Module 1

Introduction
Lecture 1

Need Identification and Problem Definition
Instructional objectives

The primary objective of this lecture module is to outline how to identify the need and define the problem so as to begin with the activities and steps involved in design for manufacturing process.

Steps involved in Engineering Design process

*Figure 1.1.1* schematically outlines the typical steps involved in an engineering design process.

**Figure 1.1.1** Discrete steps involved in engineering design process. It also mentions the important techniques used in each steps.
Conceptual Design

It is a process in which we initiate the design and come up with a number of design concepts and then narrow down to the single best concept. This involved the following steps.

1. Identification of customer needs: The main objective of this is to completely understand the customers’ needs and to communicate them to the design team.
2. Problem definition: The main goal of this activity is to create a statement that describes what all needs to be accomplished to meet the needs of the customers’ requirements.
3. Gathering Information: In this step, we collect all the information that can be helpful for developing and translating the customers’ needs into engineering design.
4. Conceptualization: In this step, broad sets of concepts are generated that can potentially satisfy the problem statement.
5. Concept selection: The main objective of this step is to evaluate the various design concepts, modifying and evolving into a single preferred concept.

Embodiment Design

It is a process where the structured development of the design concepts takes place. It is in this phase that decisions are made on strength, material selection, size, shape, and spatial compatibility. Embodiment design is concerned with three major tasks – product architecture, configuration design, and parametric design.

1. Product architecture: It is concerned with dividing the overall design system into small subsystems and modules. It is in this step we decide how the physical components of the design are to be arranged in order to combine them to carry out the functional duties of the design.
2. Configuration design: In this process we determine what all features are required in the various parts/components and how these features are to be arranged in space relative to each other.
3. Parametric design: It starts with information from the configuration design process and aims to establish the exact dimensions and tolerances of the product. Also, final decisions on the material and manufacturing processes are done if it has not been fixed in the previous process. One of the important aspects of parametric designs is to examine if the design is robust or not.
Detail Design
It is in this phase the design is brought to a state where it has the complete engineering description of a tested and a producible product. Any missing information about the arrangement, form, material, manufacturing process, dimensions, tolerances etc of each part is added and detailed engineering drawing suitable for manufacturing are prepared.

Need Identification and Problem Definition
Out of all the steps in the engineering design process, the definition of the problem is by far the most important step. A complete and thorough understanding the problem is prerequisite in achieving the targeted solution. For example, the ultimate test of a product is how well it sells. However, it is first essential to understand and provide what a customer wants in the product which can only be achieved by defining the problem precisely at the first place.

A-priori Activities
In majority of the situations, a significant amount of development work precedes the tight definition of a design problem. These a-priori development works can generally be referred to planning. The primary purpose of the planning stages is to collect all the necessary information and to decide, for example, whether manufacturing a new product is feasible or what would be the best time to market a new or modified product, or whether a specific company has the adequate resource to manufacture a new product. Usually the initial design projects can be categorized as follows.

Variation of an existing product
This includes minor changes in few parameters of an existing the product e.g. change in the power of a motor or change in the design of a typical clamping bracket, and so on.

Improvement in an existing product
This involves major redesign of an existing product primarily to improve performance and quality, update features (may be due to competitions), reduce cost in manufacturing and so on.

Development of a new product for a low-volume production run
This is primarily referred to new parts or products that would possibly be manufactured in smaller number of units (e.g. < 10000). In many cases, a large manufacturing unit may wish to
buy standard available components available from smaller manufacturing units rather than actually making the same to avoid additional costs.

Development of a new product for mass production

These include products or parts which need to be produced in large volumes e.g. in the category of automobiles, home appliance etc. Such design projects provide the design engineer the flexibility in selecting appropriate material and manufacturing process through careful planning.

One-of-a-kind design

Such projects can vary from a simple, quick design requiring minimum of analysis like designing of a welding fixture to hold parts to large exclusive projects such as building of a 200-MW steam turbine.

Product Life cycle

Every product goes through a cycle from birth, followed by an initial growth stage, a relatively stable matured period, and finally into a declining stage that eventually ends in the death of the product as shown schematically in Figure 1.1.2.

1. **Introduction stage**: In this stage the product is new and the customer acceptance is low and hence the sales are low.

2. **Growth stage**: Knowledge of the product and its capabilities reaches to a growing number of customers.

3. **Maturity stage**: The product is widely acceptable and sales are now stable, and it grows with the same rate as the economy as a whole grows.

4. **Decline stage**: At some point of time the product enters the decline stage. Its sales start decreasing because of a new and a better product has entered the market to fulfill the same customer requirements.
Figure 1.1.2  Schematic outline of a product life cycle

Technology development cycle

The development of a new technology follows a typical S-shaped curve \([Figure 1.1.3(a)]\). In its early stage, the progress is limited by the lack of ideas. A single good idea can make several other good ideas possible, and the rate of progress is exponential. Gradually the growth becomes linear when the fundamental ideas are in place and the progress is concerned with filling the gaps between the key ideas. It is during this time when the commercial exploitation flourishes. But with time the technology begins to run dry and increased improvements come with greater difficulty. This matured technology grows slowly and approaches a limit asymptotically. The success of a technology based company lies in its capabilities of recognizing when the core technology on which the company’s products are based begin to mature and through an active R&D program, transfer to another technology growth curve \([Figure 1.1.3(b)]\) which offers greater possibilities.
Identifying Customer Needs

It is usually the desire of the customers that drive the development of a new product or modification of an existing product. It is thus critical to collate the need or views of the customers when starting a design project. The needs of the customers can be gathered through multiple routes.

Interviewing with customers
An active team should constantly meet current and potential customers to identify the strength and weakness of a product so as to examine if there is any need to upgrade.

Focus group
A focus group refers to a small sub-set of existing customers or potential customers. A discussion is usually facilitated in many such groups separately to identify more closely the merits and demerits of the product.

Customer survey
A written questionnaire is possibly the best way to know the public opinions for redesigning an existing product or developing a new product.

Customer complaints
Complaints from customers provide a significant premise to identify the requisite improvement for an existing product.
Constructing a Survey Instrument

Following are some essential steps to prepare a survey document based on the views and feedbacks from the customers.
1. Determine the purpose of the survey, its result and the how the result will be used.
2. Determine the type of possible data collection method such as face to face interview or by questionnaire or some other way.
3. Determine what specific information is needed. Each question should have a clear goal. Also the number of question should be optimized and kept at as minimum as possible.
4. Design the questions in such a way that they are unambiguous, unbiased, clear, brief and simple to understand and to answer too. There are usually three basic type of questions.
   - Attitude questions: how the customer thinks or feels about something,
   - Knowledge questions: Questions asked to determine whether the customer know the specifics about the product,
   - Behavior questions they usually contain phrases like ‘how often’, ‘how much’, or ‘when’.

Following are some tips for developing the questions.
- Use simple language and vocabulary. Each question should have a specific goal and focus directly on one specific topic.
- Questions may include “yes – no – do not know” or “strongly disagree – mildly disagree – neutral – mildly agree – strongly agree”, etc.
- Open ended questions allow customers to express more explicitly,
- Arrange the question in such an order that it makes sense and provides content to what you are trying to learn from the customer,
- Pretest the survey on a small sample before distributing the survey. It helps to identify questions that were poorly built, misunderstood, whether the rating scale was adequate and whether the questionnaire is too long
- Administer the survey: Proper care should be taken that the sample of the survey should constitute a representative from all the key areas.

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Evaluating Customer Needs

The responses of the customer should be evaluated on a relative scale, say using a scale from 1 (low importance) to 5 (high importance). Those responses with high average score should be given a greater priority when redesigning an existing product or designing a new product. It is very essential to divide the customer needs into two groups: hard constrains that should be satisfied (must) and softer needs that can be traded off against other customer needs (wants). Customer needs can best be identified from face to face interview, from a focus group survey or from the higher-ranking items in the written survey.

Customer requirements

Customer requirements must be characterized on the basis of performance, time, cost and quality. The performance would refer to the specific or intended function of a product. The time would include all the time aspects that would be involved in the design. A proper design should be able to reduce the cycle time to market a new product. The cost includes all the monetary aspects of the design and hence, quite crucial. The cost aspect also determines the buying decisions of any product by the customers. The quality is a complex characteristic with many aspects and definitions and can best be defined as the totality of features and characteristic of a product that bears on its ability to satisfy its stated needs. Another important aspect of the customers requirements is the value of a product that can be envisaged as the ratio of the function (or the quality) provided and the cost. For example, the quality of a manufactured product can be envisaged from the following eight basic dimensions.
<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Does the product perform to its standards? Does the product perform for the intended service?</td>
</tr>
<tr>
<td>Features</td>
<td>What additional benefits will be added to the product? Will they be they tangible or non-tangible benefits?</td>
</tr>
<tr>
<td>Reliability</td>
<td>Is the product consistent? Will it perform well over its lifetime and perform consistently?</td>
</tr>
<tr>
<td>Durability</td>
<td>How durable is your product. Will it last with daily use?</td>
</tr>
<tr>
<td>Conformance</td>
<td>Does your product meet with any agreed internal and national specifications?</td>
</tr>
<tr>
<td>Serviceability</td>
<td>Is the product easy to service.</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Is the product appealing to the eye?</td>
</tr>
<tr>
<td>Perceived</td>
<td>What sort of quality perception does the marketing team want to convey in their marketing message? Will price charged reflect the quality of the</td>
</tr>
<tr>
<td>Quality</td>
<td>product?</td>
</tr>
</tbody>
</table>

The dimensions of performance, features and conformance are often interrelated. We therefore need to recognize that there are four levels of customer requirements as

(1) **Expectations** that refer to the basic attributes, which one would expect to be present in the product as standard features,

(2) **Spokens** that refer to the specific features, which the customer would say and want as a feature in the product.

(3) **Unspokens** that refer to the attributes of a product that the customers would not generally ask for but are still important and hence, cannot be ignored.

(4) **Exciters** which are also known as delighters and are features that make the product unique and distinguish the same from their competitors.

These requirements must be satisfied at each level before we move and address those at the next level. Not all customer requirements are equal and hence it becomes very essential to identify these requirements which are important and ensure that they are delivered in the product. To do this one must adopt a strategy for actively seeking the ‘the voice of the customer’.

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Quality Function deployment

*Quality function deployment* (QFD) is a planning and problem-solving tool that is used from transforming customer requirement into the engineering characteristics of the product. QFD helps to transform the customer needs (also referred to as *voice of customer*) into engineering characteristics (and appropriate test methods) for a product. It is a graphical technique, which systematically looks at all the elements that are deemed important based on customers survey go into the production definitions. A sample layout of the QFD diagram is shown below. Further analysis of QFD with real-life examples is presented later in Lecture 3 of Module 5 (*Design for Quality*).

![Quality Function Deployment Diagram](image)

**Figure 1.1.2** Schematic presentation of *quality function deployment (QFD)* house / table

Following are a brief outline of each section of the *quality function deployment* table.
Customer requirements (what’s)
These are typically the customer requirements.

Competitive assessment
It shows how the top two or three competitive products rank with respect to the customer requirements. This starts with ranking each customer requirements on a scale of 1 to 5 and then by considering planned improvement and any requirements that are planned for special attentions.

Engineering characteristics (how’s)
The engineering characteristics that enable satisfying the customer requirements are listed in this column.

Correlation matrix
It shows the degree of interdependence of the engineering characteristics with each other in the ‘roof of the house’.

Relationship matrix
It represents the correlation between the engineering characteristics and the customer requirements.

Absolute importance
To determine the absolute importance we need to multiply the numerical value in each of the cells of the relationship matrix(6) by the importance rating (3) and then sum the numbers in the cells of each column.

Relative importance
This represents the absolute importance but normalized on a scale of 1 to 100.

Technical competitive assessment
This refers to the benchmarking of the company performance against the top two or three competitors for each of the engineering characteristics.

Technical difficulties
These depict the ease (or the extent of difficulty) to achieve each engineering characteristic.

Target values
This would depict the final target set based on the key engineering characteristics that are deemed important and the assessment of the technical difficulty.
Product Design Specifications

The *product design specification* is the basic control and reference document that would include the outcomes of the product development exercise, and is the must to begin with and execute the design and manufacturing of any specific part or product. The *quality function deployment* tool provides the most crucial inputs in writing the *product design specifications*. Following are some of the important elements of a typical *product design specification* document. It is, however, not necessary that the *product design specification* document of any product will contain all these elements.

[A] In-use purposes and market requirements

(a) Title and Purpose or function of the product,
(b) Predictable unintended use of the product,
(c) Special features of the product,
(d) What would be the competitive products?
(e) What is the intended market and why there is a need for this product?
(f) Relationship of the product to the other company products,
(g) Anticipated market demand (units per year) and target price.

[B] Functional Requirements

(a) Functional performances such as flow of energy, information, materials, operational steps, efficiency, accuracy, etc.,
(b) Physical requirements such as shape, size, weight, surface finish, etc.,
(c) Service environment such as storage and transportation requirement,
(d) Life-cycle issues including useful life, reliability (mean time to failure), robustness, ease of installation, maintenance and repair, recyclability, etc.
(e) Human factors including importance of aesthetics, ergonomics and user-training.

[C] Corporate Constrains

(a) Is there adequate time to design a quality product and its manufacturing process (*time to market*)
(b) What are the requirements for manufacturing this product?
(c) Do existing relationships with the suppliers pose any constraint on manufacturing?
(d) Are there any constraints in using the *trademark, logo, brand name*?
(e) What are the *profitability* and *return on investment (ROI)* that must be met?

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The production team should follow professional ethics at every level of the design process when they are dealing with suppliers, dealers, corporate officials, society etc.

[D] Social, Political and Legal Requirements

(a) The *product design specification* should meet / contain all the requisite safety and environmental regulations,
(b) The *product design specification* should contain all the required standards,
(c) The *product design specification* must be completed with respect to all safety and liability norms,
(d) The *product design specification* should consider all the information related to the patents and intellectual property that are applicable.

Product Design Specifications (PDS) is explained with the following example in which the PDS is done for an adjustable wheel chair.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td>Seat width</td>
</tr>
<tr>
<td>Primary Customer</td>
<td>Patient</td>
</tr>
<tr>
<td>Metrics &amp; Targets</td>
<td>Metric Target</td>
</tr>
<tr>
<td>Seat width adjustable by</td>
<td>Inches</td>
</tr>
<tr>
<td>user</td>
<td>16 through 20 – 2 inch increments</td>
</tr>
<tr>
<td>Target Basis</td>
<td>Market research</td>
</tr>
<tr>
<td>Verification Method</td>
<td>Prototyping</td>
</tr>
</tbody>
</table>

Similarly, other dimensions of the wheel chair can be set. However, the criteria are not only based on the performance. There can be other criteria as well like *aesthetics, life in service, legal* (Patents, Product Liability) and so on. One of them is shown below.
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Life in Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td>Appropriate service life for capital asset</td>
</tr>
<tr>
<td>Primary Customer</td>
<td>Hospitals</td>
</tr>
<tr>
<td>Metrics &amp; Targets</td>
<td></td>
</tr>
<tr>
<td>Life</td>
<td>Metric</td>
</tr>
<tr>
<td></td>
<td>Years</td>
</tr>
<tr>
<td>Target Basis</td>
<td>Market Analysis</td>
</tr>
</tbody>
</table>

**Exercise**

1. Write a survey to find what customers want in a refrigerator.

**References**