility.In the case of this mini-project, the manufacturing will be done with Fused Deposition Modeling (FDM) printing. This means that the same material will be used to 3D print the whole product. And that the product will be less resistant to the force in parallel directions due to the nature of Fused Deposition Modeling (FDM).
- **Aesthetics:** As a product designer, the color, shape, form, texture and finish are major ingredients directly under your control that can lead to a product's ultimate success or failure. Therefore, The brand values should be highly visible,the company logo should be clearly seen in bold lettering at least 1/3 in (10 mm) high,a robust image must be projected to the customer.
- **Materials:** These must be readily available, easily processed, and comprise the required properties. If special materials are required, specify the appropriate standard. Harmful materials, such as lead-based paint, must not be used in consumer products, the use of existing materials for manufacture is imperative, the materials selected must withstand the environmental conditions and should not oxidize in any way, all the materials should be non-toxic.
- **Standards/Specifications:** Most products need to adhere to national and/or international standards. Bear in mind that standards are useful and essential in many areas but they should not be allowed to hinder real innovation.
- **Ergonomics** All products have a user-product interface. Ensure it is easy to operate, requiring little physical effort for both left-handed and right-handed people, Ergonomic elements can also cover cognitive issues as well as physical ones. Easily accessible control positions, hand-operated controls must not need a force of more than 1 Nm to operate, no sharp edges to be exposed, it is preferable if controls are different colors for easy use.
- **Product life span:** How long will the product that you are designing stay on the market? The longevity of the product will affect important decisions including funding.This should be as long as possible with possible passing from one generation to another?
- **Processes:** Are special manufacturing processes required, such as plating or finishing requirements?There are no limitations to the manufacturing processes.

- **Timescale:** When you schedule your project, be sure to allow enough time at the beginning for the design phase.
- **Testing:** After your product has been made, it will need a factory test to see whether it complies on every point with its PDS. You may also need to plan for acceptance and witness tests too.
- **Market constraints:** Be mindful that local conditions, especially overseas, can constrain your design.
- **Patents:** You must search all relevant information, including patents, relevant literature, and competitors' product information. You need to check that you are not infringing on other individuals' patents or products.
- **Political/Social implications:** Be sensitive to any political and social effects that your product might have in the country for which it is to be designed and manufactured. This includes local bylaws and regional trends. The name of the product should be thoroughly checked when considering exportation to non-English speaking countries. Logos and colors used in the product should be checked against individual countries' tastes. Product should be manufactured to company's social and ethical guidelines.
- **Installation:** Many products form part of assemblies into larger products and systems or need to be installed. The product must be ready assembled and does not require user assembly for use.
- **Documentation:** Product documentation is an increasingly important aspect of product design. Product accompanied by appropriate comprehensive documentation for use and maintenance.
- **Disposal:** The design of products has a significant effect on the environment. Your PDS, therefore, must include information on what is done with the product after its life. This will include things like how you best design for disassembly, dispose of any associated waste, and recycle the product. Product and constituent components are able to be disassembled for disposal and recycling where at all possible. Product components are clearly labeled for appropriate recycling/disposal.

Once it has been drafted, ask the following questions to make sure your PDS has been written correctly:

- Does each section provide clear instructions?
- Are examples and data used to ensure that points are made as facts rather than opinions?
- Are all requirements clearly specified to prevent misunderstandings?

You should then share the document with your team to identify additional queries and talk through concerns. This feedback will be valuable for improving the final document.

4.2 How to Write a Product Specification

1. **Define the problem:** What problem or challenge will this product help users solve? There's no point to building products that do not address specific business needs or consumer needs. Make sure that the needs and problems that the product will address are noted in the product summary.

2. **Understand customer input:** What do customers want in a new product? User stories give you a goal to achieve with the new product and an assessment of how it will help your customers. Use customer feedback on existing or related products for insight.

3. **Include your whole company in the discussion:** Stakeholders need to have a say and will be helpful in the development process. This can help you get lots of helpful input and more support in completing the job. It will also help employees feel that they can contribute to the project so they feel more invested in contributing and working with the team.

4. **Pick which product specifications to include:** Some requirements and specifications are critical to the product developers so the product is safe and usable. Include specs such as dimensions, safety standards, expiry details, and an overall product design specification. These specs get product creation underway more easily. You might leave other specifications, such as specific UI/UX considerations or color schemes, to be defined later in the product development process.

5. **Do user testing:** Once you have a plan in place for design and development, make a prototype. Make sure that the product is going to be right for customers. Let them test it, try it, and assess it. Check on the use or lack of useful features and things that are hard to use or irritating. Does everything work as it should?

Revise based on what your users determine works and what doesn't. Decide what is liked, disliked, complicated, or unnecessary and fix problems and revise specs as needed, based on the results of user testing. Carefully consider functionality or places where users get stuck and how can you improve it. Should you scrap this or that functionality altogether? If you would like more insight into the world of project management, learning about project specifications and product specs sign up for The Product Manager Newsletter. You'll find good advice and lots of info that you can use as you get familiar with product specifications and other areas of your work.

4.3 Example of PDS

Design Specification for a portable winch

The following example PDS, although longer than the PDS's you will produce for your projects, contains many aspects of a commercial PDS and was written with advice from a winch design company. A real design brief for a winch would contain many more aspects than outlined here. A PDS for family motor car for example, would have many more

categories specific to the product and would require several large manuals to list the 'problem' in detail.

Design brief From internal market research, it has been decided that it is needed to design a general purpose winch to sell to the cable and pipe laying market sector. The winch should be portable but have mounting points for the end user.

1. **Performance:**
   a) Lift / lower a load of 2.5 tonnes (+/- 10%).
   b) Draw in cable in at a rate of 0.2 m/s.
   c) The winch drive should cut out when the load exceeds 10
   d) Drive to stop lowering load when only 1.5 metres of cable remains on winch drum.
   e) Winch should operate with forward, reverse, stop and inch facility.
   f) Any braking system employed, should produce a braking torque of 150% the full load torque.
   g) Winch should have a manual device to control the brake release and load descent in the event of a power failure.
   h) In the event of the winch "overrunning", a manual safety relay/braking device should operate within 1 second or before the load exceeds a speed of 3m/s.
   i) The product should be portable but with the option for permanent mounting.
   j) The product must use a portable power source, preferably a diesel engine.
   k) The weight of the product must be sufficient to aid the stability of the product.
   l) Efficiency of the unit should be high, preferably in the area of 20 - 30
   m) The drum should hold 50m of cable.
2. **Environment**
   a) The winch drive and power unit should be power unit.
   b) The unit will be mainly used in European weather conditions. But we could expect sales of about 2% unit volume to the Far East.
   c) Temperature ranges: 28 - 68(^0C)
   d) The product may experience humid conditions.
   e) Corrosion resistance may be considered by the use of special materials or surface protection methods.
   f) Any noise from the equipment should not exceed 95 dB at a distance of 1.0m.
   g) The winch will be stored in suppliers warehouses before sales.
3. **Product life span**
   a) Product will be on the market for 10 years.
   b) Spare parts will be available for a further 5 years after that.

4. **Life in service**

   a) Should withstand an operating period of 1 hr uninterrupted use per day for 5 years.

   b) Life in service should be assessed against the criteria outlined in the Performance and Environment categories.

5. **Shelf life**

   a) The product will be stored on-site for up to 1 month before dispatched.

   b) Our Far East distributor may store the product for several months.

6. **Target costs**

   a) The product should have an end-user cost of 380,500 birr within Ethiopia.

   b) The cost of manufacture should be less than 130,000 birr.

   c) The cost of packaging and shipping should be no more than 15% of the manufacturing cost.

7. **Quantity**

   a) 150 units in the first year, increasing to 800 within four years.

8. **Maintenance**

   a) To be maintenance free except for light lubrication once a month and a recommended service every two years.

   b) Parts requiring lubrication should be accessible within 15 minutes without the use of special tools or equipment.

   c) All fasteners used should comply with BS6105.

   d) Spares should be available for 5 years after the product is replaced with a new model.

   e) No special tools should be required for maintenance.

9. **Marketing**

   a) Initially to be manufactured for the European market but our Far Eastern distributors in Singapore, Hong Kong and Australia will be able to find a market for the product.

   b) The winch should be operating against equivalent models which include the following companies:

   - Swansom - England
   - Oholom - Sweden
   - Winderhock - Germany

c) Applicable markets:
- Telecom - Cable laying
- Gas and Electricity operators
- Pipe laying services
- Civil Engineering Operations

d) Summary of market requirements:
- Portable winch which can be attached to vans and low loaders
- Use portable power source
- To be used in all weather
- To allow one man operation
- To have at least 40m of cable
- To pull 2000kg

10. Packaging

a) Packaging/transport cost should be kept to a minimum and preferably below 5% of the unit cost.

11. **Size and Weight Restrictions**

a) Weight should not exceed 500 kg.

b) Length not to exceed 2500 mm.

c) Width not to exceed 2000mm.

d) Height not to exceed 2000mm.

12. **Shipping**

a) Product will be shipped by road within Europe.

b) Product will be shipped by sea to far Eastern markets.

13. **Manufacturing processes**

a) Capacity is available for current market demand within scope to increase production to 200 per year without investment / expansion.

b) Motors, transmissions, bearing and ropes are bought in from the following suppliers:

Drives:

- Electric Motors - Brook Compton
- Diesel Engines - Gardener
- Hydraulic Motors - Hydrostatic Transmission Ltd

Bearings:

- RHP Bearings **Transmissions:**
- Couplings - Wellman Bibby
- Worm Gears - Reynold

- Planetary Gears - David Brown (PPG Divisions)
- In-Line Gears - David Brown Radicon Ltd, V-belts - Fenner **Ropes:**
- Bridon

c) Castings and injection moulds produced by external suppliers.

14. **Aesthetics**

a) The form can follow function.

b) If cost dictates, the winch should look attractive to improve our perception within the market.

15. **Ergonomics**

a) Controls to be mounted in an accessible position, relative to the operator i.e. waist height - around 1m, to accommodate 95% of the working population.

b) All controls should be hand operated, requiring one-hand operation with a maximum force of 1.5 (N/m^2)

c) One man should be able to operate the product.

16. **Competition**

a) The winch will be operating against equivalent models which include the following companies: Swansom England, Oholom - Sweden, Winderhock - Germany

17. **Quality and Reliability**

a) Quality should be such that winches should not generally fail within a period of three years and only 1 in 50 should fail within the first year.

b) No winch should fail in the area of the safety overload device.

18. **Standards and Specifications**

Standards to be adhered to:

BS 5000 part 99 Motor Performance, BS 6105 and BSEN 20898(1) Bolts, BS 6322(2) & BS 4320 Nuts and washers, BS 7676 and BS 4517 Gears, BS 3019 Welding, BS 5989 Bearings, BS 2754 Electrical Insulation, BS 5646 pt4 Bearing Housing, BS 4235 Keys and Key ways, BS 7664 Painting, BS 1399 Seals

19. **Company Constraints**

None - except those outlines in Manufacturing and Processes.

20. **Processes**

All components to be of metric form and comply with ISO 4900 for limits and fits.

21. **Safety**

a) No winch should fail in the area of the safety overload device.

b) Winch should not operate when maintenance is being carried out.

22. **Testing**

    a) Testing is to be carried out on 5% of units.

    b) All cables should be tested to BS3621.

23. **Documentation**

    a) Product should be supplied with a user manual covering winch operation and maintenance.

    b) Suppliers require maintenance and repair manual.

24. Disposal

    Plastic parts should be separable and marked to aid disposal.

4.4 Review questions

1. The product specifications are:

   a) expressed in the "language of customers"

   b) not required to be labeled with the appropriate units.

   c) the set of individual specifications consisting of a metric and a value.

   d) specified in a particular unit

2. For technology-intensive products specifications are established at least _____.

   a) once

   b) twice

   c) three times

   d) four times

3. Before generating product concepts product development team need to establish a:

   a) detailed development plan.

   b) product testing plan.

   c) target specification.

   d) final specification.

4. According to the module, establishing target specifications is a _____ step method.

   a) four

   b) five

   c) six

   d) seven

5. The list of specification metrics should include _____ variables.

   a) dependent

   b) independent

   c) dummy

   d) moderating

6. The following is not one of the guidelines for constructing the list of metrics while establishing target specifications:

   a) Metrics should be complete

   b) Metrics should be practical

c) The metrics should not include the popular criteria for comparison in the market place

d) Some needs cannot be translated into quantifiable metrics

7. To establish relative importance of different attributes of a product a _____ analysis can be used.

a) regression

b) conjoint

c) house-of-quality

d) correlation

8. One of the ways to set ideal and marginally acceptable target values for the metrics is to:

a) specify target value as a lower bound, or a upper bound of a metrics

b) specify target value as both lower and upper bound of a metrics

c) specify a particular value of a metrics, or a set of discrete values

d) all of the above

9. Developing a technical model may include building _____ approximations of the product.

a) analytical

b) physical

c) analytical or physical

d) both analytical and physical

10. The inputs of a technical model are:

a) different design variables

b) different metrics

c) specifications in terms of "customer languages"

d) product components

11. The outputs of a technical model are:

a) different design variables

b) specifications in terms of "customer "

c) different metrics

d) product components

12. The Target cost is the _____ cost at which the company and its distribution partners can make adequate profits while still offering a _____ price for the customers.

a) material, competitive

b) distribution, above average

c) marketing, below average

d) manufacturing, competitive

13. Which of the following tools is not used to refine the final specifications?

a) technical models

b) cost models

c) competitive maps

d) setting importance factor to metrics

14. Which of the following is not usually considered while estimating target costing:

a) customers willing to pay the price of the product

b) cost for potential recall of the product

c) the manufacturing cost of the product

d) profit margins that are required for each stage in the distribution channel

15. Which one of the following questions is not to be considered while reflecting on the result and the process of the final step of creating product specifications?

a) Is the product a winner?

b) Were all of the important types of customers in the target market interacted with?

c) How much uncertainties are there in the technical and cost model?

d) Is the concept chosen by the team best suited to target market?

Long answer questions

1. Please Describe/Define Product Design Specification (PDS).
2. Discuss how the product design specification (PDS) is developed and used in a design project.
3. The Product Design Specification (PDS) Is a widely used tool in the early stages of The design process. Discuss how The PDS was developed and used in your design project.
4. How is the PDS product design specifications developed your product?.
5. What are the limitations of product design specification?
6. In an engineering design report. How do "product design specification" and "design parameters" differentiate?
7. writing at least 100 words what is the limitation of writing product design specification?

8. Write about products design specifications PDS of a personal computer and define PDS. Should cover: - Expected product quality standards and requirements - Expected product size and weight - expected product performance.

9. How to organize and do PDS (product design specifications) for any projects for example structure of aircraft?. Also on what basis are the requirements divided?

10. Companies try to reduce the environmental impact of a product at all stages of its life cycle. Give two environmental considerations for each stage given in the table below. An example answer is already given for raw materials.

Life cycle stage	Environmental considerations
Raw materials	Example answer: Use a smaller quantity of material in the production of a product. 1._____ 2._____
Manufacture	1. _____ 2._____
Distribution	1._____ 2._____
Use	1._____ 2._____
End of life	1._____ 2._____

Answer

1. c
2. b
3. c
4. a
5. a
6. c
7. b
8. d
9. d
10. a
11. c
12. d
13. d
14. d
15. b

CHAPTER

5 Design for Manufacturing and Assembly

5.1 What is Design for Manufacturing and Assembling (DfMA)

Design for Manufacture and Assembly (DfMA) is a design approach that focuses on ease of manufacture and efficiency of assembly. By simplifying the design of a product it is possible to manufacture and assemble it more efficiently, in the minimum time and at a lower cost. Traditionally, DfMA has been applied to sectors such as the design of automotive and consumer products, both of which need to efficiently produce high quality products in large numbers. More recently, construction contractors have begun to adopt DfMA for the off-site prefabrication of construction components such as concrete floor slabs, structural columns and beams, and so on.

5.1.1 The process of DFMA

Figure 5.1 shows the typical steps of DFMA. The first step is to conduct DFA which will lead to the realization of a simpler product structure and an economic material and processes selection by optimizing initial designs for part count and assembly. DFA can start when a model/drawing/prototype of the end product together with a tentative assembly sequence are available. The DFA process should ideally go through a number of iterations to simplify the design as much as possible. Then, the best design is analyzed for DFM in order to minimize the manufacturing costs. This step is performed on the final design and is driven by cost.

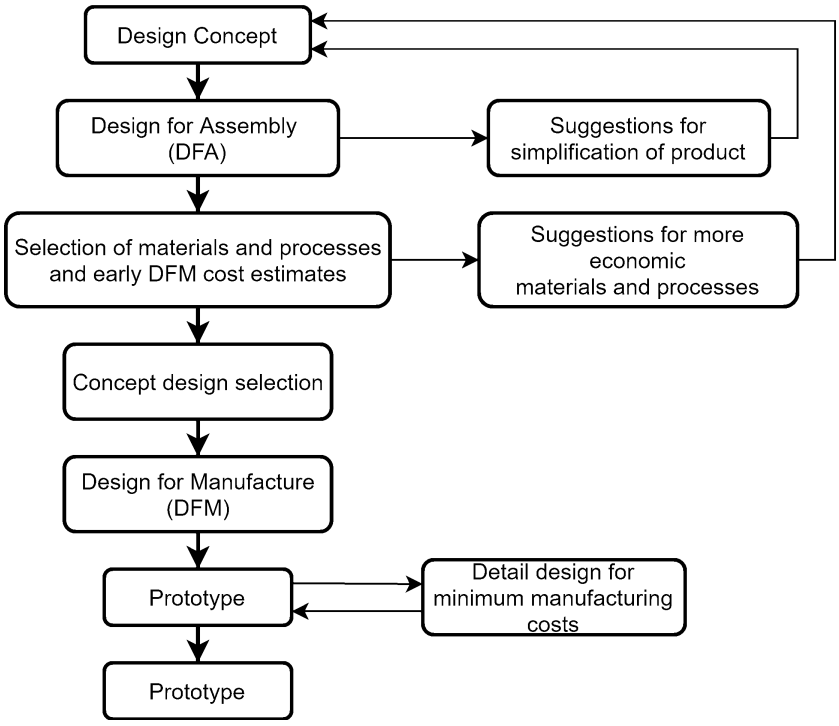

Fig. 5.1: Common steps taken in DFMA

5.2 DfMA principles

In a similar approach to lean construction, applying DfMA enables the identification, quantification and elimination of waste or inefficiency in product manufacture and assembly. It can also be used as a benchmarking tool to study the products of competitors.

The main principles of DfMA are:

- Minimize the number of components: Thereby reducing assembly and ordering costs, reducing work-in-process, and simplifying automation.
- Design for ease of part-fabrication: The geometry of parts is simplified and unnecessary features are avoided.
- Tolerances of parts: Part should be designed to be within process capability.
- Clarity: Components should be designed so they can only be assembled one way.
- Minimize the use of flexible components: Parts made of rubber, gaskets, cables and so on, should be limited as handling and assembly is generally more difficult.
- Design for ease of assembly: For example, the use of snap-fits and adhesive bonding rather than threaded fasteners such as nuts and bolts. Where possible a product should be designed with a base component for locating other components quickly and accurately.

- Eliminate or reduce required adjustments: Designing adjustments into a product means there are more opportunities for out-of-adjustment conditions to arise.

Some of the main advantages of DfMA include:
Speed: One of the primary advantages of DfMA is it significantly reduced manufacturing and assembly time through the use of prefabricated components.
Lower assembly cost: By using fewer parts, decreasing the amount of labour required, and reducing the number of unique parts, DfMA can significantly lower the cost of assembly.
Lower product development cost: An efficient DFMA at the initial phase reduces the development costs by thinking ahead of time and resolving possible issues that may crop up later. One of the leading experts on concurrent engineering and Design for Manufacturing, Dr. David Anderson explains that in DFM there is a "Rule of 10" which states that it costs 10 times more to fix defects at every successive stage of assembly. Thus, if rectifying a part defect costs x prior to assembly, it will cost 10x at sub-assembly, 100x at final assembly, 1000x at the distributor stage and 10.000x if the part has reached the customer.

DFMA removes the need for downstream design changes. It also recommends adding provisions for features that the manufacturer may want to add to a product at a later point in time.
Higher quality and sustainability: A highly automated approach can enhance quality and efficiency at each stage. There may be less waste generation in the manufacturing phase, greater efficiency in site logistics, and a reduction in transporting materials to site.
Shorter assembly time: DFMA shortens assembly time by utilizing standard assembly practices such as vertical assembly and self-aligning parts. DFMA also ensures that the transition from the design phase to the production phase is as smooth and rapid as possible.
Increased reliability: DfMA increases reliability by lowering the number of parts, thereby decreasing the chance of failure.
Reduced wastage: DFMA aims to eliminate waste from the product and assembly design. It reduces the wastage of materials, motion, inventory and overprocessing. It also minimises defect risks and wait time by eliminating redundant manufacturing and assembly steps and unnecessary features.
Greater product reliability: Due to the high focus on preventing defects and increasing the benefit;cost ratio (BCR), DFMA products naturally become highly reliable and durable. The fewer number of parts in a DFMA-conscious product also helps to reduce the failure rate.
Safety: By removing construction activities from the site and placing them in a controlled factory environment there is the possibility of a significant positive impact on safety.
Quality control: DFMA improves communication and teamwork between different teams in a manufacturing setup. A well-coordinated product development effort between designers and manufacturing engineers, for instance, informs both teams

about the best practices of each department to reach a certain end goal. This ensures a higher quality product within the allotted budget.

Shorter time to market: Time to market is defined as the duration between the idea generation phase and the introduction of a product to the market. Ideally, you'd want this time to be as short as possible. DFMA significantly reduces the time to market by simplifying the manufacturing processes and the assembly steps.

DfMA combines two methodologies-design for manufacture (DFM) and design for assembly (DFA): DFM involves designing for the ease of manufacture of a product's constituent parts. It is concerned with selecting the most cost-effective materials and processes to be used in production, and minimizing the complexity of the manufacturing operations. DFM techniques are focused on individual parts and components with a goal of reducing or eliminating expensive, complex or unnecessary features which would make them difficult to manufacture.

Design for Assembly (DFA): DFA involves design for a product's ease of assembly. It is concerned with reducing the product assembly cost and minimizing the number of assembly operations.DFA techniques focus on reduction and standardization of parts, sub-assemblies and assemblies. The goal is reduce the assembly time and cost. But if you think about it, they must be integrated to prevent one from causing negative effects on the other. Both DFM and DFA seek to reduce material, overhead, and labour costs.

5.3 Design for Manufacture (DFM)

Design for Manufacturing (DFM) is the process of designing parts, components or products for ease of manufacturing with an end goal of making a better product at a lower cost. This is done by simplifying, optimizing and refining the product design.

5.3.1 Principles of DFM

1. **Process**

   The manufacturing process chosen must be the correct one for the part or product. You wouldn't want to use highly-capitalized process like injection molding which involves building of tools and dies to make a low-volume part that could have been manufactured using a lower-capitalized method, such as thermoforming. That would be equivalent to using a tank to squash an anthill a classic case of overkill.

2. **Design**

   The more complex the design, the higher the risk.A simple design is usually the best way to go. This is in terms of cost, manufacturing, use, and maintenance. However, all designs should stick to good manufacturing principles. The design must get into more details such as thicknesses, greater specifications for tolerance, texture, and consistency.

3. **Materials**

   Choosing the right materials in the early stages can save you time and money. Your choice of materials has an impact on cost and quality. A few things play a role when

choosing materials. A good chat with your contractor can go a long way. Some properties to think about are mechanical properties, flammability, conductance, and thermal properties.

4. **Environment**

   Not only does your product need to be constructed of appropriate materials, but it needs to be designed so that those materials can perform under its likely conditions. A part that will always be in climate-controlled buildings is going to naturally have a very different design than one that will need to function at the bottom of the Atlantic Ocean.Even if your environment isn't too extreme, your product will be examined to ensure that all of it is prepared to withstand the conditions where you need it to perform.

5. **Testing**

   Finally, testing must be thorough. All products and components must comply with industry standards in each stage. These standards can be industry, internal, or company standards. These standards must be considered in all stages of DFM.

Guidelines for design for manufacturing

1. **Reduce the total number of parts:** The reduction of the number of parts in a product is probably the best opportunity for reducing manufacturing costs. Less parts implies less purchases, inventory, handling, processing time, development time, equipment, engineering time, assembly difficulty, service inspection, testing, etc. In general, it reduces the level of intensity of all activities related to the product during its entire life. A part that does not need to have relative motion with respect to other parts, does not have to be made of a different material, or that would make the assembly or service of other parts extremely difficult or impossible, is an excellent target for elimination. Some approaches to part-count reduction are based on the use of one-piece structures and selection of manufacturing processes such as injection molding, extrusion, precision castings, and powder metallurgy, among others.

2. **Develop a modular design:** The use of modules in product design simplifies manufacturing activities such as inspection, testing, assembly, purchasing, redesign, maintenance, service, and so on. One reason is that modules add versatility to product update in the redesign process, help run tests before the final assembly is put together, and allow the use of standard components to minimize product variations. However, the connection can be a limiting factor when applying this rule.

3. **Use of standard components:** Standard components are less expensive than custom-made items. The high availability of these components reduces product lead times. Also, their reliability factors are well ascertained. Furthermore, the use of standard components refers to the production pressure to the supplier, relieving in part the manufacture's concern of meeting production schedules.

4. **Design parts to be multi-functional:** Multi-functional parts reduce the total number of parts in a design, thus, obtaining the benefits given in rule 1. Some examples are a part to act as both an electric conductor and as a structural member, or as a heat dissipating element and as a structural member. Also, there can be elements that besides their principal function have guiding, aligning, or self-fixturing features to facilitate assembly, and/or reflective surfaces to facilitate inspection, etc.

5. **Design for ease of fabrication:** Select the optimum combination between the material and fabrication process to minimize the overall manufacturing cost. In general, final operations such as painting, polishing, finish machining, etc. should be avoided. Excessive tolerance, surface-finish requirement, and so on are commonly found problems that result in higher than necessary production cost.

6. **Avoid separate fasteners:** The use of fasteners increases the cost of manufacturing a part due to the handling and feeding operations that have to be performed. Besides the high cost of the equipment required for them, these operations are not 100% successful, so they contribute to reducing the overall manufacturing efficiency. In general, fasteners should be avoided and replaced, for example, by using tabs or snap fits. If fasteners have to be used, then some guides should be followed for selecting them. Minimize the number, size, and variation used; also, utilize standard components whenever possible. Avoid screws that are too long, or too short, separate washers, tapped holes, and round heads and flat-heads (not good for vacuum pickup). Self-tapping and chamfered screws are preferred because they improve placement success. Screws with vertical side heads should be selected vacuum pickup.

7. **Minimize assembly directions:** All parts should be assembled from one direction. If possible, the best way to add parts is from above, in a vertical direction, parallel to the gravitational direction (downward). In this way, the effects of gravity help the assembly process, contrary to having to compensate for its effect when other directions are chosen.

8. **Minimize secondary and finishing operations:** Minimize secondary operations such as heat treatment, machining and joining and avoid finishing operations such as deburring, painting, plating, and polishing. Use only when there is a functional reason for doing so. Machine a surface only when the functionality requires it or if it is needed for aestetic purposes.

9. **Minimize handling:** Handling consists of positioning, orienting, and fixing a part or component. To facilitate orientation, symmetrical parts should be used when ever possible. If it is not possible, then the asymmetry must be exaggerated to avoid failures. Use external guiding features to help the orientation of a part. The subsequent operations should be designed so that the orientation of the part is maintained. Also, magazines, tube feeders, part strips, and so on, should be used to keep this orientation between operations. Avoid using flexible parts - use slave

circuit boards instead. If cables have to be used, then include a dummy connector to plug the cable (robotic assembly) so that it can be located easily. When designing the product, try to minimize the flow of material waste, parts, and so on, in the manufacturing operation; also, take packaging into account, select appropriate and safe packaging for the product.

5.4 How to implement DFM

Design for Manufacturing is a great way to save costs while delivering a premium product, but how exactly can you get started with it? Implementing DFM can be a challenging undertaking for most organizations but it does not necessarily have to be like that. To help make the process a little easier, consider these considerations to begin incorporating DFM into your workflow.

1. **Start early**
   Engineering companies must integrate DFM in the early stages of their design process. This is the best time to work out any redesigns. Making design changes later can be extremely difficult and come with a hefty price tag, especially when different tooling is needed for the new design. Manufacturability evaluations must be carried out in the early stages as thoroughly as possible.Early DFM implementation allows design changes to be made quickly and at a lower cost.

   Figure 5.2 offers an excellent visual representation of the effect of an early DFM. As the design progresses through the product life cycle, changes become more expensive, as well as more difficult to implement. Early DFM allows design changes to be executed quickly, at the least expensive location.

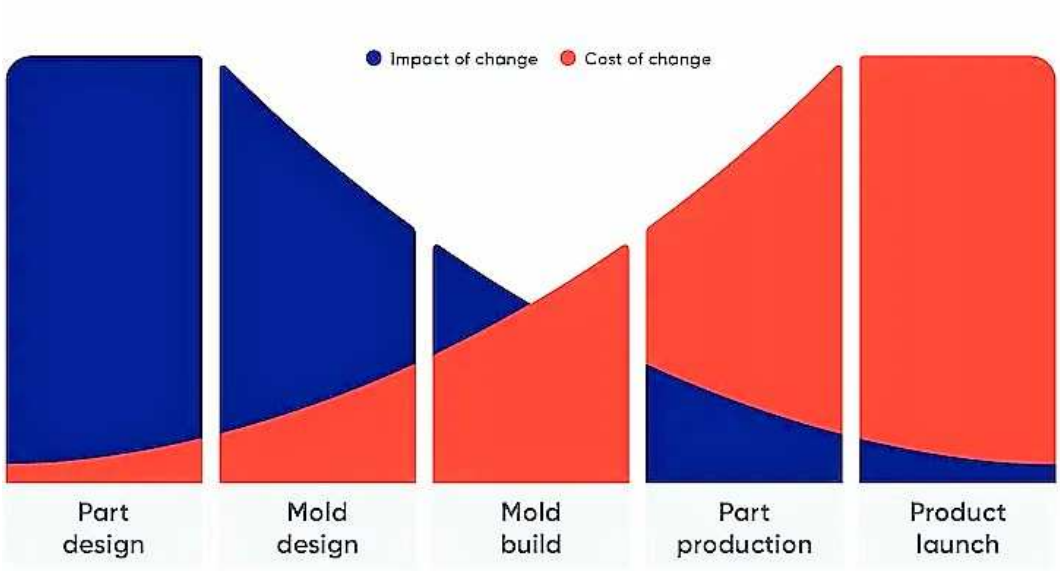

Fig. 5.2: DFM Impact vs cost

2. **Define your requirements**

Like all engineering design processes, everything stems from your product requirements. If this is sounding like the beginning of a typical design process... that's because it is! The information that you normally would use to design is the same information that will drive your manufacturing decisions. DFM just tells us to consider it in a different light. When defining requirements, don't forget to look beyond the usual function-based requirements of "what must this product do?" Instead, also consider manufacturing parameters like the rate/volume of production, intended per-part cost, alignment with surrounding assemblies, and industry/client standards.

3. **Select your materials and process**

   Material selection, from both a manufacturing and functional standpoint, is a huge milestone in your design process, however, the choice cannot be made in a vacuum. We recommend choosing both the material and the fabrication process at the same time. This simple addition to the usual thought process will force you to think about (and hopefully document) the additional considerations that come along with your given material.

   Thinking of making a steel structure out of thin sheet metal? Pause and consider the process! Think back to your manufacturing requirements. If you're looking to do production runs of tens of thousands of units per year, your design will likely include stamped components which require completely different optimization than if you intend to make just five units a year and will use manually bent components. Thinking about welding that sheet metal? You may want to think about warpage, or analyzing the stress in a heat-affected zone. By remembering to define your process with your material, as you design you can keep in mind the specific nuances inherent with that manufacturing process. This allows you to make better design decisions which will pay dividends down the line.

4. **Reach out**

   Regardless of whether this is your first year in the field, or if you lost count a few decades ago, there is always more to learn. Once you have considered your requirements and chosen the material and process, reach out and talk to your suppliers and manufacturers. Often they are more than happy to speak with you about difficulties with your past designs, or lessons learned from similar products. This knowledge is invaluable, as it allows for personal growth, and exposes you to other perspectives on your creation that you may never have been exposed to. It also helps create relationships with members of your community and can lead to small design changes that pay huge dividends on the shop floor. Don't stop at fabrication, though. Reach out to your factory floor and assembly associates, too. Often they can help you improve your design, and give you tips on assembly order, clearances, and component supply.

5. **Iterate**

This is the most important step. Engineering design is not a linear path, and each project is a unique cycle of progress forward and marathons back. Iteration is what helps make products truly great so remember not to get discouraged! Whenever you face a setback, always keep manufacturing in mind. Think back to your manufacturing requirements, material and process choices, outside advice, and let that guide you.

5.4.1 Steps in DFM

By considering the above considerations, we can now see the steps taken to implement DFM as shown in Figure 5.3.

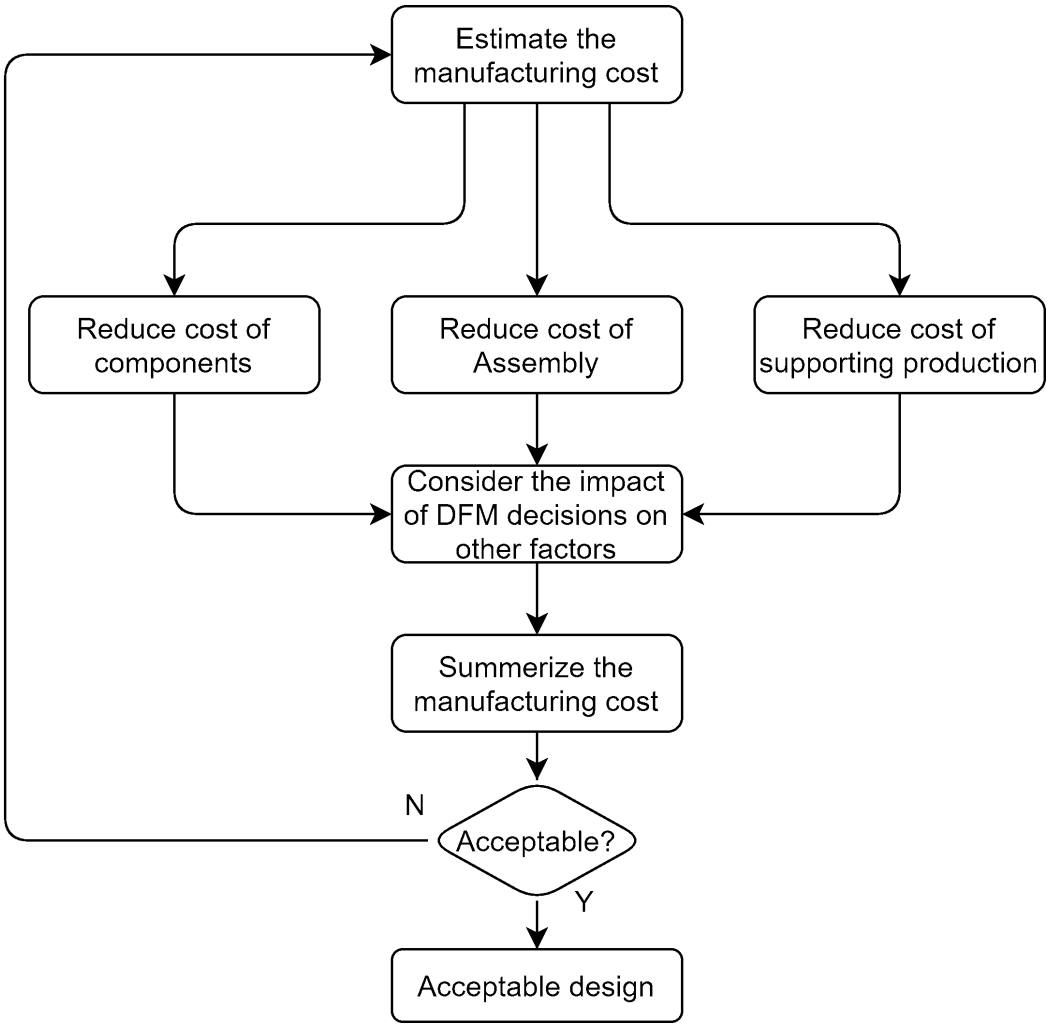

Fig. 5.3: Steps of DFM

Step 1: Estimate the manufacturing costs:

Manufacturing cost is the sum of all of the expenditures for the inputs of the system and for disposal of the wastes produced by the system. That is it is the sum of material cost, Assembly cost ,labor cost, and Over head costs (including materials handling,

quality assurance, purchasing, shipping, receiving, facilities, and equipment/tooling maintenance, indirect costs) as shown in Figure **??**. **Step 2: Reduce the costs of**

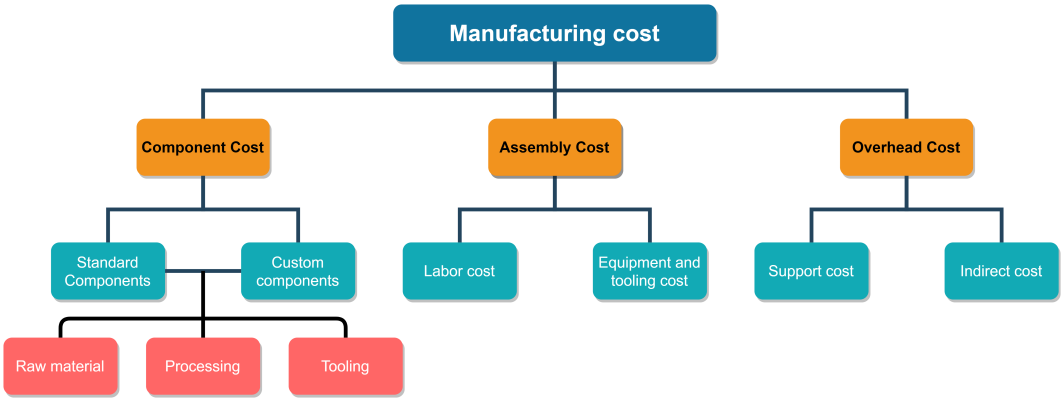

Fig. 5.4: Components of manufacturing cost

components:

The component costs of your product design can have a huge impact on the money you make from your product. If you reduce the cost each product unit this scales up to a large cost reduction.Whatever product you or your company makes, the cost of your materials is probably one of your largest expenses, directly affecting profitability. But how do you reduce material costs without impacting the quality of your final product, here are some of the ways:

1. **Substitute lower cost materials where possible:** Products can usually be manufactured utilizing a variety of different materials, depending on marketplace requirements and the practices of the manufacturers. Technology is constantly improving older materials and creating new ones, prices move up and down due to political goals as much as supply and demand, and processing methods change. When considering a change in the materials used in your products, be sure to recognize all factors involved. For example, substituting a carbon steel for a higher-cost stainless steel will save money, but will also reduce corrosion protection, which may be a valuable product feature for buyers.In addition, different materials may require changing your method of manufacture by increasing cycle times, as well as labor costs. And in some cases, changing the composition of a product may be worthwhile, even when the material costs are higher due to a simplified production process.

2. **Reduce waste:** Product engineers typically design products without considering the production consequences, particularly how non-standard purchase units of size, volume, or weight must be modified to create the final product. Production methods are usually established to minimize the costs of the highest component of production, either labor or materials, at the time the method is established.

   If, for example, the cost of the raw material is low, the volume of excess material or "scrap" may not be considered to be important relative to the labor cost. Over time,

however, prices for materials and labor may shift. This alters the ratio between the two elements and their related expense, so that the cost of scrap material becomes excessive. Modifying product designs and altering production methods in order to utilize standard raw material units may reduce excessive scrap and its associated costs.

3. **Eliminate unnecessary product features:** Custom products cost more to manufacture than mass-produced products, and any non-standard feature requires an additional step in the production process, increasing the expense. Examine your customers' motives for purchasing your products: Do they buy your products because of their low cost, high quality, unique look, or some other reason? By determining what is important to your customers, you can selectively attack elements which are not as important to reduce cost.

4. **Negotiate like a pro:** The level of your profit depends upon your ability to receive the highest possible price for your products and pay the lowest possible price to your suppliers and vendors. Every participant in the supply chain is looking for business and will take unusual, often extraordinary steps to make or save a sale this is especially true in a poor economy.

   Ask for a discount every time you request an estimate or place an order, and keep asking until you actually place the order. If you do not get a reduction in price, ask for favorable financing terms, prepaid freight, or other freebies. By negotiating, you can maximize your position as a buyer as your buyers do to you.

5. **Redesigning parts to cut down on processing steps:** A thorough examination of the proposed design may yield ideas for revision that may simplify the manufacturing process. Costs are often decreased when the number of steps in the part manufacture process are reduced. Some phases in a process may be not required.

6. **Standardize materials and processes:** By using standard components, it is possible to take advantage of significantly greater component quantities for a given predicted product volume.

Step 3: Reduce the costs of assembly: One of the simplest ways to reduce the overall cost of an assembly is to limit the number of individual components involved. Added costs are mostly attributed to individual parts. If you design your assembly with as few parts as possible, then the price per assembly will inevitably come down. When you're dealing with production volumes, having a lower cost per part can make a considerable difference in the overall cost of the assembly. Here's the list of design for assembly principles for reducing cost on part assemblies.

1. Minimize part count by combining components together
2. Minimize handling during assembly
3. Maximize ease of assembly
4. Minimize the number of operations

5. Utilize self-locating features
6. Utilize self-fastening features
7. Minimize reorientation needs
8. Design parts for ease of handling and insertion
9. Top-down assembly (start at the highest level possible, and individual parts and sub-assemblies)
10. Maximize use of standard parts
11. Reduce the number of fasteners in an assembly
12. Utilize modular assemblies (sub-assemblies)

Design for Assembly simplifies the product's structure by reducing the number of components and minimizing the number of assembly operations required. The aim is to make the manufacturing process easier, faster and more consistent, As a result, applying DFA concepts to product design typically leads to increased quality and dependability as well as a decrease in manufacturing equipment and part inventories. It has been noted often that these additional advantages frequently outweigh the assembly cost savings. DFA, in theory, understands the necessity of early analysis of the part and overall product designs for potential assembly issues in order to save costs across the whole product cycle. DFA is a procedure that focuses simultaneously on the combined elements of functionality and ease of assembly in order to improve product design for simple and inexpensive assembly.

5.4.2 Assembly methods

The different methods of assembly are as follows:

1. **Manual assembly:** With or without the use of basic, all-purpose instruments like screwdrivers and pliers, manual assembly is a process where tasks are completed manually. Since the technique needs little initial investment, the cost per unit is constant. Moving parts to workbenches, where individual components are assembled into the finished product, is known as manual assembly. Hand tools are typically used to assist the worker and facilitate simple assembly. Despite being the most flexible and adaptive assembly technique, there is typically a limitation on production capacity, and labor expenses (including benefits, workers compensation for tiredness and injury, and overhead for keeping a clean and hygienic workplace) are greater.
2. **Automatic assembly:** This technique, also known as fixed automation, employs either non-synchronous machines with free transfer devices for handling parts or synchronous indexing machines with part feeders. The system is typically designed for a single product, and as production volume rises, cost per unit drops.

3. **Fixed or hard automation:** Fixed or hard automation often comprises a specially constructed machine that assembles just one particular product and requires a significant upfront investment. The ratio of capital investment to total manufacturing costs falls as output volume rises. This intrinsically inflexible assembly process is typified by indexing tables, component feeders, and automated controls.
4. **Robotic assembly:** The items whose production quantities fall between those for manual and automatic assembly methods are best suited for this type of assembly. Volumes achieved by this form of product assembly are comparable to those of automatic assembly techniques. Robotic assembly systems are used in soft automation, also known as robotic assembly. A Microcontroller or microprocessor may concurrently control and coordinate all of the actions in either a single robot or a multistation robotic assembly cell. Although this form of assembly might have high initial investment costs, its versatility frequently aids in spreading the cost over several items. Figure 5.5 draws a comparison between the relative costs of the different methods of assembly by type as well as production volume.

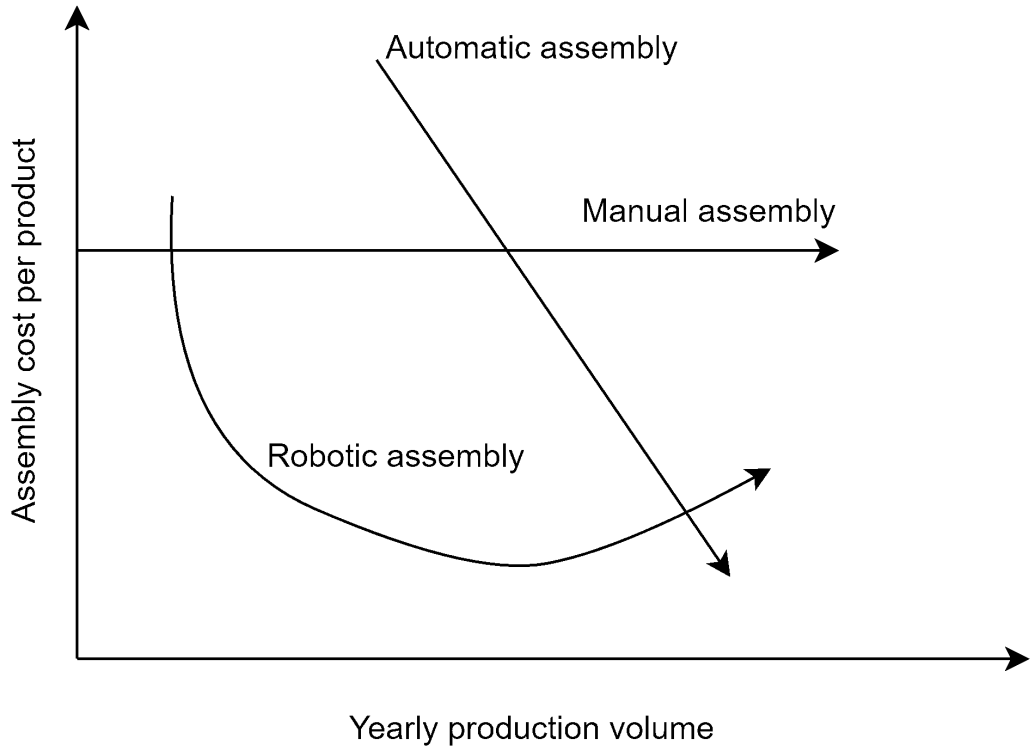

Fig. 5.5: Assembly volume vs production cost of different assembly methods

5.4.3 Guidelines for different assembly methods

1. **Manual Assembly**
   The following design guidelines may be incorporated into product design when

designing for manual assembly:

- Eliminate the need for decision making by the worker, including making final adjustments. Ensuring this step removes all subjectivity from the decision making process, thereby improving the accuracy of the assembly process.
- Ensure good product accessibility as well as visibility.
- Eliminate the need for assembly tools or special gauges by designing individual components to be self aligning and self locating. Parts that snap and fit together eliminate the need for separate fasteners. This results in speedy as well as more economical assembly.
- Minimize the total number of individual parts, if possible. To facilitate this objective, multipurpose components may be used.
- Eliminate excess parts and combine two or more parts into one, if functionally possible.
- Avoid or minimize the need to reorient the part during the assembly process. Ensure that all insertion processes are simple. Avoid the need for rotation, releasing, and reÂgripping. Vertical insertion always is preferable, since it utilizes gravity to accomplish the task.
- Design parts that have end Âto Âend symmetry and rotational symmetry about the axis of rotation. If this is not possible, the design should incorporate maximum symmetry.
- When it is impossible to incorporate symmetry into product design, obvious asymmetry should be used to facilitate ease of orientation and insertion.
- Provide features that prevent jamming and entanglement of parts.
- Design parts so there is little or no resistance to insertion. This can be facilitated by providing chamfers to guide insertion of two mating parts.
- Design for a pyramidal method of assembly, if possible. Provision needs to be made for progressive assembly about one axis of reference. In general, it is best to assemble from above.
- Avoid holding down the part. If this is unavoidable, the part should be designed so that it is secured as soon as possible after insertion.
- Design parts to facilitate location before release. Release of a part before location is a potential assembly problem.
- Use of common fasteners increases assembly cost in the following order: snap fit, plastic bending, riveting, and screwing. Bear this factor in mind when designing securing and fastening methods for holding together two or more parts.

2. **Automatic assembly** A clear distinction was drawn between manual assembly and automatic assembly in the preceding section. Due to the inherently varying natures of the two assembly methods, the design guidelines for automatic assembly are

significantly different from those for manual assembly. These guidelines are as follows:

- Self aligning and self locating features need to be incorporated into the design to facilitate assembly. Considerable improvement can be achieved by using chamfers, guide pins, dimples, and cone and oval screws.
- Use the largest, most rigid part of the assembly as a base or fixture, where other parts are stack assembled vertically to take advantage of gravity. This, in turn, eliminates the need to use an assembly fixture. The best assembly operation is performed in a layered fashion. If this is not possible, the assembly should be divided into sub assemblies and plugged together at a later stage.
- As with all other design for X principles, use a high percentage of standard parts. Employing the concept of group technology, begin with fasteners and washers. Use standard modules and sub assemblies.
- Avoid the possibility of parts tangling, nesting, or shingling during feeding, since this can complicate and unduly delay the assembly process.
- Avoid flexible, fragile, and abrasive parts and ensure that the parts have sufficient strength and rigidity to withstand the forces exerted on them during feeding, assembly, and use.
- Avoid reorienting assemblies, as such moves may require a separate workstation or machine, thereby increasing costs.
- Design parts to ease automation by presenting or admitting parts to the assembly machine in the right orientation after the minimum possible time in the feeder. Parts that are symmetrical or clearly asymmetrical can be oriented easily.
- Design parts with a low center of gravity, thereby imparting in them a natural tendency to be fed.

3. **Robotic assembly**

   Guidelines are as follows:

   - Reduce part count as well as part type. Many robot manipulators have poor repeatability; therefore, features such as lips, leads, and chamfers assume a great deal of importance.
   - Ensure that parts that are not secured immediately on insertion are selfÂ-locating in assembly.
   - Design components such that all can be gripped and inserted using the same robot gripper. Gripper and tool changes are a major source of inefficiency.
   - Design products to allow vertical assembly directly from above.
   - Design components to do away with the need for reorientation. Design parts so that they can be presented to the robot arm in an orientation suitable for gripping.

- Design individual components to promote ease of handling from bulk. It is important to avoid parts that nest or tangle; are thin, heavy, or exceedingly large or small; or are slippery.

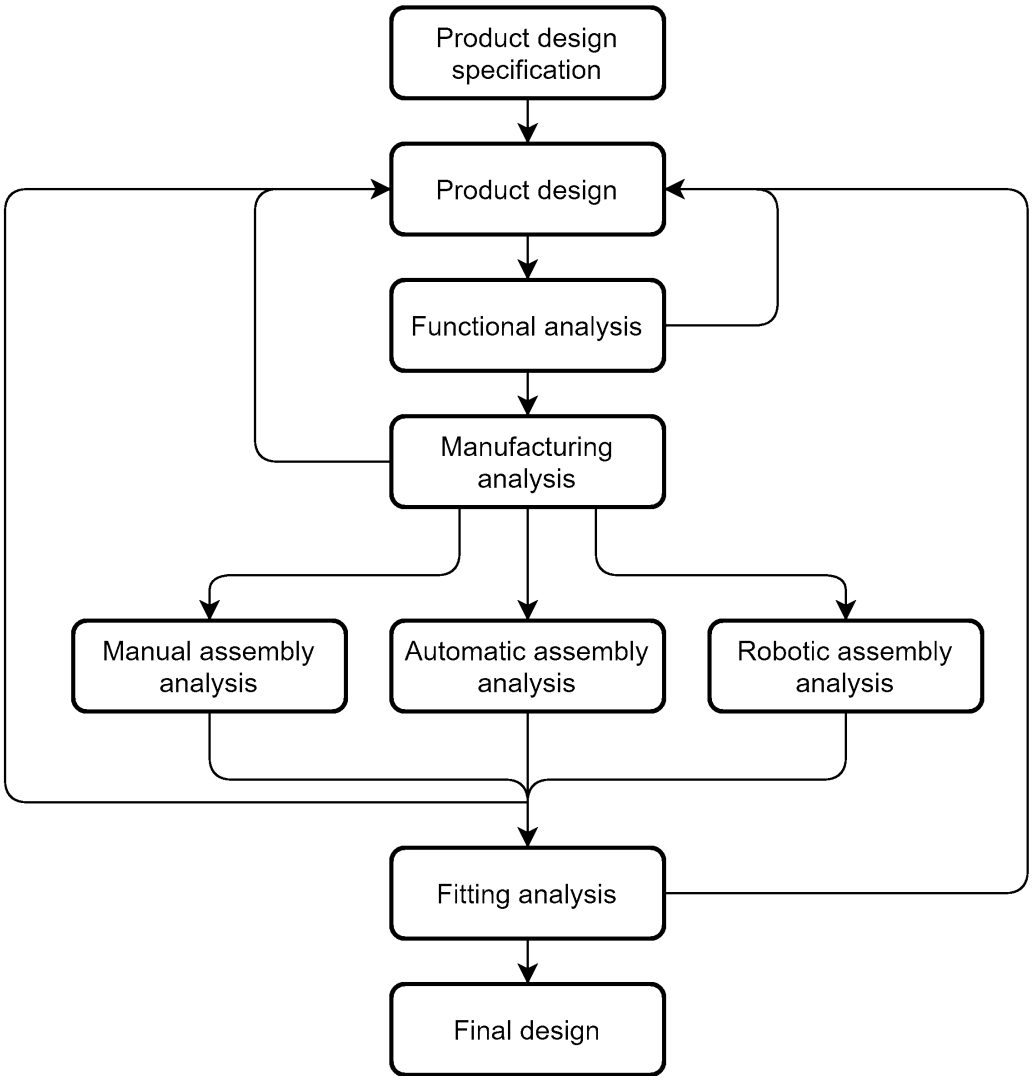

Fig. 5.6: DFA sequence flow chart

5.4.4 Functional analysis

DFA first assesses the part functionality to determine if it is a primary part or a secondary part. The primary part is the "base" part of the assembly. A secondary part is potentially a non-essential part, i.e. a candidate for elimination.

Functional analysis should include:

- List the parts in the assembly and their order of assembly.
- List the number of interfaces between the individual parts.

- Calculate the theoretical minimum number of parts for the assembly by identifying any secondary parts that can be incorporated into the primary part.
- Identify any parts that can be standardised, e.g. if you must use fasteners then reduce the types and sizes needed to the absolute minimum.
- Look for part count efficiency and assess the relative part costs.
- Calculate the theoretical minimum number of parts for the assembly by identifying any secondary parts that can be incorporated into the primary part.
- Identify any parts that can be standardised, e.g. if you must use fasteners then reduce the types and sizes needed to the absolute minimum.
- Look for part count efficiency and assess the relative part costs

Functional analysis will almost always result in design modifications to reduce the part count and improve the basic product design.

5.4.5 Assembly analysis

The handling analysis looks at the difficulty of controlling and orienting the part during both manual and automatic assembly.

Assembly analysis should consider:

- Part size.
- Part weight.
- Part flexibility.
- Any other part details that could affect storage and handling,
- Handling time and complexity.
- Easy for both people and machines.
- Capable of delivering high-quality products.

5.4.6 Fitting analysis

Fitting analysis reviews the fitting methods and looks at issues such as:

- The attachment method used for each part.
- The assembly time needed for each part.
- The elimination of non-value-adding processes

5.5 Review questions

1. Which among the following statement is false for Design for Manufacturing and Assembly?
   a) They both shorten the product development cycle time.
   b) Both DFM and DFA seek to reduce material, overhead, and labor cost.
   c) Both DFM and DFA seek to utilize standards to reduce cost
   d) Both DFM and DFA predicts the required manpower
2. Design for manufacturing and assembly delivers product improvements by emphasizing which of the following?
   a) Reducing product quality during the assembly process
   b) Simplifying production process by reducing the number of separate parts to be assembled
   c) Reducing equipment in the production process
   d) Designing products so they can be manufactured by a virtual factory
   e) Designing products that customers will want
3. Which among the following statement is false for Design for Manufacturing and Assembly?
   a) They both shorten the product development cycle time)
   b) Both DFM and DFA seek to reduce material, overhead, and labor cost.
   c) Both DFM and DFA seek to utilize standards to reduce cost.
   d) Both DFM and DFA predicts the required manpower
4. Regarding the paradigm of Design for Manufacturing and Assembly (DFMA), which one of the following is incorrect?
   a) It takes a combined consideration of product design and process planning
   b) It aims for manufacturing engineering to better support the functional needs of product design
   c) It enhances the market competitiveness of products due to manufacturing cost savings
   d) It helps shorten the product development cycle time
   e) It may not improve the product quality.
5. The main reason to do DFM is
   a) To predict costs
   b) To reduce costs
   c) To improve the design of the products
   d) To estimate cost evaluation for further system analysis.

6. What is the forth step in DFM process.
    a) Reduce the cost of supporting production
    b) Reduce the cost of assembly
    c) Estimate the manufacturing costs
    d) Reduce the cost of components
7. Which statement(s) related to DFMA is/are correct?
    a) During operation of the product, does the part move relative to all other parts already assembled?
    b) Must the part be of different material or be isolated from all other parts already assembled?
    c) Must the part be separate from all other parts already assembled?
    d) All of the above.

Long answer questions

1. State three concepts in design for manufacture and assembly (DFMA) and describe how they facilitate manufacturing or assembly.
2. Why is design for manufacturability and assembly important in terms of overall operations management?
3. Why do you consider Design for Assembly before you consider Design for Manufacturing ?
4. Why DFMA is an important methodology for industry.
5. What are the four concepts in DFMA. Elaborate and discuss each concept by choosing a product as an example.
6. What are the product design philosophies behind industrial design and design for manufacture and assembly ? Which one do you think is more important in customer-focused product development?
7. Completely and thoroughly explain how the Manufacturing Area was designed inside any company that makes any type of Plastic Product (or any product at all).
8. Many manufacturing companies have applied the concept of DFMA (Design For Manufacturability and Assembly) to improve the design of their products. Some have argued that redesigning a company's products using DFMA would make it less likely that the company would seek to move its production process overseas to a low wage country. Briefly discuss how a DFMA redesign might accomplish this. (Hint: what changes to the product would be impacted by the relative wages of the workforce?)

Answer

1. c
2. e
3. c
4. e
5. c
6. c
7. d

CHAPTER

6 Product Life Cycle

Everything in the market place is presumed to be going through several phases from birth until its death. A product or a brand is launched, it grows, attains maturity, and starts declining, and is buried on its death. Product is basically a need satisfier. In reality there may be several products satisfying the need of a customer. For example, the need for document and producing multiple documents was existent since the human civilization started communication. As the civilization matured, the need for documentation has also grown. This change in the need level is captured by the demand life cycle. For every need cycle there is a sequence of phases starting with emergence, accelerating growth, decelerating growth, maturity, and decline. A product is an embodiment of technology, and the technology in fact satisfies the need. The need for document was first satisfied by mud tablets, palm leaves, copper leaves, paper and now electronic pages. You would agree that the succeeding technologies normally satisfy the need better than the predecessor. Once you consider the need for multiple copies of the same information, the modern technology would suggest use of carbon papers, cyclostyling, photocopying, printing and so on. A product life cycle is the length of time from a product first being introduced to consumers until it is removed from the market.Product life cycles are used by management and marketing professionals to help determine advertising schedules, price points, expansion to new product markets, packaging redesigns, and more.

The concept of Product life cycle can be explained using the diffusion theory of innovations, and theory of monopolistic competition.Diffusion theory of innovations explains the process of new product adoption over period of time. Both PLC and Diffusion curve are concerned with the changes in the adoption of products over time, the cumulative diffusion curve and PLC curve exhibit considerable similarity. However there is a difference in terms of the parameters used, PLC depicts absolute sales over time and the diffusion curve relates cumulative percentage of potential consumers over time. Diffusion theory presents a five-stage adoption process, starting from, innovators, early adopters, early majority, late majority, and laggards. Monopolistic competition theory elaborates the behaviour of firms over the PLC. Monopolistic competition describes a market situation where many firms are selling the product that are similar, but not

perfect substitutes for each other. In the initial stage the number of firms in the business will be lower, many players would not enter the market due to risk involved in the new product. Once the product acceptance is realized more firms would enter the market, this leads to the growth in the market. During the maturity stage, the number of firms entering and number of firms leaving the market would be more or less equal. On the decline, only those firms, which choose to specialize, would stay in the market and others would leave the market. Monopolistic Competition theory explains the variations in the number of firms in different stages of PLC.

Levels of PLC: PLC can be used to analyze different levels of product, a product category, a product form, a product, and a. brand. Product Category is a very broad level, referring to the basic service or product satisfying the need. Hence, product category exhibits a longest life cycle. Product forms normally follow the standard PLC. Products may exhibit several variants, and brands can have shorter or longer PLC. A few brands have very long PLC, for example Lifebouy, Lux, have seen generations of consumers and on the other hand many brands have seen premature death also.

Shapes of PLC: Products go through different PLCs; there are several shapes that can be observed in practice. The shapes commonly reported are classical bell shaped curve, growthslump maturity pattern, cycle-recycle pattern, scalloped pattern, style, fashion, and fad. Growth-slump maturity pattern, exhibits an initial growth, followed by a decline and stability for fairly long time. Growth-slump maturity pattern display a multi-modal shape due to the different promotional mechanisms adopted by the marketers,Growth-slump maturity pattern manifest successive growths and declines over time. Growth-slump maturity pattern is a basic and distinctive mode of expression appearing in a field of human endeavour. Style may last for generations and also exhibit cyclic appearance and disappearance. Fashion is a style currently in stores. Fads are fashions, which are adapted and decline very fast.

6.1 Stages of Product Life Cycle

You are aware that a product or brand goes through several phases from birth until its death. Firstly a product is launched; it grows, attains maturity, then starts declining and finally is ironed out. Accordingly the product life cycle is explained by the following stages;

- Introductory stage;
- Growth stage;
- Maturity stage and
- Decline stage.

Introductory stage

The introductory stages of a product are believed to be relatively slow, even after its technical problems have been ironed out, due to a number of marketing forces and

consumer behaviour factors. The major marketing obstacle to rapid introduction of a product is often distribution. Retail outlets are often reluctant to introduce new products, and may prefer to wait until a track record has been established before including them. in their stock. Consumer acceptance of new products tends to be relatively slow. The newer the product, the greater the marketing effort required to create the demand for it. The length of the introductory period depends on the product's complexity, its degree of newness, its fit into consumer needs, the presence of competitive innovations of one form or another, and the nature, magnitude and effectiveness of the introductory marketing effort. At this stage it is usually assumed that there are no competitors, the market structure is defined as 'Virtual Monopoly'. But there are very few really radical innovations with no existing substitutes. Most new products and services face considerable competition from existing products, and also experience severe competitive pressure from other new products.

There are many cases where two firms introduce similar products almost at the same time, which is possible if the two companies. are working on similar technological developments. On noticing success of test market conducted by one company others may follow suit with similar products. If two or more firms introduce products at about the same time, the result is likely to be a shorter introductory period. The length of the introductory period is a crucial aspect of PLC. From managerial point of view, shorter this stage the better. The consumers who buy the product in the introductory stage itself are called innovators, and those who buy later are called late adopters or laggards. This may be misleading, for example a buyer who hears about a product for the first time two years after its introduction buys it at once. Can this individual be considered a laggard?

Growth stage

The growth stage begins when demand for the new product starts increasing rapidly. Innovators are satisfied with the trial, they move to repeat purchase. They then influence others by word-of-mouth, which is often considered the most effective mode of communication. The product availability and visibility in distribution and in use (e.g., new cars on the road) tend to bring new triers into the market. At this stage, the entry of competitors increase the total demand for the product through their advertising and promotional efforts.

Maturity stage

The maturity or saturation stage occurs when distribution has reached its planned or unplanned peak and the percentage of total population that is ever going to buy the product has been reached. Volume (reflecting the number of customers, quantity purchased, and frequency of purchase) is stable. At this stage it becomes difficult to maintain effective distribution, and price competition is quite common.

Decline stage

Changes in competitive activities, consumer preferences, product technology and other environmental forces tend to lead to the decline of most mature products. If decline is for a product and not brand, producers may withdraw from that product category. The typical reason for a product decline is the entry of new products and decreased consumer interest in the specific product. One of the few options left for keeping a brand alive is price reduction and other drastic means that depress the profit margin and leads to product withdrawal Product decline occurs even when most customers no longer buy the product, only few loyal customers remain. The latter continue. buying the product inspite of no advertising or promotional campaign. The company may decide to follow a 'milking strategy' that is, retain the product with meager marketing support as long as it generates some sales. But this requires maintaining distribution of the product, which becomes less profitable.

6.2 Applying Product Life Cycle

In order to utilize the product life cycle effectively it is necessary to understand how one can unambiguously determine the position of a product in the context of its life cycle. Putting the PLC concept into operation would require following decisions to be taken:

1. **Deciding upon the unit of analysis**

   As the actual shape of product life cycle curve may differ for product form, product class, an individual product and a brand it, is important to decide which particular unit of analysis is being considered. The PLC analysis can be undertaken for each of these units both at the firm and the industry level. The importance of explicitly defining a unit of analysis will become apparent to you when you consider an example of say, should all TV Sets be considered or the focus should be on either black and white or Colour sets, or portable v/s non-portable ones - it is apparent that no set rules can be prescribed at to the correct unit of analysis. Based on. their needs and intention of how to use the PLC, management should define and select the relevant unit of analysis.

2. **Definition of relevant market**

   Normally, the PLC approach assumes a single homogenous market, which is further segmented by the difference in adoption behaviour of the consumers i.e. the early adopters, late adopters and finally the laggards. Generally PCL studies focus on the product sales at the total market level, it is sometimes useful to consider the PLC by type of market (for example international v/s domestic market), distribution pattern (direct v/s retail distribution) or market segment (organizational buyers v/s individual buyers).

3. **Identification of the products stage in the PLC**

   In order to use the PLC concept one would need to answer two related questions (a) how to determine the stage of a product in the life cycle (b) how to determine

when the product moves from one stage to another. Since the shape of the PLC curve varies widely for products as does the duration of the different stages, it is not possible to assess the stage of a product in the life cycle and its transition to another stage merely by observing the historical sales graph of the product. Let us consider the operational approach suggested by Polli and Cook. The approach is based on the measurement of the percentage change in real sales from one year to the next. These changes are plotted as a normal distribution change in real sales from year to year is then measured. Products having a percentage change less than -0.5 are classified as being in the decline stage, those having percentage change greater than 0.5 were classified as being in the growth stage while those in the range of +0.5 were classified as being in the maturity stage, which was further divided into decaying maturity and stable maturity. As far as the duration of a stage in the PLC of a product and the exact point in time, of the transition of a product from one stage to another, no generalised conclusions can be drawn. Since the duration of each PLC stage depends on a large number of variables like product characterization market acceptances and competitive action.

Activity 1 Pick up two product each from consumer goods and consumer durables of your choice. Identify the stage of PLC that there are in and suggest implications for product planning and product innovation using PLC.

6.3 PLC–As a Guideline for Marketing Strategy

In considering the possible relationship between marketing strategy and the product's life cycle, one should see whether companies should adopt their marketing efforts according to the product life cycle or whether the firm's marketing strategy can change the course of the product life cycle. But unfortunately most studies of the determinants of product sales are not concerned directly with the product's PLC. Knowledge of the product's stage in its life cycle gives useful but only pa:6zl input for the design of product's marketing strategy. Recommendations have frequently been made concerning the type and level of advertising, pricing, distribution, and other product/marketing activities required at each of the product life cycle stages. Some of the more common recommendations are discussed below but should be viewed as hypotheses, and not facts or normative prescriptions.

PRICING: It is usually believed to be high at the introductory period and to decline with the product life cycle stages, as it becomes an increasingly important competitive weapon, especially at the later stages of growth, maturity and decline stages. Although price-cutting is quite common in many industries as the product matures (e.g.: Reduction in prices of pocket calculators and digital watches over a period of just a few years in the early seventies), many managers prefer to engage in non-price competition. Price cutting in the saturation stage although common, is far less important than changes in the product, promotion, and distribution policies. In determining the product's price strategy, not only the introductory price should be considered, but also what the next move might be, given alternative competitive actions. A relatively low

introductory price should not be ruled out automatically but should be fully examined.
DISTRIBUTION: Initial distribution is believed to be spotty and to reach its full coverage at the growth stage, when retail outlets are seeking the product. At the maturity stage, retail outlets are the first to suffer from changes in consumer purchase patterns; hence manufacturers may start losing outlets. At th6 same time, efforts are made by manufacturers to establish new methods of distribution (bypassing, the wholesales, for instance) and new outlets (direct mail, for example) The above attempts to prescribe a marketing strategy and guide the allocation of marketing resources over the stages of a product's life cycle .assumes that at any one stage of the PLC the firm has only a single 'reasonable' marketing strategy it can flow. This is misleading as it constrains - management's creativity in generating new marketing strategies and ignores differences among products, markets and firms.

Activity 2 Identify two Ethiopian companies who were able to extend the life cycle of their respective products. Comment on the attributes which enabled these companies to do

Self Assessment Questions

1. Briefly describe each of the four distinct stages of the product life cycle by taking an example each from consumer and industrial products you are familiar with.
2. Marketers should view PLC as an indication of opportunities to a firm. Discuss in the light of Product Planning and Business Strategy of the firm.