Plant Design and Economics
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Lecture No-11
Capital Investment

Welcome to module 3, in this module we will talk about engineering economics, while economics is a specialized subject every chemical engineer should be familiar with basic concepts of process economics. It is essential for a chemical engineer so that he or she can understand how to choose among various alternative possible the most economically efficient design.

It is also required that the engineer we able to optimize the process, and also the engineer be able to do profit analysis of the plant. As an engineer you have to estimate the product cost, to estimate the total cost of the product you need to know, what is the cost of the investment in the plant?

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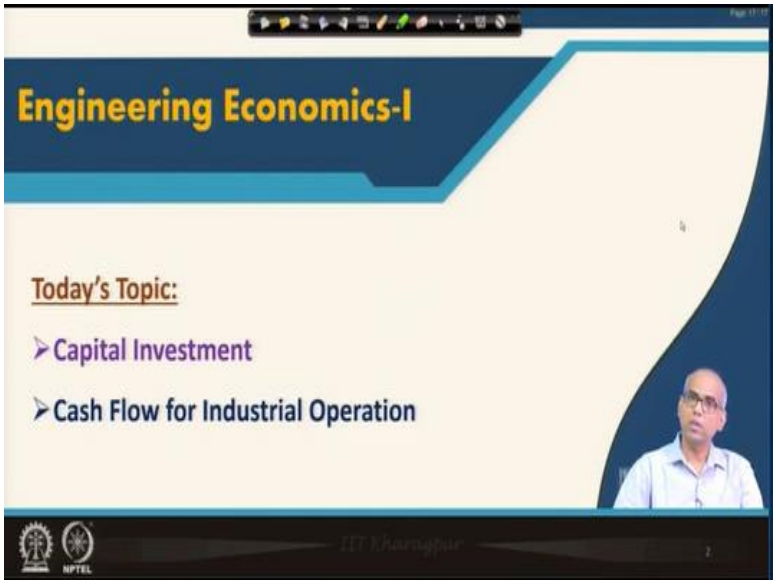

So all these basic concepts are covered in engineering economics and as a chemical engineer as a design engineer, one must be familiar with these concepts. So today, we will start with capital investment and cash flow for industrial operations. In this week, and the following two weeks will be talking about various aspects of engineering economics, we will talk about analysis of

capital investment.

We will talk about product cost estimation we will talk about time value of money we will talk about profitability analysis, taxes, depreciation etcetera. So today start with capital investment and cash flow for industrial operation.

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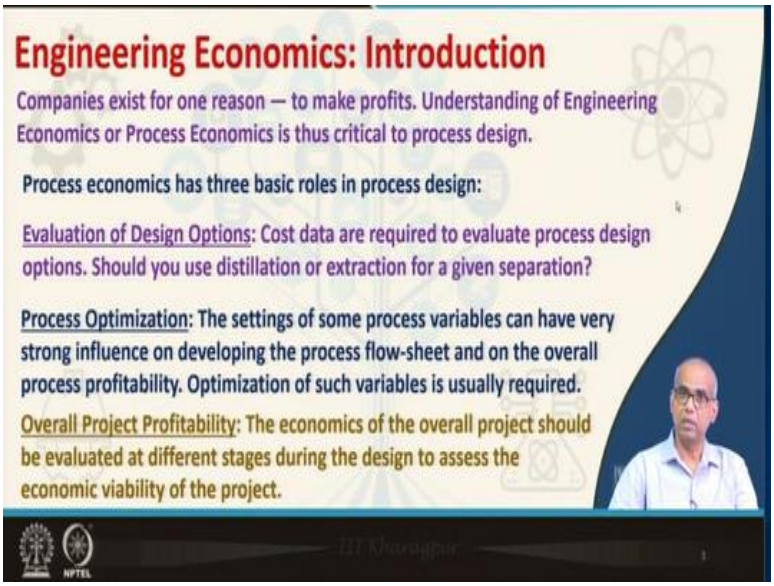

Companies exist for one reason and that is to make profits, so understanding of engineering economics of process economics is critical to process design, process economics has three basic roles in process design: evaluation of design options, cost data are required to evaluate process design options. For example; for a particular separation, should you use distillation or should you use extraction?

You definitely need cost data before you come to an definitive answer, process optimization the setting of some process variables can have a very strong influence on developing the process flow-sheet and also on the overall process profitability. Optimization of such variables is usually required. Overall project profitability; economics of the overall project should be evaluated at different stages during the design to assess the economic viability of the project.

So this is very important because the projects we shall not economically viable should be discarded as early as possible. It is very important because we know that a very small fraction of the ideas that are concept however implemented in practice.

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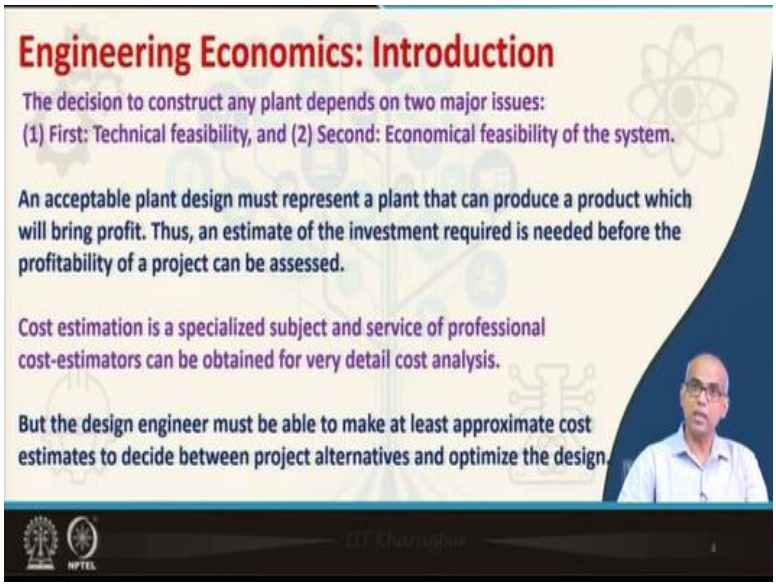

The decision to construct any plant depends on two major issues: one is technical feasibility of the proposal and second economical feasibility of the proposal. So once the technical feasibility is done economic feasibility needs to be addressed, and acceptable plant design must represent a plant that can produce a product which will bring profit to the manufacturer thus an estimate of the investment required is needed before the profitability of a project can be assessed.

Cost estimation is a specialized subject and service of professional cost estimators can be obtained for very detailed cost analysis. But the design engineer must be able to make at least approximate cost estimate to decide between project alternatives and optimize the design and make some profitability analysis of the process.

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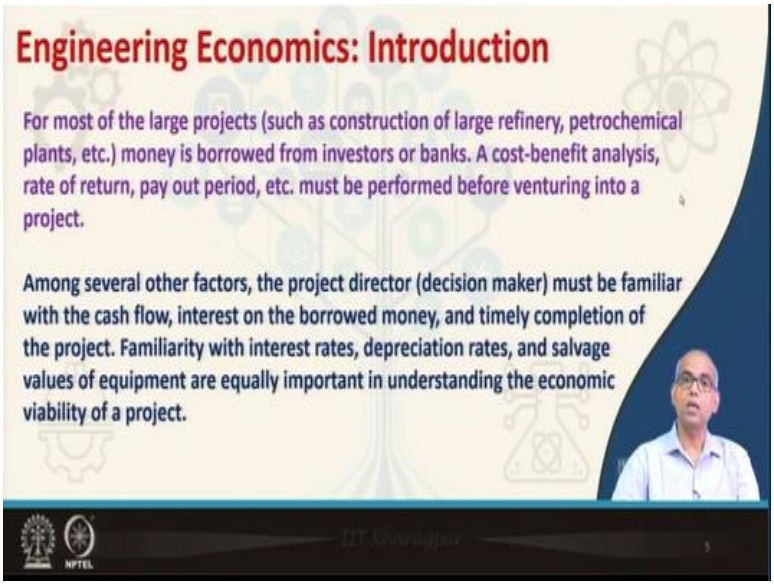

For most of the large projects such as construction of large refinery, large petrochemical complexes, etcetera money is borrowed from investors or banks. So a cost-benefit analysis, rate of return, payout period, and etcetera must be performed before venturing into a project. Among several other factors the project director or decision maker must be familiar with, the cash flow interest on the borrowed money and timely completion of the project.

Familiarity with interest rates, depreciation rates, and salvage values of the equipment are equally important in understanding the economic viability of the project.

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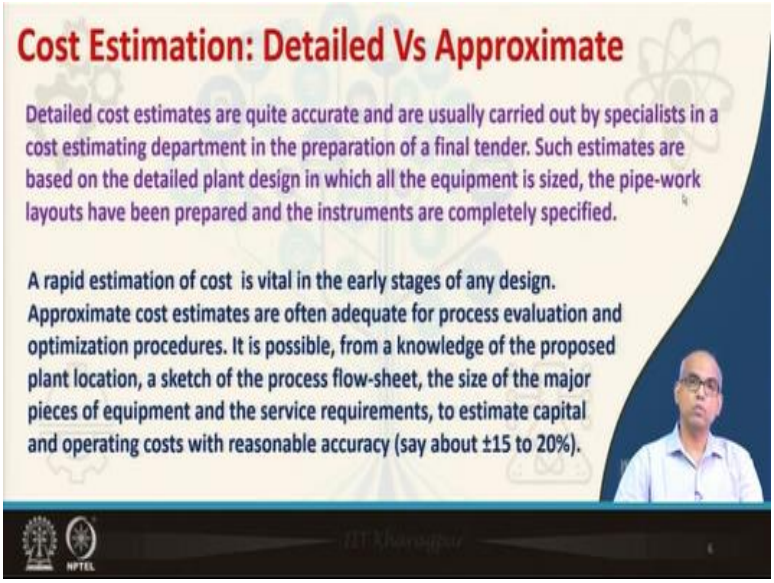

Now at the beginning itself let us make a distinction between detailed cost estimation and

approximate cost estimation. Detailed cost estimates are quite accurate and usually carried out by specialists or professionals in a cost estimating department in the preparation of a final tender, such estimates are based on the detailed plant design in which all the equipment is sized, the pipe work layouts have been prepared and the instruments are completely specified.

A rapid estimation of cost is vital in the early stages of any design. Approximate cost estimates are often adequate for process evaluation and optimization procedure. It is possible from a knowledge of the proposed plant location, a sketch of the process flow-sheet, the size of the major pieces of equipment, and the service requirements to estimate capital and operating cost with reasonable accuracy, say for example; within 15 to 20 %accuracy.

So every engineer should be familiar with the methods of quick estimation of the cost and it should be done. At the very early stage of any design process so that the designs which are not economically attractive can be discarded as soon as possible without inviting additional cost.

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Now, let us start with capital investment. What does capital mean capital means a stock of accumulated wealth? It is the savings that may be used as the owner decides, so one use of savings is investment to promote the production of useful goods to make additional income and profit. So before an industrial plant can be built a large sum of money must be available for purchase of land, purchase and install the required machinery, and equipment to build utility and service facility.

To construct an erect plant complete with all piping controls, and service for plant operation before sales revenue is available one sales revenue is available, so this part of this revenue will be coming back to the company treasury, and this can be used as working capital, will see more about this later.

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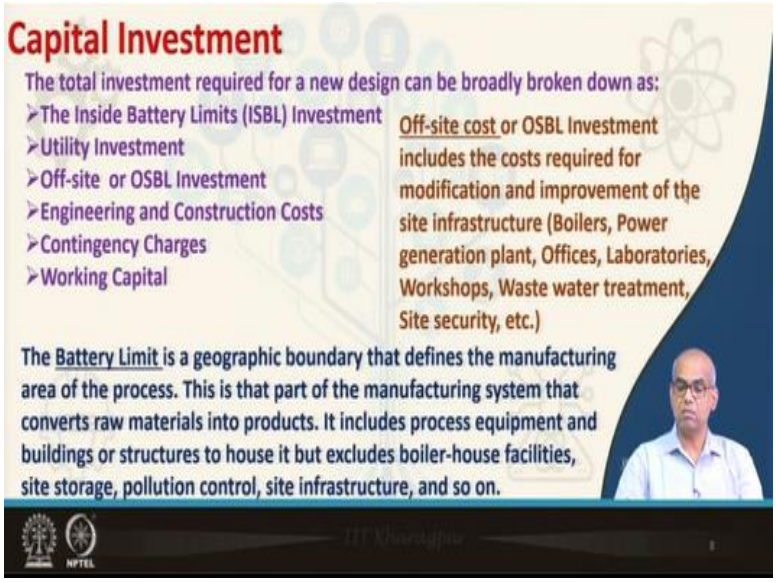

Now, the total investment required for a new design can broadly be broken down, into the following heads. The inside battery limits investment, or ISBL investment, utility investment, off-site or OSBL investment, engineering, and construction cost contingency charges and working capital. Now, let us define these two terms here inside battery limit investment, and off-site or OSBL investment.

The other terms you are familiar with utility investment engineering and construction cost contingency charges working capital will see later more about it. The battery limit is a geographic boundary that defines the manufacturing area of the process. This is the part of the manufacturing system that converts raw materials into products, so this is the main part of the plant.

This is where actual production is taking place; it includes process equipment, as well as the building or structure that houses, this process equipment, but it excludes boiler-house facilities, site storage, pollution, control, site infrastructure, wastewater, treatment etcetera. So every items that come under off-site investment they are outside the battery limit. Off-site cost or OSBL

investment includes the cost required for modification and improvement of the site infrastructure.

For example; boilers, power generation plant, offices, laboratories, workshops, waste water treatment, site security etcetera.

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Now let us classify the capital investment, we classify as fixed capital investment and working capital. Some of the fixed capital investment and working capital is known as total capital investment. The fixed capital investment is defined as follows, the capital needed to supply the required manufacturing and plant facilities is known as the fixed capital investment. These represents the total cost of designing, constructing and installing a plant and the associated modifications needed to prepare the plant site.

It is a once-only cost that is not recovered at the end of the project life, other than the scrap value. While working capital is the capital necessary for maintaining the operation of the plant. So fixed capital investment is the capital needed to supply the required manufacturing and plant facilities, while working capital is the capital needed for maintaining the operation of the plant. The total capital investment is some of fixed capital investment and working capital.

The fixed capital investment is further subdivided as manufacturing fixed capital investment also known as direct cost and non manufacturing fixed capital investment also known as indirect cost.

So total capital investment is fixed capital investment plus working capital and fixed capital investment is further divided as direct cost or manufacturing fixed capital investment and an indirect cost or non manufacturing fixed capital investment.

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Now, what are these non manufacturing fixed capital investments? Manufacturing fixed capital investment represents the capital necessary for the install process equipment with all components that are needed for complete process operation. For example; expenses for installation of all process equipment with all components, site preparation, foundations, piping, instruments, insulation, auxiliary facilities all these expenses will be considered as manufacturing fixed capital investment.

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Non manufacturing fixed capital investment represents the capital required for all plant components that are not directly related to the process operation and construction over it. So what are the items that will come under plant components that are not directly related to the process operation, their land, processing buildings, administrative, and other offices, warehouses, laboratories, transportation shipping, and receiving facilities, utility, and waste disposal facilities, shops and other permanent parts of the plant?

Under construction overhead we will have field office, supervision expenses, miscellaneous construction cost, home office expansions, engineering expenses, contractor's fees and contingencies.

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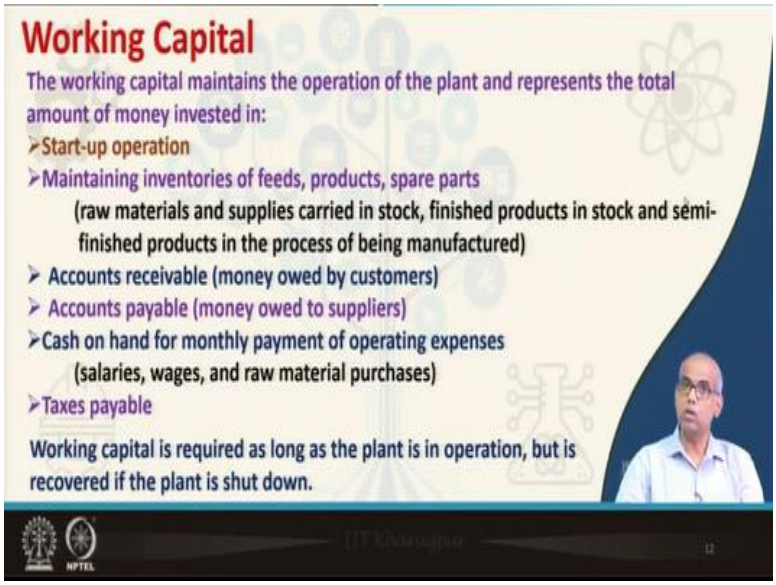

Now let us move on to working capital, so working capital maintenance the operation of the plant and represents the total amount of money invested in Start-up operation, Maintaining inventories of feeds, products, Accounts receivable. So this is the money company will get from the customers. Accounts payable this is the money company will pay to suppliers. Cash on hand for monthly payment of operating expenses, such as salaries, wages and raw material purchase, and taxes table.

So working capital maintains the operation of the plant and they represent the total amount of money invested under these heads. Working capital is required as long as the plant is in operation, but the working capital is recovered, when the plant is shut down at the end of the life cycle of the project but fixed capital is not. Fixed capital is a onetime investment and except for scrap value you are not going to recover.

The fixed capital while in principle working capital is required as long as plant is under operation and is recoverable when the plant is shut down.

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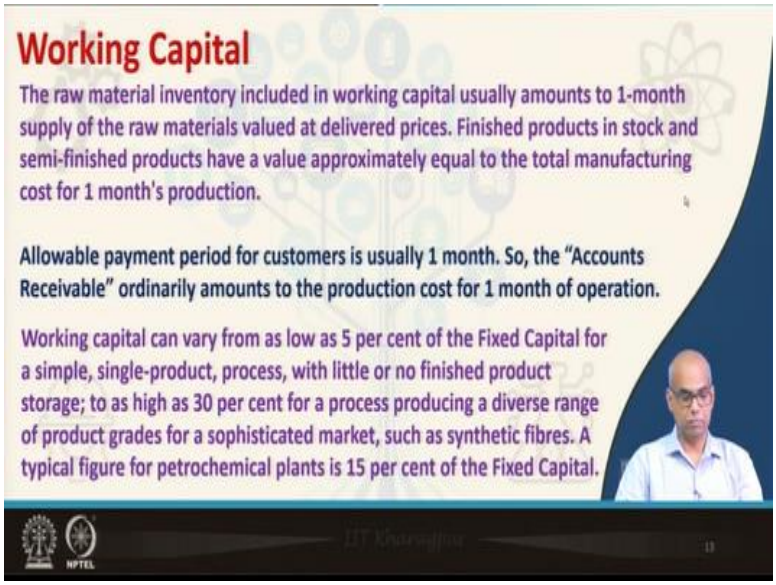

The raw material inventory included in working capital usually amounts to one month supply of the raw material valued at delivered prices. Finished products in stock and semi finished products have a value approximately equal to the total manufacturing cost per one month production. Allowable payment period for customers easily one month, so the accounts receivable ordinarily amounts to the production cost for one month of operation.

Working capital can vary from as low as 5%to as high as 30%, 5 %, and 30 %of the fixed capital. So, working capital can vary from as low as 5% of the fixed capital for simple single product process with little or no finished product storage and working capital can go as high as 30% of the fixed capital for a process producing a diverse range of product grades for a sophisticated market such as synthetic fibres. However a typical figure for a petrochemical plant is 15 %of the fixed capital.

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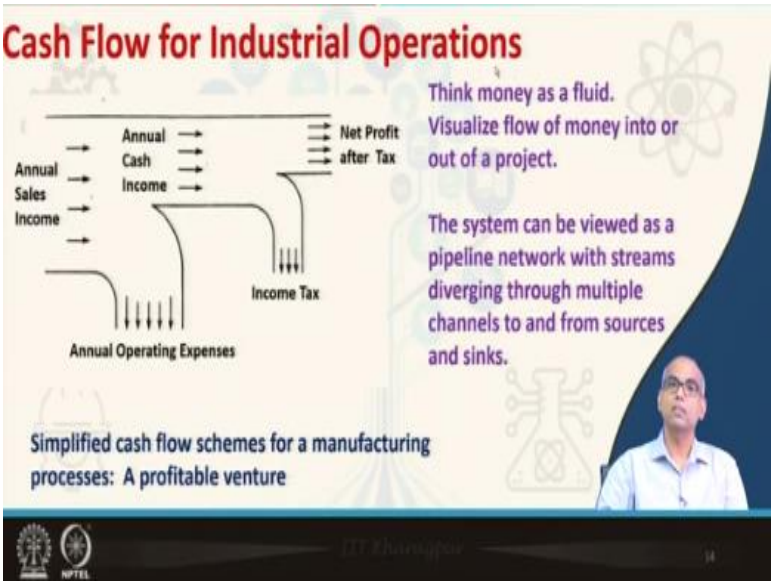

Now, we will talk about a concept called cash flow for industrial operations. Think money as a fluid, then you can visualize flow of money into the project or out of a project. The system can be viewed as a pipeline network with streams diverging through multiple channels and these are going to sinks or coming from sources, sinks are fun sources of money or fun. Let us consider this flow of annual sales income through this pipeline network.

So, annual sales income flows through the pipe and here there is an outlet which is annual operating expenses. So, all the annual sales income that enters the pipe does not come out as net profit. So, it is diverged as annual operating expenses. So, you have to meet annual operating expenses from the annual sales income after meeting annual operating expenses, you have annual cash income which starts flowing through the pipeline.

But again you see a part of this goes out through a side pipeline as income tax. After paying annual operating expense and income tax you get whatever is left and that is your net profit after tax. So, here we see a simplified cash flow scheme for a manufacturing process and you see that you are getting positive flow as net profit after tax. So, this is a profitable venture, what will happen if you are company invites losses?

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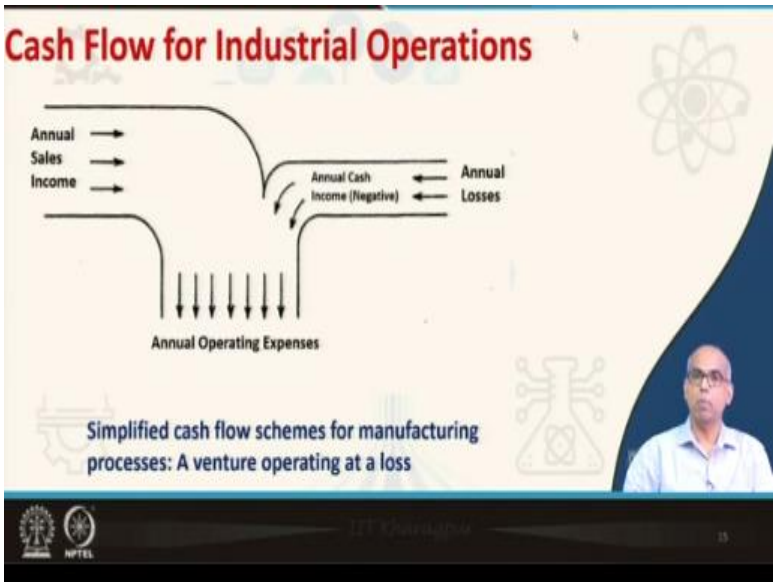

So, you have annual sales income and then you see what goes out as operating expenses is much more than your annual sales income or revenue. So, instead of profit here you are annual losses, which is actually a negative cash flow and there is no income you notice there is no income tax because you do not have income you have losses. So, this is a simplified cash flow scheme for a manufacturing process which is operating at a loss. So, now we will see two more schematic representations of the final CL situations of a plant.

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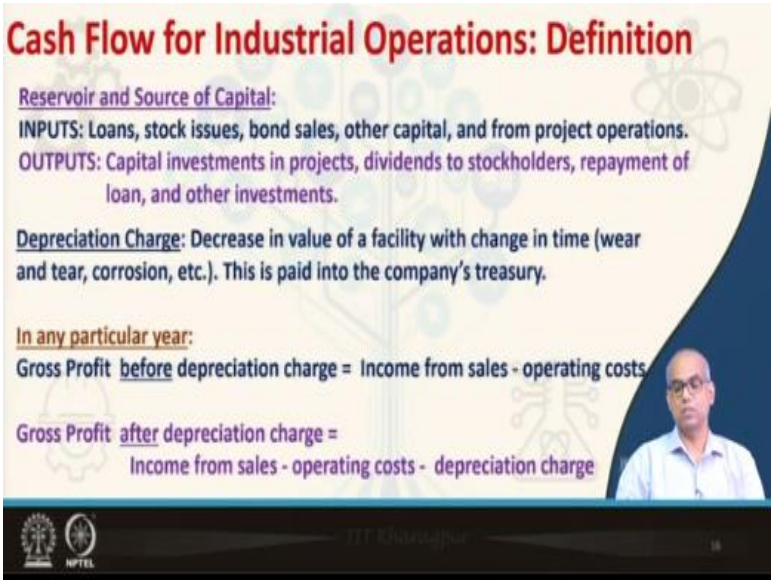

But before that, we will define certain terms. So, to start a company you need a reservoir of money or source of capital to start with. So to start with you need source of capital because you know that you need fixed capital investment, you need working capital. To support the

manufacturing as well as construction erection of the plant and then manufacturing and only when your company starts operating and you start selling products, you start making profit then there will be cash flow to the reservoir again.

Okay? So, we start with a reservoir of fund or source of capital. So, how you build this source of capital? So, what are the inputs to this source of capital? You can take loan from investors or bank, Stock issues, bond sales, other sources of capital. Stock issues mean shares your company can issue shares to the market. So, public in general can buy shares and you will get money to invest in your plant and also from project operations.

And what are the outputs from the source of capital? That means, where these funds will be utilized? Capital investment in the project, dividend to shareholders. When you make profit you share a part of your profit with the shareholders who are also investors in your company. You have taken loan so, you have to repay loan. So, that will be a source of output on the source of capital and you can also make other investments.

So, you will have a reservoir or source of capital with such inputs and outputs. Then let us define a term called depreciation or depreciation charge. This is the decrease in value of a facility with change in time due to wear and tear corrosion etcetera. So, depreciation is decreased in value of a facility with change in time. So, you buy a piece of equipment today, we say rupees X with time the value will decrease due to wear and tear and corrosion this is known as depreciation.

Depreciation is paid into the company's treasury. In a particular year gross profit before depreciation charge is defined as income from sales minus operating cost. Gross profit after depreciation charge is defined as income from sales minus operating cost minus depreciation charge.

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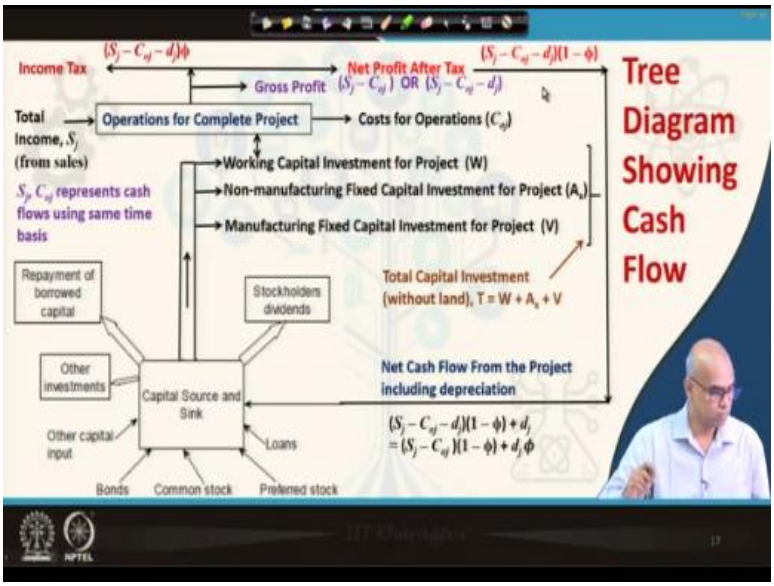

So, now we will first talk about a tree diagram showing cash flow. So, this cash flow here has an analogy with a tree. So, the trunk is the flow of the capitals to fix capital investment and working capital and at the root you have the capital source and the sink. So, this is the reservoir the company treasury source of capital. So, look at the inputs to this source, loans, stock, bonds, other capital input and also from the project operations.

What are the outputs from the source? The main output is manufacturing fixed capital investment and non-manufacturing fixed capital investment. Together they are fixed capital investment as well as working capital investment, Some are working capital investment and non-manufacturing fixed capital investment and manufacturing fixed capital investment gives you total capital investment note that land is not included here.

Often times, land is a small fraction of the total capital investment is not included here. In the next we will see another cash flow and there diagram to represent such financial situations of a plant where land will be included. Now, from the source the capital flows from manufacturing fixed capital investment, non-manufacturing fixed capital investment and the working capital. So, here we come to a stage where air completely erected the plant constructed an erected the plant and now the operations has started.

So, once operation has started you will have income from the sales. So, that it will be a cash flow, there will be cost of operations also; this is also a cash flow now both the cash flows are

represented using same time basis. Let us say rupees per hour rupees per year, etcetera. So, the fixed capital investment stops here. Then you will be supplying working capital. Now once operation starts you have income and then you have gross profit, which is the income minus the cost of operation.

Here depreciation is not included and if you include depreciation then sales income minus cost of operations minus depreciation. Now you have to pay tax. So, pay tax set the rate of five. So include depreciation and then pay tax. So, this is income tax that you pay. So, the remaining part of the profit is net profit after tax which goes back as the net cash flow from the project and if you want to include depreciation to this so, you add depreciation to this term, which is obtained like this.

Note that the other outflows from the capital sources, stockholders dividend, other investment dependent of loans or borrowed capital, etcetera. So, this is a tree diagram showing cash flow for an industrial operation.

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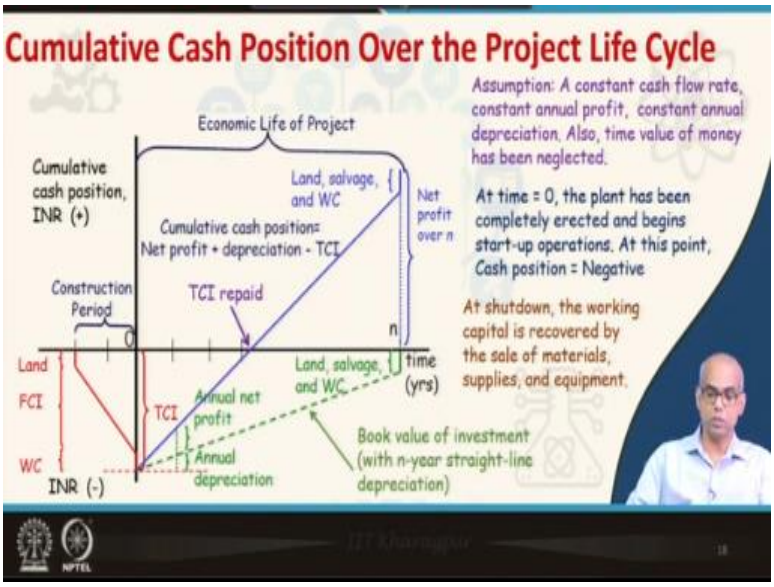

Now we will see another such representation but instead of using cash flow we will use cumulative cash position. So, here we are not representing cash flow, but we are representing cumulative cash positions with respect to time and this time will go up to the life of the project. Now if you look at this figure so, this is the access for cumulative cash position and this is the time axis, this is the zero time.

So, at time zero your plant has been completely constructed and erected and it begins startup operations at this point note that the cash position is negative, what is that? Land cost, fixed capital investment and the working capital. So, time t is equal to zero the cash position is negative and that amount is land cost plus x capital investment plus working capital negative. Okay? I mean as time increases you start making, productions, you sell it anywhere profit.

So, this profit will go back to the company treasury or the source of capital. So, you will start recovering the cost of land fixed capital investment or the working capital that means total capital investment. Now this line represents the cumulative cash position which is sum of net profit plus depreciation minus the total capital investment. Here we are assuming a constant cash flow rate, constant annual profit and constant annual depreciation.

Also, we are neglecting time value of the money we will discuss what is time value money in future classes? So, this figure represents the cumulative cash position which is net profit plus depreciation minus total capital investment. So, as time goes beyond zero your plan starts operating, you start selling products and you start making profits. So, part of that net profit goes back to the source of capital so you start repaying total capital investment.

So, a time will come when the cumulative cash position line will cross the time axis that means that at this point you have repaid the total capital investment. So, beyond that you start making profit. So, if this is the time corresponding to economic life of the project. So, you make profit from this time through this time and the net profit is this, then at shut down you can recover the capital by the sale of materials, supplies and equipment.

Land can also be sold or can be reused for some other plant. So, this figure also represents the concepts that we have discussed in the previous tree diagram, but in terms of cumulative cash positions.

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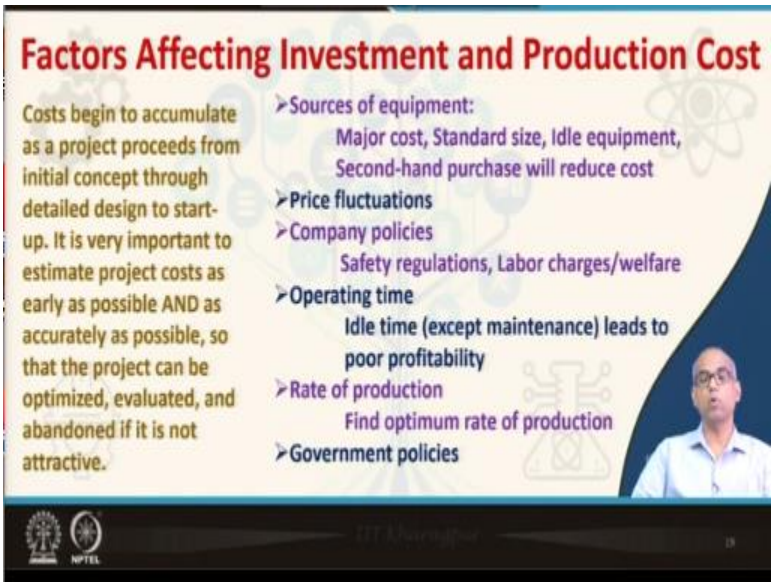

What are the factors affecting investment and production cost? Cost begins to accumulate as a project proceeds from initial concept through detailed design to start up. It is very important to estimate project costs as early as possible and as accurately as possible, so that the project can be optimized, evaluated, and abandoned if it is not attractive. So, these are the several factors sources of equipment, price fluctuations, company policies, operating time, rate of production and government policies.

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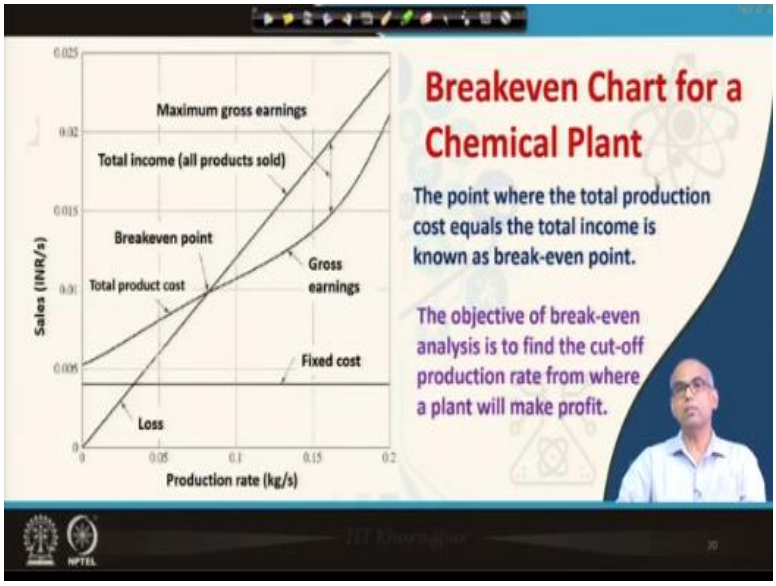

Among these let us briefly talk about rate of production this leads to a concept called breakeven point. Now here we plot sales versus production rate, this represents fixed cost and this represents total product cost and this represents total income. Now, if we look at here at this

point, the total production cost equals the total income. So, this point is known as breakeven point.

The objective of breakeven analysis is to find the cut off production rate from where the plant will start making profit. Now for production rate below this point you make loss because your total income from all products sold is less than the total product cost but beyond this point you start making profit. Because your total income is more than the total product cost and you also know that the earning is different at different production rate.

So, you definitely would like to operate at the production rate that gives you maximum gross earning. So, that is this, so this is the use of the breakeven point, The point where the total production cost equals the total income is called breakeven point and this is the point beyond which if you operate you will start making profit with this we stop our discussion today.