Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

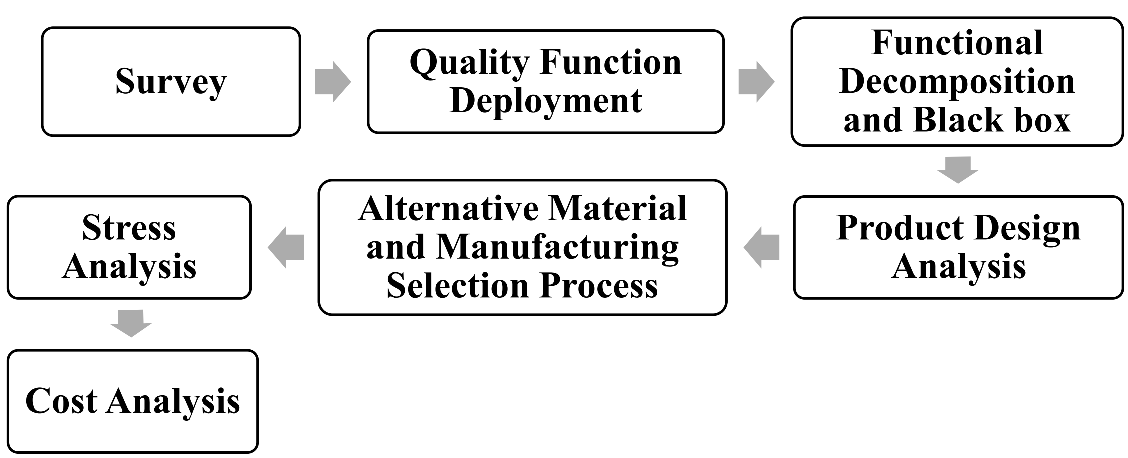
IPE 3104: Product Design and Development sessional
Credit Hour: 1.5

General Guidelines:

1. Students must form group and submit at least five ideas for product development by each group with in the first week of the beginning of class
2. Students must be present on time as per the scheduled time of each briefing
3. Report/ Assignment of a briefing must be submitted in the next briefing
4. Viva for each brief may be taken on the next day with the report/ assignment
5. The structure of the Report/ Assignment of each briefing will be provided by the respective teacher
6. Final presentation will be taken at the end of the semester before the preparatory leave.
7. Students must bring their complete product at the day of presentation for product demonstration
8. A tentative marks distribution is given below:

Report/ Assignment	Attendance and Viva	Final Presentation	Product demonstration
30	20	25	25

Steps regarding briefing of Product Design and Development sessional will be followed as mentioned below-



Brief-1

Survey

Market surveys are an important part of market research that measure the feelings and preferences of customers in a given market. Varying greatly in size, design, and purpose, market surveys are one of the main pieces of data that companies and organizations use in determining what products and services to offer and how to market them. These steps will teach you the basics of how to make a market survey and offer tips for optimizing your results.

Clarify the goal of your market survey. Before starting any planning, be certain what the goal of your market survey is. What do you want to find out? Do you want to try to assess how well your market will accept a new product? Maybe you want to figure out how well your marketing is working or reaching its designated audience. Whatever it is, be sure that you have a clear goal in mind.

Determine and define the nature, extent, and size of your market. Before conducting a survey in a given market, you need to know what market you're targeting. Choose geographic and demographic parameters, identify customers by types of product, and get an idea of how many people there are in the market.

Determine what aspects of the market you want to investigate. This will depend entirely on your marketing goals and there are a large variety of options here. If you have a new product, you may want to figure out how well it is recognized or desired in a given market. Alternately, you may want to know about the specific buying habits of your market, like when and where and how much they buy. Just be sure to have a clear idea of what you want to find out.

Find out where and when you can reach customers in your market. You might conduct a survey at the mall or on the street, via telephone, online, or through the mail. Your results may change based on the time of day and year. Choose a method and time that best suits your research.

Determine what type of survey to use. Surveys can be split into two different general categories: questionnaires and interviews. The only difference is who does the recording of the respondents' information; in the questionnaire, the respondent records their own answers to the questions, whereas in the interview, the interviewer writes down what the respondent says. Beyond that, there are other options as to how the survey is administered, whether that's online or in person. Surveys can also be done individually or in groups.

Consider online survey platforms. Online survey platforms offer a cost and time-effective way to organize your survey and survey results. Simply search for these platforms online and compare several that you find to assess which one offers the right tools for your survey. Just make sure that your choices are reputable survey platforms. You should also consider whether or not your target market is computer-savvy enough for online surveys to be effective

In order to get the best results students have to consider some important assumption before doing survey such as:

- **Choose a sample size**
- **Prepare a list of questions with answers that will provide the data you need for your market research**
- **Devise a way to quantify the answers you receive.**
- **Identify variables that might affect your results.**
- **Have someone else look over your survey.**
- **Set a time period and location for your survey**
- **Conduct your survey, maximizing sample size and accuracy of responses.**
- **Analyze your results.**

Brief-2

QUALITY FUNCTON DEPLOYMENT

Definition of QFD -QFD stands for quality function deployment. It is a very systematic and organized approach of taking customer needs and demands in the consideration when designing a new products and services or when improving existing products or services.

- Quality -meeting customer requirements
- Function - What must be done-Focusing the attention
- Deployment - who will do it, When

Benefits of QFD

- create customer driven environment
- reduces the cycle time for new products
- reduces design to manufacturing costs
- increases communication through cross functional teams
- establish priority requirements and improves quality

Characteristics of QFD

❖ **Four main phases of QFD**

- Product planning including the 'House of Quality' (requirements engineering life cycle)
- Product design (design life cycle)
- Process planning (implementation life cycle)
- Process control (testing life cycle)

Product planning - define and prioritize customer needs - analyze competitive opportunities - plan a product to respond to a need - establish target values	**Part planning** - identify critical parts and sub-assemblies - identify interaction effect between parts - identify important parts characteristics that can fulfill product needs
Process requirement - determine critical process and material flow - determine process parameters - identify equipment requirements	**Production planning** - establish operational requirement - determine operation sequence - establish process control methodology

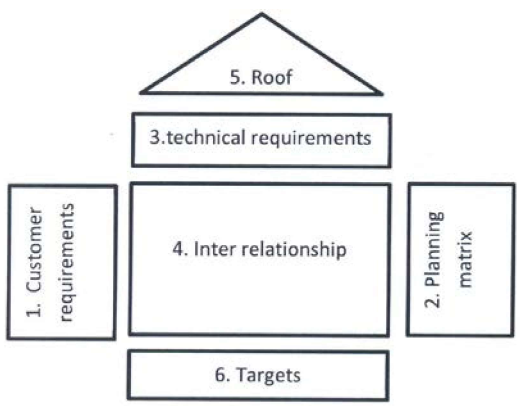
House of Quality

The primary planning tool used in QFD is the house of quality. The house of quality translates the voice of the customer into design requirements that meet specific target values and matches that against how an organization will meet those requirements. Many managers and engineers consider the house of quality · to be the primary chart in quality planning.

To build House of Quality

- Identify customer **wants**
- Identify **how** the good/services will satisfy customer wants
- Relate customer **wants** to product **how**
- Identify relationships between the firm's **how** and the customer's **how**
- Develop importance rating
- Evaluate competing products

The structure of QFD can be thought of as a framework of a house, as shown in the figure below

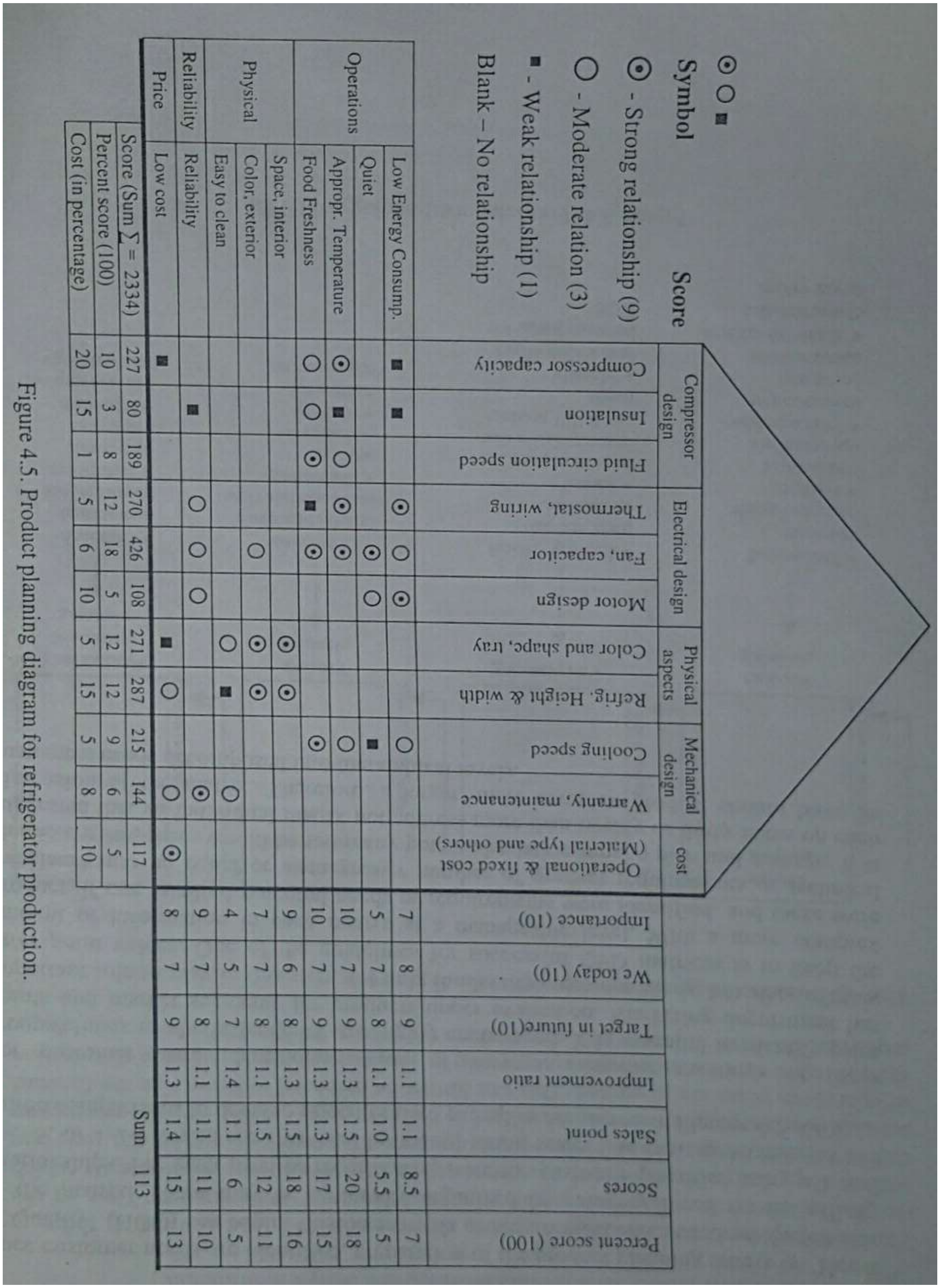


1. **Customer requirements** -the voice of customer in their own words
2. **Planning matrix**

- Customer satisfaction-existing products fulfilling specified requirements.
- Improvement ratio = (existing rating-planned rating)/highest rating+l
- Sales point-weight for marketability
- Overall weighting=improvement factor* sales point*customer importance

3. **Technical requirement -** engineering characteristics, voice of the company

4. **Interrelationships** -between customer requirements and technical requirements
5. **S. Roof –** consider impact of technical requirements on each other



		Compressor design			Electrical design			Physical aspects		Mechanical design		cost							
		Compressor capacity	Insulation	Fluid circulation speed	Thermostat, wiring	Fan, capacitor	Motor design	Color and shape, tray	Refrig. Height & width	Cooling speed	Warranty, maintenance	Operational & fixed cost (Material type and others)	Importance (10)	We today (10)	Target in future(10)	Improvement ratio	Sales point	Scores	Percent score (100)
Operations	Low Energy Consump.	■	■		⊙	○	⊙			○			7	8	9	1.1	1.1	8.5	7
	Quiet					⊙	○			■			5	7	8	1.1	1.0	5.5	5
	Appropr. Temperature	⊙	■	○	⊙	⊙				○			10	7	9	1.3	1.5	20	18
	Food Freshness	○	○	⊙	■	⊙				⊙			10	7	9	1.3	1.3	17	15
Physical	Space, interior							⊙	⊙				9	6	8	1.3	1.5	18	16
	Color, exterior					○		⊙	⊙				7	7	8	1.1	1.5	12	11
	Easy to clean							○	■		○		4	5	7	1.4	1.1	6	5
Reliability	Reliability		■		○	○	○				⊙		9	7	8	1.1	1.1	11	10
Price	Low cost	■						■	○		○	⊙	8	7	9	1.3	1.4	15	13
	Score (Sum $\sum$ = 2334)	227	80	189	270	426	108	271	287	215	144	117					Sum	113	
	Percent score (100)	10	3	8	12	18	5	12	12	9	6	5							
	Cost (in percentage)	20	15	1	5	6	10	5	15	5	8	10							

Figure 4.5. Product planning diagram for refrigerator production.

Brief-3

Functional Decomposition and Black Box

Functional Decomposition

Function:

A function of a product is a statement of a clear, reproducible relationship between the available input and the desired output of a product, independent of any particular form. The product function is the overall intended function of the product.

Sub function:

A sub function is a component of a product function. An overall function has to be divided into identifiable sub functions and the overall function is often governed by a constraint or input-output relationship.

An elementary approach to developing a function description of a product is to decompose the prime function hierarchically into sub functions that, when all are fulfilled, completes the overall product function. Function trees can be developed to understand the product function. The following is an example of the functional decomposition of Ice crusher machine.

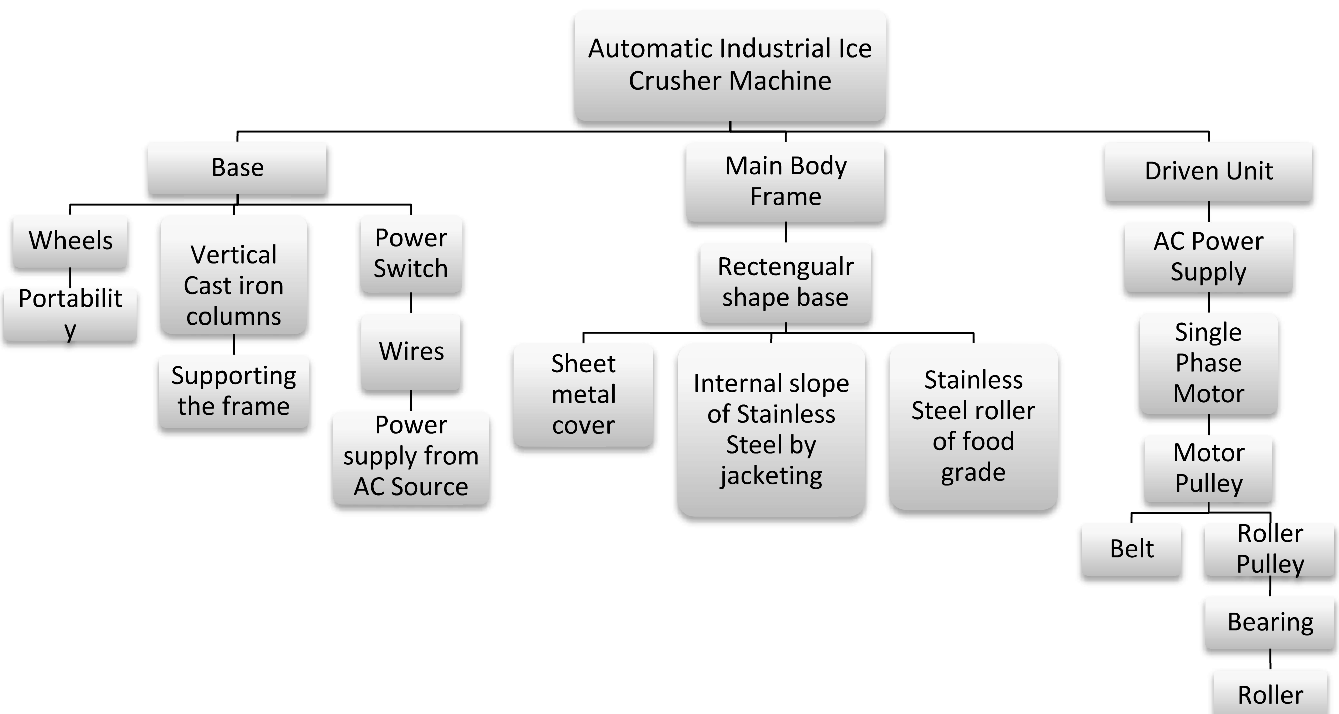
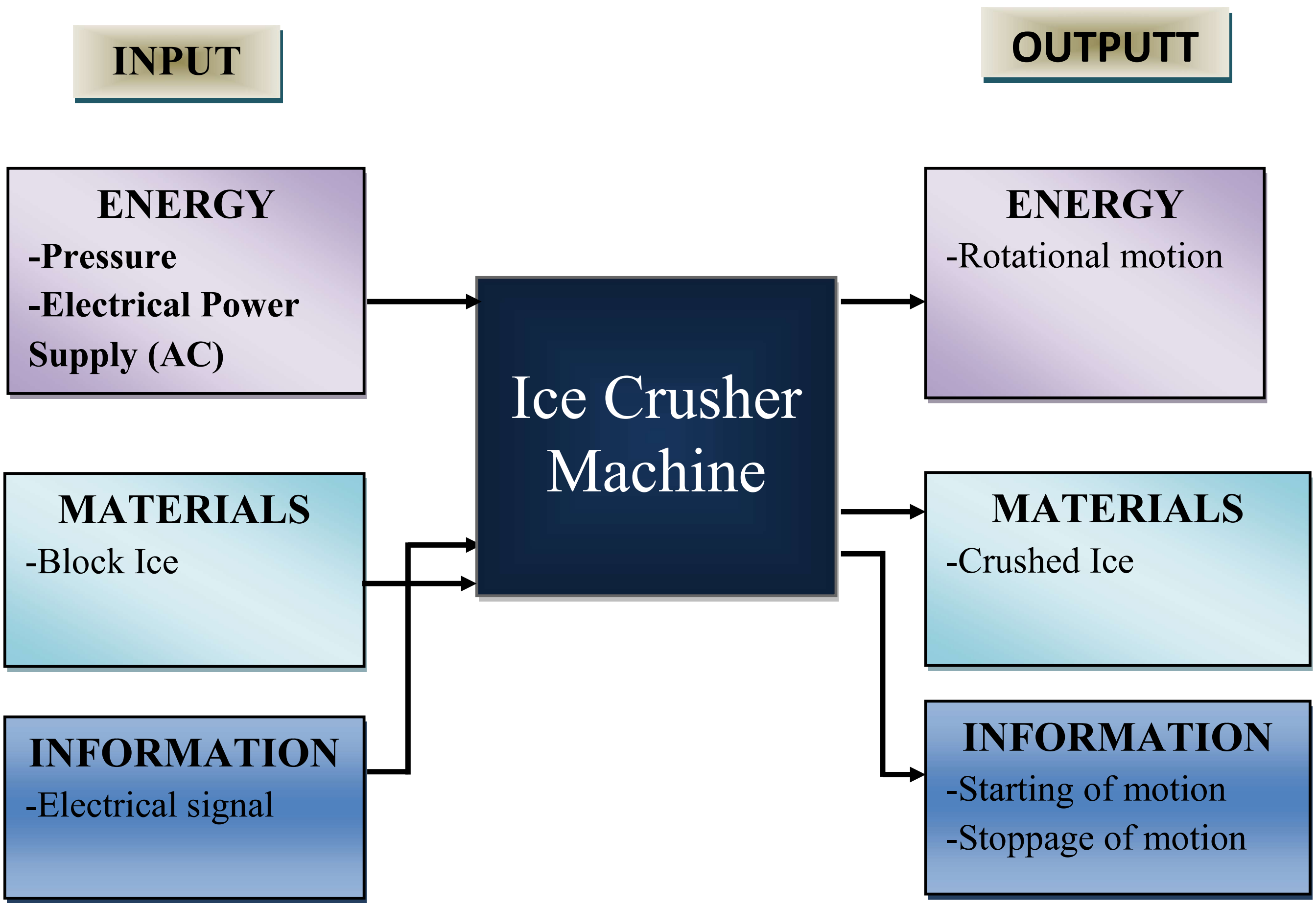


Figure 3: Functional decomposition of Automatic Industrial Ice Crusher Machine.

Black Box:

Black Box Model is a robust and complete method for modeling product's functionality. It is called "black-box" because its internal form is deemed unknown. It allows us to focus on the greatest and overall need for a product. The Black Box initiates a technical understanding of a product based on its inputs and outputs, known as material, energy and information. an example is illustrated below.



BLACK BOX MODEL OF AUTOMATIC ICE CRUSHER MACHINE

Brief -4

Product Design Analysis

Product design analysis means studying how well a product does its job. The justification of a product lies in its use, however abstract that use may be (e.g. the use of a car to boost a driver's image); the product has no right of existence in itself. In this context it is important to note that the physical appearance of a product is only one of the many possible design implementations of the set of functions it is supposed to perform.

Designers and manufacturers use product design analysis to help them develop ideas for new or improved products and to analyze the work of other designers. Quality assurance is a system of checks and inspections to ensure high standards throughout design and manufacture. The purpose of the design analysis is to define a product that performs these functions as well as possible within the constraints of cost, (development) time and performance (quality), and the design problem to be solved is how to accomplish this.

The necessary condition to be fulfilled prior to the start of the design analysis properly is to know, what the user's intended use of the product will be:

- What he wants to do with the product (so its desired functions),
- How well he wants these functions performed and why,
- Which functions are the crucial ones?

Especially the last item is of importance, as it is the source for the set of criteria to be used in taking design decisions. During the design process the design team must continuously check whether the chosen design implementation meets the requirements from the user's point of view. To be able to do this, product characteristics must be linked back to the functions the product has to perform. Also, when choosing between design alternatives the key functions, in addition to the major constraints the product has to comply with, again deliver the criteria to screen and rank the alternatives.

A list of Universal Design principles are mentioned below-

1. **Equitable Use:** The design is useful and marketable to people with diverse abilities.
2. **Flexibility in Use:** The design accommodates a wide range of individual preferences and abilities.
3. **Simple & Intuitive to use:** Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
4. **Perceptible Information:** The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

5. **Tolerance for Error**: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. **Low Physical Effort**: The design can be used efficiently and comfortably and with a minimum of fatigue.
7. **Size and space for approach & use:**The design provides for appropriate size and space for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

The attributes of a properly designed product are mentioned below-

1. **Functionality:** The product must function properly for intended purpose.
2. **Reliability:** The product must perform properly for the designated period of time.
3. **Productivity:** The product must be produced with a required quantity and quality at a defined and feasible cost.
4. **Quality:** The product must satisfy customer's stated and unstated needs.
5. **Standardization:** The product should be designed in such a fashion so that most of the components are standardized and easily available in the market.
6. **Maintainability:** The product must perform for a designated period with a minimum and defined maintenance. Adequate provision for maintenance should be kept in the product.
7. **Cost effectiveness:** The product must be cost effective. The must be manufactured in the most cost effective environment.

Product Architecture

Product contains components (CD players have a chassis, motors, disk drive, and speaker and so on), that can be combined into chunks (the base, the disk handling system, the recording system, and the sound producing system). A product is also composed of functional elements (for a CD player, these might include reading disks, recording sound, producing sound, and adjusting sound quality). The product architecture is how the functional elements are assigned to the chunks and how the chunks are interrelated.

Design for Manufacturing

Value Analysis or engineering: Simplification of products and processes. Value analysis seeks to improve the secondary function, e.g. how to open a can or make a tool box.

Terms in Value Analysis:

- Objective: Primary purpose of the product
- Basic Function: Makes the objective possible
- Secondary Function: How to perform the basic function

Modular Design: Multiple products using common parts, processes and modules.

- Allows greater variety through ‘mixing and matching’ of modules
- Develops a series of basic product components (modules) for later assembly into multiple products
- Reduces complexity and costs associated with large number of product variations
- Easy to subcontract production of modules

Design Variables & Attributes

Design Variables: Set of input variables (parameters) to the design simulation software (e.g. Motor type, Gear type, Gear ratio, DC voltage, ambient temperature)

Performance Attributes: Set of attributes that is the output of the simulation software, and identifies a product design (e.g. manufacturing cost, Weight, Time per operation per battery charge)

Design Alternative Generation

Two methods for generating design alternatives-

Multi objective Optimization

- Formulate a multiobjective optimization problem, solve for the alternatives that satisfy the objectives (performance attributes) the most.
- There is no closed form representation of the objective functions
- The design input parameters consist of both continuous and discrete variables
- Multiobjective Genetic Algorithm is a good choice to handle this type of problems
- The solution points constitute a non-dominated set w.r.t. all objective functions.

Permutation over Attributes

- Generating design alternatives by permuting the attributes over all (or certain) levels
- Mapping between the attributes and the design variables is simple(i.e. we can easily obtain the corresponding design variables, once we get the attribute levels)
- Very easy to implement but less likely to be able to handle real applications.

Brief-5

Alternative Material and Manufacturing Selection Process

It is estimated that there are more than 40,000 currently useful metallic alloys and probably close to that number of nonmetallic engineering materials such as plastics, ceramics and glasses, composite materials, and semiconductors. This large number of materials and the many manufacturing processes available to the engineer, coupled with the complex relationships between the different selection parameters, often make the selection of a materials for a given component a difficult task. If the selection process is carried out haphazardly, there will be the risk of overlooking a possible attractive alternative material. This risk can be reduced by adopting a systematic material selection procedure.

A variety of quantitative selection procedures have been developed to analyze the large amount of data involved in the selection process so that a systematic evaluation can be made. Several of the quantitative procedures can be adapted to use computers in selection from a data bank of materials. The materials and process selection is often thought of in terms of new product development

Quantitative Methods

Having specified the performance requirements of the different parts, the required material properties can be established for each of them. These properties may be quantitative or qualitative, essential or desirable. The essential material properties are tensile and fatigue strengths, while the desirable properties that should be maximized are process ability, weight, reliability, and resistance to service conditions. All these properties should be achieved at a reasonable cost. The selection process involves the search for the material or materials that would best meet those requirements. The starting point for materials selection is the entire range of engineering materials.

After narrowing down the field of possible materials using one or more of the quantitative initial screening methods quantitative methods can be used to further narrow the field of possible materials and matching manufacturing processes to a few optimum candidates that have good combinations of soft requirements.

Weighted-Properties Method

In the weighted-properties method each material requirement, or property, is assigned a certain weight, depending on its importance to the performance of the part in service. A weighted-property value is obtained by multiplying the numerical value of the property by the weighting factor (α). The individual weighted-property values of each material are then summed to give a comparative materials performance index (β). Materials with the higher performance index (β) are considered more suitable for the application.

Digital Logic Method

The digital logic approach can be used as a systematic tool to determine α. In this procedure evaluations are arranged such that only two properties are considered at a time. Every possible combination of properties or goals is compared and no shades of choice are required, only a yes or no decision for each evaluation. To determine the relative importance of each property or goal a table is constructed, the properties or goals are listed in the left-hand column, and comparisons are made in the columns to the right, as shown in Table 1. In comparing two properties or goals, the more important goal is given numerical one (1) and the less important is given zero (0). The total number of possible decisions $N = n\,(n - 1)/2$, where n is the number of properties or goals under consideration. A relative emphasis coefficient or weighting factor, α, for each goal is obtained by dividing the number of positive decisions for each goal (m) into the total number of possible decisions (N). In this case $\sum\alpha = 1$.

Table 1 Determination of Relative Importance of Goals Using Digital Logic Method

	Number of Positive Decisions $N = n(n-1)/2$											Relative Emphasis Coefficient
Goals	1	2	3	4	5	6	7	8	9	10	Positive Decisions	α
1	1	1	0	1							3	0.3
2	0				1	0	1				2	0.2
3		0			0			1	0		1	0.1
4			1			1		0		0	2	0.2
5				0			0		1	1	2	0.2
	Total number of positive decisions										10	$\Sigma\alpha = 1.0$

Performance Index

The property with higher numerical value will have more influence than is warranted by its weighting factor. This drawback is overcome by introducing scaling factors. Each property is so scaled that its highest numerical value does not exceed 100. When evaluating a list of candidate materials, one property is considered at a time. The best value in the list is rated as 100 and the others are scaled proportionally. Introducing a scaling factor facilitates the conversion of normal material property values to scaled dimensionless values. For a given property, the scaled value, B, for a given candidate material is equal to:

$$B = \text{Scaled property} = \frac{\text{Numerical value of prperty} \times 100}{\text{Maximum value in the list}}$$

For properties such as cost, corrosion or wear loss, weight gain in oxidation, etc., a lower value is more desirable. In such cases, the lowest value is rated as 100 and *B* is calculated as:

$$B = \text{Scaled property} = \frac{\text{Minimum value in the list} \times 100}{\text{Numerical value of property}}$$

For material properties that can be represented by numerical values, application of the above procedure is simple. However, with properties such as corrosion and wear resistance, machinability and weldability, etc. numerical values are rarely given and materials are usually rated as very good, good, fair, poor, etc.In such cases, the rating can be converted to numerical values using an arbitrary scale. For example, corrosion resistance rating—excellent, very good, good, fair, and poor—can be given numerical values of 5, 4, 3, 2, and 1, respectively. After scaling the different properties, the material performance index (γ) can be calculated as:

$$\text{Material performance index} = \gamma = \sum_{i=1}^{n} B_i \alpha_i$$

where *i*is summed over all the *n* relevant properties.

CASE STUDY IN MATERIAL SELECTION

The objective is to select the least expensive component that satisfies the requirements for a simple structural component for cryogenic storage tank.

Materials requirements

- used in cryogenic applications for liquefied nitrogen gas) must not suffer ductile-brittle transition at -196° C
- Using stronger material gives thinner walls, which means a lighter tank, lower cool down losses, and easier to weld
- Lower specific gravity gives lighter tank
- Lower specific heat reduces cool down losses
- Lower thermal expansion coefficient reduces thermal stress
- Lower thermal conductivity reduces heat losses
- The cost of material and processing

Table 2: **Digital logic method to cryogenic tank problem**

Property	Decision number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Toughness	1	1	1	1	1	1															
Yield strength	0						1	0	0	1	1										
Young's modulus		0					0					0	0	0	1						
Density			0					1				1				1	1	1			
Expansion				0					1				1			0			1	1	
Conductivity					0					0				1			0		0		0
Specific heat						0					0				0			0		0	1

Table 3 **Weighting factors for cryogenic tank**

Property	Positive decisions	Weighting factor
Toughness	6	0.28
Yield strength	3	0.14
Young's modulus	1	0.05
Density	5	0.24
Expansion	4	0.19
Conductivity	1	0.05
Specific heat	1	0.05
Total	21	1.00

Table 4 Properties of candidate materials for cryogenic tank

Material	1 Toughness index [a]	2 Yield strength (MPa)	3 Young's modulus (GPa)	4 Specific gravity	5 Thermal expansion [b]	6 Thermal conductivity [c]	7 Specific heat [d]
Al 2014-T6	75.5	420	74.2	2.8	21.4	0.37	0.16
Al 5052-O	95	91	70	2.68	22.1	0.33	0.16
SS 301-FH	770	1365	189	7.9	16.9	0.04	0.08
SS 310-3/4H	187	1120	210	7.9	14.4	0.03	0.08
Ti-6Al-4V	179	875	112	4.43	9.4	0.016	0.09
Inconel 718	239	1190	217	8.51	11.5	0.31	0.07
70Cu-30Zn	273	200	112	8.53	19.9	0.29	0.06

Table 5 Scaled values of properties and performance index

Material	Scaled properties							Performance index (γ)
	1	2	3	4	5	6	7	
Al 2014-T6	10	30	34	96	44	4.3	38	42.2
Al 5052-O	12	6	32	100	43	4.8	38	40.1
SS 301-FH	100	100	87	34	56	40	75	70.9
SS 310-3/4H	24	82	97	34	65	53	75	50.0
Ti-6Al-4V	23	64	52	60	100	100	67	59.8
Inconel 718	31	87	100	30	82	5.2	86	53.3
70Cu-30Zn	35	15	52	30	47	5.5	100	35.9

From the above calculations the value of performance index has shown we can choose SS 301-FH for cryogenic tank.

Brief-6
<u>Stress Analysis</u>

As the manufacturing and engineering industry tend to become more complex and challenging, the importance of stress analysis in product and systems development is experienced better than ever.

Across manufacturing, biomedical, automotive, chemicals, aerospace, electronics, energy, and Geo-technical industries, analysis and prediction of potential stress and fatigue in the product are often performed as the last step of more complex multi-disciplinary analysis of electromechanical devices. It helps in determining the response of a structure, product or system on application of load. It is critical in evaluating structural analysis based on assessing fatigue and failure analysis process.

What is Stress Analysis?

Stress analysis is the process of comprehensive industrial testing based on the calculations of mechanical strain, stress, and related deformations on application of load. It is an advanced computational method of applying load on a structure to determine its response.

The analysis method is used for counter evaluating the effectiveness of FEA structural analysis based on the report for fatigue and stress assessment and failure analysis. The calculations can be used in determining the stress and fatigue level of different industrial structures, aircraft and aerospace, sub-sea components, rail, marine components, and nuclear structures and components.

Key Features of Stress Analysis

Stress analyzing modules come with different features that are of key benefit to engineering and manufacturing companies. However, some of the most important features include:

- Plane stress and strain
- Anisotropic stretch properties
- Electric and magnetic forces
- Thermal stresses
- Rigorous and dispersed loading

Stress Analysis example:

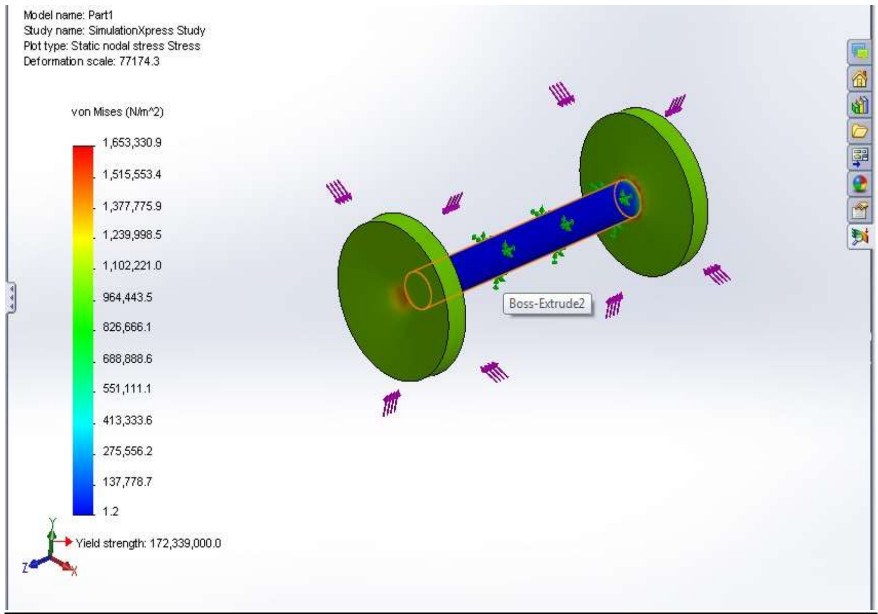


Figure 1: Static Stress Analysis for a Roller

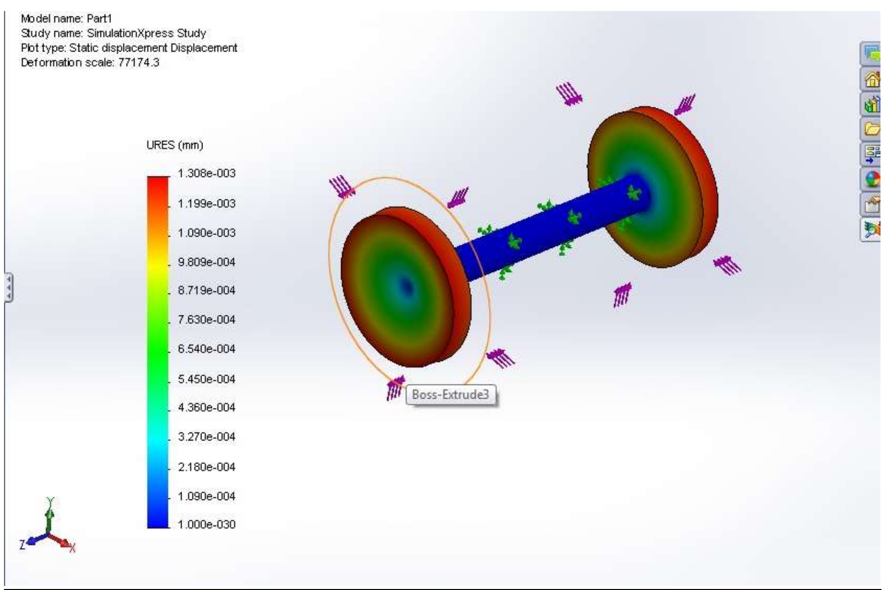


Figure -2: Static Displacement Analysis for a Roller

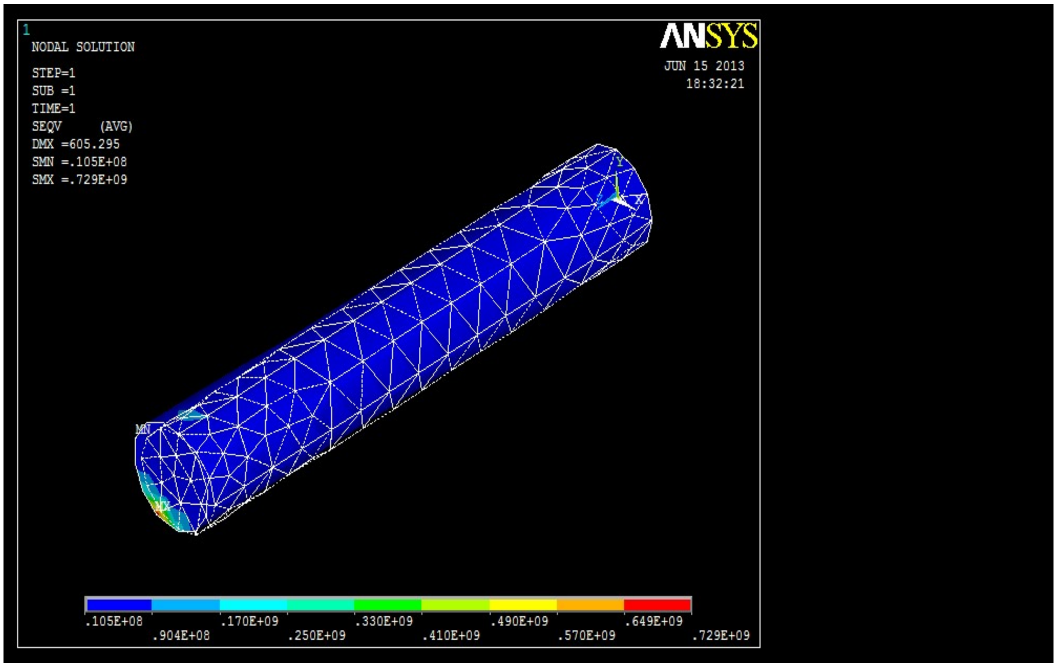


Figure -3: Nodal Solution for stress analysis of a motor Shaft

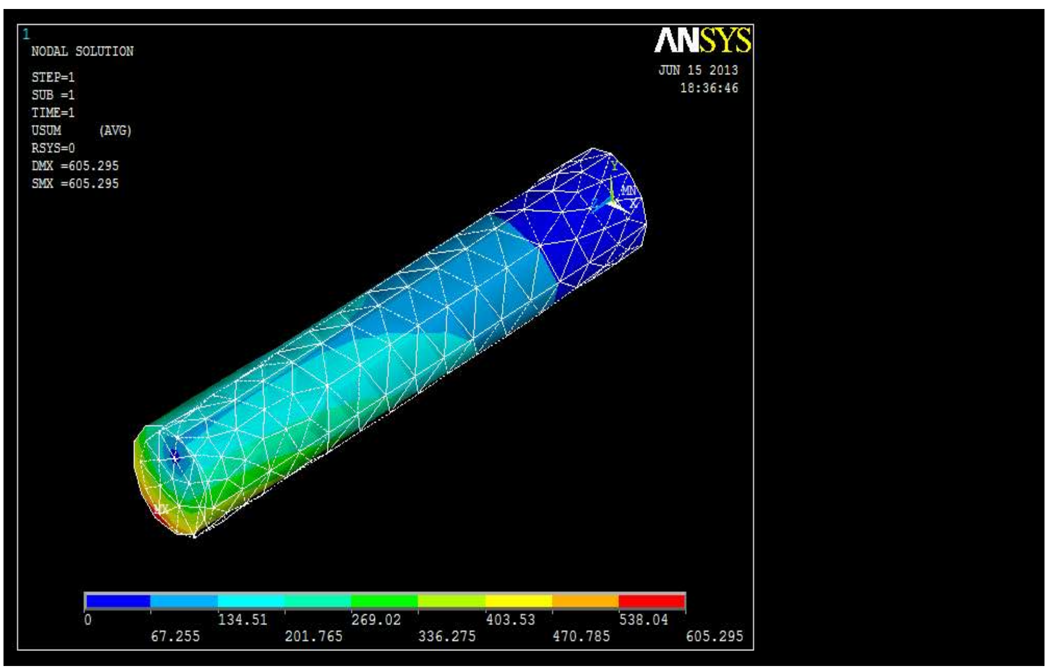


Figure -4: Nodal Solution for Displacement Analysis of a motor Shaft

PRNSOL Command

File

PRINT S NODAL SOLUTION PER NODE

***** POST1 NODAL STRESS LISTING *****
PowerGraphics Is Currently Enabled

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0
NODAL RESULTS ARE FOR MATERIAL 1

NODE	S1	S2	S3	SINT	SEQV
1	0.55116E+08	0.58021E+07	-0.35734E+08	0.90850E+08	0.78775E+08
2	0.46245E+08	-0.27993E+06	-0.46526E+08	0.92771E+08	0.80342E+08
4	0.53465E+08	0.48825E+07	-0.37608E+08	0.91073E+08	0.78930E+08
6	0.50495E+08	0.21217E+07	-0.41317E+08	0.91812E+08	0.79553E+08
8	0.35748E+08	-0.49749E+07	-0.54891E+08	0.90639E+08	0.78632E+08
10	0.41346E+08	-0.20357E+07	-0.50262E+08	0.91608E+08	0.79375E+08
12	0.37550E+08	-0.50746E+07	-0.54344E+08	0.91893E+08	0.79652E+08
14	0.43559E+08	21750.	-0.43570E+08	0.87128E+08	0.75455E+08
16	0.35908E+08	-0.49033E+07	-0.52277E+08	0.88185E+08	0.76441E+08
18	0.39176E+08	-0.22733E+07	-0.47880E+08	0.87056E+08	0.75421E+08
21	0.48090E+08	0.22571E+07	-0.39243E+08	0.87333E+08	0.75664E+08
23	0.52376E+08	0.47746E+07	-0.35769E+08	0.88145E+08	0.76417E+08
55	0.32815E+08	0.28848E+07	-0.23219E+08	0.56033E+08	0.48564E+08
56	0.18265E+08	0.19442E+06	-0.17699E+08	0.35964E+08	0.31146E+08
57	0.20134E+08	-0.21893E+07	-0.27484E+08	0.47618E+08	0.41265E+08
58	0.21439E+08	-0.24581E+07	-0.29634E+08	0.51072E+08	0.44260E+08
59	0.23955E+08	-0.21785E+06	-0.24664E+08	0.48619E+08	0.42105E+08
60	0.19662E+08	0.13955E+07	-0.15021E+08	0.34683E+08	0.30051E+08
61	0.55682E+07	-0.59918E+06	-0.75654E+07	0.13134E+08	0.11381E+08
62	0.10357E+08	0.12102E+07	-0.40949E+07	0.14452E+08	0.12684E+08
63	0.24565E+08	-0.14255E+08	-0.38748E+08	0.63313E+08	0.55328E+08
65	0.19007E+07	-27573.	-0.10617E+08	0.12517E+08	0.11708E+08
67	-0.72543E+06	-0.16698E+07	-0.30371E+08	0.29646E+08	0.29186E+08
69	0.86704E+07	0.27707E+07	-0.48567E+07	0.13527E+08	0.11763E+08
71	0.31485E+08	-0.12469E+08	-0.40883E+08	0.72368E+08	0.63152E+08
73	0.21763E+08	0.18828E+07	-0.12891E+07	0.23052E+08	0.21641E+08
75	0.38989E+09	0.78807E+07	-0.38416E+09	0.77405E+09	0.67053E+09
77	0.46123E+07	0.19645E+06	-0.36187E+08	0.40799E+08	0.38781E+08
79	0.26370E+08	-0.23539E+07	-0.23101E+09	0.25738E+09	0.24432E+09
82	0.22990E+09	-0.15627E+07	-0.11291E+08	0.24119E+09	0.23654E+09
84	0.40269E+08	-0.16017E+07	-0.26727E+07	0.42942E+08	0.42418E+08

Figure -5: List of result For Stress Analysis of a motor shaft

The Process of Stress Analysis

Analysis of stress within a structure encompasses determining the capability across all the points of the structure on application of load. The stress and fatigue rate is determined on a scale of 9-stress components to give a comprehensive view of the structure's performance and response in the face of the load. It helps in determining the purpose of interior allocation of stress within a structure.

The process of stress analysis includes the following stages:

- Building a part or structure to serve the function but at the same time, with reduced material usage and minimal cost
- Determining and setting the nature of the loads that can act on a structure, which includes density, tension, torsion, winding, trim, or amalgamation of these loads.
- When force is continuously applied to the structure, it tends to fail or get ruptured over time; more so due to lack of stable load condition. Stress analysis determines the level of stress under such cyclic load conditions

- To make sure that a particular part can efficiently work without breaking under force, it is tested based on the level of stress that it can take

Benefits of Stress Analysis Services

The key benefits of stress analysis services to engineering and manufacturing industries are underlined below:

- Facilitates accurate and reliable calculation of strain, distribution of load, and deflection
- Vast domain expertise in structure and thermal stress
- Leverage the power of efficient FEA solutions for product designing and development
- Minimum errors and loopholes, which ensures no product failure
- Cost-effective solutions

Brief-7

<u>Cost Analysis</u>

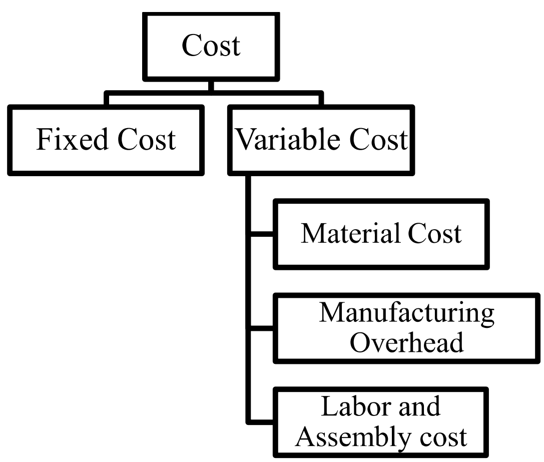
Cost analysis is a detailed outline of the potential risks and gains of a projected venture. The accumulation, examination, and manipulation of cost data for comparisons and projection are called cost analysis.

Cost estimate is the approximation of the cost of a program, project, or operation. The cost estimate is the product of the cost estimating process. The cost estimate has a single total value and may have identifiable component values.

Project underestimation of resources and costs is one of the most common contributors to project failure. Project teams should estimate costs for all resources that will be charged to the project. This includes but is not limited to

- Labor
- Materials
- Equipment
- Services
- Facilities
- Software etc.

Cost Analysis hierarchy for mass production



Fixed Cost

Fixed costs are costs that are independent of output. These remain constant throughout the relevant range and are usually considered sunk for the relevant range (not relevant to output decisions). Fixed costs often include rent, buildings, machinery, etc.

Variable Cost

Variable costs are costs that vary with output. Generally variable costs increase at a constant rate relative to labor and capital. Variable costs may include wages, utilities, materials used in production, etc.

Break Even Analysis

The main objective of break-even analysis is to find the cut-off production volume from where a firm will make profit. Let

s = selling price per unit
v = variable cost per unit
FC = fixed cost per period
Q= volume of production
The total sales revenue (S) of the firm is given by the following formula:
$S = s \times Q$
Total Cost= Total variable cost + Fixed cost = $v \times Q + FC$

The linear plots of the above two equations are shown in Fig. 1.

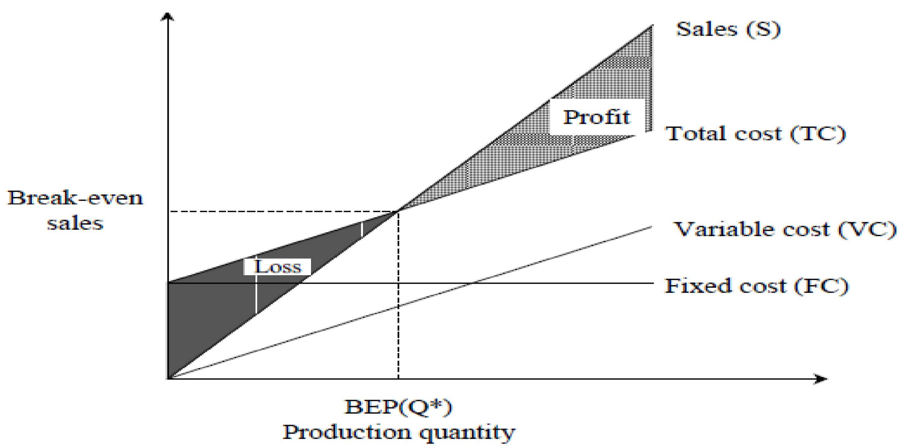


Fig. 1: Break-even chart.

The intersection point of the total sales revenue line and the total cost line is called the break-even point. The corresponding volume of production on the X-axis is known as the break-even sales quantity. At the intersection point, the total cost is equal to the total revenue. This point is also called the no-loss or no-gain situation. For any production quantity which is less than the break-even quantity, the total cost is more than the total revenue. Hence, the firm will be making loss.