Construction Methods and Equipment Management
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Lecture-15
Earth Moving Equipment-Trucks

Hello everyone I welcome you all to the lecture 15 of this course construction methods and equipment management. So, in this series of lecture on the earth moving equipment today we are going to discuss about the trucks.

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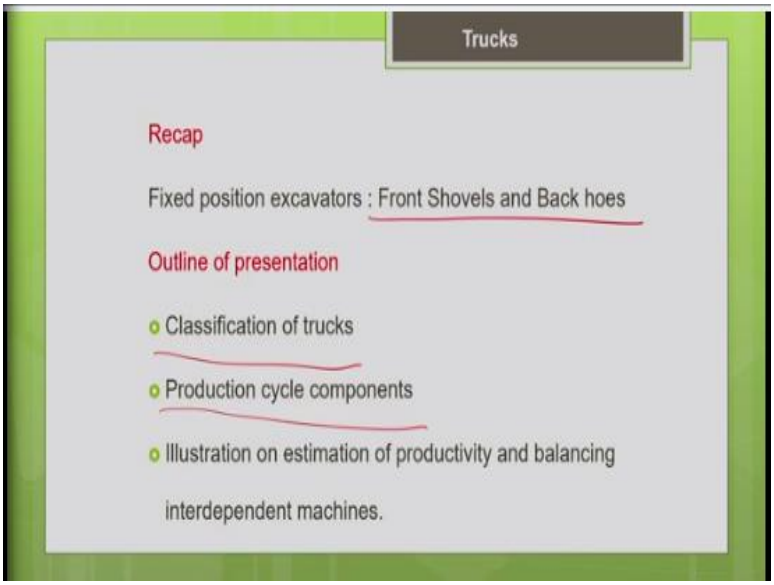

So, in the last lecture we discussed about the fixed position excavators that is front shovels and the backhoes**.** So, let us look into the outline of today's presentation, in today's presentation we will be discussing about the types of trucks and we will define what is the production cycle of the truck, what are all the components of the production cycle, let us see how to estimate the productivity of trucks.

And we will work out some problems on how to balance the interdependent machines. So, as you know that the trucks and the loaders are going to work together, how to balance size of the machines and how to balance the number of trucks for the loader? So, we will work with some examples in this regard.

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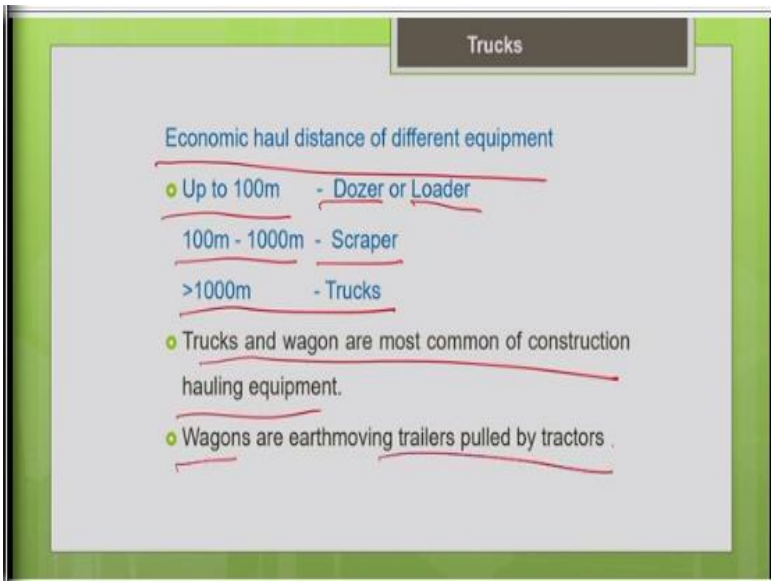

So, basically for any earth moving equipment we are more concerned about the economic haul distance of the equipment. So, as you know that different equipment has their own economic haul distance. So, in the early lectures I have discussed that with bulldozer has an economic haul distance up to 100 meters. And your loader is say, crawler mounted loaders will have an economic haul distance of less than 100 meters.

So, but your scraper has a better economic haul distance say it is good in loading as well as in hauling, so it can have a haul distance up to 1000 meters. But for haul distance greater than 1000 meter we are supposed to select the truck. So, truck and wagons are the most common of the construction hauling equipment, so they are the commonly used hauling equipment. So, what is this wagon, wagons are nothing but earth moving trailers which are pulled by tractors.

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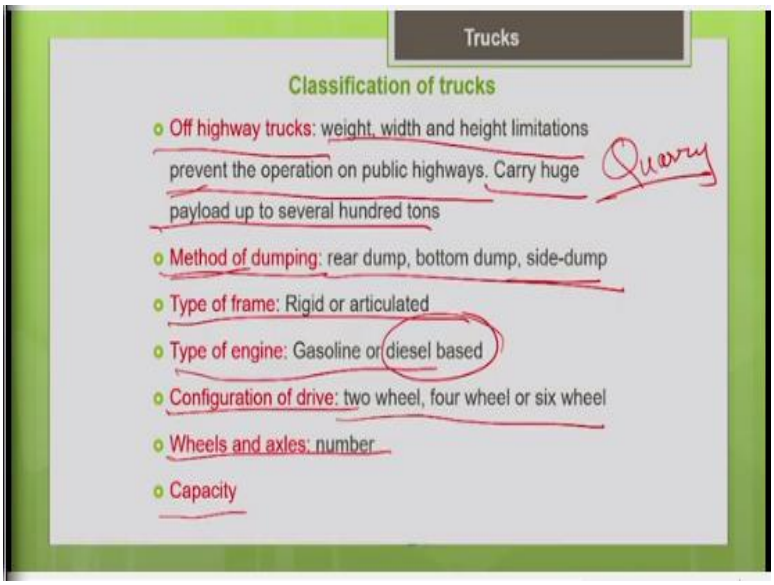

So, let us now look into the classification of trucks. So, in different context we can have different types of classification of trucks. So, basically some trucks are permitted on the highways but some trucks are not permitted on the public highways**.** So, those which are not permitted on the public highways we call it as off highway truck, why they are not permitted because their weight, width and height.

So, or beyond the limitations which is the permissible for the public highway, these are very huge trucks whose weight, width and height are too high. So, that prevents it is operation on the public highways. But obviously the advantage will be it can handle huge capacity, it can carry huge payload up to several hundred tons. The productivity of this truck is going to be very high, so very commonly you can see these trucks in quarry, so that is why it is also called as the quarry truck.

So, these trucks are very huge in size as I mentioned just now. So, commonly you can find it in the quarry, I will show you the pictures later. So, based on the method of dumping you can classify the truck into rear dump, bottom dump and side dump. Some trucks can dump the material at the rear end, some can dump the material through opening at the bottom, some can dump the material through the sides**,** so depending upon that we can classify.

Then depending upon the type of frame, as we discussed for the earlier missions also, here also we have rigid frame and articulated frame. And based upon the type of engine either it can be gasoline

or diesel-based engine, but more commonly you can see that most of the trucks are diesel-based engines. Then based upon the configuration of drive**,** this also we have discussed earlier, like how many axles are powered and the corresponding wheels will be driving wheels**.**

So, based upon how many wheels are driving, you can call it as 2-wheel drive, 4-wheel drive or 6-wheel drive. And depending upon the number of wheels and number of axles in the truck also you can classify. And depending upon the capacity of the truck, that is a capacity of the dumb body you can classify the truck**.** So, there are different means by which you can classify the truck.

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So, this is the picture of the off-highway quarry truck. As I told you it is commonly used in quarry, it is not permitted on public highways because it is size and weight is greater than the limitations allowed for the public highways. And one thing you can note that is, it will not have a tailgate, so that is why you can see that the body floor will be sloping upward, you can see it is sloping upward. This kind of arrangement facilitates easy loading of the truck with the loader**,** so that is why it has this shape.

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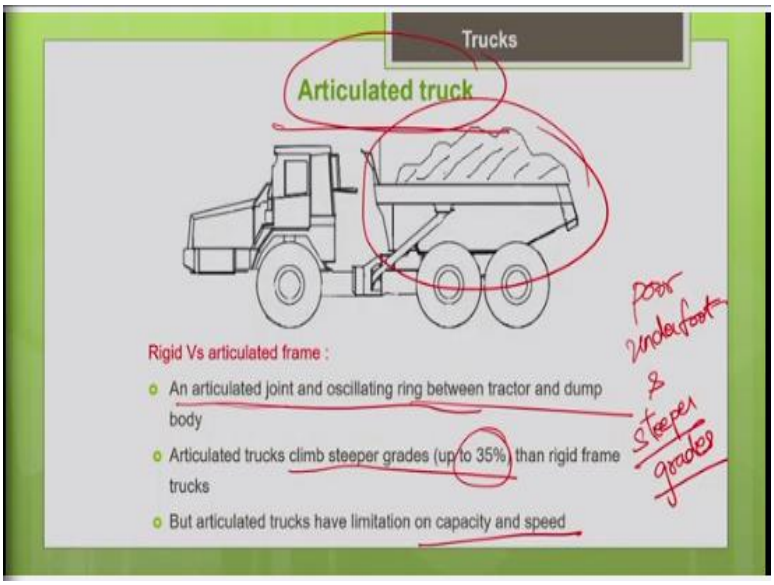

So, the next type is based on the frame. As we mentioned earlier, we have rigid frame and articulated frame. Basically articulated frame is there will be a pivot joint, so the machine will be hinged between the front part and rear part, that permits the articulation, it will have a better turning ability when compared to the rigid frame. So, you have a articulated joint and an oscillating ring between the tractor and the dumb body, so this is the dump body.

So, between the tractor and the dumb body you have the articulated joint, so that will facilitate better articulation. So, this is commonly used for poor underfoot conditions, so poor underfoot conditions in the sense the terrain is very bad and you have to climb steeper grades. In that case you have to go for this articulated truck for tough conditions if the mission has to climb steeper grade or the terrain is to it is a clay area**.**

So, which is not possible for a rigid frame to maneuver, in that case you can go for the articulated trucks. They are basically designed for tough underfoot conditions, so they can claim steeper grades up to 35% while the rigid frame is commonly used for only up to 10% slope, I am talking about the slope. But another limitation of this articulated truck is, it is designed for poor underfoot conditions**,** so these trucks will have a limitation on it is capacity and the speed.

So, it is capacity as well as the speed will be lesser than the rigid frame truck**,** so depending upon your requirement whether it can go for rigid frame or articulated truck. And also, in confined areas

it is easy to work with this machine which has a better turning ability. So, based upon your requirement you have to make the selection but obviously articulated trucks are costlier when compared to rigid frame. So, but you have to justify the cost based upon the application.

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And the next one is your highway rear dump truck**.** So, you can see the picture the material is being dumped through the tailgate in the rear end. So, you can see the machine will be having a hydraulic jack system with that you can lift the dumb body and dump the material at the end. So, this is the one which is commonly seen, the commonly used one is rear dump truck. But if you look into the dump time, so basically when you go for real dumping, so it takes little bit more time**.**

This is because since you are dumping at the rear end you have to correctly locate the location where you have to dump it. Sometimes you have to travel some back distance to exactly locate the place and then dump it. So, this may increase the dump time, so for the rear dump mechanism the dump time is slightly higher. Obviously, it depends upon your type of material also, some material maybe easily flowing, in that case dumping will be relatively easier.

It also depends upon the capacity of your truck your truck capacity, the type of material all these things will influence the dump time. But basically, rear dumping takes more time because you have to exactly locate the location and then you may have to even travel in a backward direction to locate that location and then you have to dump it. **(Video Starts: 07:58)**

This video shows you the how the rear dump truck unloads the material you can see that with the help of this hydraulic jack system**.** So, the dumb body is lifted**,** so this is lifting it you can see that**,** it is lifting the dump body and the material can be unloaded through the tailgate. **(Video Ends: 08:24)**

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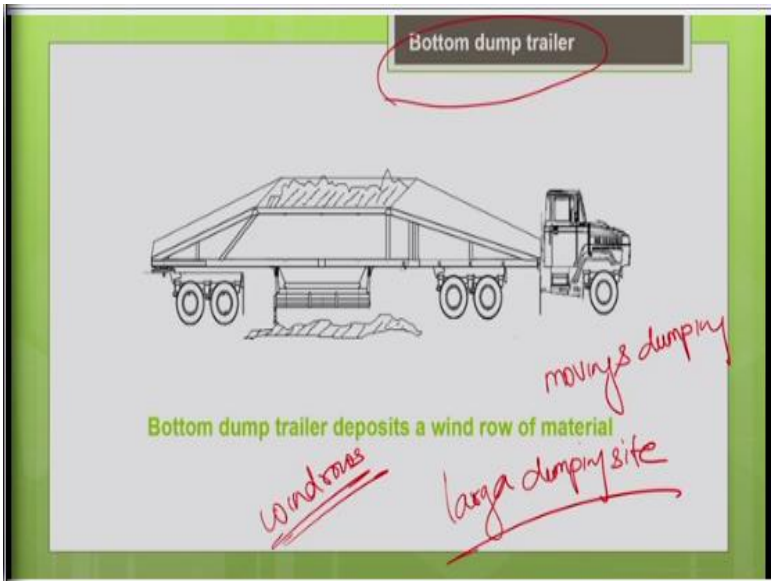

So, the next is about the bottom dump trailers. So, here you can see that dumping will be from the bottom opening. See you have a facility to unload the material to the bottom opening, so when compared to rear dumping this bottom dumping it will have a lesser time. So, this is because basically we go for these trailers this bottom dump trailers when you have to dump the material over a large area, you have to dump it and as well as spread it.

Actually, the machine will be moving and dumping together, the machine will be traveling and dumping together both the operations will be done in one stage**.** So, the machine will keep on moving as well as it will keep on dumping the material through the bottom end. So, for that you need a larger dumping area, so that this trailer can easily deposit the material in windrows they call it as windrows.

So, you can deposit the material in layers uniformly with this bottom dump trailers. Wherever you want to dump the material over a larger area and spread it uniformly and spread it in layers then

you can go for this bottom dump trailer. Since it is moving as well as dumping you can see that the dumping time is relatively lesser when compared to the rear dumping trucks.

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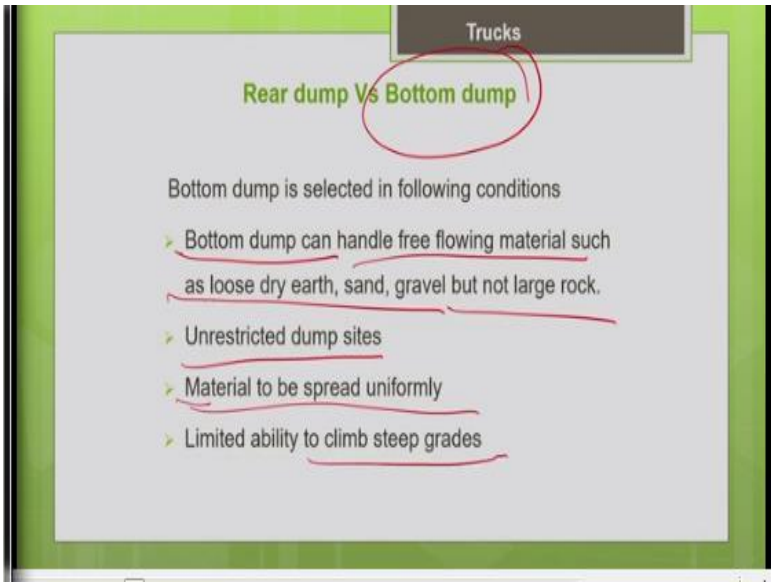

But it has some certain conditions like as I told you the material should be free flowing in nature for the bottom dump. Like your loose dry earth or sand or gravel it should be loose material and it should not be large rock, so that can be handled with the bottom dump trailer. So, the material should be free flowing in nature and it should be unrestricted dump site.

That means we need a larger dumping site where you can uniformly travel and deposit the material in windrows. So, wherever you want to spread the material uniformly this will be the right choice, a bottom dump will be a right choice. But it has it is own limitation it cannot climb steeper grades. These kinds of trailers cannot climb steeper grades.

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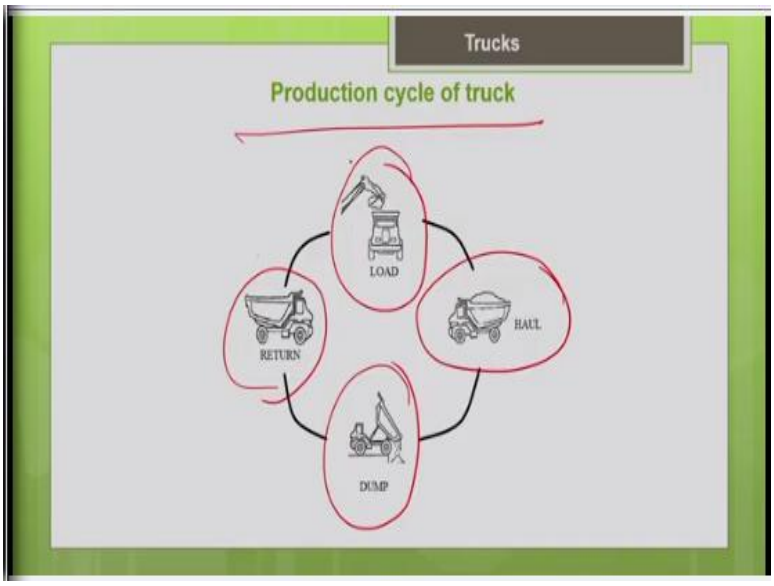

So, now let us look into the production cycle of the truck we have discussed so far about the different types of trucks**.** Now let us move on to what is the production cycle of truck and what are all the different components of the production cycle? So, the first thing is your truck should spot the loader, so the truck is helping the loader, the loader should be spotted by the truck, so that spotting time is also included.

Then the loader will be loading the truck that is loading time, then your truck will be traveling with the load that is hauling. Then at the required dumping site it has to dump the material, then it will be returning in the empty condition get ready for the next cycle. So, all these things make up the one production cycle of the truck.

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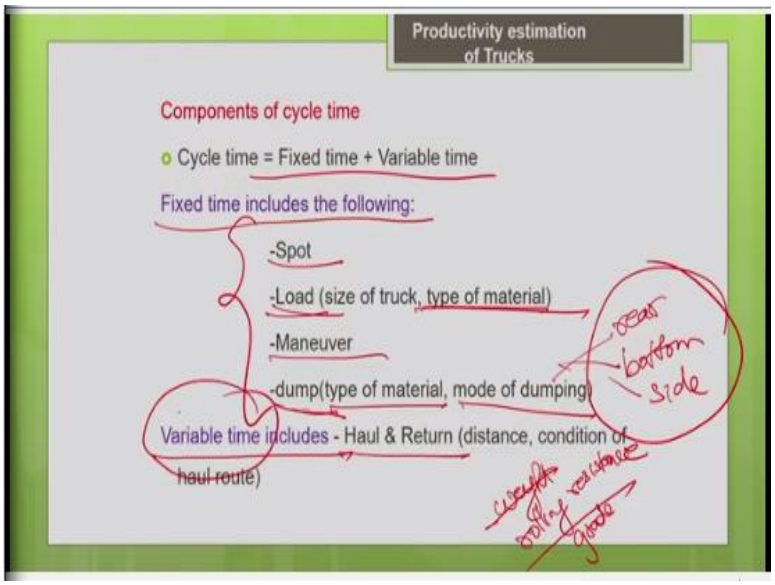

So, as we discussed earlier some are fixed and some are variable. Some of the components are fixed and some are variable. So, what comes into the fixed time? So, under fixed time you are spotting of your loader, loading the truck obviously it depends upon the size of the truck and also depends upon the material. Some materials are easy to load, dry earth your sand and gravel are easy to load**.**

But blasted rocks, clay material are difficult to load so all these things will affect the loading time. Then whatever maneuvering changing gears and other things turning then dumping also comes under the fixed time. So, as I told you dumping will depend upon the type of material, some material can easily flow out there the dumping time will be less. Then it also depends upon the mode of dumping, in the sense whether you go for rear dumping or you go for bottom dumping or you go for side dumping.

So, all these things are going to affect your dumping time. But all these things make up your fixed time, because these are not going to vary with your haul distance. Then the variable time that is going to depend upon your haul distance your haul time and the return time that depends upon your distance as well as the speed. Speed you can get it from the performance out of the machine.

So, if you know the weight, if you know the resistances, that is a rolling resistance in your project side and the grade resistance in your project site, if you know this input data you can find the speed

of the machine. So, once you know the speed and once you know the distance I can calculate the variable time.

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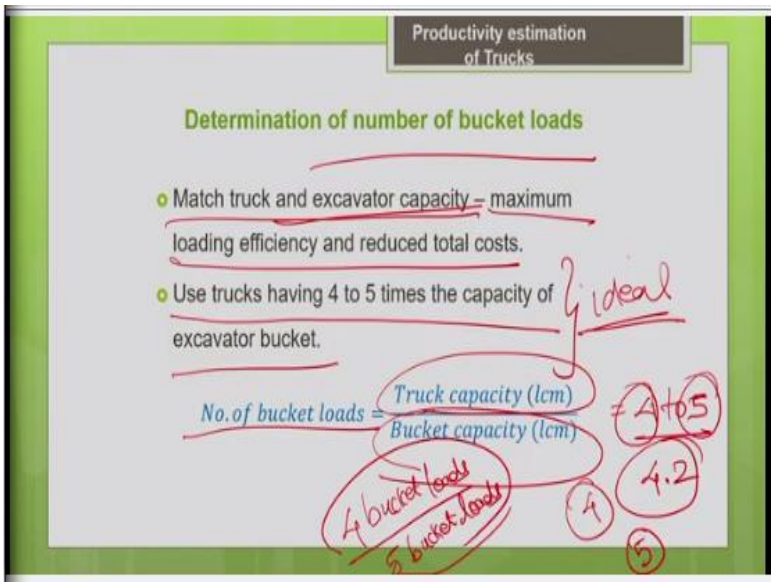

So, now let us see how to estimate the productivity of the truck. To estimate the productivity of the truck these are the steps to be followed. First, I need to find what is the number of bucket loads needed to fill the truck, how many bucket loads are needed to fill the truck? That depends upon the capacity of your truck and the capacity of your bucket of the loader**.** So, as I told you these are interdependent machines we should go for compatible capacities.

That means you should not go for a small truck and a bigger loader or a bigger truck and a smaller loader. In both the cases your cycle time will be longer there will be unnecessary wastage of time**.** So, that is why you need to balance the capacity of the truck and the loader or the excavator. So, as we mentioned earlier it is based on the studies they have found out the truck capacity should be at least 4 to 5 times the bucket capacity**.**

Use trucks having 4 to 5 times the capacity of the excavator bucket, so this is the ideal case. So, this will give you a maximum productivity. So, match the truck and the excavator capacity that will result in maximum loading efficiency and reduced total cost. Because your cycle time will be reduced, your productivity will increase, so unit production cost will reduce**.** So, that is why we have to match the size of the interdependent machines**.**

Now let us determine how many number of bucket loads are needed to fill a truck. That depends upon the truck capacity and the bucket capacity, divide truck capacity by bucket capacity you will get the number of the bucket loads needed to fill the truck. This is the balance number, hopefully you should get between 4 to 5 for the ideal case. See if you get a whole number it is fine you can either go for the 4 buckets or 5 brackets.

But if you are getting some decimal numbers say 4.2, in that case you have to round the bucket load either I should round it to 4 or I should round it to 5. But basically, when it is less than 4.5 we round it to 4, but if it is greater than 4.5 in that case it is better to work out the economics of both the cases. Then if I go for 4 bucket loads what will be the unit production cost? If I go for 5 bucket loads what will be the unit production cost? It is always better to work out the economics of both the cases and make the choice.

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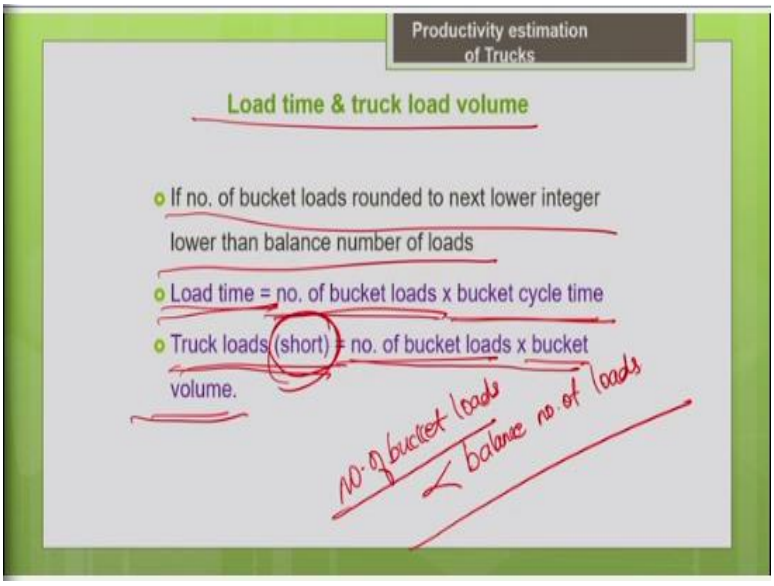

Now let us see the cases like one thing is say for example if I am going to round the bucket load to the lower number. Say I got a decimal number and I am rounding it to lower number.

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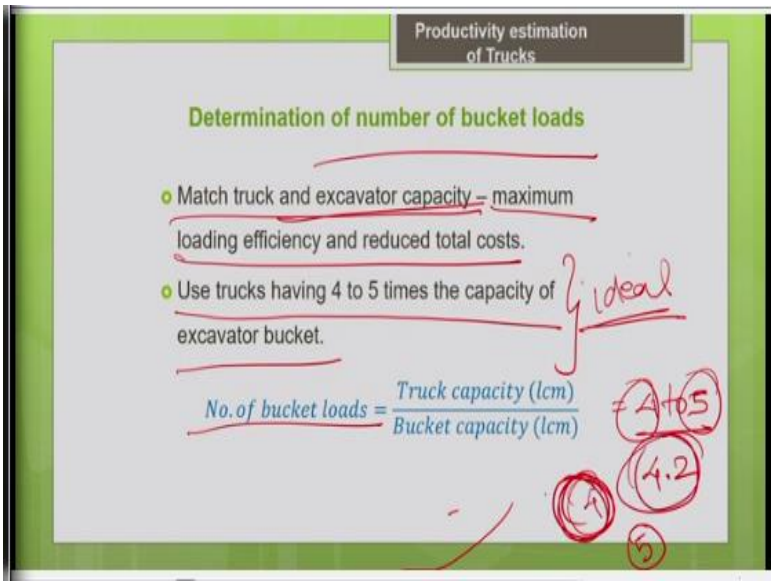

So, I got 4.2 and I am rounding it to 4 buckets. In that case how to work out the truck load and the load time, that is what we are going to see now. How to estimate the load time and the truck load volume? When the number of bucket loads are assumed to be lesser than the balance load. If the number of bucket loads rounded to next lower integer lower than the balanced number of loads, then what will be the load time?

Load time is nothing but your number of your bucket loads that is the number of cycles of the bucket loads multiplied by the bucket cycle time what is the per cycle bucket cycle time. So, number of bucket loads multiplied by the bucket cycle time will give you the loading time**,** loading time for your truck. Now how to find the truck load? In this case since the number of bucket loads is lesser, here we are taken number of bucket loads lesser than the balance number of loads needed to fill the truck.

So, obviously we are not going to fill the truck to it is full capacity the truck will be short load, truck load will be short. So, sometimes we prefer for short load say for example when you are climbing steeper grades we do not prefer loading the truck to it is fullest capacity we prefer short loads. So, in this case since the number of bucket loads is lesser than the balanced number of bucket loads it is called as short load.

So, the truck load is not equal to the truck full capacity, here how to calculate the truck load? It is nothing but number of your bucket loads multiplied by the bucket volume, number of bucket loads multiplied by the bucket volume will give you the truck load. And this is not going to be equal to the full capacity of a truck as you know.

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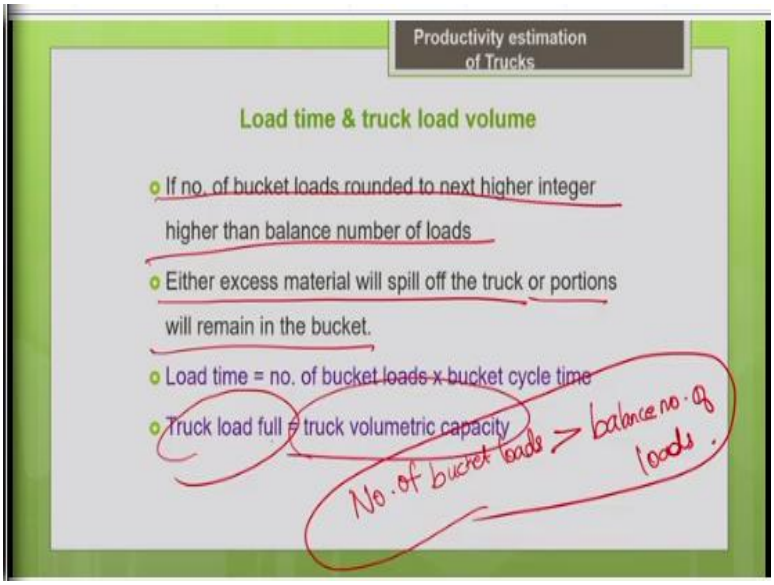

Now the next case is say the number of bucket loads which we are going to adopt is greater than the balanced number of loads. So, now we have rounded it to the higher end say instead of I got 4.2 and I am rounding it to 5**,** say for example I am rounding it to 5. In this case it means I am trying to load the truck beyond it is capacity, so obviously there will be spillage of material.

So, if number of bucket loads rounded to next higher integer higher than the balanced number of loads either the excess material will spill off the truck or some portion of material will remain in the bucket of excavator itself. So, either way it can happen but one thing you should know that what you can load only to the truck capacity, we cannot load beyond that, excess material will definitely will spill off. So, here you have to take the truck load is full and it will be equal to the truck volumetric capacity.

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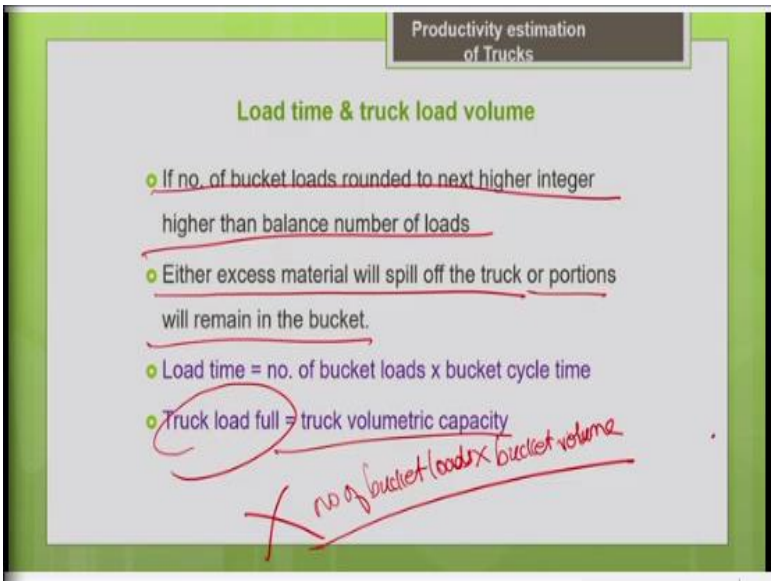

Your truck load is full here and it will be equal to the truck volumetric capacity, you should not take it as the number of bucket loads multiplied by the bucket volume as you did for earlier**.** Number of bucket loads by bucket volume you are not going to follow that earlier formula. This way you should not calculate for this, because here the number of bucket loads are more than the balance number of loads.

But even though it is more than the balanced number of loads I cannot load it beyond the capacity of the truck, truck maximum capacity will be the limiting capacity. So, in this case you should not go by this the truck load will be equal to truck volumetric capacity only, you have to follow that.

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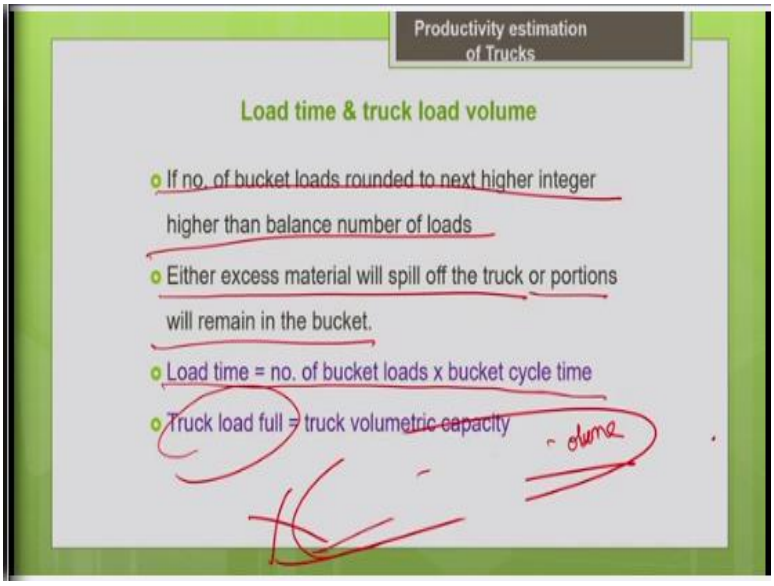

But the loading time will be number of bucket loads multiplied by the bucket cycle time**.**

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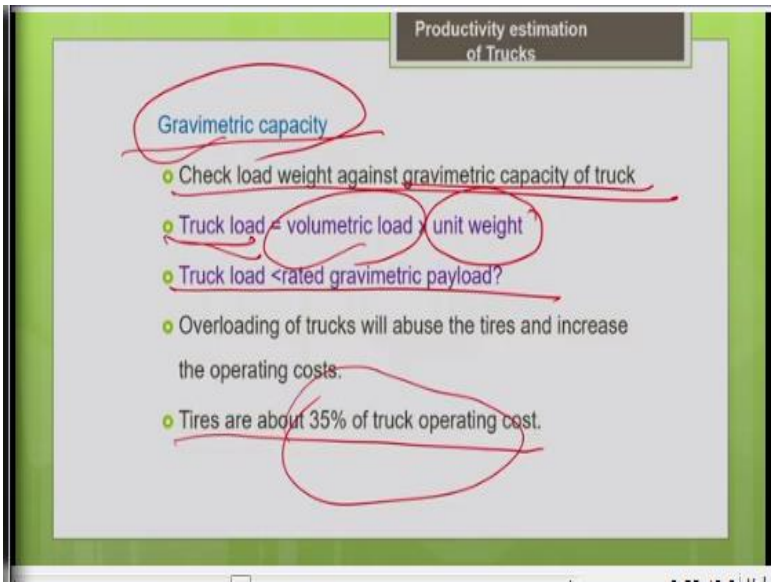

Another important thing you have to keep in mind is, for any machine whatever maybe the mission we have discussed about different types of machines so far. All the machines we are concerned about the safe gravimetric capacity of the machine. For every machine what is this safe operating load in terms of weight is given by the manufacturer, so that we call it as a gravimetric capacity.

So, only that capacity your machine can take because the structural frame of the machine is designed to handle that particular load only. So, we are not supposed to load the machine beyond the gravimetric capacity. So, since the density of material can vary from case to case, it is always advisable to check whether the load weight is within the safe gravimetric capacity. Check the load weight against the gravimetric capacity of the truck, how to check that?

For that you need to know what is the unit weight of your material, if you know the density of your material you can multiplied by the volumetric load you will get the actual weight of material in the truck, you will get the truck load. That should be within the rated gravimetric capacity of the machine given by the manufacturer, check truck load is less than rated gravimetric payload.

See many times you can see that people will put these side boards, and in the trucks commonly you can see they put the side boards and try to increase the volume of the truck. If the material

which you are going to handle is less denser, in that case it will not create much problem, you have to check whether the loaded weight in the truck is within the gravimetric capacity.

But if the material is going to be denser like wet sand or other denser material, what happens is there are more chances that your machine maybe overloaded. That means the weight of material in the truck will be above the safe gravimetric capacity defined by the manufacturer. In that case it will result in lot of wear and tear to the machine**,** so particularly your tires will flex and it will result in abusing of tires**.**

So, you know that for most of the machines the tire cost almost to 35% of the truck operating cost**.** So, if you overload the machine it will result in abusing of tires and it will increase the tire cost significantly. So, this thing you should keep in mind that like by keeping side boards and the keeping overloading the trucks though you are able to increase the productivity for a shorter time.

Those benefits will be only for a shorter time, this is because if you keep on overloading your truck it will result in premature aging of the truck, and it will result in huge loss for you, it will result in yearly replacement of your truck**.** So, you have to replace the truck with a new truck, that will result in huge ownership cost for you**.** So, that is why you should not overload the truck.

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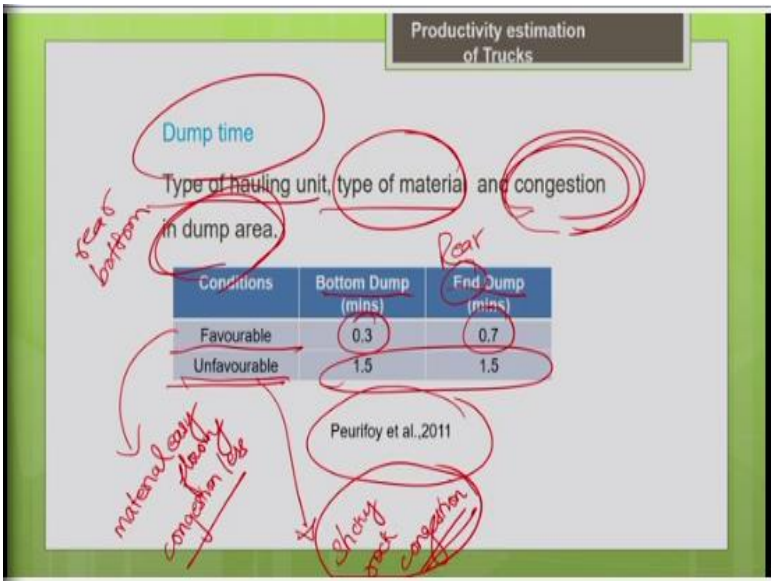

So, next is about the dumping time**.** So, as we discussed earlier the dumping time will depend upon the type of hauling unit whether it is going to be rear dump or it is going to be bottom dump or side dump accordingly the dump time will vary. Whether the material is easy flowing material or sticky material, rock**,** blasted rock**,** all these things will affect your dumping time.

And the congestion in the dumping area, you know that in the construction site, so many equipment will be working parallel. Say for example in the dumping site there may be bulldozers and graders, leveling. So, in that case there may be possibilities of a lot of congestion in the dump area then your machine may have to wait. So, till it to get it is chance for unloading or dumping, so the congestion of the dump area all these things will affect the dump time.

So, that is why these values are taken from the textbook by Peurifoy et al. So, they have given you the time needed for bottom dump truck and end dump truck, end dump is nothing but your rear dump. So, for different types of conditions say they have classified the condition to favorable, unfavorable. Favorable in the sense, say easy flowing material and the congestion in the dump site is less, so all these are favorable conditions**.**

Unfavorable conditions mean, the material is a sticky material or rock as I told you, which is unfavorable. So, in that case there is more congestion in your dump site, so machine has to wait, that is unfavorable condition. So, they have given you the time approximate estimate of time for favorable and unfavorable condition. So, you can compare the bottom dump and rear dump you can find it if the conditions are favorable the bottom dump time is very much less when compared to the rear dump**.**

That is what I told you earlier also when compared to rear dumping your bottom dump time will be relatively lesser, provided the conditions are favorable. But in the unfavorable conditions you can say that both are comparable only bottom dumping and rear dumping. So, if the conditions are favorable it is preferable to go for the choice of bottom dump, so that you can have reduced cycle time and increase productivity.

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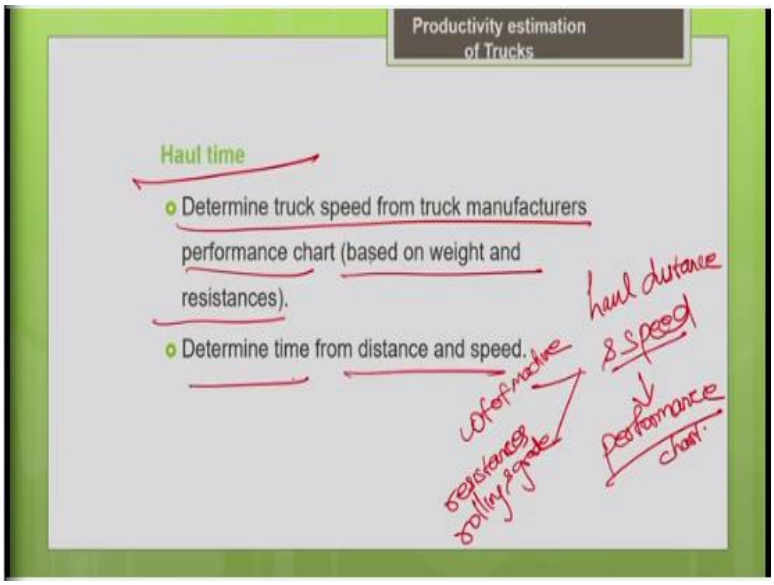

Now next is about the haul time. Haul time it depends upon your haul distance and the speed, speed you can get it from the performance chart. So, to use the performance chart you need to know what is the weight of the machine and also you need to know what are all the resistances in your project site, so the rolling resistance and the grade resistance.

If you know all these input data you can find the speed from the performance chart. So, determine the truck speed from the truck manufacturer performance chart. If you know for that you need to know the weight of the machine and the resistances in your project site. So, once you know the speed and the distance I can calculate the haul time.

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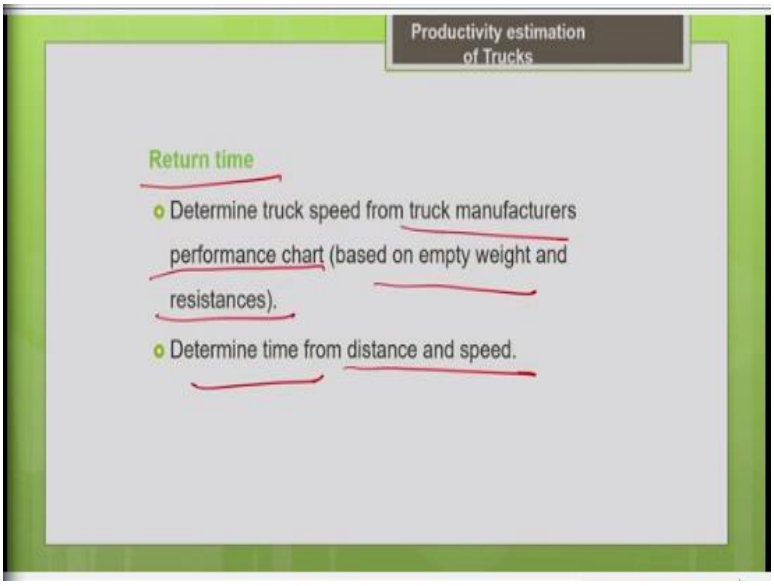

The return time the same way using truck manufacturer performance chart, but here the truck will be in the unloaded condition, empty weight, and consider the resistances also. So, you know the distance and speed I can calculate the return time, obviously the return speed will be more, so the return time will be less as the truck is in the empty condition.

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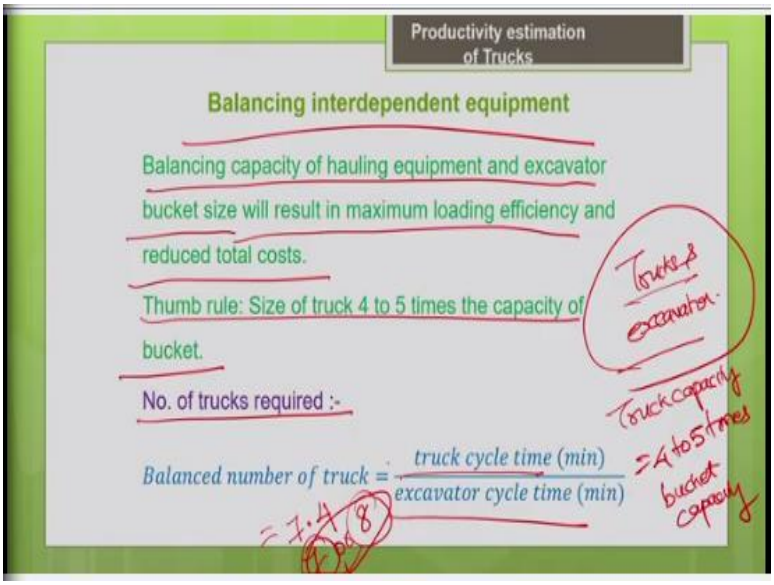

Now let us see how to balance the interdependent machines, trucks and the excavators. I hope you remember earlier we have discussed how to balance the interdependent machines your scraper and the pusher? In a similar manner we are going to discuss how to balance the number of trucks and the excavator? So, balancing is very important, just now we discussed balancing the capacity of the interdependent machines very important.

So, balancing the capacity of the hauling equipment and the excavator bucket size will result in maximum loading efficiency, and reduce total cost. So, that is why I told you based upon the studies they have found that the truck capacity should be 4 to 5 times the bucket capacity that is what is going, this is the thumb rule, size of the truck 4 to 5 times the capacity of the truck that is the ideal case.

So, when they are compatible you can see that the cycle time will be less both will be working at maximum production. Now let us find what is the balanced number of trucks, so how many trucks are going to be served by one excavator, that is what we are going to find. So, that depends upon

the cycle time of your truck and the cycle time of your excavator**.** So, divide the truck cycle time by the excavator cycle time, you will get the balance number of trucks.

So, the balance number indicates a particular number at which both the machines are working at same production level. They will give you the maximum productivity, there would not be much waiting time, so the cycle time will be less the productivity will be maximum**.** It is preferable to go by the balance number**.** But more often you can see that you may not get a whole number.

Say for example I am getting the balance number say 7.4 whether I should round it to 7 or I should round it to 8 trucks, we have to decide, how to decide that? We have to work out the economics, if I go for 7 trucks for 1 loader or 1 excavator. If I go for 8 trucks for 1 excavator, what is the unit production cost associated with that. You consider both the cases and then make a decision, that will be more logical.

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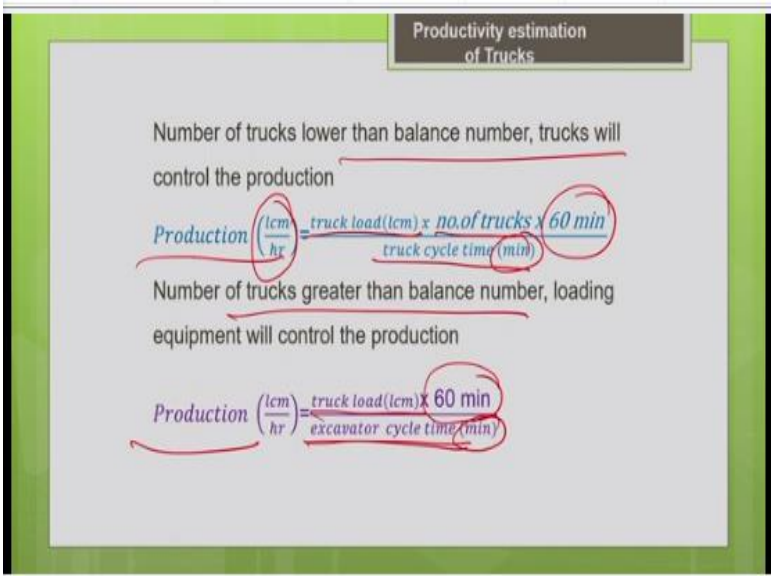

Now let us consider the case say the number of trucks lower than the balance number. Say I am going to round it to lower number, say I got 7.4 now I am going to round it to 7. When I round it to lower than the balanced number that means trucks are less than what is needed. So, trucks are more critical for the production, so here the loader will have the idle time, loader will be waiting for the truck**,** so truck cycle time will control the productivity of this stream**.**

So, the truck productivity will be controlling**,** so production, how to estimate the production in this case? Truck load multiplied by number of trucks divided by the truck cycle time**.** So, here truck cycle time I have taken in minutes, so I am converting it to hour, because I need the productivity loose cubic meter per hour, so I am just multiplying by 60 minutes.

$$\textbf{Production} = \frac{\textbf{truck load} \times \textbf{no. of trucks} \times \textbf{60 min}}{\textbf{truck cycle time}}$$

In the case when I round it to the number greater than the balanced number. So, instead of rounding it to 7, I am rounding it to 8. In this case number of trucks are greater than the balance number, so the trucks will have the idle time, truck will be waiting for the loader, loader will be critical here**.** Beyond the balance number you can see that the productivity will be controlled by the loader cycle time**.**

Unless the loader is available though the trucks are more in number they cannot do the job**.** So, the production is going to be controlled by loader, loader cycle time or excavator whatever excavator cycle time. Now how to estimate the productivity? Truck load divided by the excavator cycle time it is in minutes, so converting into hour I need to multiply by 60 minutes, this will give the production of the system when the number of trucks is greater than the balance number.

If I choose, if we round it to number greater than the balanced number. But very commonly you can see that people prefer to round it to lower than balanced number. One reason is basically when it is lower than the balance number you can engage the excavator or the loader to address the loading site and it will get ready for the next truck. And people also do not prefer working with loader continuously, because if the loader or excavator works continuously and if it breaks down it will severely affect your entire system.

Say for example you have only one excavator and if the excavator breaks down that will hamper your project seriously. But the trucks are more in number even if the truck breaks down, if one truck breaks down it will affect the production but that would not be as serious as the breakdown of a loader or the excavator, that you have to always keep in mind. That is why routine maintenance of the loader or the excavator is very important for the continuous running of the system**.**

That is why people always prefer rounding it to lower number, but the logical way is to work out the economics of both the cases and then take a decision, that will be more logical**.**

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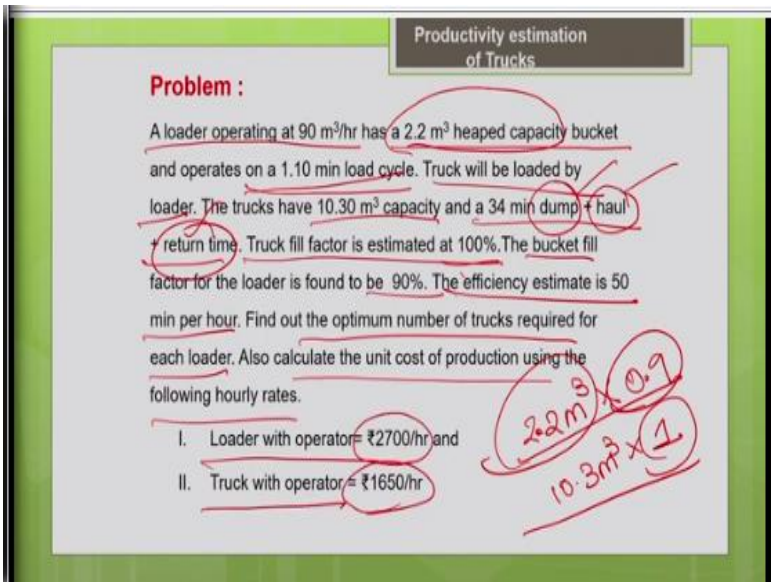

Now let us work on the problem on balancing the interdependent machines**.** So, here a loader is operating at 90-meter cube per hour and it has a 2.2 heap capacity bucket, and operates on 1.1-minute load cycle. The cycle time of the bucket is given as 1.1 minute, a cycle time per cycle it is 1.1 minute for the bucket of the loader. Truck will be loaded by the loader and the truck's capacity is 10.3-meter cube capacity and 34-minute dump + haul + return time.

Other than loading what is the time needed for dumping, hauling and returning is given directly to you**.** If it is not given then you have to go for the performance chart to find out the haul time and the return time and you can go by the manufacturer's data for the dump time. Truck fill factor is estimated at 100%, so based upon the filling ability of the material it is given as 100% for truck but for the bucket it is given as 90% based upon the filling ability of the material.

So, whatever the rated heaped capacity given by the manufacturer I have to adjust with the fill factor. Say for the loader bucket it is 2.2-meter cube, this is the rated heaped capacity given by the manufacturer adjacent with the bucket fill factor 90% 0.9. Similarly, for the truck it is 10.3-meter cube, here the filling factor is 1 that is it. So, you have to get the realistic estimate of the load

volume by adjusting the rated heaped volume with the bucket fill factor or the truck fill factors accordingly.

The efficiency estimate is 50 minute per hour the job efficiency is given that means the machine is working for 50 minutes in a hour. Find out the optimum number of trucks required for each loader. So, we are going to find the balance number at which your productivity is going to be optimum. Also calculate the unit cost of production using the following hourly rates the hourly rate or the hourly cost associated with the loader including the operator cost is given as rupees 2700 per hour and for the truck it is given as rupees 1650 per hour.

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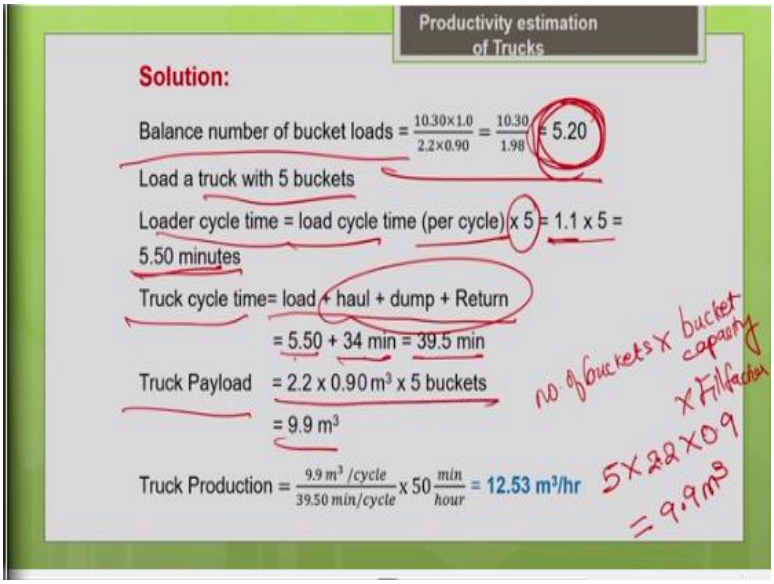

Now let us work out the solution, the first step will be to find the balance number of the bucket loads needed to fill the truck. How will you find the balance number of bucket loads needed to fill the truck? It depends upon your truck capacity and by your bucket capacity, so what is your truck capacity? It was given as 10.3-meter cube, you adjust it with the fill factor, truck fill factor is given as 1.

$$\textbf{Adjusted truck capacity} = 10.3 \times 1 = 10.3\text{m}^3$$

Similarly, the bucket capacity is given to you as 2.2-meter cube, you adjust it with the fill factor it is nothing but 0.9,

$$\textbf{Balance number of bucket loads} = \frac{10.3 \times 1}{2.2 \times 0.90} = 5.2$$

So, you will get the answer is 5.2**.** You can see here 5.2 is the balanced number of bucket loads. So, we did not get a whole number, now I have to round it. In this case it is lesser than 5.5, so I can round it to 5 bracket loads, but if it is going to be 5.5 or greater than that it is preferable to work out the economics of both the cases as I mentioned earlier.

If with 5 buckets what will be the 5-bucket load, what will be the unit production cost, with 6 bucket loads what will be the unit production cost? You are supposed to work it out to make a right decision**.** But in this case, it is lesser, so I am rounding it to lower number 5 buckets. So, obviously I am going to load the truck not to it is fullest capacity, the truck load is short load here short load**.**

Now how to find the loader cycle time to fill the truck? It depends upon the number of the bucket loads that is 5 multiplied by the cycle time of the bucket per cycle

Loader cycle time = 5 × 1.1 = 5.5 minutes

Now what will be the truck cycle time, truck cycle time is nothing but loading + hauling + dumping + returning.

So, this value is completely given to you in the problem is 34 minutes haul + dump + return, loading time you have just now estimated 5.5 minutes. So, 5.5 + 34 gives you 39.5 minute as a truck cycle time, now I need to find the truck payload. So, here you know that I am not going to load the truck to it is full capacity because I am rounding the bucket loads to lesser than the balance number.

Truck cycle time = 5.50+34 = 39.5 minutes

So, the truck payload will be equal to your number of buckets into bucket capacity rated bucket capacity multiplied by the fill factor. So, number of buckets balance number we have taken is 5, bucket capacity is given to you as 2.2-meter cube, fill factor is 0.9. If you multiply you will get the answer is 9.9-meter cube that is what is given here 9.9-meter cube. Now you find the truck production you can easily find the truck protection.

Truck payload = 2.2 × 0.9m^3 × 5 buckets = 9.9m^3

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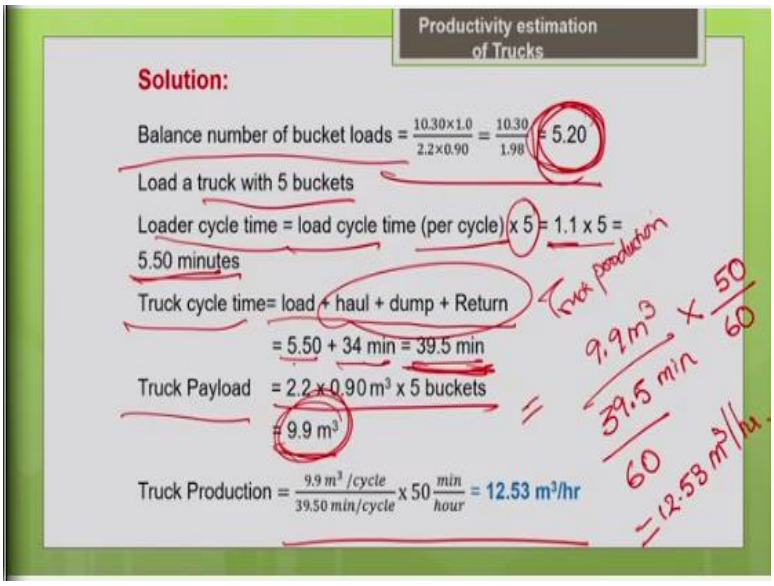

So, what is the volume of truck you are going to load in this case 9.9 meter cube, you are also supposed to check whether the truck payload is within the gravimetric capacity. If say gravimetric capacity is given by the manufacturer you have to check whether the weight of the load of material in the truck is within the gravimetric capacity. For that you need the input data of the density of the material also.

Now let us calculate the truck production, truck production is nothing but your truck capacity, I mean the truck payload**.** Here it is not full load, it is short load 9.9 meter cube we have derived here divide by the truck cycle time, cycle time is 39.5 minute. Since it is in minute I need to convert it into hours, so let me divide it by 60. And another important thing you should never forget is job efficiency, the machine is going to work for 50 minutes an hour 50 by 60. So, this will give me the answer is 12.53-meter cube per hour, so this is how you have to estimate the truck productivity.

$$\textbf{Truck production} = \frac{\textbf{9.9m3/cycle}}{\textbf{39.5m3/cycle}} \times \mathbf{50}\boldsymbol{min/hr} = \textbf{12.53 m}^{\textbf{3}}\textbf{/hr}$$

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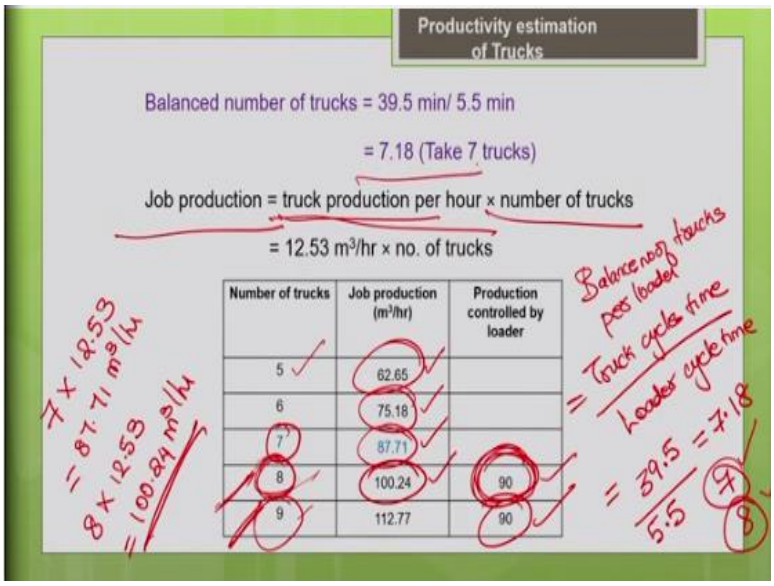

Now let us find the balance number of trucks needed for one loader. So, that depends upon your the balance number of trucks per loader going to be serve by one loader is equal to your truck cycle time divided by load of cycle time. So, you have estimated the truck cycle time earlier, so estimated it is 39.5**.**

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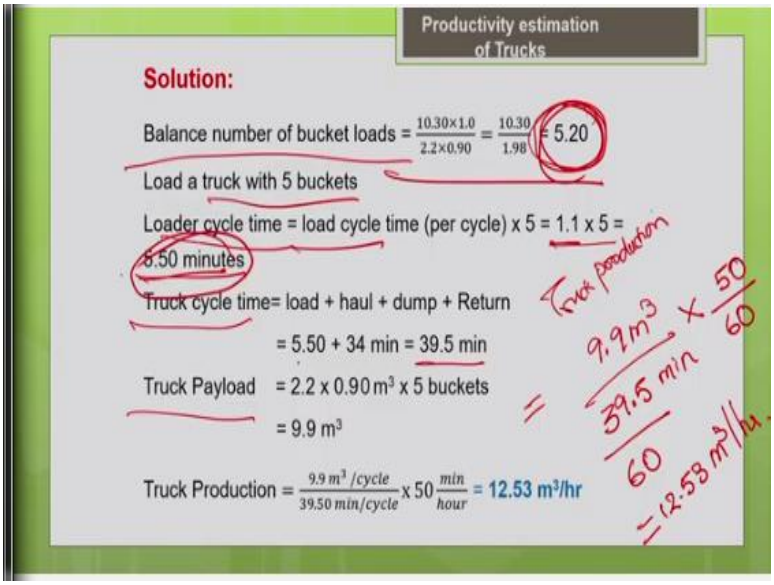

The truck cycle time is 39.5 and the loader cycle time is 5.5, we have calculated the loader cycle time as 5.5. So, this gives me the balance number of 7.18, here also I did not get the old number, so I have to do the rounding either I can round it to 7 or I can round it to 8. So, but the logical thing is you have to work with the economics of both the cases and then take the decision. So, here I am going to work out the economics of both the cases.

So, just to give you a better explanation I am just working out what will be the economics when I go for different number of trucks. Say if I go for 5 number of trucks 6, 7, 8 and 9**,** how the productivity will vary, how the unit production cost will vary? We will work it out and see, so that will get a clear picture on what is the effect of number of trucks, and what is the effect of increasing the number of trucks beyond the balance number on the unit production cost**.**

So, we will do in-depth analysis by working out for all the number of trucks. So, basically how to estimate the job production? So, it is nothing but your single truck productivity multiplied by number of trucks, that will give you the job production. So, provided the number of trucks are lesser than the balance number. In that case you can calculate by that, because when the trucks are lesser than the balance number or equal to balance number your truck cycle time will govern the productivity**.**

But when the number of trucks is your balance number say 7, so actual balance number is 7.18. So, when the numbers of trucks are lesser than the balance number say 5 trucks, 5 into productivity of your truck, individual truck productivity is 12.53-meter cube per hour. So, that gives me the value is 62.65-meter cube per hour**,** this is what you got. Similarly, when the number of trucks is 6, 6 into 12.53-meter cube per hour that will give me the answer is 75.18**.**

When the number of trucks equal to 7, 7 multiped 12.53 gives me the productivity as 87.71-meter cube per hour. When the number of trucks is 8, 8 into 12.53, I am getting the value as 100.24-meter cube per hour**.** But I cannot go by this productivity, this is because when the trucks are lesser than the balance number equal to balanced number your truck will be controlling the productivity of the system.

Beyond the balance number**,** so you can see that number of trucks are more so the truck will be waiting for the loader unless the loader is available your truck cannot do the job. So, the productivity here will be controlled by your loader. So, beyond the balance number you can see that you cannot go beyond the productivity of the loader because the load of cycle time will control the productivity of the system, for cases above the balance number.

You cannot go beyond the productivity of the loader beyond the balance number. Though the number of trucks or more you have 8 trucks, you have 9 trucks but the trucks will be simply waiting for the loader only. That is why it is not preferable to increase the number of trucks beyond the balance number. Because the trucks will be just waiting for the loader**,** so you cannot go beyond the productivity of the loader.

So, unnecessarily it will increase your production cost because of the increase in the cost of trucks. Even though I get the productivity as 100.24, if I go for 8 trucks but the actual productivity will be only 90-meter cube per hour. Because I cannot go beyond the productivity of the loader, loader will be controlling beyond the balance number.

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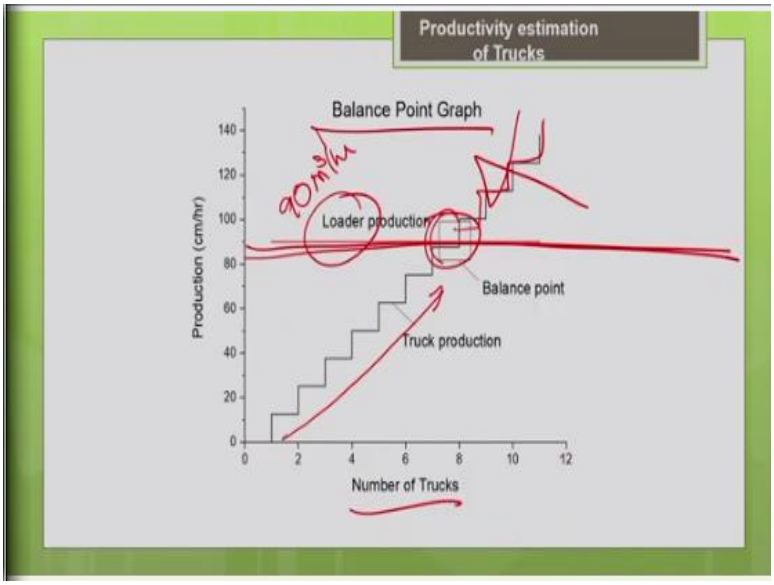

This picture the balance point graph clearly illustrates what is the significance of the balance point. So, as you keep increasing your truck number you can see that the productivity is significantly increasing. At the balance point you can see that the productivity of your truck and the productivity of the loader will be same**,** loader productivity is 90, the load of productivity is 90-meter cube per hour.

At the balance point both the machines are working at same productivity, but beyond the balance point even if you increase your trucks you cannot get this productivity, you cannot go beyond the

load of productivity level, that will be the limited value. Because you have only one loader whether you have 8 trucks or 9 trucks or 10 trucks, all these trucks are going to just wait for the loader**.**

So, it is not advisable to increase the number of trucks beyond the balance number because there is only one loader here that will be controlling the productivity of the system.

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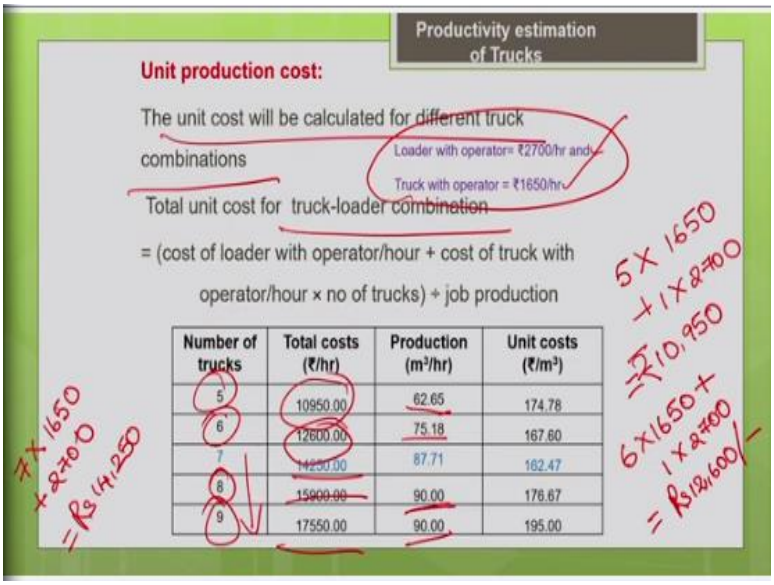

Now let us work out the economics because most of the decisions are based upon the economics. People are more concerned about the unit production cost associated with the machine. So, whichever combination gives you lesser unit production cost we will advise that combination**,** so that is how we are supposed to follow**.** The unit cost here will be calculated for the different combinations**.**

So, how to calculate the total unit cost for the truck loader combination I need the input data, so the input data is given to you what is the cost associated with the loader and the truck**.** The hourly cost data is already given to you as rupees 2700 per hour for the loader and rupees 1650 per hour for the truck. Now let us estimate the total unit cost for the truck loader combinations for different number of trucks**.**

Say for first for 5 number of trucks, how will you calculate the total cost? Total cost is nothing but 5 multiped what is the hourly cost of truck 1650 plus there is only one loader 1 multiplied by 2700.

So, this gives me the cost is 10950 rupees, this will be the cost associated with the 5 trucks. Similarly for the 6 trucks, 6 multiped 1650 + 1 multiped 2700, so this gives me the cost is rupees 12600, you can get this.

Similarly for the 7 trucks, 7 multiped 1650 + 2700, this gives me the cost is the rupees 14250 per hour**.** Like this you keep calculating for 8 trucks and 9 trucks you can calculate the cost, total cost per hour. Now your productivity already you have estimated the productivity in the earlier table 62.65, 75.18, 87.71, but you have to note that beyond the balance number the productivity will be only 90, I cannot go beyond 90.

Because beyond the balance number the productivity is controlled by loader whose productivity is 90-meter cube per hour**.** So, that is why you can say the productivity is only 90 beyond the balance number**.** Now you have to calculate the unit cost of production, how to estimate the unit cost of production?

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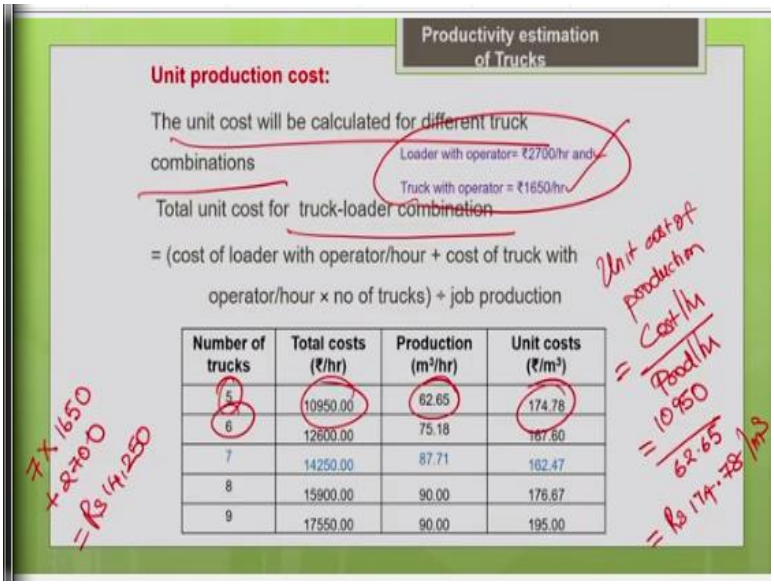

Unit cost of production is nothing but cost per hour divided by productivity per hour. So, for the number of trucks 5, so for 5 trucks what is the total cost 10950 divided by productivity is 62.65**.** So, this gives me the answer as rupees 174.78 per meter cube, this is the unit production cost associated with 5 trucks, similarly for 6 trucks you have to calculate, 6 trucks.

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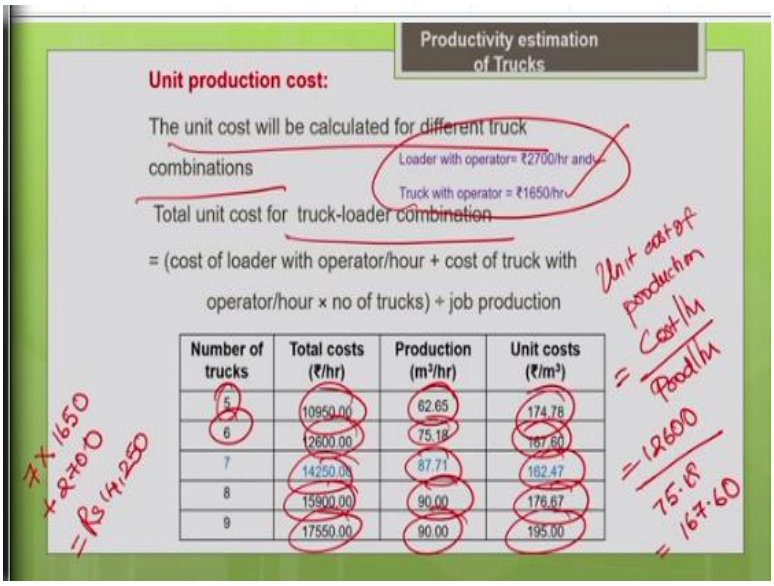

It is nothing but 12600 divided by 75.18 gives me the value is 167.60, you can see here. Similarly, you find the unit production cost by dividing total cost by productivity, you will get the unit production cost for all the cases you can just find it for all the cases 5 trucks, 6, 7, 8 and 9**.**

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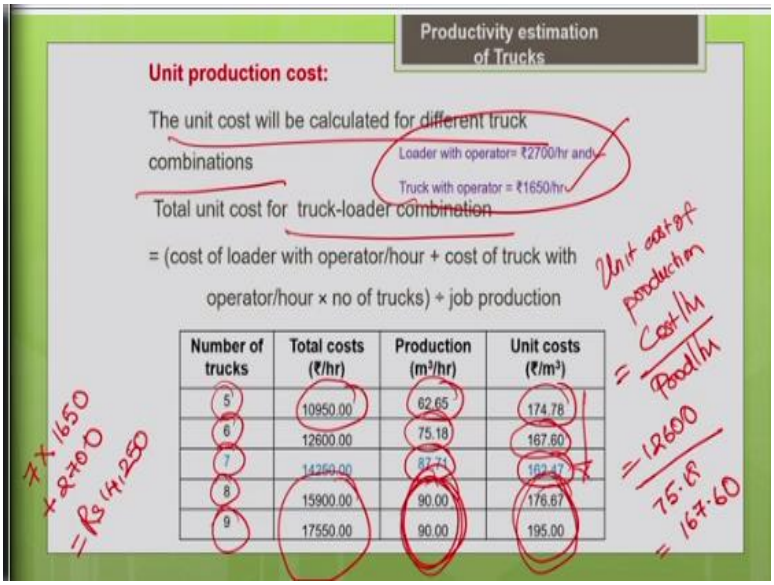

So, one important thing you have to note here is when the number of trucks is 5 though the total cost is less in this case, but the productivity is also less, that is why you can see that the unit cost is high. But as your number of trucks increases you can see that the productivity increases significantly, that is why your unit cost of production reduces**,** it is reducing. But beyond the balance number 7 when I try to increase the number of trucks, there is no increase in productivity.

Because the productivity is limited by loader, I cannot go beyond 90, but your truck causes unnecessarily increasing**.** So, because of that I can see that the unit cost increases significantly, unit production cost increases significantly, that is why it is not advisable to go beyond the balance number**.**

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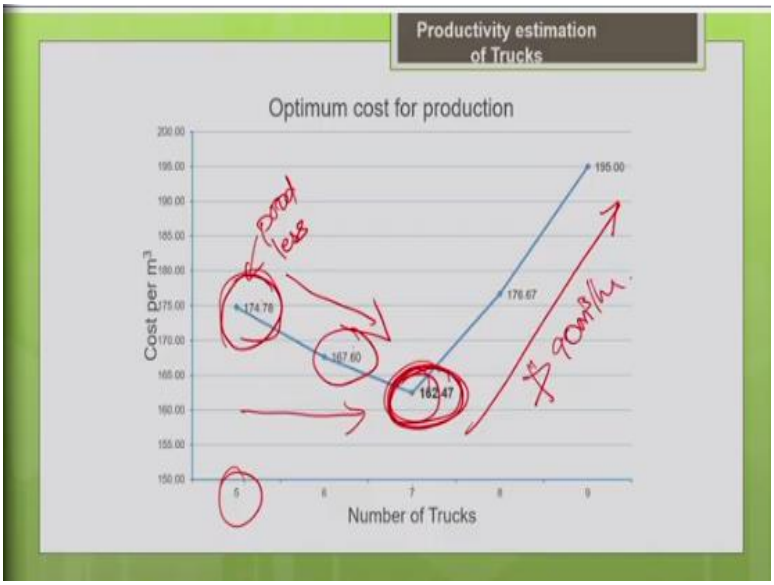

So, graphically you can see this**,** so when the number of trucks or less your unit protection cost is less when the number of trucks is 5, when the number of trucks is less the unit production cost is higher than the optimum value. You can see the optimum value for the number of trucks 7 the unit production cost is 162.47**.** But when you go for 5 trucks you can see that the unit production cost is higher than the optimum value, why it is higher than the optimum value?

Because here productivity is less in this case, but when you increase the number of trucks you can see that the productivity will increase significantly, so your unit production costs keep reducing**.** And when you reach the balance number you can see that you can have the minimum unit production cost. But when you try to increase number of trucks beyond the balance number, what is happening? There is no increase in productivity.

Beyond the balance number the productivity is limited by the loader, so I cannot go beyond 90 meter cube per hour that was the productivity of the loader I cannot go beyond 90 meter cube per hour.

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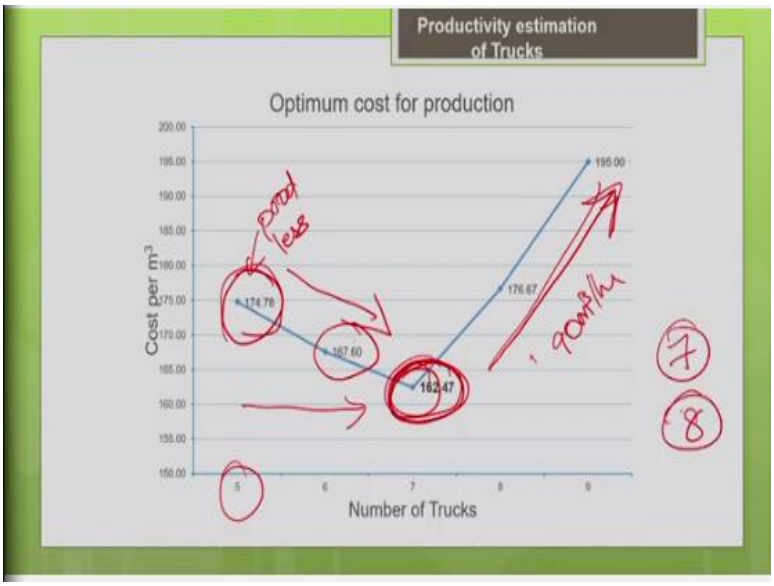

But and your cost of the truck is increasing that is why you can see that unit production cost significantly increases. So, it is always preferable to go by the balance number, but in this case our balance number was 7.18**,** it was 7.18. So, whether to round it to lower number or round it to higher number, whether I should go for 7 or whether I should go for 8. If I go for 7 my unit production cost is 162.47.

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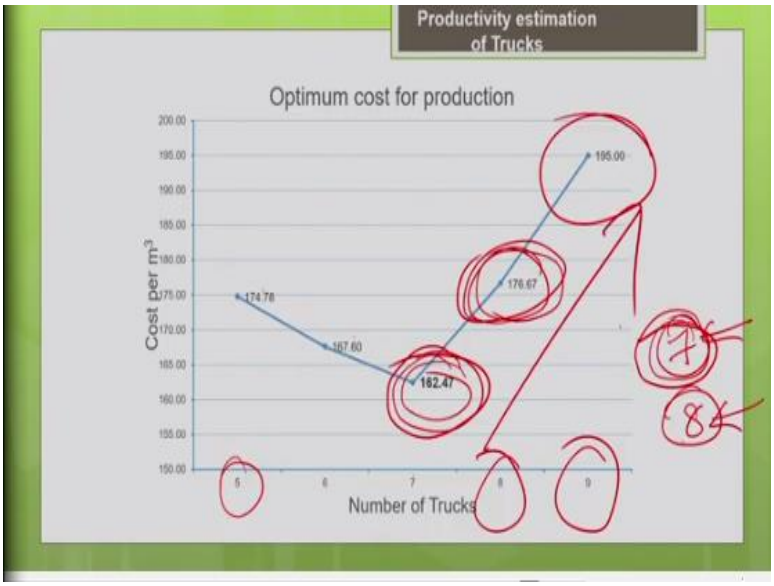

If I go for 8 trucks my unit production cost is 176.67, so it is preferable to round it to the lower number, rounding to lower number is preferable. As I told you this is what is commonly followed,

when you round it to lower number you can avoid you can give some break time for your loader**.** That is also one way good, the loader will help you in clearing the addressing the site as I told you**.**

The site as well as there will be some break time for the loader, and it will get ready to load the next truck. That is why people always prefer to round it to lower number, but anyway it is always preferable to work out the economics of both the cases, I have worked out and showed you. You can see that for lower number of trucks the unit production cost is very less for 7 in this case.

For when you go for 8 there is no significant increase in productivity that is why you can see that the unit production cost increases significantly**.** So, whether you go for 8 trucks or 9 trucks there will not be increase in productivity, there will be just increase in the truck cost, that is the reason which is significantly increasing.

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So, we have come to the end of this lecture, let me now summarize**.** We have discussed about the different types of trucks and I told you the importance of checking the payload the weight of load inside the truck against the rated gravimetric capacity. You should never overload the machine which will result in premature aging of your truck as well as the tires**.** And dumping time when you calculate, you should know that it depends upon the mode of dumping whether you are going for rear dump trucks or bottom dump trucks.

And the material type easy flowing or tough material and also it depends upon the congestion in the dump area, all these things are going to affect your dumping time. So, when you work in a team with machines, so basically the all the interdependent machines should be balanced in their size as well as it should be balanced in number. Excavator and truck should be of compatible capacities**.**

Based on studies they found that truck capacity should be 4 to 5 times the bucket capacity of the excavator, that is the ideal case. So, then the number of machines also to be balanced at the balance number of machines you can see that both the loading unit and the hauling unit will operate at the same production level**,** you will get your maximum efficiency at the balance number, the waiting time will be minimum.

And always whether you are going to round it to a lower number or round it to the higher number, work out the economics. Work out the unit production cost associated with both the cases and then evaluate the balance number and decide your selection**.** Estimation of job cost I have done it already by evaluating the equipment balance.

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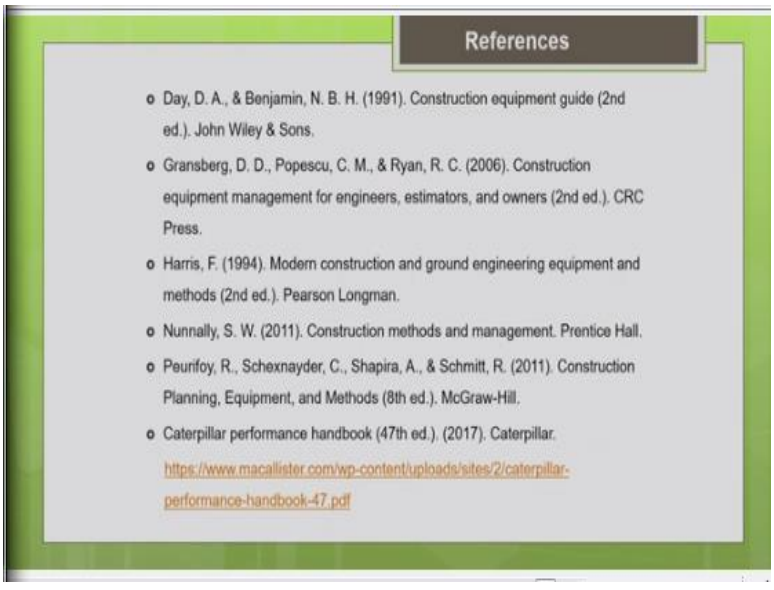

So, these are the references which I have referred for this lecture, you can try to procure these textbooks for preparation. In the next lecture we will be discussing about the piles and the pile driving methods, thank you.