So, basically that is what is this economic life. Economic life means it is a time during which the cost of holding the machine will be minimum. So, beyond the economic life you can see that there will be increasing costs associated with the machine, either due to increase in the operating cost that is repair and the maintenance costs or increase in downtime costs or increasing obsolescence cost.

All these things will be resulting in the shooting up of your total cost of the machine. So, which is not desirable that is why when the cost is meaning of itself, we should try to replace the old machine with the new machine. So, that we do not enter into loss. So, now, let us work out an example.

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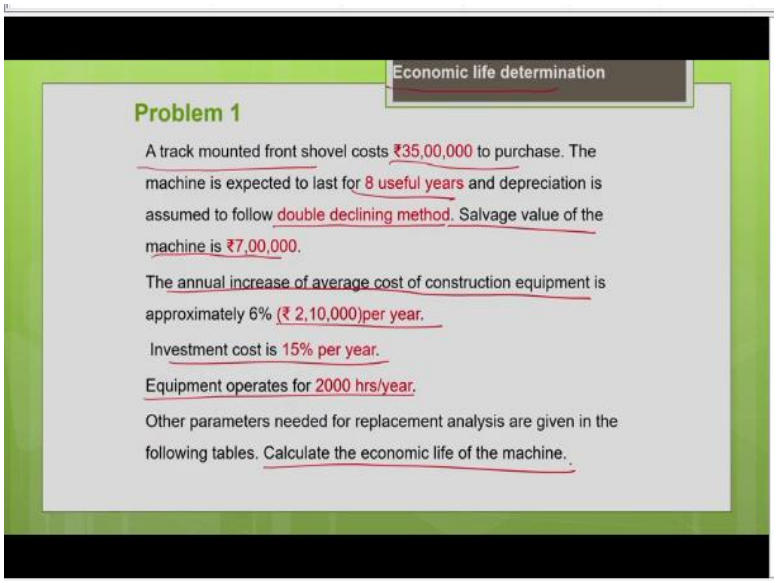

In this example, we are going to see how to estimate the economic life of the machine. So, basically, so, here we are going to estimate economic life for a track mounted front shovel. The purchase price is 35,00,000. So, the machine is expected to last for 8 useful years and the depreciation is assumed to follow double declining balance method. So, we are going to follow double declining balance method to estimate the depreciation.

And at the end of the 8 years you will be able to sell the machine at the cost of rupees 7,00,000. That means the salvage value of the machine is 7,00,000. So, due to inflation, you can see that annual increase of the average cost of the equipment is approximately 6%. That means, the

machine cost is going to increase by 2,10,000 every year, due to the effect of inflation. So, this also needs to be considered during the replacement analysis.

And the cost of investment is 15% per year. So, this you can consider it as a percentage of the book value of the machine, then the equipment is going to operate for 2000 hours in a year. So, the annual usage is given 2000 hours. So, the other parameters needed for the replacement analysis are given in the following tables, we are going to discuss that. So, we have to estimate the economic life of this machine.

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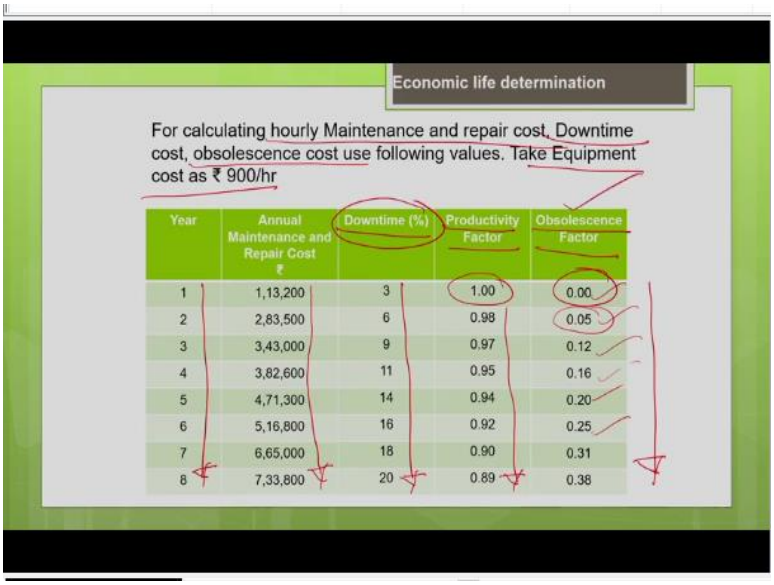

So, what are the other parameters needed for the replacement analysis which are given as input data for this problem, let us see. So, for calculating the hourly maintenance and the repair cost, downtime cost and the obsolescence cost of the machine, we have to use the following values and the equipment cost is given approximately as rupees 900 per hour. So, every year maintenance and repair costs is given for the entire useful life of the machine.

So, you can see that the annual maintenance and repair costs is increasing with the age of the machine, as the age of the machine increases, you can see that maintenance and repair cost is increasing. And another thing I hope you remember what is downtime? Downtime is nothing but the non availability of your machine for the productive work. So, it may be either due to the breakdown of the machine.

So, mostly it is due to the breakdown of the machine, machine may be spending its time in the repair yard and it will not be available for the productive job. So, that time is called as a downtime of the machine. So, in order to estimate the downtime costs, we express it as a percentage of the operating costs of the machine or the equipment cost of the machine. So, you can see that, with the increase in age of the machine your downtime costs is also increasing.

As the machine becomes older, you can see the time it spends in the repair yard will be more. So, the downtime percentage is more and another thing as I told you, when the machine is not available for the productive job, so you will be facing some loss in productivity. So, that productivity factor is also given. So, maybe for the first year there is no change in productivity, but from the second year onwards you can see that there is loss in productivity of the machine with the increase in the downtime of the machine.

So, all this loss in productivity is going to result in increase in the cost of the machine. We are going to estimate in the upcoming slides. So, another thing to be noted is the obsolescence cost is also important as the age of the machine increases, it becomes obsolete you know that. So, there may be different reasons for the obsolescence either due to technological obsolescence, that is due to wear and tear, its productivity may get reduced, or it may be even due to market obsolescence.

The customer tastes would have changed, the customer will be opting for more advanced machines with more ease of operation, with more safety features, with more updated technology. So, it means if your machine is obsolete. There are so many competitive models on the market which are having updated technological features. So, these obsolescence factors are available from the literature for different types of equipments.

And you can see that with increase in age your obsolescence factor is increasing. For the first year, it is 0, it means machine is not obsolete. By the end of second year you can see there is a percentage of obsolescence. And your obsolescence factor increases with the age of the machine,. It is clearly evident; you can get this data from the literature for different types of equipment. This we are going to use it in the estimation of obsolescence cost.

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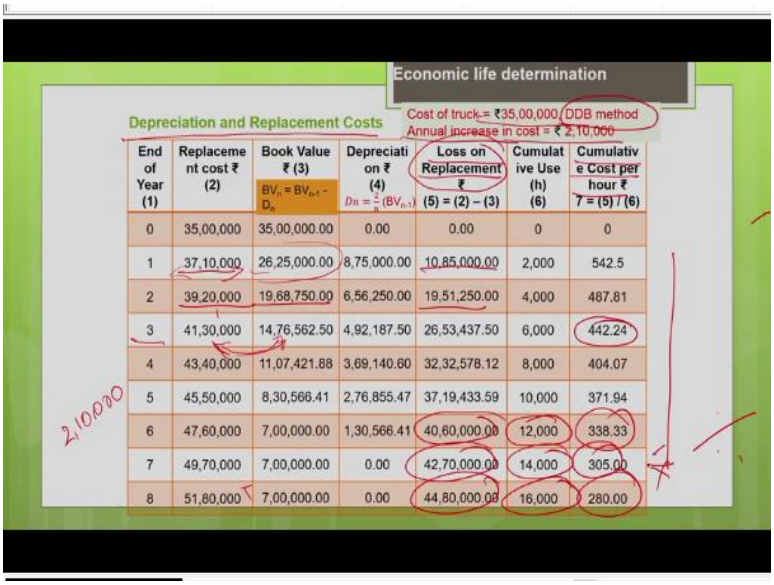

So, now let us work out the cost associated with the machine from the replacement analysis perspective. So, as I told you, we are supposed to consider all the components of the cost associated with the machine, so that you can have an accurate estimation of the optimum replacement time. So, first we are going to estimate the depreciation and the replacement cost associated with this machine.

So, as I told you due to inflation, there is an increase in cost of the machine every year. So, it is given as input data in the problem that the initial cost of the truck is 35,00,000 and the annual increase in the cost you can see that it is 2,10,000 every year, annual increase in the cost is rupees 2,10,000, due to the inflation. So, after 1 year, if you want to replace the particular machine, the increase in the cost will be 2,10,000. So, initial cost is 35,00,000, at the end of one year if we want to replace a machine, so, we have to spend 37,10,000 to replace the machine.

Replacement Cost for 1st year = 35,00,000 + 2,10,000 = 37,10,000 rupees

Replacement Cost for 2nd year = 37,10,000 + 2,10,000 = 39,20,000 rupees

Replacement Cost for 3rd year = 39,20,000 + 2,10,000 = 41,30,000 rupees

So, like that every year the cost increases by 2,10,000 due to inflation, this you have to take into account when you do the replacement analysis. Another important thing you need to see is, every

year the machine is depreciating, there is a loss of book value. So, in this problem we are going to estimate the depreciation using double declining balance method. So, I hope you remember what was the formula used for the double declining balance method to estimate the depreciation.

$$D_n = \frac{2}{n} \times (BV_{n-1})$$

Say, for the first year, I have to estimate the depreciation now, D 1 is nothing but 2 by n into book value of the previous year, book value at the end of the previous year, it is nothing but the book value at the beginning of the current year. So, both are same, book value at the end of the previous year is same as the book value of the beginning of your current year, for which you are calculating the depreciation.

$$D_1 = \frac{2}{8} \times (35,00,000) = 8,75,000 \text{ rupees}$$

$$BV_1 = 35,00,000 - 8,75,000 = 26,25,000 \text{ rupees}$$

You subtract both, you will get the book value at the end of first year, it is nothing but 26,25,000. So, book value at the end of the first year. So, to get that you have to subtract the book value of the beginning of the first year and these 2 and depreciation for the first year, if you subtract these 2 you will get the book value at the end of the first year. So, this is how you calculate. So, that is why it is given, here you can see the book value for the current year is nothing but book value at the end of the previous year minus a depreciation for the current year.

So, book value at the end of the previous year is same as the book value at the beginning of the current year. Now let us calculate the depreciation for the second year.

$$D_2 = \frac{2}{8} \times (26,25,000) = 6,56,250 \text{ rupees}$$

$$BV_2 = 26,25,000 - 6,56,250 = 19,68,750 \text{ rupees}$$

So, if we subtract both we will get the book value for the second year as 19,68,750, So, this is the book value the at the end of second year. So, hope you understand. So, how are you calculating that? So, basically, if you subtract the book value at the end of the first year minus depreciation for the second year you will get the book value at the end of the second year. So, one more example, sample calculation will show so that your understanding will be better. So, now, we are going to calculate the depreciation for the third year.

$$D_3 = \frac{2}{8} \times (19,68,750) = 4,92,187.5 \text{ rupees}$$

It is nothing but book value at the end of second year minus depreciation for the third year.

BV_3 = 19,68,750 – 4,92,187.5 = 14,76,562 rupees

So, this is how you are going to estimate the book value and the depreciation for the 8 years. So, the remaining calculations you can do. Now, let us say what is the loss associated with the replacement? As I told you due to inflation, there is an increase in costs every year. So, at the end of first year I told you there is an increase in cost of 2,10,000.

Now, your new cost is 37,10,000, there is an increase in costs, there is a loss actually. Similarly, there is a decrease in value of machine due to depreciation with time. So, at the end of first year, the book value is 26,25,000, that means from 35,00,000 it has gone down to 26,25,000. Similarly, the initial price has increased from 35,00,000 to 37,10,000. If you subtract both these 2 you can find the loss of replacement.

So, basically you can see here, see basically the end of first year if I wanted to replace the cost of the machine is 37,10,000 due to inflation from 35,00,000 it has increased by 2,10,000. But at the end of the first year, if I replace my old machine with a new machine, the inflow I can get is only 26,00,000 because your machine has depreciated 26,25,000.

Loss for year 1 = 37,10,000 – 26,25,000 = 10,85,000 rupees

Loss is nothing but 10,85,000. This is your loss, loss on replacement, if I replace the machine at the end of first year. Similarly, if I replace machine at the end of second year, at the end of second year, you can see the machine has increased in cost by 39,20,000 due to inflation, and the book value has gone down to 19,68,750. So, this is your inflow actually. So, actual loss will be for the replacement at the end of second year will be 19,51,250.

Loss for year 2 = 39,20,000 – 19,68,750 =19,51,250 rupees

So, this is a loss on replacement at the end of second year. Similarly, you can calculate for the third year

Loss for year 3 = 41,30,000– 14,76,562 = 26,53,437 rupees

So, already this is on cumulative basis only. Now, you find the cumulative use of the machine every year you know the machine is being used for 2000 hours.

The annual usage of machine every year is 2000 hours. So, you find the cumulative use of the machine say for second year, 2000 + 2000 it is 4000, for third year 4000 + 2000 it is 6000. Now, for the fourth year the cumulative use will be 6000 + 2000 hours it is 8000 hours. Like that you find the cumulative use of the machine. This entire replacement analysis will be on cumulative basis, I will explain you later, we have to do it on cumulative basis only.

So, I will explain the reason later. Now, you find what is the cumulative cost per hour? Cumulative cost per hour is nothing but the cumulative cost on replacement. So, the cumulative cost on replacement. So, you can see here the cumulative cost on replacement,

Cumulative cost on replacement, end of the first year = $\frac{1085000}{2000}$ = 542.5 rupees per hour

That means, at the end of the first year the depreciation and the replacement cost associated with the machine is 542.5 per hour. Similarly, at the end of second year if we wanted to find. So, the depreciation on the replacement cost you can see that it is 19,51,250. At the end of second year the cumulative use is 4000 hours. So, the replacement costs associated with this machine per hour is 487.81 for 2 years.

Cumulative cost on replacement, end of the second year = $\frac{19,51,250}{4000}$ = 487.81 rupees per hour

So, the replacement costs associated with this machine per hour is 487.81 for 2 years. We are calculating on the cumulative basis. Similarly, for the third year,

Cumulative cost on replacement, end of the third year = $\frac{26,53,437}{6000}$ = 442.24 rupees per hour

You can see the cost per hour associated is 442.24 per hour for the past 3 years. So, like this you calculate the depreciation the replacement costs for 8 years, so the entire useful life of the machine.

So, one thing you can see that the depreciation and the replacement cost is decreasing with time, as the usage of the machine increases, as the cost is distributed over a greater period, as the cost is distributed over a greater period, you can see that the costs per hour is getting reduced. So, mostly the ownership cost is getting reduced with time because as the usage increases, because the cost is getting distributed over a greater period.

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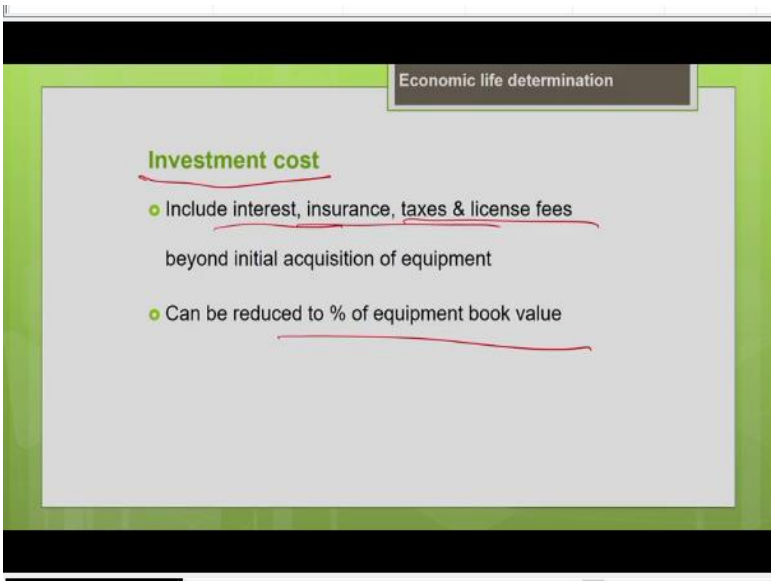

Now comes the investment cost. So, this investment cost includes all the costs associated with the investment, like the interest you pay for the loan, your insurance taxes, license fees, everything we are adding under investment. So, it can be calculated as a percentage of the equipment book value. So, in this problem, the cost of investment is given as 15% per year.

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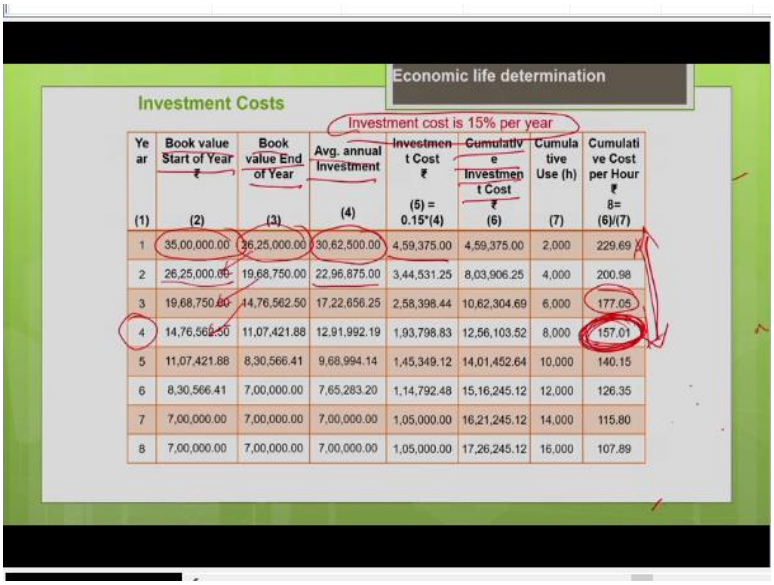

Year (1)	Book value Start of Year ₹ (2)	Book value End of Year (3)	Avg. annual Investment (4)	Investment Cost ₹ (5) = 0.15*(4)	Cumulative Investment Cost ₹ (6)	Cumulative Use (h) (7)	Cumulative Cost per Hour ₹ 8= (6)/(7)
1	35,00,000.00	26,25,000.00	30,62,500.00	4,59,375.00	4,59,375.00	2,000	229.69
2	26,25,000.00	19,68,750.00	22,96,875.00	3,44,531.25	8,03,906.25	4,000	200.98
3	19,68,750.00	14,76,562.50	17,22,656.25	2,58,398.44	10,62,304.69	6,000	177.05
4	14,76,562.50	11,07,421.88	12,91,992.19	1,93,798.83	12,56,103.52	8,000	157.01
5	11,07,421.88	8,30,566.41	9,68,994.14	1,45,349.12	14,01,452.64	10,000	140.15
6	8,30,566.41	7,00,000.00	7,65,283.20	1,14,792.48	15,16,245.12	12,000	126.35
7	7,00,000.00	7,00,000.00	7,00,000.00	1,05,000.00	16,21,245.12	14,000	115.80
8	7,00,000.00	7,00,000.00	7,00,000.00	1,05,000.00	17,26,245.12	16,000	107.89

Investment cost is given as 15% per year. Now, we are going to calculate the investment costs for the entire useful life of the machine. And we will calculate the investment costs as a percentage of the book value of machine. Here we are taking the average book value for every year, you are

going to calculate. So, I need to know the book value at the beginning of the year and book value at the end of the year to find the average book value of the particular year.

So, obviously book value at the beginning of year is a purchase price 35,00,000, book value at the end of every year, you can get from the previous table, we have calculated the book value at the end of every. So, this column you can use it for this investment calculation book value the end of every year can be obtained from this table. So, we are going to use it and another thing as I told you book value the end of first year is same as the book value to the beginning of the second year.

Similarly book value at the end of second year is same as the book value at the beginning of third year. So, it goes on like this. Now, you find the average book value for every year, average book value for every year is nothing but

Average for year 1 = 35,00,000 + 26,25,000 = 30,62,500 rupees

Average book value for the first year is 30,62,500. Now, you calculate the investment cost. So, investment cost is nothing but 15% of average book value of the particular year.

Investment cost for year 1 = 0.15 × 30,62,500 = 4,59,375 rupees

So, this is how we have to calculate the investment costs for every year. So, one more sample calculation I will show, so that you will understand better. Now, the average book value for the second year,

Average for year 2 = 26,25,000 + 19,68,000= 22,96,875 rupees

So, this is your average book value for this you calculate the investment cost. So, investment costs is nothing but 15% of the average book value,

Investment cost for year 2 = 0.15 × 22,96,875= 3,44,531.25rupees

So, this is your investment cost for a second year. So, like this you can calculate the investment costs for all the years. Now, you find the cumulative investment. So, you can easily find the cumulative investment. So, investment for the first year added to the second year you will get you will get cumulative investment at the end of second year.

So, cumulative investment at the end of second year added to the third-year investment, you will get the cumulative investment at the end of third year. So, like that you keep on adding you will get the cumulative investment. Now, the cumulative usage now, every year the usage is 2000 hours

add 2000 + 2000, 4000 + 2000, 6000. So, keep on adding it you will get the cumulative usage of the machine for every year.

So, the entire replacement analysis is on cumulative basis only. So, now you can see the cumulative cost per hour. So, how do you find the cumulative investment cost per hour? So, cumulative investment costs is

$$\textbf{Cumulative Investment cost, end of the first year} = \frac{4,59,375}{2000} = \textbf{229.69 rupees per hour}$$

So, this is your cumulative cost per hour for the first year. Similarly, find the cumulative cost per hour for the second year.

$$\textbf{Cumulative Investment cost, end of the second year} = \frac{8,03,906.25}{4000} = \textbf{200.98 rupees per hour}$$

$$\textbf{Cumulative Investment cost, end of the third year} = \frac{10,62,304}{6000} = \textbf{177.05 rupees per hour}$$

So, basically so what I am trying to say is if you are going to hold your machine with you for 3 years, say for example, 3 years, the cumulative investment cost per hour for the 3 years is 177.05. Similarly, if you are going to hold your machine with you for 4 years, the cumulative investment cost per hour for the 4 years will be 157.01. So that is why we are trying to find cumulative basis so that we can get a clear picture for the replacement. So, this value indicates a cumulative investment cost for the past 4 years per hour.

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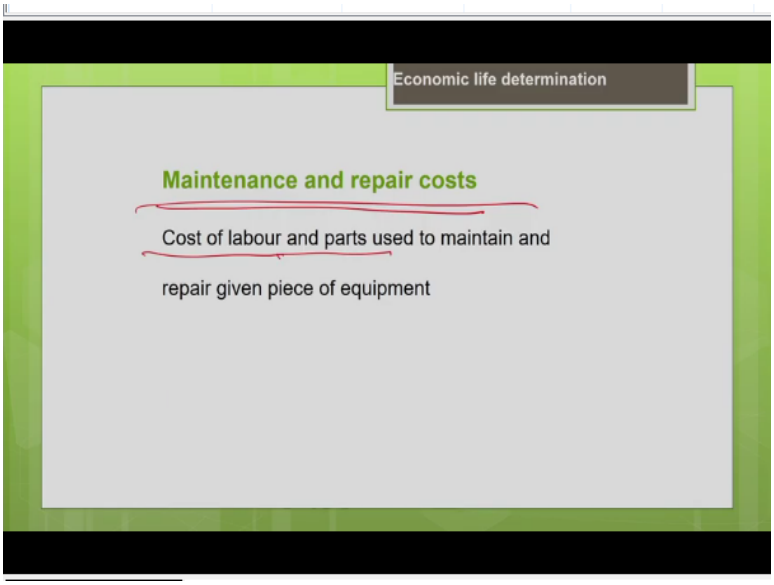

Now, let us calculate the next important component of the equipment cost. It is nothing but your maintenance the repair cost. So, as you know all the costs associated with the repair and the maintenance like the cost of the labour you engage for the repair work and the replacement parts, the costs associated with the replacement parts, everything will come into the maintenance and repair.

So, basically for a very big project site, you may have your own maintenance yard, you have a maintenance facility and you might engaged a labor for doing the regular maintenance or the periodic maintenance for your machine. So, the costs associated with those things will be included under the maintenance of the repair cost. So, as you know, with increase in the age of the machine, you can see that the maintenance and the repair costs will increase.

But in the previous table do remember. So, the investment cost you can see with increase in age of the machine, your accumulated cost per hour is decreasing, as I told you the reason, so, when the investment cost is distributed over a greater period, when the cost is distributed over a greater period, you can see that the cost will reduce. As the usage is increasing, you can see that the cost is reducing with the time.

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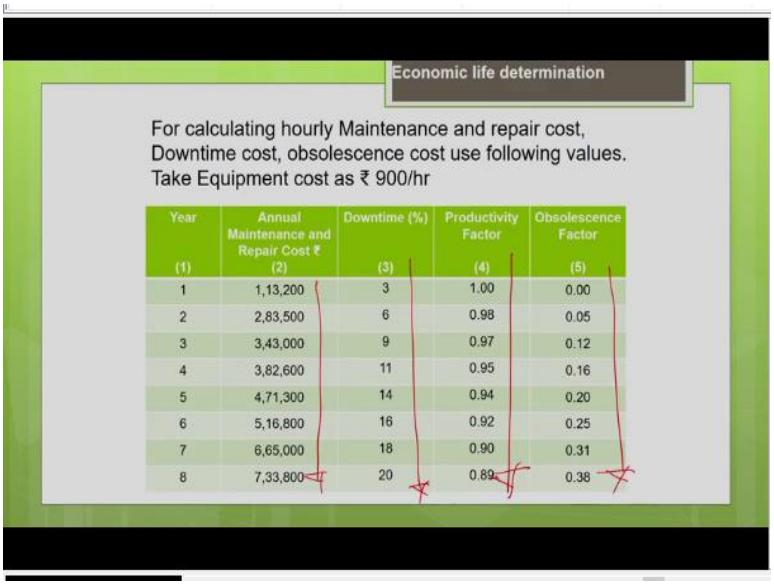

But in the case of operating costs, the maintenance and repair costs, downtime costs, you can see that your costs will increase with the age of the machine. So, the thing you have to noted very

carefully. Now let us calculate the maintenance and repair costs. So, this table I showed you already, this is the input table, input value is given in the question, every year maintenance and repair costs is given, you can see that the maintenance of the repair costs is increasing with the time duration.

Downtime cost is also given, it is increasing with the age of the machine, the productivity loss is increasing, there is a loss of productivity with age of the machine and the obsolescence factor is increasing with the age of the machine. Let us calculate all these costs in the upcoming slides.

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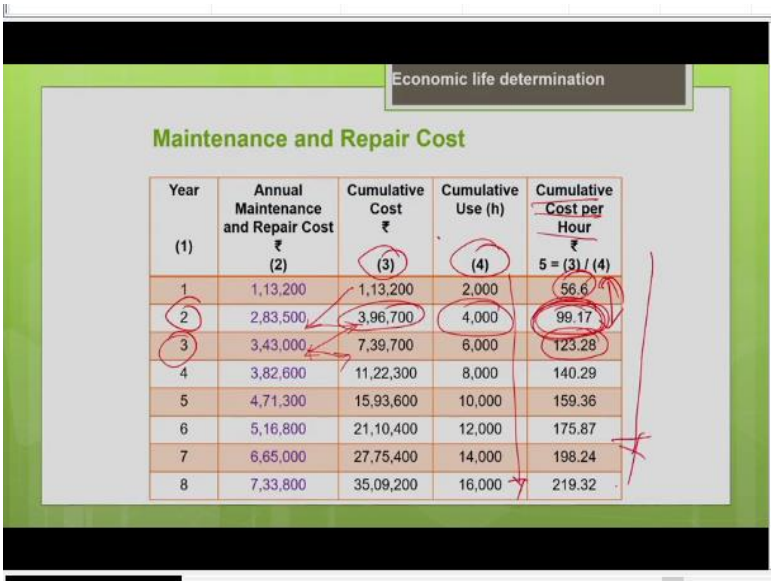

Year (1)	Annual Maintenance and Repair Cost ₹ (2)	Cumulative Cost ₹ (3)	Cumulative Use (h) (4)	Cumulative Cost per Hour ₹ 5 = (3) / (4)
1	1,13,200	1,13,200	2,000	56.6
2	2,83,500	3,96,700	4,000	99.17
3	3,43,000	7,39,700	6,000	123.28
4	3,82,600	11,22,300	8,000	140.29
5	4,71,300	15,93,600	10,000	159.36
6	5,16,800	21,10,400	12,000	175.87
7	6,65,000	27,75,400	14,000	198.24
8	7,33,800	35,09,200	16,000	219.32

The first one we are going to calculate is your maintenance and the repair cost. So, every year annual maintenance and repair cost is given. Now, you find the cumulative cost because everything is done on cumulative basis. Find the cumulative maintenance and the repair costs for every year, you just add it. The first year the cost with the second year cost, you add it. So, you are going to add the first year maintenance and repair cost. So, with this second year cost, if you add you will get cumulative cost at the end of second year.

Similarly, cumulative costs at the end of second year add it with the cost of third year you will get the cumulative cost the end of third year. So, like that to keep up the calculating you know the cumulative usage of machinery every year it is 2000 hours, we can add it. Now similarly, you find

the cumulative cost per hour, you are going to divide the third column by the fourth column to get the cumulative cost per hour,

$$\textbf{Cumulative cost, end of the first year} = \frac{1,13,200}{2000} = \textbf{56.60 rupees per hour}$$

Similarly, for the second year,

$$\textbf{Cumulative cost, end of the second year} = \frac{3,96,700}{4000} = \textbf{99.17 rupees per hour}$$

So, if you are going to hold your machine for 2 years, your accumulative repair and maintenance costs will be 99.17 rupees per hour for the past 2 years. Similarly, if you are going to hold it for 3 years, your cumulative repair and maintenance will be 123.28 rupees per hour for the past 3 years.

So, that is way we are calculating in the cumulative basis. And you can clearly see that your maintenance and the repair cost is increasing as the age of the machine increases.

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Now we are going to calculate the downtime costs of the machine. So, because of non availability of the machine for a productive job, what is the cost associated with that we are going to calculate. So, the downtime percentage is given, the input as the input data for this problem. So, we are going to calculate the downtime costs as a percentage of the equipment cost. So, equipment cost has given as approximately 900 rupees per hour. So now you calculate the downtime cost.