

# Chapter 1

## Product design and development

### 1.1 Need of new product development:

The economic success of manufacturing firms depends on their ability to identify the customer needs of customers and quickly create the products to meet the needs that can be produced at low cost. A product is anything that can be offered to a market for attention, acquisition, use, or consumption that must satisfy a want or need [1]. Products can be classified as shown in figure 1.1 and briefly given below.

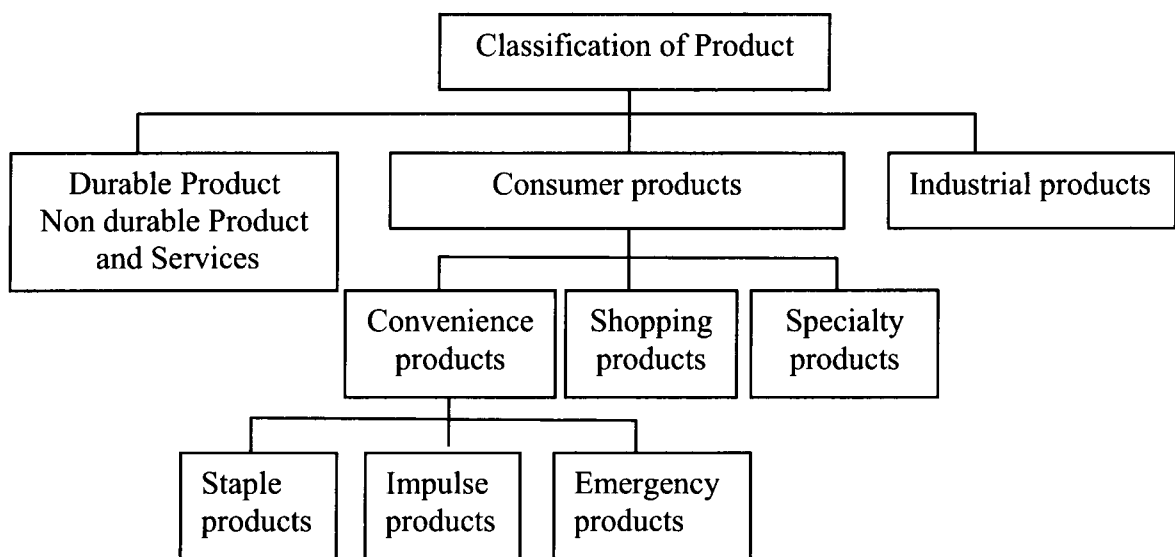


Figure 1.1 Classification of product

- Durable products; Non-durable products and services:
  - Non-durable products: These are tangible products that normally consumed quickly in one or few uses. For example: soap, salt, food items.
  - Durable products: These products are used over extended period of time and normally survive many uses. For example: automobile, vacuum cleaner, refrigerator, machine tools.
  - Services: These are intangible by which the benefits or satisfaction are offered for sale. For example: bank loan, insurance.
- Consumer products: These are produced for and purchased by households for their use. They include:

- Convenience products: These are bought frequently with little time usually low priced items. These types of products further divided into three groups:
  - Staple products: These are purchased on regular basis. For example: tooth paste, news paper.
  - Impulse products: These are purchased without any planning. For example: ice cream, fast foods, and magazines/books at railway stations/airports.
  - Emergency products: These are purchased when a need is urgent. For example; Medicine, first aid item like bandage.
- Shopping products: The products for which the consumer is willing to spend considerable time and effort in gathering the information on price, quality and other attributes. For example: furniture, mobile, clothing.
- Specialty products: These products have unique characteristic and/or brand identification. For example: Reebok shoes, Mercedes cars, fancy goods, cigarettes, and deodorants.
- Industrial products: These products are manufactured, assembled and are primarily to be sold for producing other products. For example: raw material, parts (components), sub-assemblies, installations, tools (hand or power operated), and MRO (maintenance, repairs, and operating) supplies.

This work mainly focuses shopping type consumer products.

In the current scenario of globalization and strong competitive environment, it has become imperative for the companies to offer wide variety of products in order to satisfy wide spectrum of customer demands. Product design influences a firm's competitive priorities and needs to be considered during the strategic planning process. Product design can be defined as a strategic activity that takes a concept for a product and creates specifications that allow production of the product, possibly in prototype form [2]. Product design is increasingly-important in today's competition as it has significant impact on the performance of the firm [3]. Profits can be maximized by lowering production costs through careful product design. A well-designed product will enable the firm to achieve a higher market share [2]. Consequently, when the firm undertakes a new (existing) product design activity, it is important to employ a technique that will generate optimal solutions prior to its launching in an increasingly competitive global market.

In today's market scenario, manufacturers compete on the basis of price, adaptability (i.e. flexibility to suit new demands) and also on variety of products offered that drives the

customer satisfaction [4]. Deciding the final design is the most critical decision in product development and is influenced by many factors [5]. Besharati et al. [5] identified three important factors namely;

1) **Market demand based on customers' preferences.** For example, a design alternative may fail to become a successful product if it does not gain and maintain enough market demand. On the other hand, considering the market demand by itself does not secure a successful product in the market. For instance, introducing a product at low price into the market might increase the initial product demand significantly. However, it may not be possible to sustain such a demand in the longer run (repurchase of the product) due to the poor performance (and reliability) with respect to some of the product attributes.

2) **Designer's preferences based on his/her knowledge and experience** with design issues and market issues. A designer's knowledge and experience can be very useful in predicting product performance if customers' evaluations are not known a priori. As such, the designer's preferences can be used to specify the product performance in terms of its attributes, which customers may not know or consider at the point of purchase. Also, a designer can incorporate the specifics of competitive products in his/her preference function so that the new design can be appropriately positioned in the market relative to competition, and

3) **Uncertainty in achieving the predicted design performance.** Because of the uncertainty in product design parameters (such as, manufacturing tolerances and variations in the product usage environment), the design attribute levels can deviate from their nominal values and affect the product performance. Such uncertainty can make or break a product in the market and thus, important to consider these variations in selecting a final product design.

Other factors that influencing product designs are cost / budget [6] and life style of the customer [7].

## **1.2 Importance of new product development:**

The growth of an industry depends on its ability to develop new products and /or to improve the existing products to expand the market share. The cost of development can account for up to 85% of total cost of product [8]. Seventy percent of the product cost is influenced by the decision made during the product conceptual stage [9]. Therefore; greater efforts are required to optimize product cost at design stage. Product design is also important because it directly impacts the design and management of a firm's production systems, and the functions that support those systems. The production and support of a product is affected by its design over the entire product lifecycle.

To survive in the competitive market the manufacturing firm must have the ability to out-perform along the five dimensions [10, 11].

- Speed: The ability to respond quickly to customer or market demands and to incorporate new ideas and technologies quickly into products.
- Consistency: The ability to produce a product that satisfies customer’s expectations.
- Acuity: The ability to see the competitive environment clearly and thus to anticipate and respond to customer’s evolving needs and wants.
- Agility: The ability to adapt simultaneously too many different manufacturing environments.
- Innovation: The ability to generate new ideas and to combine existing elements to create new source of values.

Aberdeen survey [3] reported new product development as a leading driver of revenue, profit, and market share growth in more than seventy five percent consumer companies also it had the most significant impact on revenue growth (figure 1.2).

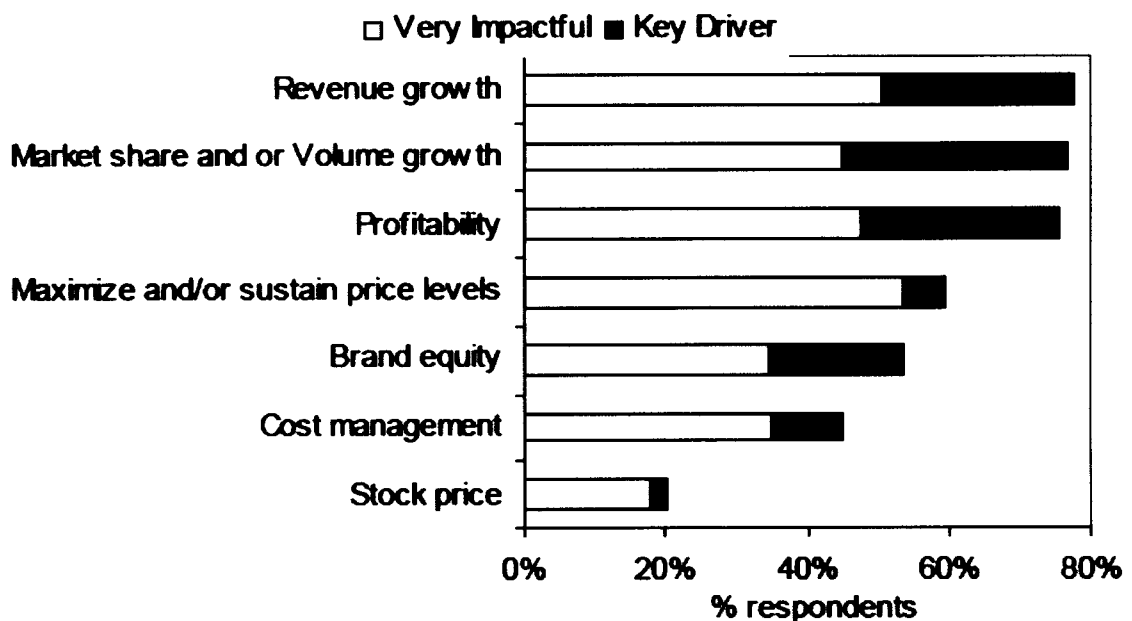


Figure 1.2 Impact of new product development on company performance [3]

### 1.3 Product development process:

#### 1.3.1 Product life cycle

Product design and development is one of the important phase of product life cycle. Product life cycle management (PLM) is an integrated system approach to improve the product development process and its management. PLM allows co-ordination and assures the

integrity of work performed on behalf of product development across the entire manufacturing industry. Product development is a collective strategy for managing products during the four phases (introduction, growth, maturity, and decline) of the product life cycle as shown in figure 1.3. During introduction phase a customer can tell a company what feature of the product is appealing and what are the characteristics that should / should not appear on the product. During the growth stage the firm adds new product features and new models and enters in new marker segment and lowers the price to increase market growth. During the period of maturity; new brands or modified version of the existing product are introduced even when they compete with the company's existing product. It is difficult for a company to conceptualize the decline signals of a product. Usually a product is said to be in decline phase as sale of the product in the market decreases. This is the time to start withdrawing variations of the product from the market that are weak in their market position.

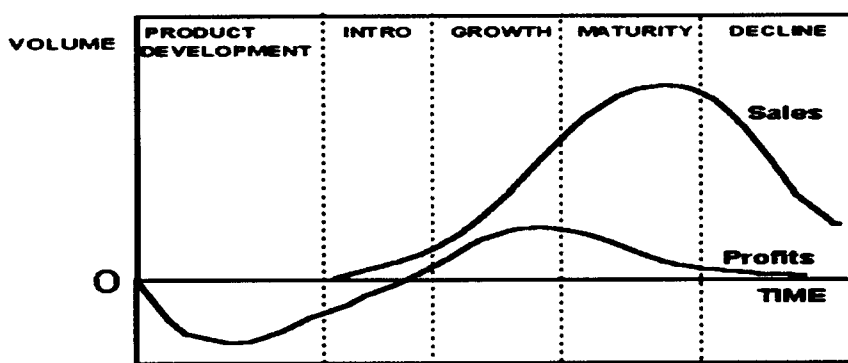


Figure 1.3 Product life cycle [12]

### 1.3.2 Steps in product development

#### 1.3.2.1 Generic approach to product development

A product development process is a sequence of activities which an enterprise employs to conceive, design, and commercialize a product. The six phases of the generic product development process are shown in figure 1.4. These are briefly summarized below [13]:

**Planning:** This phase begins with corporate strategy and includes assessment of technology developments and market objectives. The output of the planning phase is the project mission statement, which specifies the target market of product, business goals, key assumptions, and constraints.

**Concept development:** In this phase, the needs of the target market are identified, alternative 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. The concept development process includes the following activities:

- Identifying customer needs: The goal of this activity is to understand customer needs.
- Establishing target specifications: Specifications are the translation of the customer needs into technical terms.
- Concept generation: The goal of concept generation is to generate product concepts that may satisfy the customer needs. A product concept is an approximate description of technology, working principles, and form of the product. The degree to which a product satisfies customers and can be successfully commercialized depends to a large measure on the quality of the concept. Concept generation is relatively inexpensive and can be done relatively quickly in comparison to the rest of the development process. The concept generation process begins with a set of customer needs and results in a set of product concepts from which the development team will make a final selection. In most cases, team will generate hundreds of concepts of which 5 to 20 will merit serious consideration during concept selection activity. The concept generation method consists of five steps:

- Clarify the problem: Many design challenges are too complex to solve as a single problem and can be usually divided into several simpler sub problems (i.e. problem decomposition).
- Search externally: External search aimed at finding existing solutions to both the overall problem and the sub problems identified during the problem clarification step. The external search for solutions is essentially an information gathering process. Information is to be gathered from published literature (journals, conference proceedings, trade magazines, market/consumer/ product information), internets, competitors, patents, lead users, experts, and related benchmarked products.
- Search internally: Use individual and group methods to retrieve and adapt the knowledge of the team.
- Explore systematically: As a result of the external and internal search activities, the team may generate hundreds of concept fragments. These fragments are to be organized and synthesized by considering all of the combinations of the fragments associated with each sub problems. If more the number of combinations, then it will be a difficult task. However, some of the combinations do not make sense.

- Reflect on the solutions and the process: Identify opportunities for improvement in subsequent iterations or future projects.
- Concept selection: Concept selection is the process of evaluating concepts with respect to customer needs and comparing these concepts with various criteria and then selecting one or more concepts for further investigation. This is the activity in which various product concepts are analyzed and sequentially eliminated to identify the most promising concept(s). The process usually requires several iterations and may initiate additional concept generation and refinement. The methods used for concept selections are:
  - External decision: Concepts are turned over to the customer, client, or some other external entity for selection
  - Product champion: An influential member of product development team chooses a concept based on personal preference.
  - Intuition: The concept is chosen by its feel.
  - Multivoting: Each member of the team votes for several concepts. The concept with the most votes is selected.
  - Pros and cons: The team lists the strengths and weakness of each concept and makes a choice based upon group opinion.
  - Prototype and test: The organization builds and tests prototypes of each concept, making a selection based upon test data.
  - Decision matrices: The team rates each concept against prespecified selection criteria, which may be weighted.
- Concept testing: One or more concepts are then tested to verify that the customer needs have been met, assess the market potential of the product, and identify any shortcomings which must be remedied during further development.
- Setting final specifications: The target specifications set earlier in the process are revisited. At this stage, the product development team must commit to specific values of the metrics reflecting the constraints inherent in the product concept, limitations identified through technical modeling and trade-offs between cost and performance.

**System – level design:** In this phase, the product is decomposed into subsystems and components. The final assembly scheme for production system is defined during this phase.

**Detail design:** This phase includes the complete specification of the geometry, materials and tolerances of all of the unique parts in the product. The output of this phase is control

documentation (i.e. drawings, computer files, tooling required, standard or purchased part list of the product, process plan for fabrication and assembly etc.).

**Testing and Refinement:** It involves the construction and evaluation of multiple preproduction versions of the product (prototype). The prototype is tested to determine whether the product will work as designed and also tested by customers to check whether the product satisfies the key customer needs.

**Production ramp-up:** In the production ramp-up phase, the product is made using intended production system and then supplied to preferred customers to identify the remaining flaws. During the transition from production ramp-up to ongoing production, the product is launched.

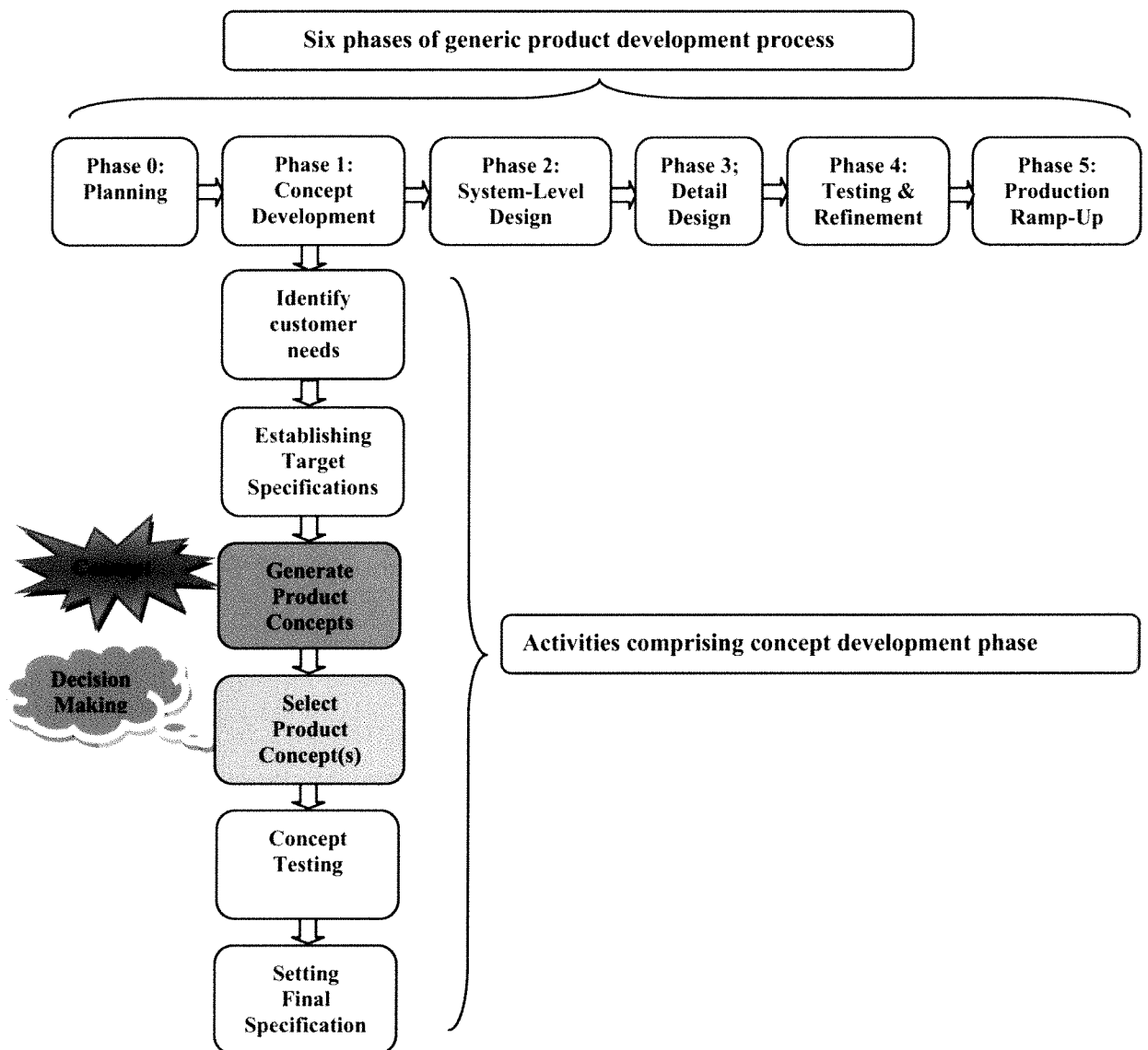


Figure 1.4 Six phases of generic product development process and activities comprising concept development phase [13]



### 1.3.2.2 Stage Gate approach to product development

There is another approach for product development called 'stage gate' system [14]. Product development initially starts with an idea and finally ends with the successful launch of a new product. A Stage-Gate system is used for transforming a new product idea to new product launch. In Stage-Gate system, this transforming process is divided into number of activities (stages) which are separated by decision points (gates). The product development team must successfully complete a set of activities in each stage. After approval of management (i.e. at management decision gates), the activities of the next stage of product development are taken place. A Stage-Gate system is shown in figure 1.5. It consists of various stages as follows:

**Stage 0: Discovery:** Activities designed to discover opportunities and to generate new product ideas.

**Stage 1: Scoping:** A quick and inexpensive assessment of the technical merits of the product development project and its market prospects.

**Stage 2: Build Business Case:** Technical, marketing, economic and business feasibility are evaluated resulting in a business case which has three main components: product and project definition; project justification; and project plan.

**Stage 3: Development:** In this stage, the actual design and development of the new product occurs, the manufacturing or operations plan as well as the marketing launch and operating plans are developed, and the test plans for the next stage are defined.

**Stage 4: Testing and Validation:** The purpose of this stage is to provide validation of the entire project: the product itself, the production/manufacturing process, customer acceptance, and the economics of the project.

**Stage 5: Launch:** Full commercialization of the product - the beginning of full production and commercial launch.

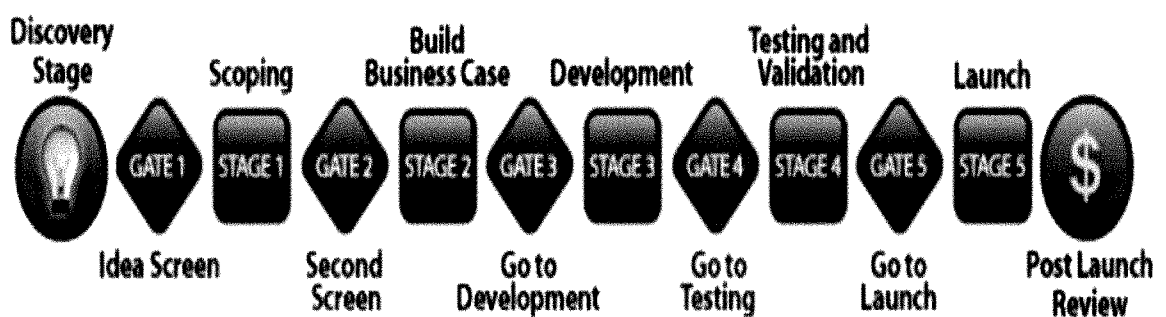


Figure 1.5 Stage - Gate system for product development [14]

#### **1.4 Customers role in product development:**

While developing the product, a product concept must define the benefits that product will offer to the customers. A product is a bundle of attributes and the benefits are to be delivered through the products attributes such as quality, features and design. These attributes must be modified over product's life cycle to remain competitive. To improve sales or profits, the quality might be raised or lowered (in case of over- engineered product), features might be added or withdrawn, and design (or styling) might be changed [12]. The term 'quality' means 'conformance to requirements' of the customer. The manufacturer must choose quality levels (i.e. low, average, high, superior) for a target market segment. Other important attribute is 'product feature'. Any product can be offered with varying features. A 'Stripped –down' model or 'Bare-Bones' model is starting or basic model without any extra or additional feature/features. The company can create higher-level models by adding one or more extra features. For example, in case of an automobile, the buyer can order for power windows, power steering, automatic transmission, air conditioning, stereo, navigation system, fog lamp, and additional safety systems such as air bags and so on. Features are competitive tool for differentiating the company's product from competitor's product. Company should periodically contact to the buyer regarding the addition of new feature or withdrawn of unnecessary/unused features. Being the first producer to introduce a needed and valuable new feature is one of the most effective ways to compete in the market [12]. Another attribute is 'design'. Good design contributes to a product's usefulness as well as attractiveness (i.e. aesthetics).

Customers may have different preferences over a set of product attributes. Depending on the nature of the demand, it is necessary to make product differentiation based on multi attributes. The use of product differentiation is to expand the demand through maximizing the number of individuals for whom a new product is closest to their respective ideal point (preference). Customer voices are diverse and there is no one monolithic voice of the customer. In consumer markets, there are varieties of needs. Even within one buying unit, there are multiple customer voices (e.g., children versus parents). These diverse voices must be considered, reconciled and balanced to develop a truly successful product. The customers' desires and tests should reflect in the product during product development process. There are four levels of customer requirements, which must be satisfied at each level before addressing those of the next level. These four levels are [11]:

- Expecters: These are the basic qualities one must offer to be competitive and to remain in business. These are the characteristics that customers assume as a part of the product or service; that is, they expect them as standard features.
- Spokens: The specific features that customers want in a product. A company must be willing to provide these features to satisfy its customers.
- Unspokens: Product characteristics that customers do not talk about, and, though silent, they are important and cannot be ignored.
- Exciters: Unexpected features of product the product that make the product unique and distinguish it from the competition. It is also referred as 'delighter', because it defines product attributes or features that are pleasant surprises to customers when they first encounter them. However, if they are not present, then the customers will not be dissatisfied, since they will be unaware of what they are missing. Kano model [15] is proposed to understand these customer requirements.

### **1.5 Decisions in product development:**

Satisfying customer's true requirements is a difficult task as it needs decisions from customers (features they want in product) and designers (how to collect, interpret and combine customer expected features in a product to produce efficient and effective product variants also called configuration). A common problem faced by an individual is the choice of most preferred product based on his / her expectations about product features / attributes out of set of alternatives. Those products may be different brands of mobile phones, computers, cars, washing machines etc. Individual differ in their choice of the attributes out of the existing set of attributes of that product. A problem with a firm is to categorize the customer requirements and to understand the nature of the requirement and how to transfer these requirements in the product.

In addition to attribute composition of product their prices also affect the consumer decision. The consumer first decides on his budget for the product class and then he evaluates subsets of attributes within the product class, which have prices approximately equal to his budget constraint [6]. Cost is an important factor in setting the price but there is another important factor 'customer value' (customer worth) i.e. what a product or a service worth to the customer in monetary units [16]. Therefore, it is necessary to design a product based on preferred attributes of the customers (or group of customer i.e. segment) and customer value. The manufacturers can customize the product as per the needs of variety of segments in order to maximize the profits.

Different organizations may have different design perspectives about the issues such as product concept, architecture, configuration, schedule, etc. Some product development decisions may be related to technology or assembly of product or variants of the product or may be regarding product development team. Krishnan and Ulrich [17] suggested the product development decisions related to concept development in which product's basic physical configuration and specifications are defined are:

- What is the core product concept?
- What is the product architecture?
- What variants of the product will be offered?
- Which components will be shared across which variants of the product?
- What are the target values of the product attributes, including price?
- What will be the overall physical form and industrial design of the product?

Clausing [18] identified the some important issues (i.e. 'cash drains') which affects entire product development process. To improve the chances of creating profitable products, the firms have to overcome these issues and are to be resolved. These issues are:

- Disregarding the voice of customers.
- Not subjecting new product idea to competitive evaluation.
- Introducing new technology that doesn't satisfy the customer needs.
- Not continually improving and optimizing the product and the manufacturing processes.
- Designing without the input from manufacturing and production early in the development process.

The motivation for the research came from literature as well as own observations on practical problems. The motivational thought behind this research work is how a customer can get a product of his / her own expected and desired features (configuration decision) with the most competitive price (product cost and customer worth decision). These decisions are also addressed / reported by Krishnan and Ulrich [17] in the review article on product design decisions. Out of large number of decisions related to product lifecycle referred in this review. This research work tries to address two important decision in the concept development for the consumer product domain. These are:

- What variants of the product will be offered?
- What are the target values of the product attributes, including price?

Although there have been significant mathematical modelling and data analysis technique reported in the literature, but there is shortage of theory development in

segmentation based on the product attributes. That is, segmentation techniques are scarce in product development literature [19, 20]. The work carried out in this research will propose a descriptive model for product development and segmentation; and therefore it will contribute to theory of product design and development.

### **1.6 Organization of the report:**

In chapter 1, need and importance of product development, classification of products, stages of product life cycle and phases (stages) of product development process has been discussed. The report is organized as follows: Chapter 2 provides detailed literature review related to product design and development. Problem definition, methodology and objectives are stated in chapter 3. A priori approach for the best product design using MADM method, is discussed in chapter 4. Chapter 5 provides comparative analysis of Multi-Attribute Decision Making methods for selection of the best product design alternative. Chapter 6 describes a post-hoc methodology for product design and customer segmentation. Conclusion, thesis contribution and scope for future work is given in chapter 7.

In a scientific contribution, the results claimed and confirmed by earlier reserchers are to be true as approved by scientific community. The detailed literature review of the proven knowledge is discussed in the next chapter.