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# BASIC ENGINEERING CONSIDERATIONS FOR ENGINEERES AND ENTREPRENURES

**Author:**

**ARUN CHANDRA SAWHNEY**

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## INTRODUCTION

Based on my 50 years of experience in the field of Technical Consultancy for steel and power sectors it has been found that our engineering education system lacks imparting an holistic approach and entrepreneurship skills which does not prepare them fit for setting up a new venture or solve day to day problems in an holistic manner. It has been found that there is acute shortage of engineers lacking in entrepreneurship skills. Almost all fresh as well as experienced engineers from core branches require extensive training for 2-3 years to take up assignment in the field of technology (know how), process engineering, design & engineering, operation, maintenance, manufacturing, production, procurement, logistics, technical marketing, construction, erection testing and commissioning, Techno Economics , Finance and costing.

Drastic Changes in technical education is needed to bridge the gap that existing between the needs of the industry and the academic curricula. Our formal engineering education system shall inculcate a holistic engineering thinking in the minds of young engineers so that they are trained in such a manner to tackle any kind of engineering challenges in future with ease. This holistic approach means that once any engineer applies the basic engineering considerations given in this paper to any project/venture/ system then he is sure that he has not left any major technical glitch.

The following basic engineering considerations have been given in brief here and are taken from my forthcoming book on the same subject. Full description of each consideration is beyond scope of this article due to its

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length. The purpose of this article is to highlight such basic engineering considerations to be included in the engineering curriculum for all engineering and technical disciplines. Even non-technical persons can learn these principles and apply them in their day to day working in industrial and service sectors or even buying any equipment. Most of the examples cited in this article are from Steel Industry as per actual experience of the author in the field, but the principles of engineering considerations can be applied for any industry/service as well as day to day engineering challenges.

**Following are the basic engineering considerations which every engineer must learn and apply during course of practicing his profession.**

1. MARKET SURVEY
2. SITE LOCATION & LAYOUT
3. TECHNOLOGICAL CONSIDERATIONS
4. DESIGN CONSIDERATIONS
5. OPERATION CONSIDERATIONS
6. MAINTENANCE CONSIDERATIONS
7. STANDARDISATION/INTERCHANGABILITY
8. SAFETY REQUIREMENTS & CONSIDERATIONS
9. STATUTORY CONSIDERATIONS
10. ERECTION CONSIDERATIONS
11. IMPLEMENTATION / PROJECT MANAGEMENT
12. ERGONOMICS CONSIDERATIONS
13. TRANSPORTATION LOGISTICS
14. NORMAL, COMMISSIONING & INSURANCE SPARES CONIDERATIONS
15. CAPITAL COST ESTIMATIOM
16. OPERATING COST ESTIMATION
17. FINANCIAL INDICES CALCULATION

## 1. MARKETING CONSIDERATIONS

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Any engineer/ entrepreneur must have basic knowledge of following aspects of marketing considerations before setting up of a new industry or recommending the same for others.

- Challenges facing the given industry
- Key drivers for stimulating growth
- Demand – Supply analysis
- Identification of potential markets
- Analysis of Competitors' positioning
- Pricing trends
- Performance-gap analysis
- Formulation of growth strategy
- Export Potential
- Market Share & Inter Shifting of demands

An engineer/entrepreneur must be able to comprehend the challenges being faced in the present industry at macro & micro level. As an example, Indian Steel Industry faced number of challenges in the past and present- some of which are highlighted below:

- Scarce natural resources (Iron Ore & Coal crisis)
- Over capacity
- Price Volatility
- Dumping of inferior quality steel from China
- Demand volatility
- Currency Devaluation
- Increase raw mats and energy costs
- Low Productivity
- Higher Production Cost
- Higher Cost of capital
- Lack of infrastructure (Rail, Road, Port Water, Power)
- Delay in environmental clearances
- Technology Obsolescence
- Structural problems
- Delay in carrying economic reforms
- Poor Monsoon

An engineer must be able to recognize the key drivers of the industry to estimate demand forecasting. For example, following are considered the key drivers in fueling the growth of Steel Sector:

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- Infrastructure development (capacity building in Power Rail Road, Bridges, Ports, Airports)
- Speeding up and modernization of railway, ports, airports, road transport
- Economic Growth
- Massive Water Supply & Sanitation Programs
- Make in India Program.
- Atam Nirbhar Bharat
- Housing and urban development (Smart cities & Amrut Cities)
- High degree of urbanizations
- High demand in the auto sector
- Capacity building in steel making
- Speedy reforms (GST & Land Acquisition)
- Supportive environment for investors
- Full FDI in all non-sensitive sectors.
- Socio-economic indicators coupled with announced directional plans of the Government
- World economic situation
- Export Potential

Similar challenges and key drivers can be studied in details before venturing out for any new industry/project.

## Demand Supply Analysis

There are some basic principles of Demand supply forecasting. With the increase in population, increase in urbanization and service industry, the basic needs of the masses like Food, Clothing, Housing, Telecommunication Information highway, Transport, Education, Health & Hospitality Sectors, Insurance, Entertainments, Tourism & Event Management, Digital Marketing & Payment, Pharmacy, House Hold appliances, the demand for products related to above ( For example Food grains, Pulses, Vegetable Oils, Fruits & Vegetables, Houses, House hold appliances like Smart TVs, Air Conditioners, Refrigerators, Ovens, Lighting Equipment, Water Supply & Sanitation wares, Furnitures, Smart Mobile Phones, Tablets, Smart Televisions , Two & Four wheelers, Petroleum Products, Chemicals & Fertilizers, Hospitals, Schools, Banking , Entertainment games, movies, ) are bound to increase and it shall be the duty of the Central Government Agencies to estimate the short term, medium term and long term demands in

each sector. Based on the demand estimated by these agencies and available capacity, the short fall shall be estimated for each sector. These short falls shall be translated into skills demand and a holistic planning model shall be prepared for every field right from Agriculture to space industry. Accordingly, whole education system shall be planned to fill the gap by skills development and engaging students in production activities after finishing their education. (Refer my separate article on same[1]). Technical Colleges shall become the hub for turning engineers into entrepreneur and supply of skills manpower to the industry and service industries.

Conventional demand forecasting methods like Time Series Analysis, Trend Projection, A Barometric Forecasting, Casual Forecasting, Expert Demand forecasting are useful but becoming less relevant due to growth of e commerce, on line marketing, B2B Marketing, B to C marketing.

The other factors to be considered are Pricing, Growth, Marketing / Distribution Channels, Trade Practices and Export Potential.

## 2. SITE LOCATION & LAYOUT CONSIDERATIONS

Every engineer shall be given an exposure for selection of site for any new venture whether small, medium or large industry. If due attention is not paid for this, it may have serious techno economic, commercial, social and environmental considerations after the investment is made and the factory/shop/industry is set up.

### Site Selection & Layout Considerations

### Site Selection

Following aspects shall be studied and looked into before any site is chosen.

1. Location proximity to Raw Materials & Market. Optimization? Minimization of Total “t-km” route length and cost. (Operation Research Tools, Linear programming, Simplex method, Charts, Statistical methods)

2. Proximity to Rail connection, railway station for receipt and dispatch of the raw materials/semi-finished and finished products. Also, it is necessary for export and import of goods for transportation to and from nearest Sea Ports.
3. Road Connection: Proximity to all weather road, State and National Highways for easy access to nearest market/warehouse/ distribution center as well as transportation and receipt of raw materials and finished products. The overall objective is to minimize transportation cost (Both inward & outward Combined)
4. Proximity to Sea Port. This plays a crucial role in economics of site selection where large amount of raw materials (Like Coking Coal, Thermal Coal, Various types of Ores for ferrous and nonferrous industries, Pellets, Steel Products, Pig Iron, Non Ferrous Products, Chemicals, Bulk Products like Sugar, Fertilizers, Salts, Refractories Bricks and mortar, Ceramics, Timber & Timber products, Crude Oil, Petroleum Products etc.
5. Proximity to Airport -This is to be considered for those units needing receipt and dispatch of goods by air.
6. Water. Proximity to all weather availability of water required for the operation of the industry to be set up. The quality of water also plays a pivotal role. The idea is to locate the industry at a place where required quantity and quality of water is available at the cheapest cost and also it shall ensure meeting future requirements for expansion. This may call for tie up with local/State Government for supply of water continuously for a long period with fixed tariffs. Further the cost of for bringing the water to the plant from the nearest water source by installation of pump house and pipelines to be considered.
7. Power Requirement is another area which plays a very crucial role in setting up any industry. Uninterrupted Power shall be available throughout the year. The site shall be selected near to the source of required HT or LT Power in required MW/kW and in desired voltage. The cost of drawing/tapping power from the nearest tower/sub Station shall be minimal. This may call for tie up with local/State Electricity Board for supply of industrial power continuously for a long period with fixed tariffs.

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8. Skilled Manpower: Checking of easier availability of skilled manpower in and around the site is essential for ease of operation of the industry as well as minimizing the cost of hiring as lot of unnecessary expenditure may have to be incurred on training, housing, transport, leave and high turnover in case of outside manpower.
9. Metrological data (earth quake, Wind, rain, Temp. humidity, corrosive atmosphere). It is essential to study metrological data thoroughly before locating a plant. The site shall be checked for severity of earth quack (Earth Quake Zone Classification as per IS). Severity of wind, magnitude of rain fall, humidity, high or low temperature conditions effect the location of plant/industry and a wrong location may result in either higher investment, damage to the plant due to earth quake, hurricane, damage to the product due to high humidity, damage to the plant equipment due to corrosive atmosphere prevailing near sea.
10. Soil Condition- This is another vital area to be looked before locating a plant. It is necessary to check the soil data by undertaking soil investigations of the site to understand the strata of soil viz. Black cotton, Hard strata, murum, rock etc. as the Civil engineering cost will depend on it. Deep Excavation, driving piles, pile foundation, higher depth of foundation may result in increased cost compared to another nearby site where soil conditions are better.

## Layout Considerations

After the selection of site is finalized, finalization of the layout of plant is an important area which an engineer/entrepreneur shall have to pay attention. Layout shall be planned on basic fundamental considerations which every engineer shall be aware of. If proper or optimum layout is not made, it may result in higher capital cost, higher handling and operating cost.

Considering the actual availability of land following factors shall be considered for the preparation of layout of the plant.

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1. The layout must ensure Rational flow of materials. For this many one of the types of layouts can be considered depending upon shape area and topography of the site. The types of layout can be chosen from following.

   Horse Shoe U Type- Best suited for raw mats coming in from one side and finished products from other side of the same road.

   Straight Type-Suited for linear land where raw martials enter from one end and finished products get out from other end in straight line)

   L shaped Type- Materials come and go in L shaped manner due to two perpendicular road configuration and shape of land.

   Parallel/Parallel Type- This is adopted mostly in square size of plot.

   Parallel Perpendicular Type -Best suited for multi operations and rectangular plot size and site topography.

   Oblique angle, Saw Tooth type layouts- These are adopted for irregular plot sizes.
2. Provision for future expansion must be kept in finalization of layout.
3. Shortest possible communication network.
4. Predominant wind direction. It is important to know the Windward and Leeward direction of the wind mostly prevailing at site during the year. This is an important aspect as the units emitting chimney gases/smokes shall be located towards windward side so that the harmful gases do not travel towards residential area, township, administrative offices during predominant wind directions during the year.
5. Existing road around the plot & exit & entry gates. Planning of exit and entry gates are an important consideration which is often overlooked. It is essential that separate gates must be planned for

entry of Raw Materials and exit of finished products for smooth flow of transport vehicles. Separate weigh bridges can be planned accordingly. It is also necessary to plan separate entry and exit gates for movement of workers and staff in case large manpower is deployed to ensure uninterrupted flow and security.

6. Existing Terrain and slope shall be carefully considered and every endeavor shall be made to avoid large scale cutting and filling of soil. It is not necessary to have a common Ground/Finished Floor Lever for all the units of the plant. Different Ground Floor levels can be planned for different units to minimize cutting and filling.
7. Roads & drainage system inside the plant. Nearest nullah for disposal of drainage.
8. Soil conditions- Heavy foundation can be planned in the area having hard soil and light foundation can be planned in loose soil area of the site to minimize cost and time.
9. Direction of possible railway link, railway yard shall be considered for receipt and dispatch of goods.
10. Landscaping & Green Belt-This is another area needing great attention. The layout shall be planned in such a way that at least one third of the area of the plant shall be left free for plantation and green belt as per statutory requirements.
11. Water Reservoir, Rain Harvesting. It is essential now-a-days to plan rain harvesting and storage of water in the plant for conservation of water.
12. Switch Yard- It shall be planned near to the external HT tower so that no HT lines pass over the plant area.
13. Vaastu Requirements – These days some entrepreneur prefer layout to be made as per Vaastu. Hence it would be advisable for

engineers to understand Vaastu requirements so far, they are applicable for layout planning.

14. Space for Construction, Fabrication, Steel storage & Pre assembly yard
15. BIS:8091 Code of Safe Practice for Industrial Plant Layout shall be referred while planning the layout
16. Segregation –Explosives/hazardous to be isolated. It is essential to plan separate area for storage of explosive and hazardous solids/liquid/gases away from main units, office, buildings as safety measure.
17. Minimum Over head & Ground Clearances: This is often missed while planning the layout. Statutory requirements stipulate minimum overhead clearances for any overhead structures like conveyor and cable galleries, pipe lines, flyover etc. for passing of Road, Railway Lines inside the plant. These shall be strictly followed.
18. Seismic design of buildings shall be considered if the plant is located in such zones.
19. Environmental factors. Environment clearance shall be obtained from local/State/Central Govt as per the requirements and type of industry. Other factors to be considered are Socio-Political, Labour unrest, extortion etc.
20. Miscellaneous Facilities such as fire station, fire water pump house, fire water tanks, fire fighting network, security office, medical post, parking facilities, welfare facilities like Canteens, rest rooms, recreation rooms, crèche shall be planned

## 3. Technological Considerations

Selection of technology plays crucial role for setting up of any venture/plant/industry as there may be many available technologies,

processes, methods to produce the desired end products. It is imperative for an engineer to study and work out a most cost effective, technical and viable solution which results in lowest procurement cost, optimum capital and operating cost as well as to achieve the required quality and quantity of end products with the locally available raw materials and skilled manpower.

For example, sponge iron can be produced by Coal Based or Gas Based DRI Plants.

Iron ore pellets can be produced by either Straight Grate technology (Lurgi) or Grate Kiln Technology (Mainly Chinese). Further it may adopt dry or wet grinding of iron ore fines.

Coking coal can be produced either by Recovery Type Coke Ovens or Non-Recovery Type Coke Ovens. Again, there may be variety of Non-Recovery Coke Ovens using various types of bricks (Silica, High Alumina), stamping and blending of coals, vertical or horizontal charging, 4 or 6 linked flue channels etc. Further there can be dry or wet quenching of coke.

Sinter can be produced by straight line or circular grate, annular or circular cooler, use of BF Gas, producer Gas, Pulverized coal, LD/HD/furnace oil.

Steel can be produced by adopting Blast Furnace-BOF Route or DRI - EAF (Solid Charge) route or DRI BF EAF (With hot charging of metal with DRI) or using Corex route.

Steel can be produced in EAF, BOF, EOF or Induction Furnace.

Refining Technologies can be LRF, VD, VAD, Desulphurization, De-Phosphurization

Rolling Mills can be Hot & Cold. Flat and Non-Flat types.

Coating of Sheets can be Galvanized, Color Coating or some other coating.

Buildings, Junction Houses, Conveyor Galleries, Bunkers may be constructed out of 100 % structural Steel, 100 % RCC or mix of RCC and Steel.

Various types of technologies are available in the market from China, Russia, Europe, Japan, US, South Korea for the same type of end product.

Charge of Blast Furnace may consist of Iron Ore, Sinter, Pellet, CDI, Oxygen Enrichment in various proportions.

There may be different methods adopted for beneficiation of ores.

***Though their may be many technologies, manufacturing process and methods for production of the same end product, but on close scrutiny and by applying basic technical knowledge it can be discovered that not all alternative technologies/methods are suitable for the intended product. Some technologies are not suited for the given capacity planned, some not suitable for the quality of raw materials being used, some not suited for the type of fuel locally available, some not suited due to land size and shape, some not suiting for the higher specific consumption of raw materials, energy, water, fuel, power etc. Some technologies are suitable for a particular raw material or standalone plant***

For example, Blast Furnace-BOF route of steel making is generally chosen for annual capacities range of 1.5 Million Tonnes and above. DRI -BF- EAF is chosen for mid-range capacities from 0.5 MT to 1.5 MT. Whereas DRI-EAF or DRI-IF route is chosen for capacities below 0.5 MT.

Similarly, Recovery Type Coke oven plant is chosen for an integrated steel plant where the bye product coke oven gas can be utilized for reheating of furnace. Non-Recovery Coke Ovens are chosen for stand alone plant for production of coking coal for sale or for smaller plant

not needing bye product plant or for minimizing pollution abetment cost. The bye product in this plant is waste heat power which can either be utilized in house or can be sold.

Straight Grate Technology for pellet plant is most suited for Indian conditions as the predominant quality of iron ore is of Hematite whereas Grate Kiln Technology is more suited for Magnetite iron ore mostly found in China.

Similarly, wet grinding of iron ore is suited where input raw materials is in slurry form or where water is easily available. Else dry grinding is adopted though power consumption per t of grinding may be higher.

In some cases, not all the units are installed initially. In some cases, units are installed for production of semi-finished products (For example Pig Iron) and later steel making and rolling mills can be added (Forward integration). In other cases, backward integration can be adopted by installing Rolling Mills first and then install hot metal and steel making facilities later. Technology selection is chosen accordingly. Technology selection for standalone plant and integrated plant will be different. For example, for production of Ductile Iron Pipe in stand Alone Plant, Ductile iron is made from 100 % of the solid charge consisting of recycled iron scrap, iron castings and Pig Iron. The solid charge is melted in conventional Cupola using low ash coke (LAM coke) to make the hot metal. The liquid hot metal is then transferred to induction furnaces of duplexing.

In an integrated plant DI Pipe plant is part of Iron Making Complex consisting of Coke Oven (Non Recovery or Recovery), Sinter Plant, Mini Blast Furnace along with all the auxiliary & associated facilities the hot metal produced from Blast Furnace is transferred to DI plant and after

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desulphurization/dephosphurization, and kept in dual track holding furnace for further processing.

## SELECTION OF PROCESS ROUTE

The selection of process route depends on the following factors:

**Technology selection shall be made considering following main parameters**

- Grade and quality of finished product desired. For example, there are two grades of pellets, namely BF grade and DR Grade. As per IS: 11092-2001 (2nd revision), DR grade pellets require superior pellet specifications with plus 66.5% Fe- content to ensure adequate solid-state metallization with minimum gangue. Hence, beneficiation of iron ore fines is mandatory to bring down the total Al2O3, SiO2 content. BF grade pellets have less stringent a specification as compared to that for DR grade pellets
- Higher Productivity
- Process Control & Equipment Design
- Desired Mechanical, Chemical, Metallurgical properties
- Flexible to suit change of fluctuations in input raw materials quality
- Selection of single machine/unit carrying multiple operations. For example, Drying, preheating, induration & cooling process are done in single unit in case of Travelling Grate Technology and are done separately in three units (Pre heater, Kiln and Cooler) in grate kiln technology for production of iron pellets.
- Economics of scale of Production
- Better yield of product
- Less Downtime resulting in higher annual working hours
- Capital Cost
- Production Cost

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- Minimum Specific consumption of Raw Materials, Water, Energy, Fuel, Power, auxiliary facilities,
- Minimum Generation of waste materials. If generated it shall be able to recycle.
- Minimum Air Water and Noise Pollution and its Control.
- Zero discharge Technology.
- Well established Commercially Proven Technology.
- Minimum Space requirement
- Gestation Period

**Selection of Know how supplier**

Following steps are generally followed for selection of know how supplier

- Selection of product mix, capacity and quality of product
- Preparation of brief technical specifications of various packages for global tender enquiry for optimum performance and selection of cost-effective supplier
- Evaluation of technical bids of various foreign/Indian suppliers
- Selection of Competent & cost-effective Know-how suppliers
- To check completeness of drawings & documents supplied by Know-how suppliers
- To take care of Indian statutory norms/standards/steel sections/soil & wind conditions while finalizing the contract with foreign know how suppliers
- Draft finalization of contracts with selected Know-how supplier.

## 4. Design Considerations

Design Considerations is the soul of engineering thinking and consideration. Any lapse on the part of Engineer or entrepreneur will result in tangible and intangible losses which cannot be made up after

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the plant is set up and commissioned. Major design considerations are briefly given below taking Steel industry as an example but they are equally applicable for any other industry

1. Must fulfill the objectives –Desired Production, Quantity/Quality
2. Raw Materials Balance
3. Water Balance
4. Energy Balance
5. Sizing of Plant Capacities. Balancing the capacities at each stage (for example Beneficiation Plant works for 300 d/y and pellet Plant works 330 d/y)
6. Modular Design e.g. 0.2 MTPA, 0.4 MTPA, spacing of columns, building sizes
7. No of machines -2 EAF v/s 1 EAF, 2 BF of smaller capacity v/s 1 of bigger capacity, DRI Plants, Combo Mills instead of 3 different mills etc.
8. Productivity of machines (e.g. 1.2t/m2.hrto 1.5 t/m2.hr Sinter), 24 MW v/s 30 MW for 0.2 MTPA (4 Link v/s 6 link design of NRCO, 2.4 to 3.2t/m3/day productivity of BF, 18 to 21t/m2. d
9. Inbuilt capacity for future expansion (Time, cost, shutdown) e.g. Conveyor capacity of Coal & Coke handling in Coke Oven Plants, Sinter Plants, Power plants, Pellet Plants, Raw Mats Handling System, Pumps. Piping, Pusher Car/Quenching Car/Stamping Machines, Cooling Beds, EOT Cranes, Building Design.
10. Rated Capacity & Design Capacity (20 % More than rated capacity) For aging, contingencies, increase in productivity (e.g. Sinter Plant, Blast Furnace, Pellet Plant etc.)
11. Safety Factors/Dynamic Loading Factors/Slope Factors/Filling Factors/Free Board/Utilization factor to be taken into account while selecting any machine, vessel or storage system.
12. Availability of machines per year. E.g. 330 days per year for Straight Grate and 300 days per year for Grate kiln technology. 20 h/d versus 24/d (Beneficiation Plant)
13. Life span of Plant/machines. e.g. Non-Recovery Coke Ovens with silica bricks-based design life is 20 years, Beehive Oven design life is 3-4 yrs based on Fire clay and 68 years with Alumina Bricks.

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14. Materials Characteristics-Physical, Chemical, Metallurgical, Abrasive, Corrosive, Fragile, Hydroscopic, Foul smelling, Gas, Liquid, Lumpy, Powder, Free Flow, Sluggish etc.
15. Specific Consumptions of utilities, power, water, fuel, refractories, spares, grinding media per t. (e.g. Grate Kilns have heat consumption of 3.5 Lacs K cal /t v/s 1.8 Lacs K cal /t for Straight Grate), Energy Efficient Ignition furnace for Sinter Plant heat consumption is 15000 Kcal/t of sinter v/s 30000-45000 Kcal/t of Sinter for other Furnace, For thermal power plants water consumption is 4 m3/MW for Water Cooled condenser v/s 1.2 m3/MW for air cooled condenser. Similarly, in Ball Mill or Rod Mill, use of gravity for flow of water can avoid pumping of water in some cases etc.
16. Checking for Strength, Stability & Deflection
17. Degree of automation required.
18. Requirements of Inserts.
19. Check for weight of Individual equipment & plant and compare it with similar plants/equipment.
20. Check for installed power and compare it with similar plants/equipment
21. Requirements of man power for operation and maintenance. Check with similar plants and equipment
22. Requirements of all utilities, auxiliary facilities, power, water, air, gases, hoisting & handling, mounted electrics, instruments. Check with similar plants and equipment
23. Check for painting requirements considering duty, environment, place, temperature etc.
24. Provision of Ramps, Lifts, Platforms, stairs, doors, corridors, restrooms of desired slopes, widths & dimensions considering normal persons, disability and old age
25. Nature of the Project: The proposed project falls under Category-A, under section 3 (A) as per the prevailing EIA Notification, dated 14th September 2006.
26. Use of Thumb rules –Check weight of equipment (EOT Crane, Conveyors, Wagons, Transfer Cars, Raw Mats handling System, Building Structures, Conveyor Galleries, Junction House-Dead Weight to live load ratios), Check Horse Power, Pump Capacity

by using thumb rules to immediately check the adequacy of machines offered by suppliers.

A successful holistic design is a solution that is greater than sum of its parts and takes following into account:

- Equitable Use
- Flexibility of Use
- Simple and Institutive
- Size and Shape for easier and comfortable operation
- Low Physical Effort
- Perceptible Information
- Tolerance for Error

## 5. Operation Considerations

After evaluating the plant from design perspective, the next important parameter is to pay attention to operation considerations. Any plant or equipment shall be selected for ease and simplicity of operation, with minimum man power, pollution and maximum safety. Following operating considerations shall be considered while selecting a plant and equipment or manufacturing of the same.

1. Ease of operation – For example Operation of Non-Recovery Coke Oven is quite simple in nature compared to operation of Recovery Type Coke Oven which is quite complex and need highly skilled man power. Similarly, operation of a DRI Plant is much easier than operation of a Blast Furnace.
2. Flexibility in operation. (Increase decrease capacity, flow rate, t/h rate, product mix, temperature, pressure, gradient, altitude, humidity, wind)
3. Degree of automation desired. (Manual, Semi-Automatic or Fully Automatic)
4. Degree of protection desired (Ambient Temperature, humid, corrosive or hazardous atmosphere, higher altitude, under pressure etc.)

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5. Should be able to operate smoothly in all prevailing weather conditions considering Temperature variations, Rain, Wind, Extreme hot, extreme cold etc. (Specially for Cooling Towers, AC plants, Ventilation, Motors etc.)
6. Take care of type of duty-Light, Medium, Heavy or Extra Heavy duty conditions (Motors, Gear Boxes , Cranes, Hoists etc.) Starting Cycles-No of starts per hour.
7. Quick changeover of stream from one to another (e.g. Changing the rolling mills stream in finishing stage
8. Quick changeover of parts (e.g. Rolls, Screen, Screen Deck, PCB Cards, Teeth of Crushers, bearings
9. Comfortable environment (e.g. Loco Drivers, Crane Drivers, Pulpit operators, Toll Plaza Collectors)
10. Lower pollution –Air, Water & Noise ( Lesser fatigue in operation to legs, eyes, hands, ears, nose.
11. Easy access to control switches, pedals (Ambassador v/s Maruti, Ford) Nagpur air port Charging Point location.
12. Operators manuals
13. Operators Room

## 6. Maintenance Considerations

This is another area needing attention while selecting any plant or equipment. The plant or equipment shall be selected which need minimum maintenance, less downtime from maintenance perspective. Following are the maintenance considerations needing attention of engineer/entrepreneur while procuring any plant or equipment or manufacturing the same.

1. Should require lesser maintenance
2. Minimum Down time
3. Fit & forget concept
4. Easily approachable-all parts needing maintenance
5. All casings, shells and frames shall be split on machine horizontal centerline. Upper halves may be lifted individually for access to internal parts.

6. All seals and shaft packings shall be separate from the main bearing housings and casing structures and may be readily removed and replaced
7. Proper hoisting and handling facility (EOT Crane, Manual or Electric Hoist) with adequate headroom, within the reach of part. Weight of heaviest part/equipment to be lifted
8. Easy lowering & lifting into Truck/Trailer
9. Corrosion & Abrasion
10. Inspection covers to be provided
11. Man Holes to be provided
12. Lifting Lugs to be provided
13. Within road approach. Design of Junction Houses, Pump Houses, MCC, ECRs, Process Buildings, Aux Buildings.
14. Choice of lubrication system-Individual , Group, Manual Centralized/Whether emergency lubrication system needed.
15. Repair Bay
16. Repair station
17. Workshop
18. Maintenance Manuals
19. Stores
20. Quality Assurance Plans (QAPs), Inspection Reports, Manuals

## 7. STANDARDISATION/INTERCHANGABILITY

The plant and equipment to be procured, manufactured shall conform to national or international standards. It must comply with BIS Codes & Standards or some other reputed standards –Firstly it shall comply with Indian Standards. If the same is not available, the it may comply with any International standards acceptable to client or consultant. Following standards shall be followed as applicable to the plant and equipment.

1. BIS Codes & Standards
2. Codes and Standards applicable to particular industry. For example, IPSS (Inter Plant Steel Standards) Codes & Standards is available for many equipment/plant/systems for Steel Industries. The same shall be checked also and incorporated in the specification.

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3. To the extent possible every endeavor shall be made to limit the type of equipment by selecting similar types e.g. Motors, Gear Boxes, Couplings, Bearings, Idlers, Beltings, Pumps, Sections of Steels, Steel Plate Thickness and sizes, Reinforcement bars diameters, doors & windows sizes, type pipes and their diameter, flanges, gaskets etc. This will reduce the cost, inventory as well spares
4. IRC Codes & Standards (Indian Road Congress) For Roads & Bridges
5. SP7 National Building code Of India
6. RDSO Codes & Standards for Railways
7. ASME Codes-Piping, Pressure Vessels
8. ANSI Codes & Standards
9. AISC Codes
10. ASTM Standards
11. IEEE Standards
12. AISE Standards
13. JIS Standards
14. API Codes & Standards
15. Euro Codes
16. Russian Codes (GOST Standards)
17. Chinese Codes
18. ISO Standards
19. IEC Standards
20. IS:1870 Comparison of Indian and Overseas Standards for wrought steels for general engineering purposes
21. Handbook of Comparative World Steel Standards
22. Fire Fighting Standards (TAC Rules) TARIFF ADVISORY COMMITTEE.

## 8 Safety Requirements

It is necessary that every engineer/entrepreneur must be well aware of the safety requirements for all the buildings, plant & equipment as specified by State & Central Government bodies/agencies and strictly complied for the Safe & accident free operation. Following standards, acts and codes must be taken into considerations for safety of Plant, Equipment, Storage Vessels and buildings:

**1.** National Building Codes.

2. Indian Standards
3. TAC Rules for fire safety
4. Fire Protection System
5. Factories Acts & Rules (Pertaining to safety)
6. All the tall buildings like Chimney, Towers must be specially checked for stability, deflection & strength.
7. All buildings /plant/equipment shall be provided with following (as applicable)
    I. Ramps
    II. Elevators
    III. Toe Guards & Rails/Handrails
    IV. Platforms
    V. Railings
    VI. Walkways
    VII. Stairs & landings
    VIII. Doors/Windows
    IX. Ventilation/Air Conditioning (As per norms)
    X. Corridors
    XI. Fire Protection, Fire Escape & exit (for tunnels two exits)
    XII. Earthing
    XIII. Lightening protection/Civil aviation lights (as per norms)
    XIV. Under voltage, over voltage/current. Frequency, Load protection

Apart from above every engineer shall have knowledge of safety requirements during construction of plant & buildings.

## 8. STATUTORY REQUIREMENTS

All plants, Buildings, equipment must comply with the law of the place where the plant is being erected/constructed/installed. Each State may have different provisions pertaining to same requirements. Following are the legal acts/rules applicable and must be known to all of the engineering fraternity as well to the entrepreneurs.

1. Indian Factories Act.
2. Indian Factories Rules of the State in which the plant is being built.
3. The Environment (Protection) Act, 1986
4. The Environment (Protection) Rules, 1986

5. The Air (Prevention and Control of Pollution) Act, 1981
6. The Water (Prevention and Control of Pollution) Act, 1974
7. The Water (Prevention and Control of Pollution) Cess Act, 1977
8. Indian Electricity Act, 1910.
9. Indian Electricity Rules
10. The Air (Prevention and Control of Pollution) Rules, 1982
11. The Noise Pollution (Regulation and Control) Rules, 2000
12. The Water (Prevention and Control of Pollution) Rules, 1975
13. The Air (Prevention and Control of Pollution) (Union Territories) Rules, 1983
14. The Hazardous Wastes (Management and Handling) Rules, 1989 & amended in 2003
15. Indian Boilers Act, 1923.
16. Indian Explosives Act, 1884.
17. Indian /State Explosives Rules, 1983.
18. Static and Mobile Pressure Vessels (Unfired) Rules, 1981.
19. Gas Cylinders Rules, 1981.
20. Explosive Substances Act, 1908.
21. Petroleum Act, 1934.
22. Petroleum Rules, 1937 & 1976.
23. Calcium Carbide Rules, 1987.
24. Inflammable Substance Act, 1952.
25. Radiation Protection Rules, 1971.
26. Indian Mines Act, 1952.
27. Mines & Mineral (Regulation and Development) Act, 1957.
28. Bombay Weights & Measures Act, 1958 & Rules 1958.
29. Bombay Lifts Act 1939 and rules, 1958.
30. Civil Aviation acts and rules.
31. Dock Workers (Safety, Health & Welfare) Act 1986, Rules & Regulations.
32. Port Act, 1908.
33. Forest Act, 1927 and Wildlife (Protection) Act, 1972.
34. Motor Vehicles Act, 1988 and Rules 1989 including Transport of Hazardous Goods Rules.
35. Hazardous Wastes Rules, 1989.
36. The Building and other Construction Workers (Regulation of Employment and Condition of) Service Act, 1996, and Rules.

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**Laws of Foreign Countries :**

1 Occupational Safety & Health Act (OSHA) 1970, USA.
2 United States Department of Transport's Hazardous Material Regulations.
3 Health & Safety at Work Act (HSWA), 1974, UK.
4 Notification of Installation Handling Hazardous Substances Regulations (NIHHS), 1982, UK.
5 The JK Blue Book (Governing the carriage of dangerous goods in ships).
6 The European Agreement concerning International carriage of Dangerous goods by Road (ADR).
7 International Maritime Dangerous Goods (IMDG) code published by Inter Governmental Maritime Consultative Organization (IMO).
8 Code of Safe Practice for Shipment of Bulk Cargoes (BC Code), 1965.
9 IMO/ILO guidelines for packing cargo in freight containers, or vehicles.
10 World Bank and IFC Guidelines for identifying, analyzing and controlling major hazard installations in developing countries 1985.
11 EEC Directive on Hazardous Installations.
12 UN (Numbers) List of dangerous chemicals.
13 Chinse standards on BF, Sinter Plants, Coke Ovens , Structural Buildings, Fire Safety

**NB:-** For more details visit CPCB / MoEF websites

**Some of the important laws/considerations for Industrial Buildings and installation of equipment therein are given below:**

1. Factories approval
2. CPCB Guidelines & Rules
3. CEA Guideline & Rules
4. Indian electricity rules
5. Indian Boiler Acts & Boiler Inspector approval for Steam & HP pipelines, pressure vessels and boilers
6. RDSO Codes & Standards
7. Center and State rules for EOT Cranes

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8. Center and State Rules for Elevators & Lifts
9. Fire safety
10. Min Road Widths, Overhead Clearances, Curvatures etc. as per IRC
11. Minimum side & overhead clearances for railways. RDSO
12. Doors & windows Sizes as per national building codes.
13. Min height of railings, max angle of stairs, landing height, step width, height, spacing etc.
14. MCC Rooms, Switch Yards, Overhead HT Lines –Minimum side, front, back & OH clearances
15. Rest rooms
16. Canteens
17. Creches
18. Air, Water & Noise pollutions
19. Walkways
20. Fire escape exits
21. Lightening protection for high rise buildings and chimneys
22. Aviation lights for high rise buildings and chimneys
23. Min Height of chimneys

Special requirements for the above shall be checked pertaining to Central and Concerned State rules.

## 9. Erection Considerations

It is seen that if proper erection sequence and methodology is not followed, it may result in time and cost overrun, duplication of jobs, dismantling & re-erection, accidents, loss of life and property. Therefore, this is also one of the main basic consideration which every engineer/entrepreneur must be aware of. The following erection considerations shall be taken into account

1. Erection Sequence
2. Erection Methodology
3. Special Requirements/OD consignment, Before building roof erection,
4. Minimizing Erection Time. In situ erection (THF Example)

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5. Temp Protection Requirements
6. Erection of Cranes-Tower Cranes, Jib Cranes, Hydra,
7. Batching Plants-Capacity & Number
8. Alignment, lining, levelling & grouting
9. Inserts Placements (Requirement to be checked at design stage)
10. Rate of RCC per day, per Month
11. Rate of fabrication per month at site t/month
12. Rate of Structural erection per month
13. Rate of Mechanical/equipment erection per month
14. Rate of Refractories erection per month
15. Rate of electrical erection cables, equipment, MCC.
16. Rate of Instrumentation
17. Rate of Piping erection
18. Water requirement Peak &Average
19. Temporary Power requirement Peak &Average
20. Manpower requirements
21. Interfacing with other units
22. Welding requirements
23. Space requirements-Fabrication, storage and temp assembly.
24. Safety considerations in erection/construction/Safety Manager

It is now-a-days mandatory to appoint a Safety Manager at site for safety compliance.

## 10. Implementation /Project Management Considerations

### GENERAL

It is necessary to have the basic knowledge of project management for the smooth implementation of the project. An engineer must be able to identify major activities involved in the implementing of the project and estimate average completion time for each of the activities. This will enable him to estimate desired rates of construction work and proposed time schedule for completion of project. However, if required expert help may be taken for detailed micro-planning, monitoring and, control during construction stage

### Volume of Work

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An engineer must be well conversant with estimation of volume of work involved for the proposed project. Basically, these estimation of Concrete Work (RCC& PCC) in m3, Fabrication and Erection of Steel work (Building and Technological Structures) in tonnes, Erection of Plant & Equipment in tonnes, Refractories Erection in t, Electrical Work

## STEPS FOR PROJECT IMPLEMENTATION

### Environmental Clearance

The environmental clearance (if required) is the first requirement for initiating the project as per notification dated 14th Sept 2006 of the Ministry of Environment and Forests (MOEF).

### Project Implementation

For the project to be commissioned within schedule, the following advance actions have to be initiated by Project Authority to meet the proposed schedule.

- Financial tie-up
- Finalization of modus-operandi for project
- EMP/EIA & approval from environmental ministry of State/Center (If required)
- Clearance from local statutory authorities
- Leveling, Cutting & Filling.
- Selection of Technology Supplier
- Appointment of Technical Consultants
- Appointments of contractors for civil, structural, mechanical electrical work
- Quality Control set up for construction work
- Planning for enabling works, like construction water lines, power lines and sewerage, labor camps, communication facilities
- Planning for construction materials like cement, aggregates, steel etc., wherever needed

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- Planning for construction manpower
- Planning and organizing structural steel availability, wherever needed.

Enabling facilities at site include construction of temporary offices, open and covered storage, fabrication yard, temporary firefighting system, construction water and construction power facility, developing temporary drainage facility etc.

The above activities consume very little capital expenditure but will help in the smooth progress of project activities as per the proposed schedule. These activities can be taken up 2-3 months prior to zero date.

After above zero activities the following activities are taken up in sequence or in parallel

- Basic Engineering
- Preparation and Issue of Tender Specification for procurement of plant & Equipment
- Scrutiny of tenders and placement of orders for Main & Auxiliary Plants. (Orders for Long lead items to be placed earliest)
- Preparation and issue of excavation plan, Civil Engineering Drawings for building.
- Site Preparation for starting civil & steel fabrication work
- Preparation and issue of Structural Design and fabrication Drawings.
- Civil Construction Work
- Receipt of load data for equipment Foundation
- Issue of civil foundation drawings for equipment
- Fabrication of Steel Structures

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- Erection of Steel Structures
- Issue of erection drawings for equipment
- Issue of electrical installation drawings
- Inspection & supply of equipment at site
- Erection of mechanical equipment
- Supply and Erection of electrical equipment, instrumentation and cable laying work
- Cold start for auxiliaries and main equipment
- Testing, trial run and commissioning

The work execution at site to great extent is dependent on the availability of site infrastructure like water, electric power etc. It is assumed that these facilities will be developed in time to meet the requirement of site works as per schedule.
The timely completion of the project also depends on the association of proven construction agencies in the similar field, who can mobilize requisite resources of men, materials and construction machinery as well as construction and erection expertise to execute the above project.
An engineer must have basic knowledge of Bar Charts, CPM/PERT Network (Master Network L1, L2, L3 types) for project monitoring and controlling time and cost overrun.

## 11. Ergonomics

Every engineer and entrepreneur must have a basic understanding of Ergonomics principles It is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system in order to optimize human well-being and overall system performance. Ergonomics is the science of making things simple, comfortable and efficient

If a plant or machine is simple to operate, it will be more acceptable.

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Comfort in the human-machine interface and the mental aspects of the product or service is a primary ergonomic design concern.

The utility of an item is the only true measure of the quality of its design. Making an item intuitive and comfortable to use will ensure its success in the marketplace. Physical comfort while using an item increases its utility.

Better ergonomics mean better quality. Efficiency is quite simply making something easier to do. Efficiency comes in many forms. Following are the prime ergonomic considerations:

1. Reducing the strength required to operate makes a process more physically efficient.
2. Reducing the number of steps in a task makes it quicker (i.e. efficient) to complete.
3. Reducing the number of parts makes repairs more efficient.
4. Reducing the amount of training needed, i.e. making it more intuitive, gives you a larger number of people who are qualified to perform the task.
5. If something is easier to do you are more likely to do it. If you do it more, then it is more useful. Again, utility is the only true measure of the quality of a design.

## 12. Transportation Logistics

An engineer should have knowledge of transportation logistics to understand the economics of transport of material within and outside plant. Whereas for longer distances Rail, Ship Inland Water Ways and Pipe Line transport are cheaper, for shorter distances Road, Conveyor, Aerial Ropeway, Pneumatic Transport may be cheaper. The manta is that total tonne-km cost must be minimum.

Similarly, before ordering an engineer must have the knowledge of overall dimensions and size of equipment (OD Dimensions) so that the same can be freely transported to site by rail or road without any obstruction/hinderance on the way.

Similarly, due attention shall be paid to packaging considering the nature of material, and equipment with respect to damage due to

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breakage, humidity, self-ignition, loss due to evaporation, pilferage, hazardous nature of substance, parts identification etc.,
Following considerations shall be of concern to engineer while considering transportation of goods to and from site.

- Ship/Rail/Road/air/Conveyor Transport/Pipeline Transport/Aerial Ropeways/Pneumatic Transport/In land Water Transport
- OD Size of consignment
- Packaging
- Container or Loose
- Special requirements-Special Bogie, Trailer,

## 13. Normal, Commissioning & Insurance Spares

It is another area which need attention by engineer/entrepreneur.
Following aspects shall be considered during setting up of any plant or ordering any equipment

Spare part for two Years Normal Operation shall be considered. Operational spare parts are those required for normal operation and day-to-day maintenance in the two-year period, following the initial operation period. Typical examples include First Pinion Shafts, bearings, Pulleys, Limit Switches, Fixed & Moving Contacts, steam traps, valves, pumps, fuses, control buttons, brake linings, shoes, brake drums, indicating lamps etc.

Commissioning spare parts are to enable uninterrupted installation and start-up of the plant and equipment in the commissioning stage.

All spare parts and consumables required for Construction, Pre-Commissioning, and Commissioning shall be identified and ordered

Commissioning Spares include such things as would be required for testing, vibration testing and hot alignment and are normally supplied as a part of the main equipment. Parts included would be bearings and seals for major rotating equipment, spools, seals, gaskets, contacts, shims, o rings, relays, paper rolls, Power contacts, coils,

Insurance spare parts are those parts of equipment, equipment assemblies or complete items of equipment that are required for

replacement of items not subject to deterioration by normal use, but failure of which is critical for continued and safe operation of equipment or plant.

***Insurance Spares:***An insurance items is a spare part that will be used to replace a failed identical part in an operating equipment whose penalty cost for downtime is very high. Hence, by definition, it is an insurance against such failures for which the down time costs are very high. They do not become obsolete until the parent equipment is retired from service no matter if they do not move for many years

These are parts or assemblies that are quoted, evaluated and purchased along with the original equipment because of cost factors, engineering, fabrication, testing and fitting requirements, long delivery problems or are specified by Client. Usually one of a kind assembly such as rotor assemblies, reduction gear sets, special forgings, castings etc.

## 14. Financial Management

Engineer shall have knowledge to enable him to carry out Estimation of capital cost of Project, Working capital, margin money, Interest during construction, term loan interest, Cost of Raw materials, Energy, Utilities, power, water, fuel, consumables, manpower cost, repair and maintenance costs, production cost, Sales realization, profit & loss statements, payback period, internal rate of return, Debt Service Coverage Ratio, Break Even Point.

### Capital Cost

This is often overlooked area. Estimation of capital cost, cost of capital, interest rates, duration of payment are the factors to be considered by engineer/entrepreneurs.

It is essential to have the basic knowledge as under:

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Capital costs are fixed, one-time expenditure incurred on the purchase of land, buildings, construction, and equipment used in the production of goods or in the rendering of services. Put simply, it is the total cost needed to bring a project to a commercially operable status.

Capital costs include expenses for tangible goods such as the purchase of plants and machinery, as well as expenses for intangibles assets such as trademarks and software development, know how fees, Basic engineering, detailed engineering, inspection, testing commissioning and Performance Guarantee tests.

Capital costs are one-time expenses but payment may be spread out over many years in financial reports and tax returns. Capital costs are fixed and are therefore independent of the level of output.

For example, a thermal power plant's capital costs include the following:

- Purchase of the land upon which the plant is built
- Permits and legal costs
- Costs involving the construction of the plant
- Equipment needed to run the plant
- Financing and commissioning the plant (prior to commercial operation)

They do not include the cost of the natural gas, fuel oil or coal used once the plant enters commercial operation or any taxes on the electricity that is produced. They also do not include the labor used to run the plant or the labor and supplies needed for maintenance.

There are various ways to calculate the capital cost. These are

1. From the budgetary offers.
2. From historical costs.
3. From similar cost of recently constructed plants
4. From detailed estimation
5. By indexing
6. By adopting Novel Method (Percentage Cost Method)
7. By relative cost index method

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Methods from S No 1 to 5 are common but the method at S Nos 6 & 7 are new and developed by author over a period spanning 50 years to Technical Consultancy Practice.

Percentage Cost method is based on the analysis of historical data of similar plants. It is discovered that cost of various activities for a similar plant fall within percentage of total cost of Mechanical Equipment. For example, in case of Sinter Plant the break up cost of various activities is given as under considering 100 as the basic unit for mechanical equipment

Percentage Wise Capital Cost Estimation Example

| S No | Description | Percentage In terms of Mechanical | Unit Cost in percentage of Mech cost | Qnty unit | Percentage Qnty w.r.t to Mech Equipment |
|---|---|---|---|---|---|
| 1 | TECH EQUIP | 100 | 100 | | |
| 2 | DESIGN/ENGG. | 10 | 10 | | |
| 3 | ELECT(@30-40%) | 30-40 | 30 | t | 0.1-0.15t |
| 4 | CIVIL(@15-20%) | 12-18 | 19.5 | m3 | 3-4 m3/t |
| 5 | STRUCT(@15-20) with fabrication | 15-20 | 19.5 | t | 1.2 t/t |
| 6 | REFRACTORIES if applicable | | | | 1-8 t/t |
| 7 | ERECTION(MECH+ ELECT) | 10 % of 1+3 | 13 | t | 1 |
| 8 | ERECTION (STRU.) | 8-10 % of 5 | 1.95 | t | 1 |
| 9 | ERECTION (REF) | 14-15 % of 6 | 1 | | |
| 10 | TAXES & DUTIES | 12-18 % | 25.935 | | |
| 11 | F/F/HANDLING | 3 % | 2.73 | | |
| 12 | PAT/FAT | 5 % | 3.9 | | |
| 13 | TESTING/COMM | 3-5% | 3.9 | | |
| | TOTAL | | **230.415** | | |
| | | | | | |
| 14 | OTHER TAXES Oct, Local etc.) | 2-3 % | 3.3 | | |
| 15 | CONTIGENCIES | 5 % | 3.9 | | |
| 16 | SPARES | 5 % | 6.5 | | |
| 17 | Working Capital | Type of RM | | | |

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| | | | | | |
|---|---|---|---|---|---|
| 18 | IDC | On time & int rate | | | |
| 19 | Land & development | | 5-10 % | | |
| 20 | | | | | |
| | Total | | **250-255** | | |
| Note:<br>Once any one cost is known/estimated other cost can be calculated as above.<br>The above principle can be applied for any other plant/project for capital cost estimation. | | | | | |

**Relative Cost Ratio/Index Method**

This is another interesting and novel method of calculating capital cost developed by author during his experience over the years. This is based on the concept that relative cost of any plant and equipment; industrial products remain constant and fixed over the period of time for any place or country. For example, relative cost of a bicycle, scooty and car will be same irrespective of time and place. Similarly, relative cost ratio of a three-phase motor and matching gear box and coupling is a constant not affected by time or place. Similarly, relative cost ratio of one Million Tonnes (MT) steel plant & four MT steel plant is constant (Not necessarily linear). Similarly, ratio between 1000 MW Thermal Power Plant with 1 MT steel plant, Cement Plant is constant for a place at any time. By knowing the cost of one the cost of other can be easily calculated. Engineer shall work out these ratios and use them for the calculation of capital cost. These can be cross checked with other methods.

Author has found this method so effective that by knowing the average cost of one cup of tea at particular place, the cost of a plant of a particular capacity can be approximately estimated quickly for estimation purposes.

**Operating Cost**

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1. Fixed Cost
2. Variable Cost

**Fixed Costs**

1. Fixed costs are those business costs that are not directly related to the level of production or output. In other words, even if the business has a zero output or high output, the level of fixed costs will remain broadly the same. In the long term fixed costs can alter - perhaps as a result of investment in production capacity (e.g. adding a new factory unit) or through the growth in overheads required to support a larger, more complex business.
2. ***Examples of fixed costs:***
   - Rent and rates
   - Depreciation
   - Research and development
   - Marketing costs (non- revenue related)
   - Administration costs

**Variable Costs**

1. Variable costs are those costs which vary directly with the level of output. They represent payment output-related inputs such as raw materials, direct labour, fuel and revenue-related costs such as commission.
2. A distinction is often made between **"Direct"** variable costs and **"Indirect"** variable costs.
3. **Direct** variable costs are those which can be directly attributable to the production of a particular product or service and allocated to a particular cost center. Raw materials and the wages those working on the production line are good examples.
4. **Indirect** variable costs cannot be directly attributable to production but they do vary with output. These include maintenance and certain labour costs.

**Profit & Loss Calculations**

Every engineer/entrepreneur must learn to calculate profit and loss for the industry being set up and this shall be part of curriculum. Following cost to be calculated for arriving at the profit/loss.

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**Variable Cost**

Calculate variable cost as follows:

i. Raw materials cost /yr of finished product
ii. Consumables @ 2-8 % OF Raw Mats Cost
iii. Utilities – Power Cost
iv. Utilities – Water + Land use
v. Factory Salary & Wages
vi. Repairs & Maintenance 5 %
vii. Factory insurance 1-1.5%
viii. Other Factory overheads

Total Variable Cost/t (Sum of i to viii above)

**Fixed Cost**

Calculate fixed cost as follows:

i. Admn. Salary & R&D
ii. Term Loan interest
iii. Bank borrowing interest
iv. Depreciation

Total fixed cost/t (Sum of i to iv above)

Fixed Cost +Variable Cost = Total operating cost

Calculate Profit as follows

Realization from Sales (Turn Over) = Gross Turnover

Gross Profit (Gross Turnover-Variable Cost)

Net Profit/yr (Gross Profit - Fixed Cost)

Net Profit/Year

Income Tax

Profit after tax

Retained earnings per yr.

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Cash Generation Over 10 yrs.

This can be calculated on yearly basis or per t basis.

## Financial Indices Calculations

Knowledge of financial indices is important for taking investment decision. Below are given some important indices which every engineer/entrepreneur shall be able to work out and take appropriate investment decision.

### Debt-Service Coverage Ratio

The debt service coverage ratio (DSCR), also known as "debt coverage ratio," (DCR) is the ratio of cash available for debt servicing to interest, principal and lease payments. It is a popular benchmark used in the measurement of a company's ability to produce enough cash to cover its debt (including lease) payments. The higher this ratio is, the easier it is to obtain a loan.

### Internal Rate of Return

The internal rate of return on an investment or project is the "annualized effective compounded return rate" or "rate of return" that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero.

In more specific terms, the IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment.

An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital

### Break-Even Capacity (Average)

Break-even analysis is a technique widely used for financial analysis of a project. It is based on calculating operating cost (production costs) between those which are "variable" (costs that change when the

production output changes) and those that are "fixed" (costs not directly related to the volume of production).

Total variable and fixed costs are compared with sales revenue in order to determine the level of sales volume, sales value or production at which the business makes neither a profit nor a loss (the "break-even point").

**Pay Back Period**

The length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions.

Calculated as: **Payback Period = Cost of Project / Annual Cash Inflows**

All other things being equal, the better investment is the one with the shorter payback period. For example, if a project costs 100,000 and is expected to return `20,000 annually, the payback period will be `100,000/`20,000, or five years. There are two main problems with the payback period method:

- It ignores any benefits that occur after the payback period and, therefore, does not measure profitability.
- It ignores the time value of money.

## 18. Contracts Management

Engineer shall have basic knowledge of managing contracts. It includes understanding of following:

Legal aspects of contracts: definition of contracts, elements of a valid contract, offer and acceptance, capacity of the parties to the contract, types of mistakes encountered in contracts, misrepresentation, consideration, express and implied terms and statute of limitations.
Contract documents: drawings, specifications, bill of quantities.
General conditions of Contracts, Special Conditions of contracts.
Types of Contracts-Supply, Semi Turn key, Turn Key contracts

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Contracts on BOO, BOOT etc.
Sample contracts
Contractor selection: -parties to a contract: duties of each party
Conditions of contract: clauses of conditions, quality of work during construction, contractor duties, site engineer contractual job, costs of construction, essence of time factor of construction, insurance and bonds and arbitration

## Conclusion

As can be seen from above it is imperative that all the aspects discussed above are necessary to be learned during course of technical education for development of entrepreneurship temperament in the minds of young engineers. Once any entrepreneur/engineer applies above considerations and concepts for implementing any project, then it can be safely said that the project has been taken care holistically from 360 degree and nothing more is left to chance. This all-round approach can turn all young engineers to think in holistic sense or “Engineered Thinking”

This think like engineer approach can help even non engineers and immensely benefit them for day to day purchasing of house hold or industrial appliances, equipment, construction of house. By applying above approach they will be able to select proper land, buy equipment considering ease of operation, needing less maintenance, less spare parts and inventory, keep interchangeability in mind (Say buy similar smart phones for family), compliance to safety requirements (lower radiation levels from smart phones), design (buying smartphone which works universally suiting to all the bands say in India and US), better ergonomic design and so on. For example, one of my colleagues who did not think like engineer bought Nokia Smart Phone from India for use in USA. Sadly, it did not work in USA as the same was not designed for US frequency bands.

It is recommended that all the above concepts shall become part of curriculum of all hard-core degree and diploma engineering courses. Also, this shall form part of one-year entrepreneurship course to be introduced as finishing school for the engineering graduates and

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diploma holders who have already finished their education and wish to become entrepreneurs in near future.