Process Design Decisions and Project Economics
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Module - 8
Chemical Project Economics
Lecture - 40
Project Cost Estimation (Part II)

Welcome we are in module 8 and we are looking at Estimation of Project Cost. In the previous lecture we got introduction of the project cost the we saw how does the cash flow tree can be constructed for a particular industry. What are the steams and roots of such a tree, then we also saw how does the cash flow or cash position varies for a particular industry. Then we saw the components of total capital investment first fixed capital, working capital and the total production cost, then we saw various components of fixed capital investment.

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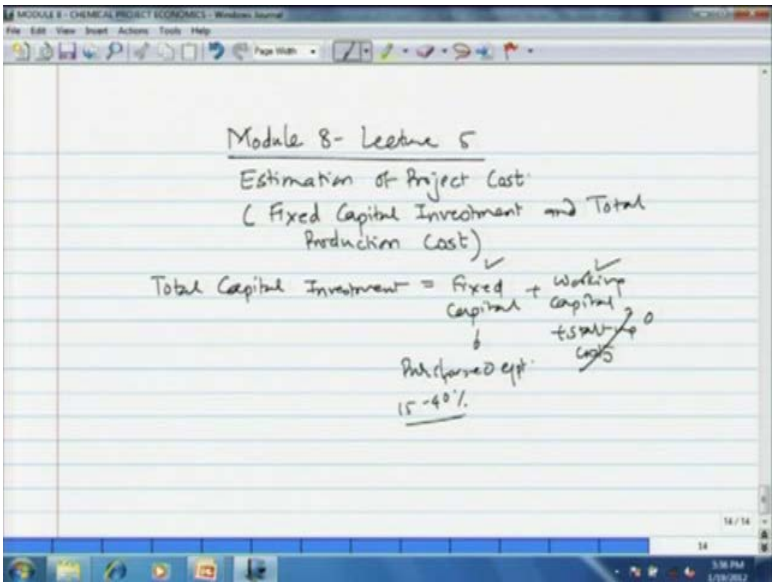

So, that point we note the total capital investment is equal to fixed capital plus working plus some start up cost in any changes are required, but if the technology is well proved then start up cost are 0, so we that we do not consider. So, fixed capital, working capital and in the previous lecture we saw various components of fixed capital and there percentages, typical percentages or range of percentage. There are two types of plant;

one plant is the multi process cross root plant or a small scale plant or just capacity addition what we can say or what is known as better limit addition.

A gross root plant is defined as a complete plant erected on new site this investment for such a plant includes all the costs of land site development better limit facilities and auxiliary facilities. A geographic boundary defining coverage of a specific project is called the better limit, and usually these better limits includes only the manufacturing area of proposed plant in addition to other process equipment such as auxiliaries, but definitely not the storage, utilities, administrative buildings so on and so forth or the general auxiliaries like steam and cooling water, these are usually not included in better limit.

Normally, this kind of plant or this kind of this kind of a capacity addition plant it excludes a site preparation. And therefore the relative cost for such the components relative cost of various components are little bit lower and that is why we got a large range of the cost, one the lower limit let us say is could be for the better limit addition and a larger in limit is for a new gross root plant.

Now, we had seen we concluded our previous lecture on the issue of cost index like the major component of capital fixed capital investment is the purchase equipment which is about 15 to 40 percent of the total cost. Then how do we get the cost of purchase equipment, an easy way is through vendors quotation, but vendor may not give a quotation unless and until he receives conform order. So, if we are going for pre-design estimate, where we are estimating cost only with sufficient accuracy or only with limited accuracy of data or with limited data, then we can go for certain thumb rules for estimating the cost of equipment.

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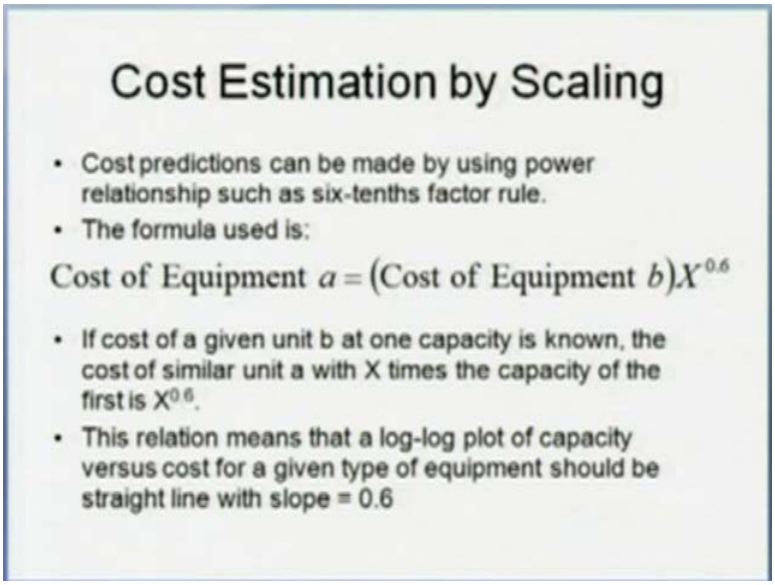

Now, one such thumb rule that we saw was the cost estimation by scaling were we saw the formula, that cost of a particular equipment a is equal to cost of equipment b into X raise to 0.6. Where X is the capacity ratio and exponent for that capacity ratio is typically 0.6 at is called as six-tenths factor rule.

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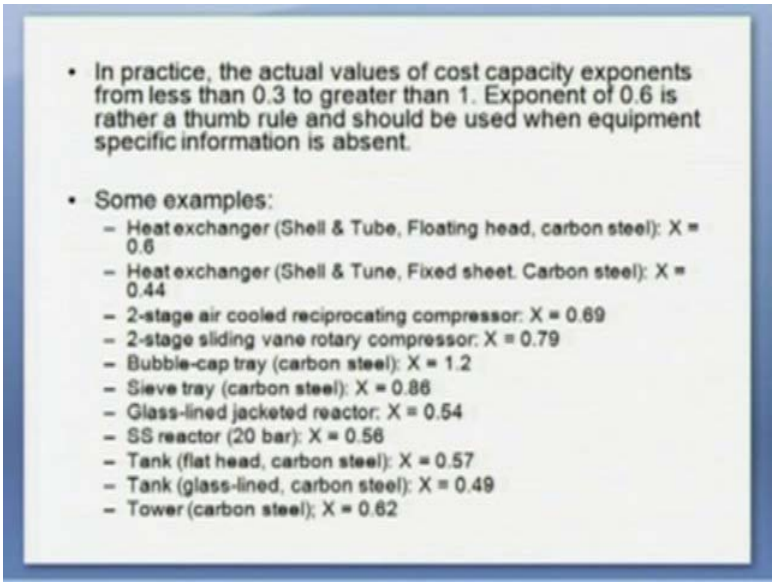

Now depending on the particular equipment this exponent may vary most of the times it is less than point less than 1, but in some cases it could be greater than also 1 there is a large range for it could be less than 0.3 or greater than 1. What I have listed on for you

on screen are some examples like heat exchanger, shell and tube type, floating head, carbon steel index is equal to 0.6, Then heat exchanger shell and tube fixed sheet, but carbons steel, floating head was 0.6, fixed sheet is 0.44, two stage air cooled reciprocating compressor x equal to 0.69.

Two stage sliding vane rotary compressor x is equal to 0.79, bubble cap tray carbon steel x is equal to 1.2, sieve tray x is equal to 186, metal of construction carbon steel, stain less stingers steel reactor of 20 bar x is equal to 0.561 so forth. So, you have depending on the type of equipment and it is specification and capacity, the capacity ratio exponent varies, but typical value is 0.6.

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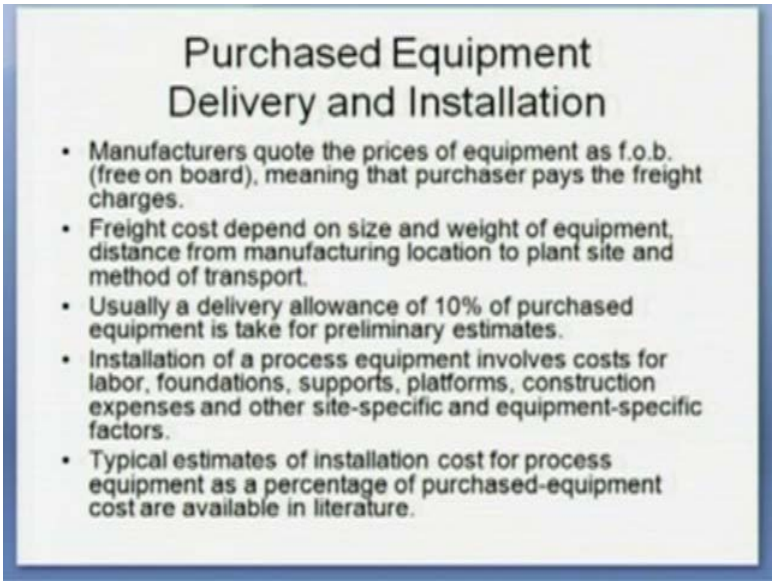

The aspect of purchased equipment delivery and installation, what we get from the quote is may the f. o. b cost manufacturer quote, the prices as f o b, cost free on board. Meaning that the purchaser has to pay for the freight charges, the freight cost depends on the size and weight of equipment and distance from manufacturing location to the plant site and the method of transport; whether it is getting transported by road on trucks or by rail, so on.

Usually transport is not by air for large scale equipment, usually the delivery allowance of 10 percent of purchased equipment is taken for preliminary estimate, then installation of a process equipment involves the cost of labor, making concrete foundations, if the metal is heavy. Then certain supports, steel support or structural support and platforms,

construction expenses and other site specific and equipment specific factors. Now, these also add the total installed cost of the equipment what from the purchase cost.

The typical estimate of installed cost for a process equipment as the percentage of purchase equipment are available in literature. Now, let us see what are those total installation cost depends on the complexity of equipment and the type of plant in which the equipment is being installed. The typical range of installation cost is 25 percent to 55 percent of the delivered and typical range of installation cost is 25 to 55 percent of the delivered equipment purchase cost.

Insulation and typing of equipment is included in the installation cost, total cost of labor and metal required for insulating, equipment and piping in ordinary chemical plants is approximately 8 to 9 percent of the derived purchased equipment cost. Then the instrumentation in controlled this is typically 8 to 55 percent depending on the type of equipment. The total cost varies the 8 to 55 percent of the total delivered equipment cost remember it is not purchased per delivered cost, that includes the transportation. Then for normal solid fluid chemical processing plant typically 26 percent of the delivered purchase equipment cost is recommended as the instrumentation and process control cost.

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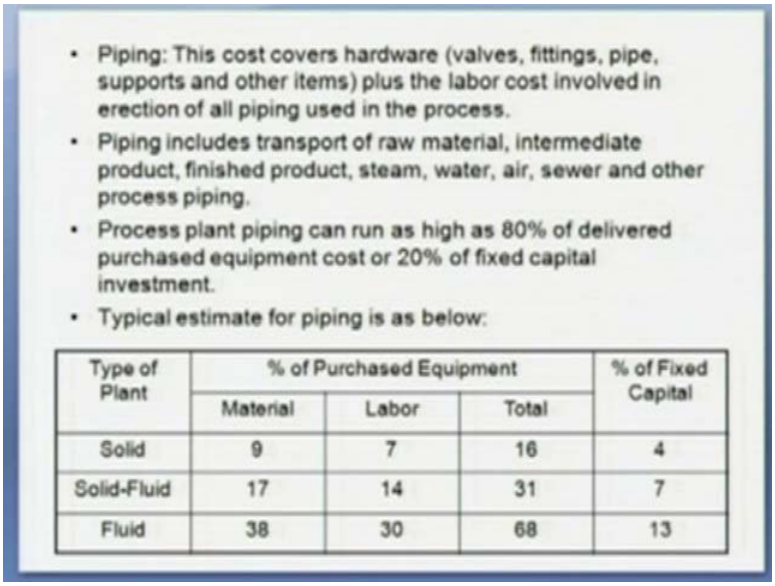

Type of Plant	% of Purchased Equipment			% of Fixed Capital
	Material	Labor	Total	
Solid	9	7	16	4
Solid-Fluid	17	14	31	7
Fluid	38	30	68	13

Then comes the piping this cost covers hardware the valves, fittings, pipe support and other items, plus the labor cost involved in erection of all piping used in the process,

special piping that needs to be build around a particular equipment. Piping includes the transport of raw material intermediate product, finished product, steam, water, air, sewer and other process piping. Now, depending on the type of chemicals that a plant is handling, we have to choose the proper metal of construction usually carbons remain enough, but in certain cases, where highly corrosive chemicals are used you may have to go for stain less steel.

Process plant piping can run as high as 80 percent of the derived purchase equipment cost or 20 percent of the fixed capital investment. Now, I have listed for you here some typical estimates for a type of plant handling only solid raw material, the purchased equipment. Cost purchased percentage of purchased equipment that the piping cost as percentage of purchased equipment for material it is 9 percent metal cost 9 percent labor cost 7 percent, so total 16 percent.

And or if you talk the piping cost as percentage of fixed capital, then it is 4 percent of the fixed capital then a plant which is handling solid and fluid material 17 percent of the material and 14 percent labor. So, total 31 percent of the purchased equipment or 7 percent of the fixed capital. And for plants handling fluid material you can see the cost fraction is much higher 68 percent of the purchased equipment cost is piping cost, piping cost amounts to 13 percent of the fixed capital investment.

So, as the as we go from solid to fluid materials the cost of piping increases, then the electrical system for the equipment there are four major components of electrical system power wiring, lighting, transformation and service and instrumentation in control wiring. The typical installed cost of electrical systems is 15 to 30 percent of the delivered purchased equipment cost or 4 to 8 percent of the fixed capital investment, then the cost of building.

Now, it is the cost of building plus services depending on the type of process plant and consist of expenses for labor, materials and supplies involved in erection of all building connected with plant then cost of plumbing heating, lighting, ventilation and similar building services. Once again I have listed here the typical percentages like percent building cost as percentage of fixed capital investment, if it is a solid handling plant, then if it is a gross root plant then the building cost is typically 18 percent of fixed capital investment, if it is a new capacity addition new units that exist in-site then it is 7 percent.

And if it is expansion at existing site then it is 4 percent. Then for solid fluid handling the 12 percent of the fixed capital investment is the cost of building 7 percent if it is new units at existing site and 2 percent if it is expansion at existing site. Fluid handling process the cost of building is typically 10 percent of fixed capital investment for gross root plant and 2 to 4 percent or 2 percent for expansions or new units. Yard improvement and service facilities, yard improvement for process plant includes cost of fencing, grading, roads, sidewalks, railways rail road siding, landscaping etcetera. The typical contribution of this cost component for most of the process plant is about 10 to 20 percent of purchased equipment cost or approximately 8 to 5 percent of the fixed capital investment.

The service facilities include the utilities for supplying steam water power compressed air and fuel, which are the essential part of service facilities. And then also included in this category or the cost of waste disposal, fire protection, miscellaneous service items such as shops, first aid, cafeteria, equipment and facilities. So, the typical cost of service facility in a chemical plant depending on the type of plant is in the range of 30 to 80 percent of the purchase equipment cost. I have given you here a representative table that depicts a typical range of percentage of fixed capital investment for service facilities, service facility first like steam generation and distribution the range is 2 to 2.8 percent to 8 percent typical value you can take as 4 percent of purchase equipment cost.

Water supply cooling and plumbing 0.4 to 3.7 percent typically you can take 1.8 percent. Then air plus gas supply, compression and distribution the range is 0.4 to 3.4 you can take 1.3 as the special as a as a typical value. Now, these values are essentially the percentage of fixed capital investment that point you should note, what I told you is that the service facilities are in the range of 30 to 80 percent of purchased equipment, but these are percentage of the fixed capital investment.

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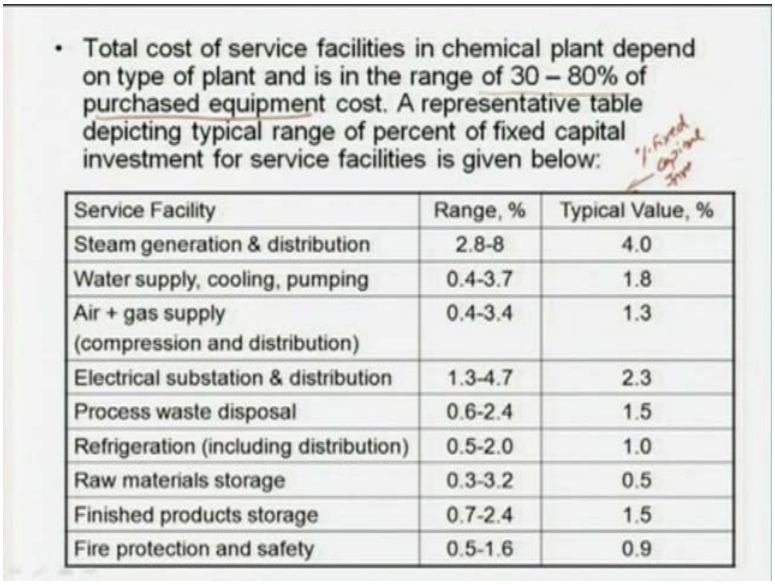

- Total cost of service facilities in chemical plant depend on type of plant and is in the range of 30 – 80% of purchased equipment cost. A representative table depicting typical range of percent of fixed capital investment for service facilities is given below:

Service Facility	Range, %	Typical Value, %
Steam generation & distribution	2.8-8	4.0
Water supply, cooling, pumping	0.4-3.7	1.8
Air + gas supply (compression and distribution)	0.4-3.4	1.3
Electrical substation & distribution	1.3-4.7	2.3
Process waste disposal	0.6-2.4	1.5
Refrigeration (including distribution)	0.5-2.0	1.0
Raw materials storage	0.3-3.2	0.5
Finished products storage	0.7-2.4	1.5
Fire protection and safety	0.5-1.6	0.9

In finished product storage the cost range is 0.7 to 2.4 and typical value 1.5 percent of fixed capital investment so on and so forth. Then the S H E issues Safety Health and Environmental issues the requirement of our or occupational health safety and environmental functions in chemical plant has increased over time, the investor has to keep allowances for this provision, then there are no general guide lines.

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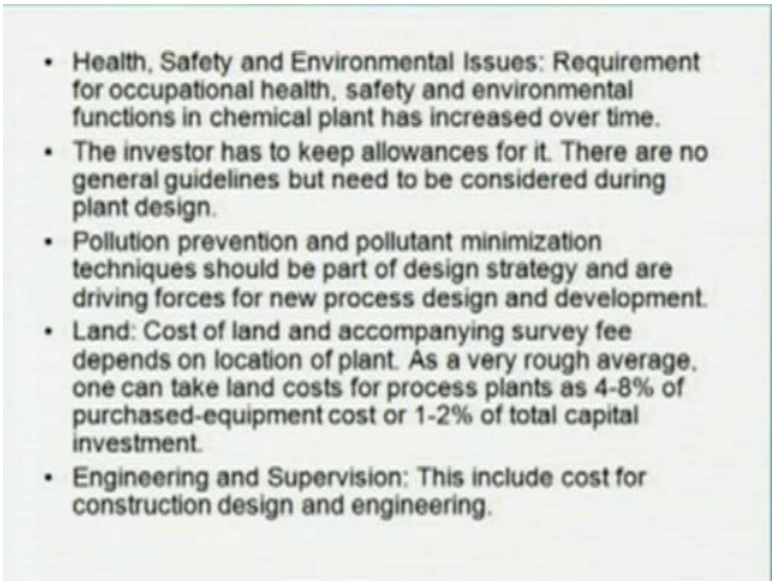

- Health, Safety and Environmental Issues: Requirement for occupational health, safety and environmental functions in chemical plant has increased over time.
- The investor has to keep allowances for it. There are no general guidelines but need to be considered during plant design.
- Pollution prevention and pollutant minimization techniques should be part of design strategy and are driving forces for new process design and development.
- Land: Cost of land and accompanying survey fee depends on location of plant. As a very rough average, one can take land costs for process plants as 4-8% of purchased-equipment cost or 1-2% of total capital investment.
- Engineering and Supervision: This include cost for construction design and engineering.

But, we need to account for a typical hospital that can exist as at the plant site that can treat the personally some injury or some accident occurs. Then the pollution prevention

and pollution pollutant minimization technique, that also should be a part of design strategy and this a driving force for new process and design development in many countries. Then land, cost of land and accompanying survey fee depends on the location of the plant, this actually site survey and site related aspects we have seen in greater detail later on greater detail in previous lecture.

As the very rough average one can take the land cost for process plant as 4 to 8 percent of purchase equipment cost or 1 to 2 percent of fixed capital investment. The engineering supervision this includes cost of construction design cost for construction and construction design and engineering the detailed cost components. For engineering and supervision are firstly, internal or license software, computer based drawing, purchasing, accounting, construction and cost engineering, travel communication, home office expenses and over heads. Now, this is an indirect cost in fixed capital investment estimated at 30 percent of delivered equipment cost or 8 percent of fixed capital investment.

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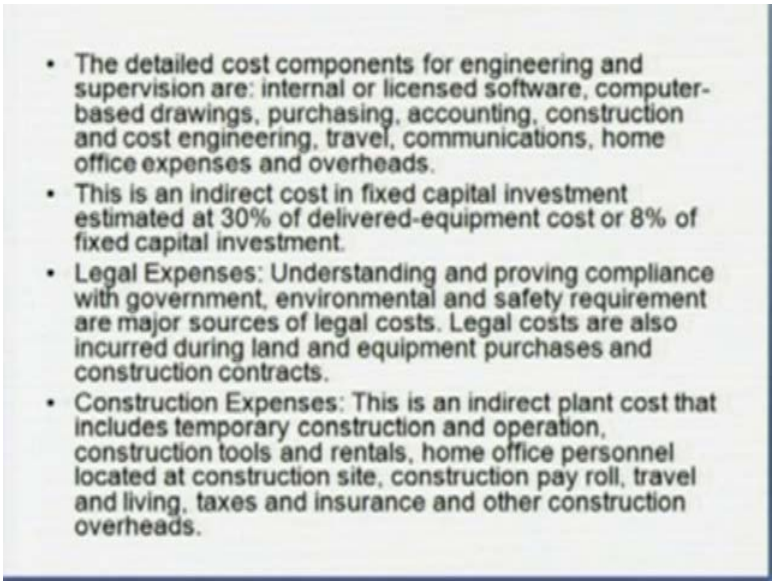

Then the legal expenses understanding and providing compliance with government environmental and safety requirement, these are the major sources of legal cost. Legal cost are also incurred during land and equipment purchases and the construction contracts. Then construction expenses this is an indirect plant cost that includes temporary construction and operation, construction tools and rentals, home office

personnel, located at construction site, then construction pay roll, travel and living, taxes and insurances and other construction over heads.

These things are typically 8 to 10 percent of fixed capital investment of the plant then the contractor fee. Contractor fee this component varies widely with the type of process plant and site, it is estimated in the range of 2 to 8 percent of direct plant cost or 1.5 to 6 percent of fixed capital investment. Then the contingency this cost are the money reserved for unexpected events and situation that inevitably increase the project cost, this include the storms floods, other natural calamities, transportation accidents strikes, price changes, last minute design changes, errors in estimation and other un force in expenses.

The contingency factor here varies in the range of 5 to 15 percent of fixed capital investment and 8 percent being a reasonable average value. So, this was the detailed like discussion on components of the fixed capital investment. Now, we go further to exert estimation of the project cost or what methodology that we need to adopt for estimating the fixed capital investment.

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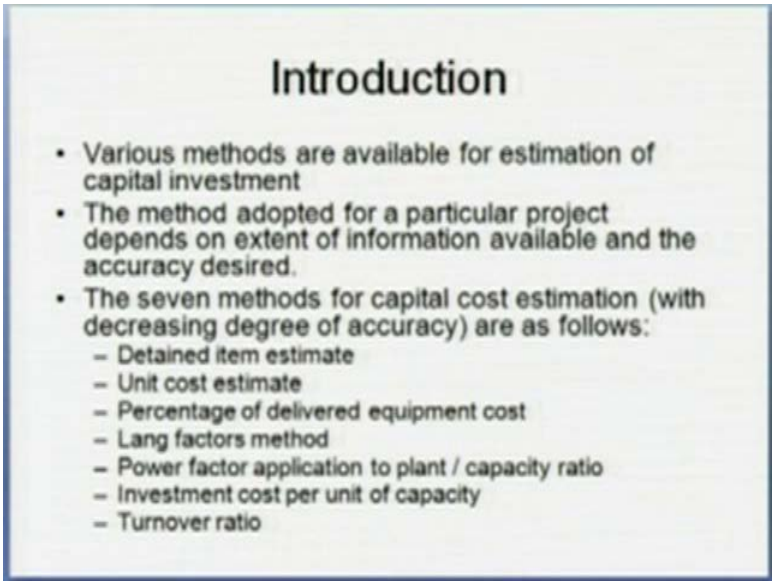

The methods that are available for estimation of project investment this can be listed as typically seven methods, I have listed. The detailed item estimate, then unit cost, the percentage of delivered equipment cost, then lang factor method, the power factor application to plant capacity ratio and investment cost per unit of capacity and turnover ratio. What method we should adopt for a particular project depends on the extent of

information that is available with us and the accuracy of the estimate that is desired. Now, let us see more details of these estimates one by one.

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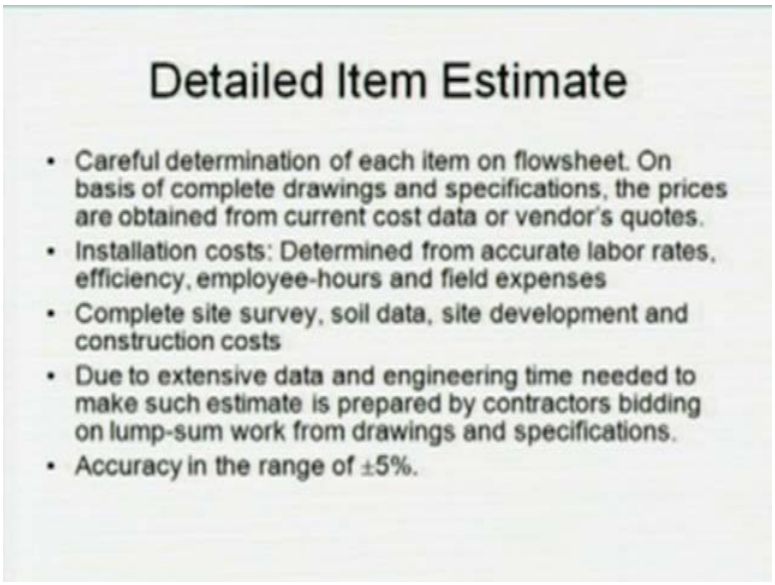

First the detailed item estimate, careful determination of each item on the flow sheet, that is needed to make this kind of estimate. On the basis of complete drawing and specification, the prices are obtained from the current cost data or directly the vendors quote. Then we have to account for the installation cost these are determined from accurate labor rates, efficiency, employee hours and fixed expenses sorry field expenses, then the complete site survey, soil data site development and construction cost.

Due to extensive data that is available the engineering data and also engineering the time needed to such an estimate is prepared by the contractor bidding on lump-sum work from drawings and specification. So, detailed item estimate is typically the last quote that we get from the vendor the accuracy is quite high accuracy is in the range of plus minus 5 percent. In this type of estimate an attempt is made to form up as much as estimate as possible by obtaining quotation from vendors and suppliers. So, remember this is the like the most detailed or most accurate estimate that we have, but this comes at the end like we are write now in the process of screwing of process alternatives. Therefore, we need not consider this kind of detailed estimate at this time, then the unit cost estimate

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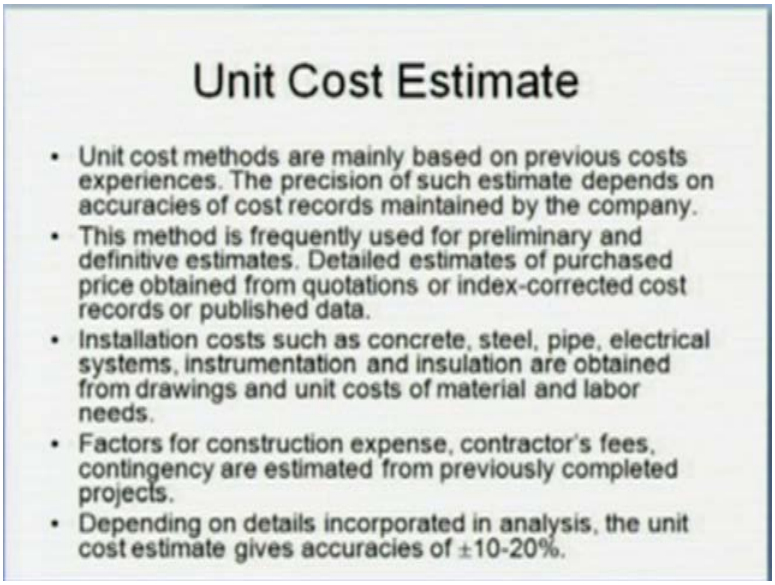

Unit cost methods are mainly based on previous cost experiences, the precision of such estimate depends on the accuracy of cost record, which is maintained by the company, other cost data which is available in literature. Then this method is frequently used for preliminary and definitive estimate, detailed estimates of purchase price are obtained from quotations or cost corrected, cost index corrected, cost records and other published data. Then installation cost such as concrete or steel, pipe, electrical systems, instrumentation and insulation, these are obtained from drawing and unit cost of material and labor needs. Then factors for construction expense, contractor fee, contingency are estimated from previously completed project. Now, depending on the details of a detailed information that you incorporate in this analysis, the unit cost estimate gives accuracy of plus minus 10 to 20 percent.

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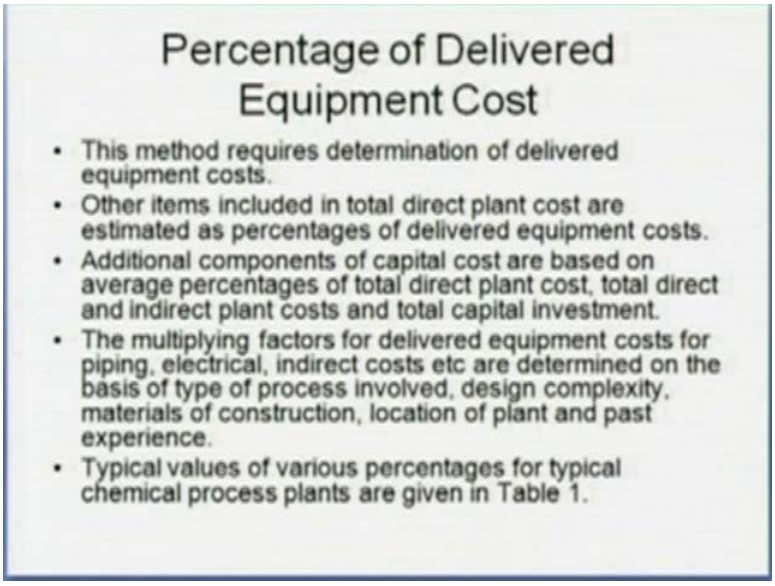

Then the percentage of delivered equipment cost, this equipment requires determination of the delivered equipment cost, because it takes that cost as the basis for estimating other cost. Other items included in the total direct plant cost are estimated as percentage of delivered equipment cost I just said then additional components of capital cost or estimate based on the average percentages of the total direct plant cost.

The total direct and indirect plant cost and total capital investment, the multiplying factors for delivered equipment cost for piping electrical connections, electrical equipment, then indirect cost these are determined on the basis of type of process involved. The design complexity, the material of construction and a location of the plant and the past experiences.

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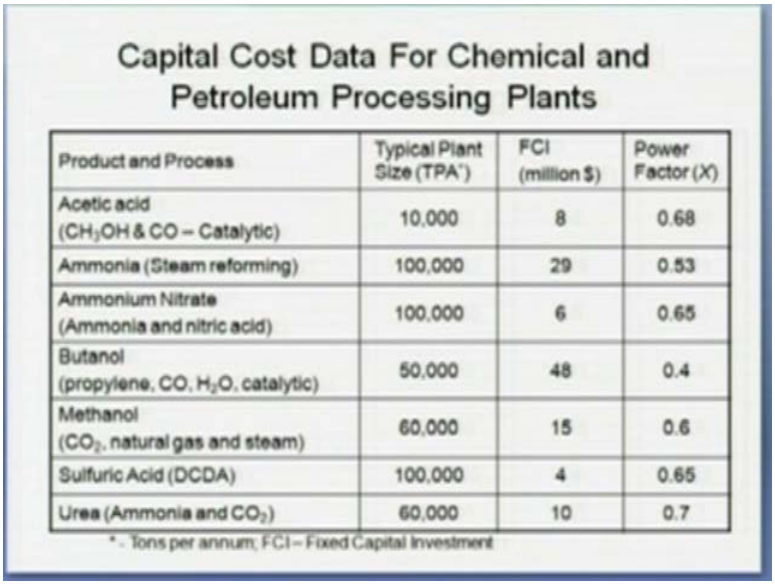

Now, what I have given you are the typical values for various percentages for plants like capital cost data for chemical and petroleum processing plant. Let us say you consider a catalytic process for acetic acid, methanol reacting with carbon monoxide, carbonaylation of methanol, typical size plant is 10,000 tons per annum. The fixed capital investment million in million dollars is eight of course, this data in 2002 we have to update it, that again I leave as a exercise to do it with cost indices.

So, for acetic acid plant of 10,000 tons per annum capacity, the fixed capital investment is 2 million dollars and the power factor is 0.68. So, accordingly you can estimate the cost for a new plant with different plant size, using this data, then ammonia, ammonia by a steam reforming if you consider a plant of hundred thousand tons per annum capacity, the fixed capital investment is 29 million dollars and the power factor is 0.53.

Then ammonium nitrate ammonia plus nitric acid again a hundred thousand tons per annum plant, the fixed capital investment is 6 million dollars the exponent 0.56 then butanol plant with propylene, propylene hydration, carbonylation hydrogen. So, that is 50,000 tons per capacity the 50,000 tons per annum the fixed capital investment is 48 million dollars power factor is 0.4. So, you can go ahead like urea 60,000 tons per annum, fixed capital investment is 10 million dollars and capacity ratio power factor is 0.7.

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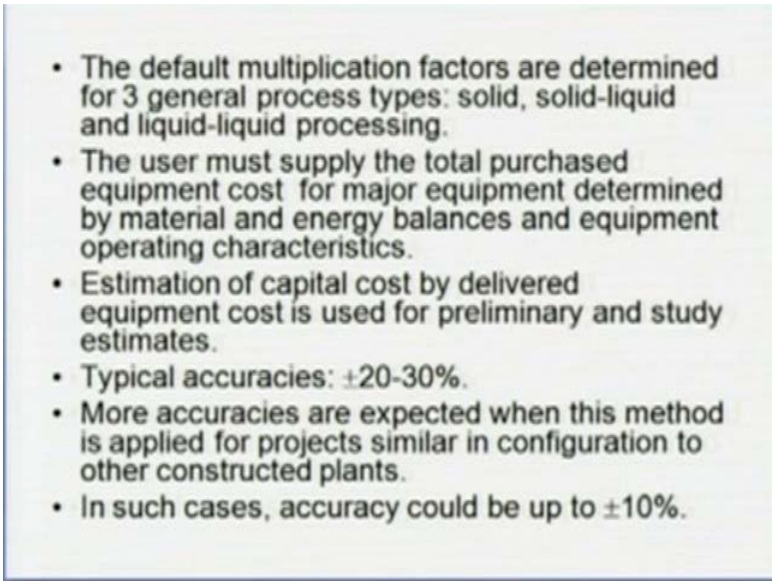

The default multiplication factor these are determined from three general process types, whether you are handling a solid process or a solid liquid process or liquid-liquid process. The user has to supply the total purchase equipment cost for major equipment determined by the material and energy balance and the equipment operating characteristics, estimation of capital cost by the delivered equipment cost method is used for preliminary and study estimate.

The accuracy of such an estimate is plus minus 20 to 30 percent more accuracies are expected, when this method is applied for projects which are similar in configuration to the other plants which are already operational. In this case the accuracy could go up by significantly that is it could be plus minus 10 percent then the method of lang factors, lang factor approximation for project cost, this technique was originally proposed by lang in 1947. And even it is used frequently to obtain order of magnitude estimate of investment. The basis of this method is that cost of a process plant can be obtained by multiplying equipment cost by some factor to approximate the total fixed capital investment.

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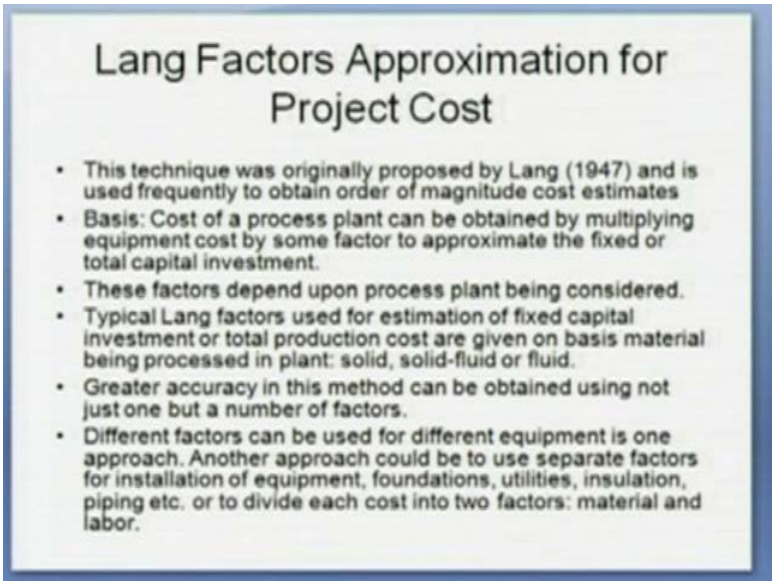

These factors depend on the process plant being considered the typical line factors that are used for estimation of fixed capital or the total production cost are given on the basis of material begin processed in the plant. Whether it is a solid or solid fluid or fluid material a completely fluid material, greater accuracy in this method can be obtained by using not just one, but a number of factors. Different factors can be used for different equipment, that is one approach and another approach could be to use separate factors for insulation of equipment, then for foundation utilities, insulation, piping etcetera. So, many multiple factors and or to divide each of the cost into two factors that is material and labor, the typical lang factors I am giving here type of land if it is a solid operating solids handling plant, then the lang factor for fixed capital investment is 4 and total capital investment is 4.7.

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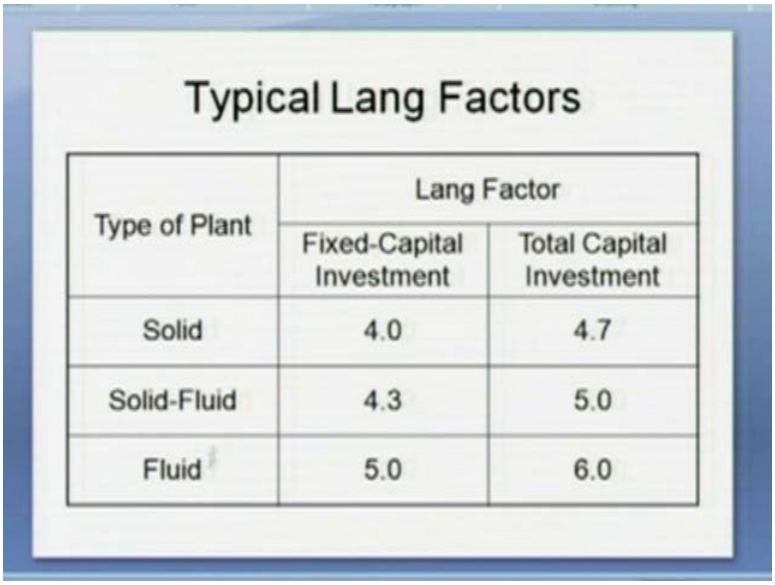

If it is a solid fluid plant then lang factor for fixed capital investment is 4.3 total capital investment is 5. If it is a fluid plant wood handling plant then the lang factor for fixed capital investment is 5 and total capital investment is 6. The next method is similar to what we saw the power factor method or plant to capacity ratio, this method is for obtaining order of magnitude estimate that relates the capital investment to of new process plant, when investment are similarly previously constructed plant by an exponential power ratio. Now, this is very similar to what we had seen for equipment, assumption is that for certain similar process plant configuration the fixed capital investment and of the new plant, C new is estimated as C old into f e into R raise to x. Now f e is the cost index ratio, C old is the fixed capital investment for previously constructed plant, R is the capacity ratio of new to previous plant and x is the power factor.

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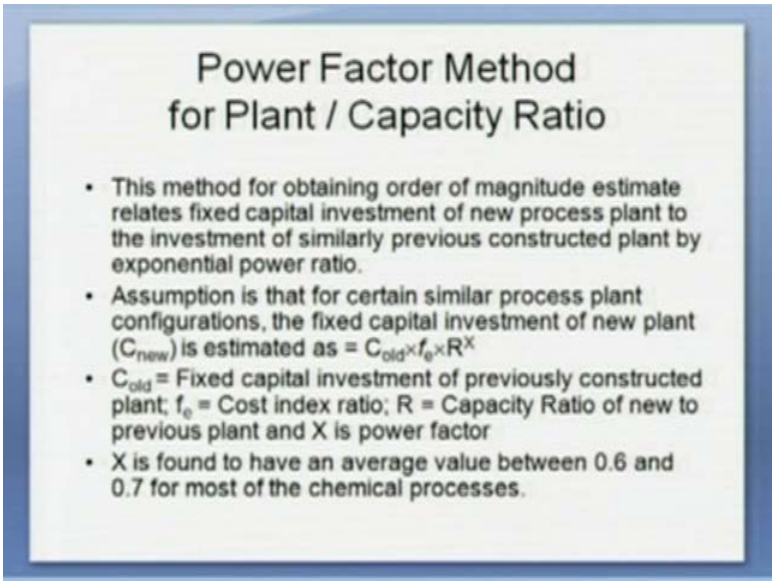

X is found to have an average value between 0.6 and 0.7 for most of the chemical processes this is very typical to again equipment. A better approximation in this approach is given as C new is equal to f into d older R raise to x plus l, l not one this is l. Where d old is the direct cost of previous plant and l is the total indirect cost for a previous plant installed on the same site. So, here you are not actually here you separate the two components of the fixed capital investment direct and indirect cost and only multiplying by the capacity ratio to the direct cost. Because the indirect cost most of the times are fixed charges that remain constant which are and they are independent of the capacity of the process, the value for power factor approach is unity, when the capacity of a process plant is increased by addition of identical process units, instead of increase in size of a process equipment.

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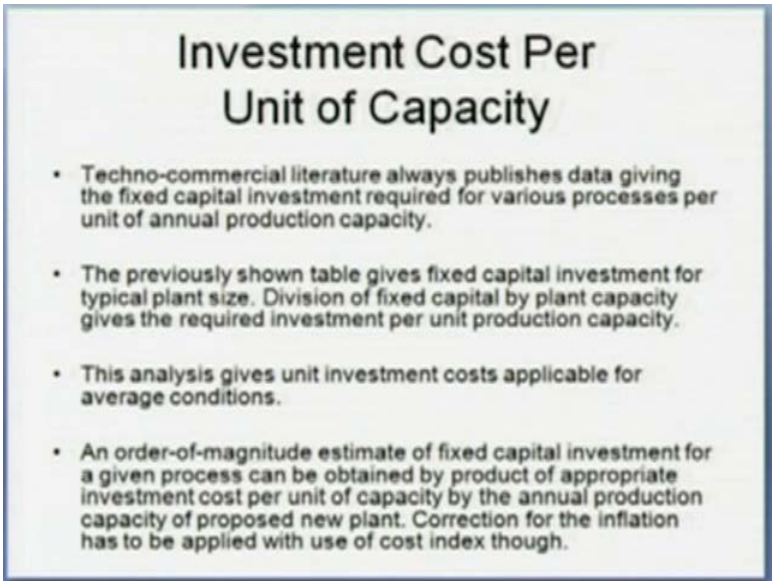

F is the lumped cost index factor and it is a product of a geography labor cost index corresponding area labor productivity index and a material and equipment cost index. Then the investment cost per unit of capacity method. The techno-commercial literature always publishes data giving the fixed capital investment required for various processes per unit of annual production capacity. Previously shown table gives the fixed capital investment for typical plant size the table which I had shown earlier, the division of fixed capital by plant capacity gives the required investment per unit production capacity.

And this analysis gives unit investment cost applicable for average condition and order of magnitude estimate of fixed capital investment for a given process can be obtained by product of a appropriate investment cost per unit of capacity by the annual production capacity of the proportional plant. The correction for the inflation has to be applied through use of a cost index and then the turnover ratio method. This is a rapid evaluation method suitable for order of magnitude estimate.

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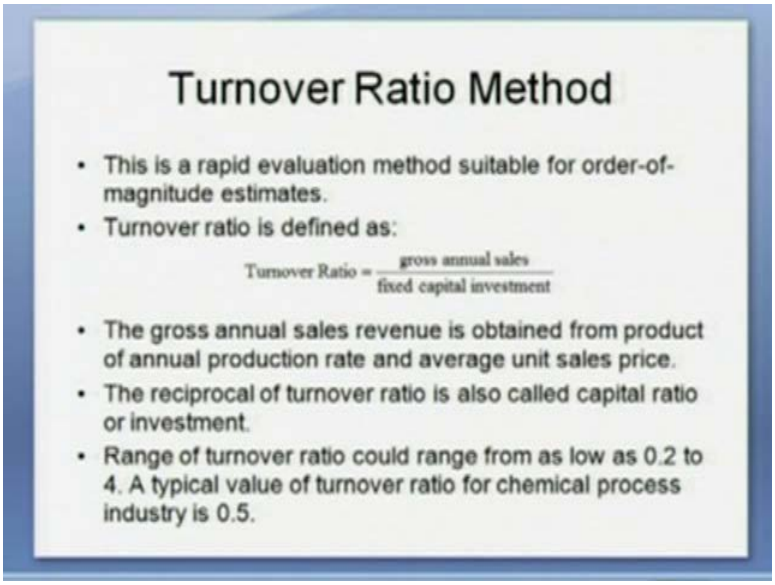

The turnover ratio is defined as gross annual sales divided by fixed capital investment. The gross annual sales revenue is obtained from the product of annual production rate and average unit sales price, the reciprocal of turnover ratio is also called as capital ratio or investment. How much is the fixed capital per unit sale, the range of turnover ratio that could be the range of turnover ratio that could range as low as from 0.2 to 4. Now, typical value of turnover ratio for a chemical process industry is 0.5; that means, the fixed capital investment is approximately twice the annual revenue that you get once the plant is fully functional.

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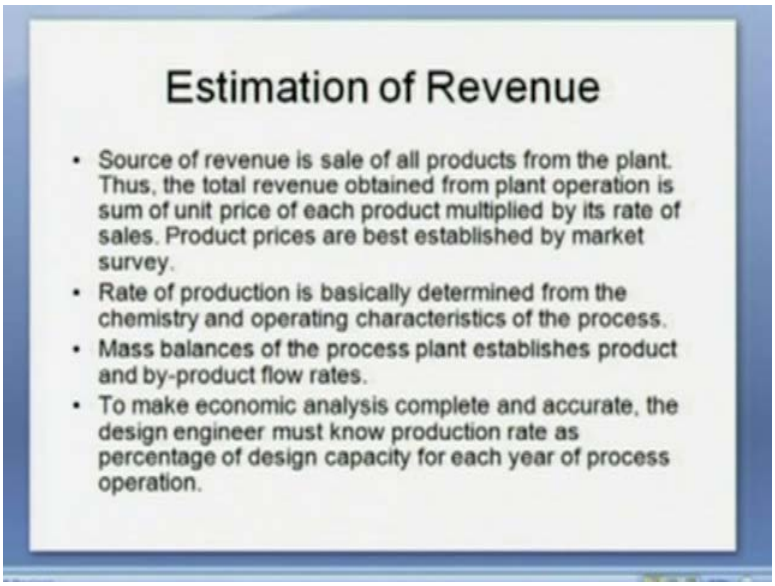

Then the estimation of revenue of the plant, the sources of revenue is sale of all products from the plant, not just the main product, but also the side products. Thus the total revenue obtained for the from plant operation is the sum of unit price of each product multiplied by it is rate of rate of sales. And the product process are best established by market survey rather than the estimates you just go to market and find out the price of the chemical that you are going to manufacture or you want to manufacture.

Then the rate of production is basically determined from the chemistry and operating characteristics of the process, mass balances of the process plant establishes product and by-product flow rates to make economic analysis, which is complete and accurate the design engineer must know the production rate as percentage of design capacity for each year of process operation. It may not happen that the process will function to its maximum capacity, so that ratio is important.

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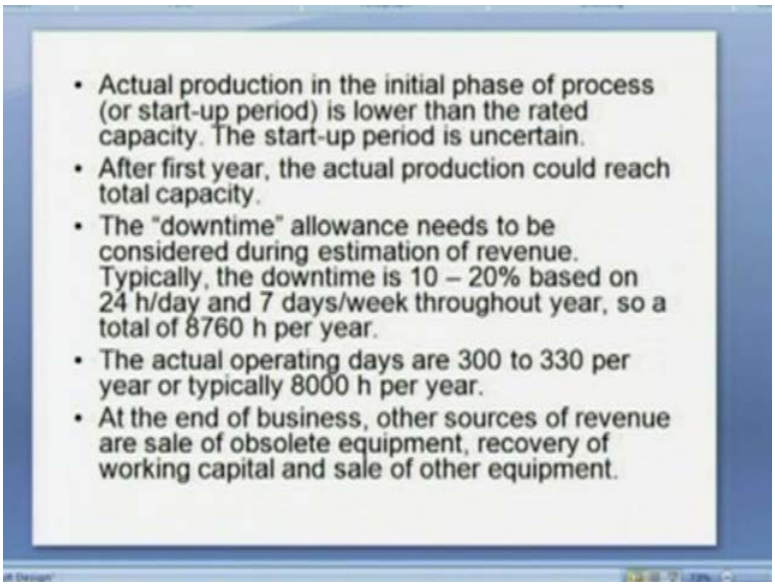

The actual production in the initial phase of the process startup period is lower than the rated capacity the startup period is also uncertain. So, after 1 year the actual production should start the full capacity, but usually it takes about 2 to 3 years for the plant to become fully functional the down time allowance needs to be consider during the estimation of revenue. Typically the down time is 10 to 20 percent based on 20 hour day and 7 days a week throughout year.

So, a total of 8760 days, so that is how it is the actual operating days are 300 to 330 per year or 8000 hours per years at the end of business the other sources of revenue are the sales of absolute equipment in the recovery of working capital and sale of other equipment. So, these are various methods of estimating the fixed capital investment. Now, with this back ground let us go a step further and get an idea of the total production cost, the total production cost is the sum of total of all cost for a operating of a plant that is then selling of the product then recovering the capital investment and corporate funds or functions such as the management and RND.

This is the total cost that is incurred for all these operations, then the total production is divided in two categories the manufacturing cost or the what you can say the direct cost or operating or production cost and the general expenses. The manufacturing cost these are further divided into three types of cost variable cost fixed cost and override cost the accuracy of the estimate of total production cost it depends on whether all cost are associated with market with making and selling of the product that are taken into consideration. And the check list table is many times available to get the correct estimation of the cost that it precludes all our missions.

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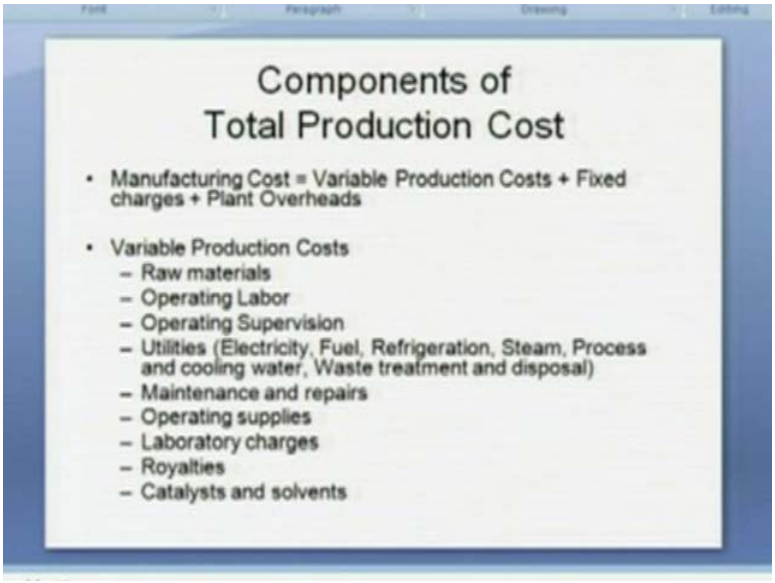

Now, let us see the composition of the total production cost as we had seen for the fixed capital investment and working capital. The manufacturing as I said the total production cost has two component manufacturing cost and general cost, the manufacturing cost has

further three components variable production cost fixed charges and plant overheads. The variable production cost include the cost of raw material, the cost of operating labor, the cost of operating supervision, the cost of utilities.

Now, utilities including electricity, fuel, refrigeration, steam process and cooling water, waste treatment and disposal, then the cost of maintenance and repairs, then the operational supplies, then laboratory charges, the royalties and catalyst and solvents, the fixed charges. Fixed charges the first component is depreciation and second is the property tax it is not income tax remember property tax, then the interest on loan or financing, then insurance and finally, the rent if that land owned by you is not yours. The plant owned cost they are medical safety and production cost, then storage facilities and packaging payroll over head, general plant over head, restaurant and refreshing facilities.

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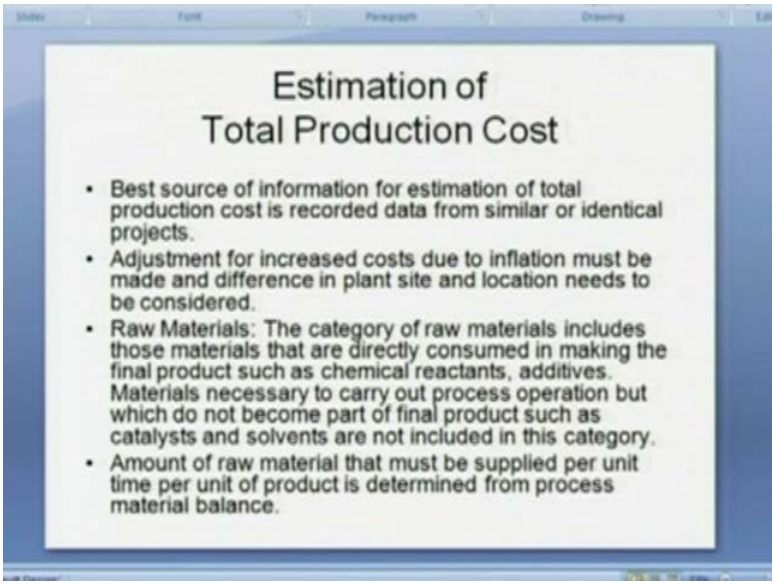

The quality control laboratories, plant supervision then general expenses like administrative expenses, distribution and marketing expenses, research and development cost. Then administrative expenses, executive salaries, clerical wages, engineering, legal cost, the office maintenance and communication, then the distribution and marketing expenses, sales officers, sales personnel, shipping, advertising technical sales service, then the research and development cost.

Now, let us see how we can estimate the total production , the best source of information for estimation of total production cost is a recorded data from a similar product, which is

constructed earlier. Now, adjustment of the interest cost due to inflation must made as we do for the fixed capital investment and the difference in the plant site location needs to be considered. First the raw material, the category of raw material includes those materials that are directly consumed in the market, while making final products such as the chemical reactants, additives so on and so forth.

Then materials necessary to carry out a process operation, but which do not become part of the final product such as catalyst and solvents are not included in this category. So, raw material does not include the catalyst and solvent price remember. Then amount of raw material that must be supplied per unit time, per unit product is determined from process material balance.

Usually the basis for process design is production rate of the key product and then calculations are made starting with that as input. The cost of raw material can be obtained from direct quotation, when these are not available the published process in either technique commercial journal such as chemical marketing recruiter or chemical weekly can be used for preliminary estimate.

The ratio of raw material to total production cost varies considerably for different types of plants, but for chemical plant, there the raw material cost are in the range of 10 to 60 percent of the total production cost, now this implements the petrochemical plant size well. So, you can see that the cost of raw material becomes a major cost in the total production or as a major fraction in total production cost. Then the operating labor, operating labor is divided into skilled and unskilled labor, the operating labor is required in terms of implies hours per day processing step. And this depends on two factor the plant capacity and number of principle number of principle steps in the process.

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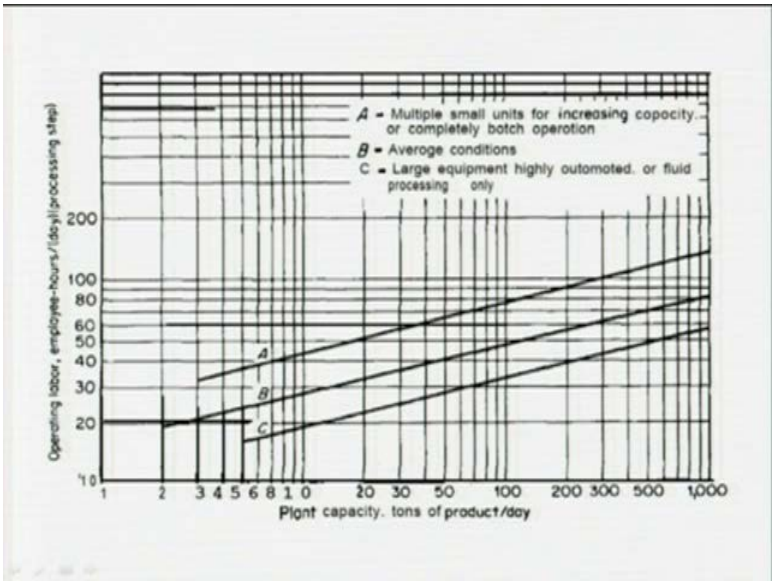

Now, what I will show you is a is a graph is like a log plot for estimation of number of labor on y axis you see operating labor as a function of plant capacity, tons per day and then the cost means cost is y axis and plant capacity per day is the x axis. Where plant capacity of thirty tones if you have a large equipment highly automated plant you need only, let us say 25 labors. If you have average condition plant you did something like 35 labor, and if you have a multiple small scale unit plant for increasing capacity or completely batch operation you need as many as 60 labor. So, this chart gives the operating hour and the operating labor, employee hour per day, per processing step as the function of plant capacity and a type of plant.

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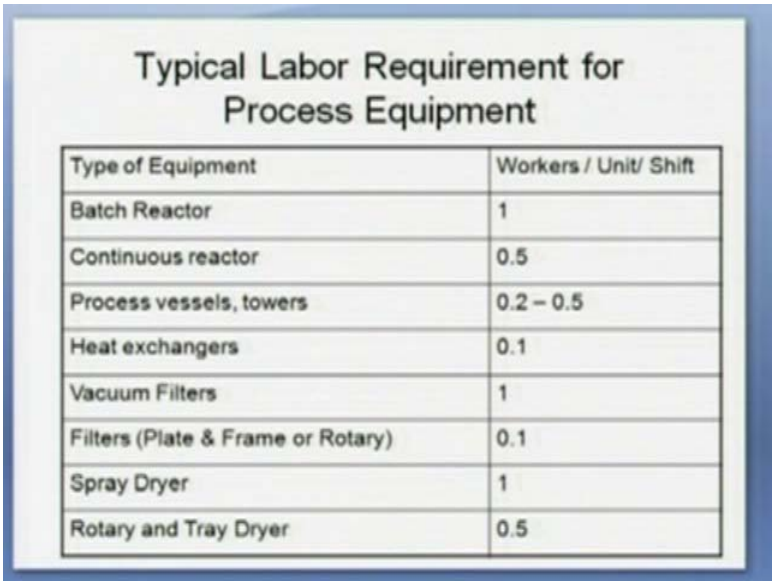

Then I have listed here for you the typical labor requirement for process equipment batch reactor you need a 1 worker per unit per shift, continuous reactor half worker per unit per shift process, vessels towers 0.2 to 0.5 worker per unit per shift heat exchanger 0.1 worker per unit per shift, then for rotary and tray dryer or spray dryer. Now, rotary and tray dryer 0.5 worker unit worker per unit per shift spray dryer 1 worker per unit per shift.

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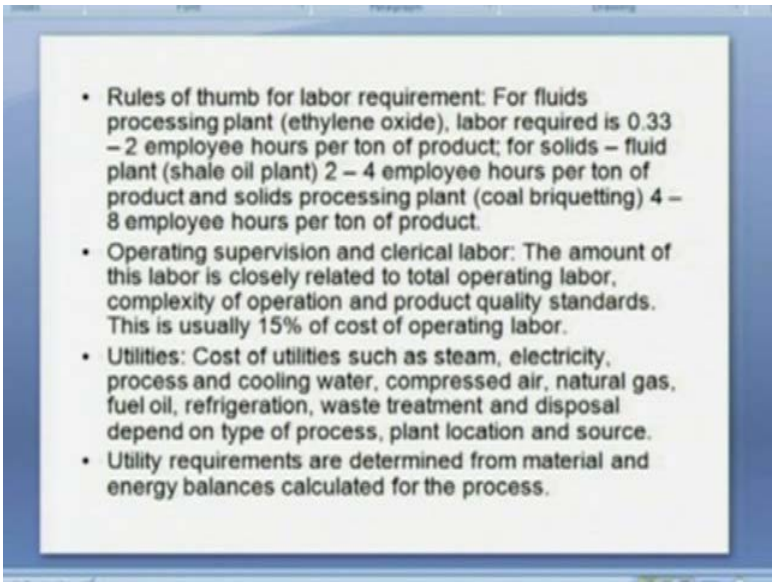

The rule of thumb for labor requirement for fluid processing plant, let us say ethylene oxide as example the labor required is 0.33 to 2 employees employee hours per ton of the product. For solid fluid plant like shale oil plant 2 to 4 employees per hours per ton of product and the solid processing plant like coal briquetting 4 to 8 employees hours per ton of the product, so that is how it is the typical distribution. The operating supervision and clerical labor the amount of this labor is closely related to the total operating labor complexity of operation and product quality standards depending on these two factors the operating supervision varies.

The typical cost of the operating labor as if percentage of the clerical labor is 15 percent cost is required, so very few supervisors are required at that time if it is an automated plant. Then utilities the cost of utilities such as steam electricity for the process then cooling water and compressed air, natural gas, fuel, oil, refrigeration, waste treatment and disposal they depend on the type of process the plant location and source.

The utility requirements are determined from the material energy balance calculations, utility made purchase from outside source or the service may be available within the company itself, heat losses in the plant should be considered while calculating the utility requirement you have to go for heat integration, so as to utilize as much as the waste heat in your process for meeting the energy demands. Now, those kinds of things like heat exchanger network synthesis etcetera, we are going to see in the next module that is on heat exchangers.

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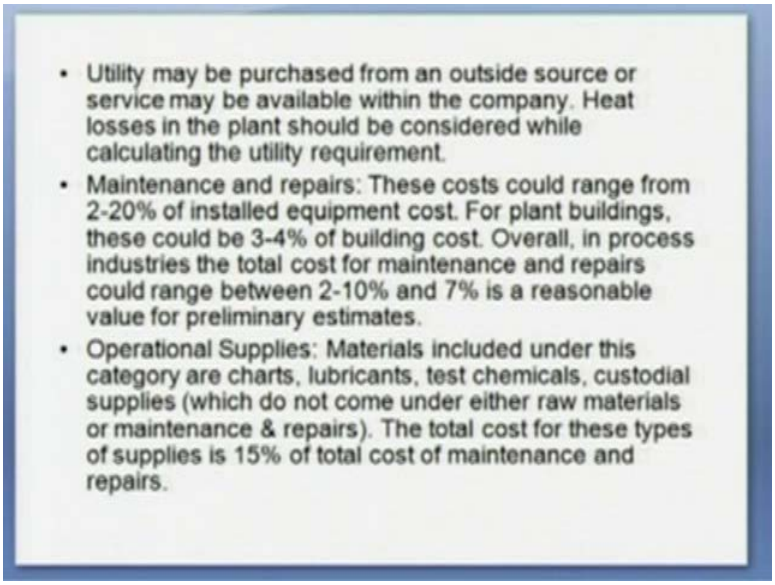

Then maintenance and repairs cost these are this cost could range from 2 to 20 percent of the installed equipment cost for plant building this could be 3 to 4 percent of the building cost. And overall in process industry the total cost for maintenance and repairs could range between 2 to 10 percent and 7 percent a reasonable value for preliminary estimate then operational supplies materials included under this category are charge, lubricants, test chemicals, custodial supplies, which do not come under either raw material and maintenance and repairs.

The total cost for these types of supplies is 15 percent of the total cost of maintenance and supply. Then the laboratory charges this includes the cost of laboratory test, for control of operation and product quality control during manufacturing, typically these are 10 to 20 percent of the operating labor charges. Then patents and royalties charge the for the patented process we have a rough estimate of patents and royalty cost is typically 6 to 10 percent of the total production cost then fixed charges.

These are the costs that are relatively independent of the production level I have already talked about these charges, these include depreciation local property taxes, insurance on loan interest so on and so forth. Or some maintenance cost the expenses of this type are direct function of the capital investment and financing arrangement rent could be taken as zero for preliminary estimate assuming the land is already available.

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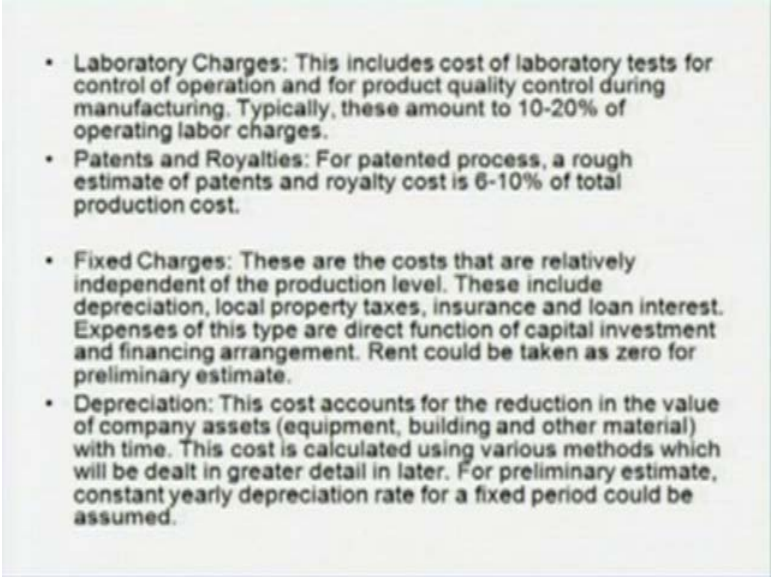

For the depreciation we are going to treat this particular topic in greater detail later in the subsequent lecture, this cost accounts for the reduction in value of the company asset the either equipment or building or other material with time. So, this is very general definition or brief definition on depreciation, this cost is calculated using various methods which will be dealt with in greater detail that is what I said. For preliminary estimate you can take a constant yearly depreciation rent that per year the value reduces by certain amount and the fixed rate period can be assumed.

Then the interest the part of whole part or whole of capital if it is borrowed from bank or other financial bodies then we have to pay the interest on this cost, interest is fixed when capital is borrowed, if interest rate changes then you have to pay for greater interest that is that is inevitable. Now, local taxes amount of local property taxes depend on particular locality of the plant and the regional large as the thumb rule the local property taxes could be taken as 2 to 4 percent of fixed capital investment, in a densely populated area while 1 to 2 percent in case of a remote area, so this factor is very important. Then local taxes these remain a big problem in having industries in near urban areas the local taxes, so please note this point. Then the property insurance, insurance rates depend on the type of process and also on the extinct of extinct of available protection facilities this cost in again amounts to about 1 percent of the total fixed charges for the year.

And the rent as I just said that if we take rent to be 0 for initial calculation, but let us say if the land on which the plant is build does not belong to the company, then company has to rent the rent that particular area and rent typical for this is 8 to 10 percent. Then plant overhead cost many other cost in addition to the cost already considered or incurred, when the plant functions as the efficient unit. These are the overhead cost these are related to all the labor connected issues with or issues with product of production operation these are typically 50 to 70 percent of the total expenses for operating labor supervision and maintenance. Then the general expenses the three components of general expenses are administrative expenses distribution and marketing and research and development expenses, but research is development of market not the actual process research and development.

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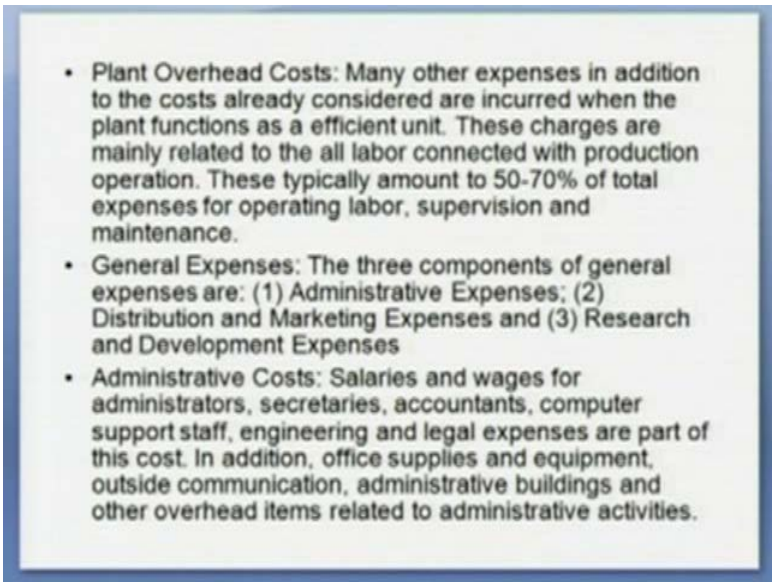

Then the administrative cost, cost and salaries wages of administrator, secretaries accountants, computer supporting staff, engineering and legal expenses, then the distribution in marketing cost these are the cost required for distribution and sale of product. This includes salaries, wages supplies and other expenses for the sale office installed in various parts of the company, then travelling expenses for self representative, shipping expenses cost of containers, advertising expenses, local storage facilities that we need to built for certain chemicals.

These cost are typically high for new or small scale product sold too large number of customers while bulk chemicals their cost are small. Then research and development cost, company has to reveal competitive in the industrial world it has to undertake research and development activity continuously. This cost includes the salary and wages of all personnel directly involved in R N D. Then fixed and operating expenses for all machineries cost of material and supplies, suppliers the consultant fees, for pharmaceutical companies R N D is the major is a significant component of a total production cost.

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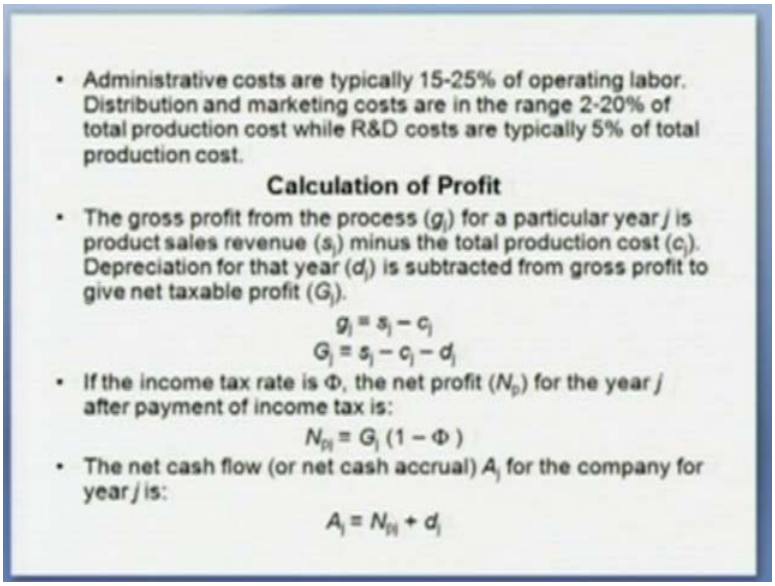

Administrative costs are typically 15 to 25 percent of the operating labor, distribution and marketing cost are 2 to 20 percent of the total production cost while R N D cost are typically five percent of the total production cost. So, that completes our discussion on the components of total production cost. Now, let us see very briefly at the end of this lecture the definition in calculation of profit.

The gross profit from the process we denote as g j for a particular year, j is the product size revenue s j minus the total production cost c j and the depreciation for that year is d j that is abstracted from gross profit to give a net profitable profit. The d j is equal to s j minus c j is the profit taxable profit is capital g j is equal to s j minus the depreciation allowed allowance. Gross profit minus depreciation allowance then if income tax rate is p and the net profit per year is n p j is equal to g j the profit before tax into 1 minus p.

And then the net cash flow for the company at any year j is equal to the n p j which is the net profit at year j plus depreciation allowance that is j, now this is how we calculate the profit. Now, this completes our discussion on the project cost estimate we have seen a very detailed discussion this we first found out what were the cost components as how we categorize the cost. First is the total capital investment is fixed capital plus working capital, then the total production cost then we saw components of fixed capital investment as how we can express them in terms of the fixed capital.

And fixed capital is again subdivided onsite cost offsite cost or I S B L or O S B L inside better limit outside better limit. So, with this we have basically come up with a broad definition of profitability, in the sub sequent lectures we shall see concept of depreciation and then we shall try to quantify the profitability using various measures.