Municipal Solid Waste Management
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Lecture - 11
Analysis of Collection System (Part I)

So hello students. So today again we will go for another lecture on the collection of solid waste. Until now we discussed the different collection services, collection systems, especially the haul container system and stationary container system. Also, we discussed different parameters in stationary and haul container systems. I think another lecture also we will discuss how to compare both these different collection systems.

But before that, we will go for an analysis of the collection system. Here we will see the different equations. We will solve a few numericals also and we will go one by one. First, this is the part 1 lecture, which is specially on to the haul container system, how best we can design the haul container system.

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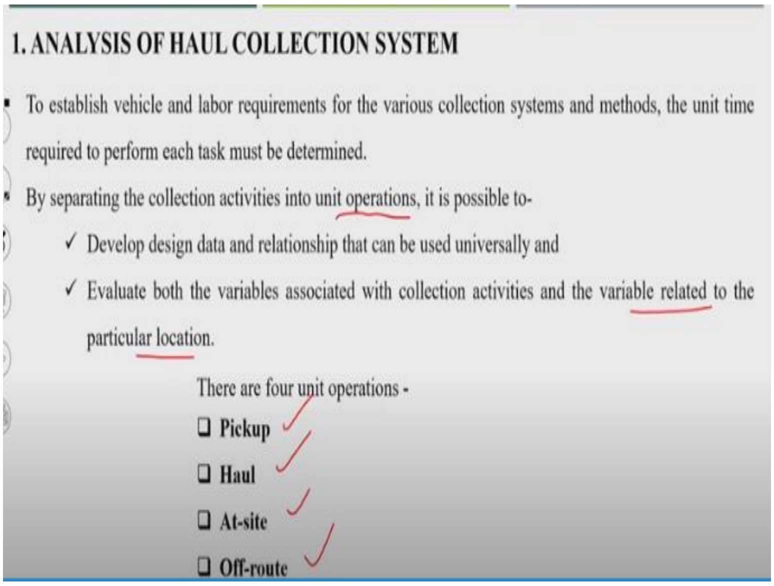

So this is an analysis of haul collection system. Now to establish vehicle and labor requirements for the various collection system and methods, the unit time required to perform each task must be determined. This is one of the very important parameters while designing or while establishing the number of vehicles required, the number of labor required, number of manpower required.

We required specially the unit time required to perform each task. And there are different tasks under the collection which we will see in the further slide. And by separating the collection activity into unit operations. Here, we are seeing the unit operations it is possible to develop design data relationship between different the different unit operations.

Universally also we can compare and also evaluate both the variable associated with the collection activity and their variable relation to the particular location also we can see that. So what are the different unit operations? There is a four-unit operation. First is the pickup. This is the first operation or the time required that pickup time. Another is the haul time or haul unit operation at-site and off-route.

So one by one we will discuss all the four unit operations under the haul collection system.

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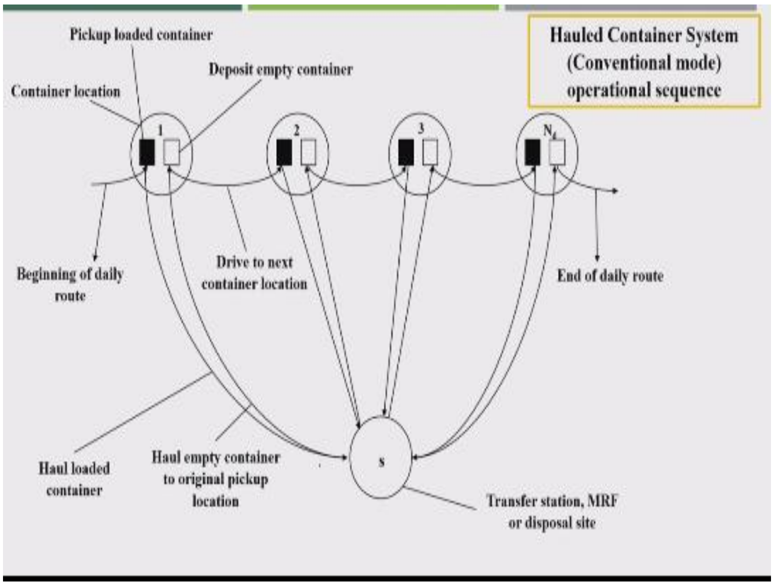

So before going to the different unit operations, I just want to show one more time how this haul container system will work okay, which are already shown in the first lecture on collection systems. But again you see that the beginning of the daily route from the dispatch center and it will go to the first location. It will take the full container, pickup loaded container.

And it will travel to the transfer station or recycling facility or disposal site to haul loaded containers along the vehicle with the haul loaded container. And it will again go to the empty container with the same location. It will deposit the empty container. Similarly, it will go to the next location and again it will follow the same way of collection or operation until the nth location.

And finally, it will and the daily route okay once the time we will get over in a day. This is one way.

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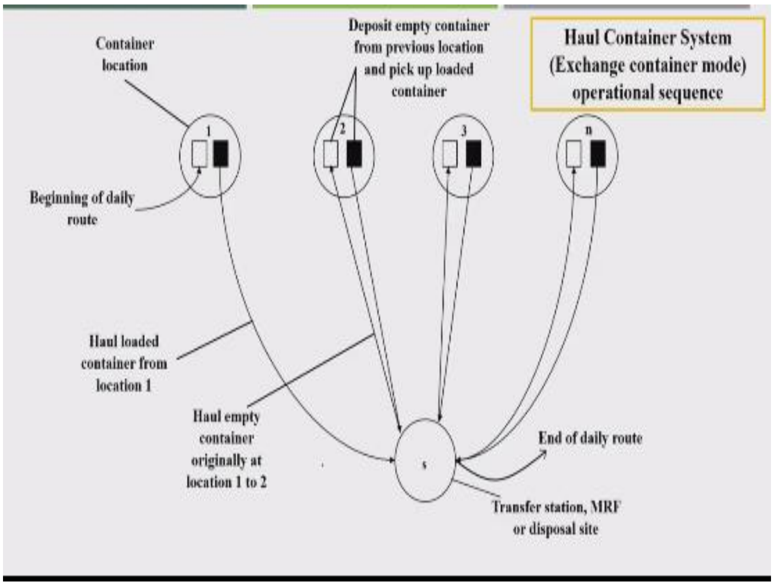

Another way where the vehicle will have one empty container. It will first deposit the empty container and same time it will load the full container. And it will again continue with other locations. It will deposit first the empty container and also pick up the loaded container at the same time. So likewise it will go and finally, the route will get end or it will start to the new route. Now we will see one by one what are the different unit operation.

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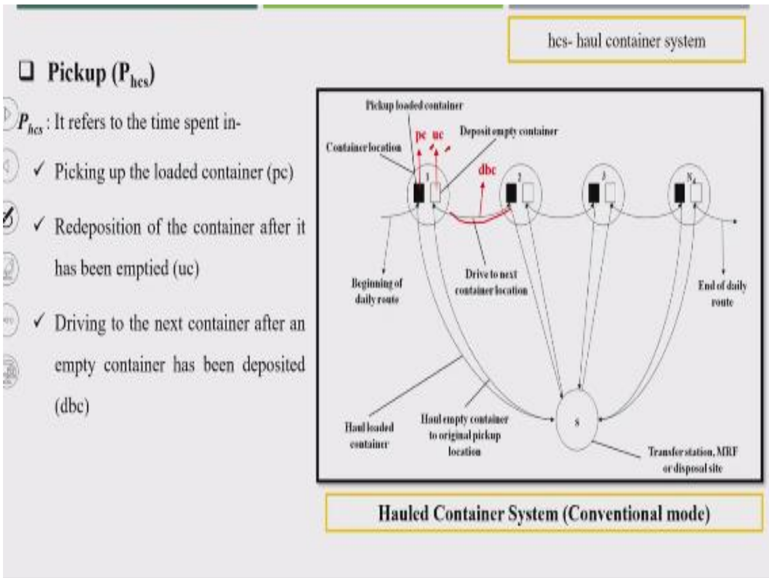

So you see here the first is the pickup time or that nominated by P_{hcs}. Here "hcs" is a named as haul container system, okay. So now here, this is what we see that the flow of the vehicle in a different location. So what will the pickup time or pickup unit operation? That picking up a loaded container. So that is you see here pc that we normally called as a pc picking up the loaded container.

Next is the redeposition of the container after it has been emptied, that is "uc", redeposition of empty container and driving to the next container after an empty container has been deposited. So this is the "dbc" value. So sum of these all these three unit operations called pickup time, or P_{hcs}. It will be pc + uc + dbc.

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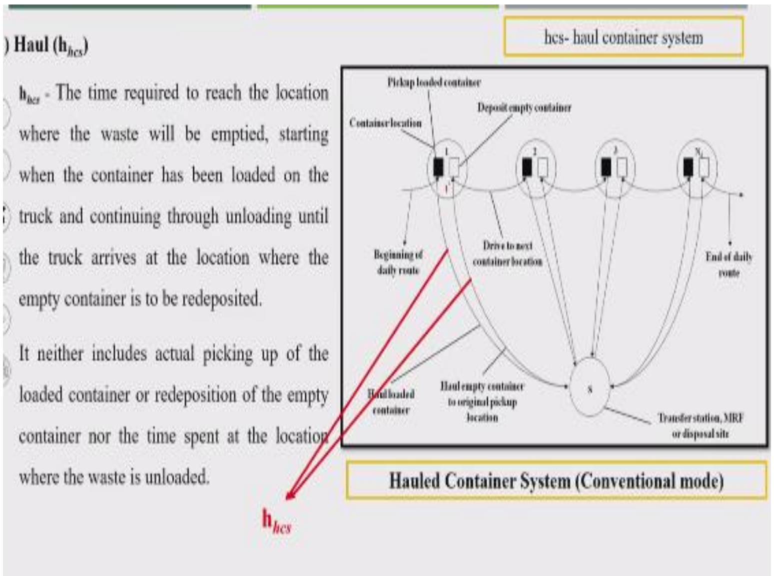

So the next functional unit operation is a haul. That is the time required to reach the location where the waste will be emptied and starting when the container has been loaded on the truck can continue through unloading until the truck arrives at the location where the empty container is to be redeposited.

So in this case, the haul time will start when the unloading of the full container until it will go to the disposal site or recycling facility. And again it will go to the same location. This time required that considered as a haul time that is a unit operation. And it neither includes actual picking of loaded container or redeposition of the empty container nor the time spent at the location where the waste is unloaded.

That is also not here there the time required for unloading of waste onto the disposal site or recycling facility that is also not including into the haul time.

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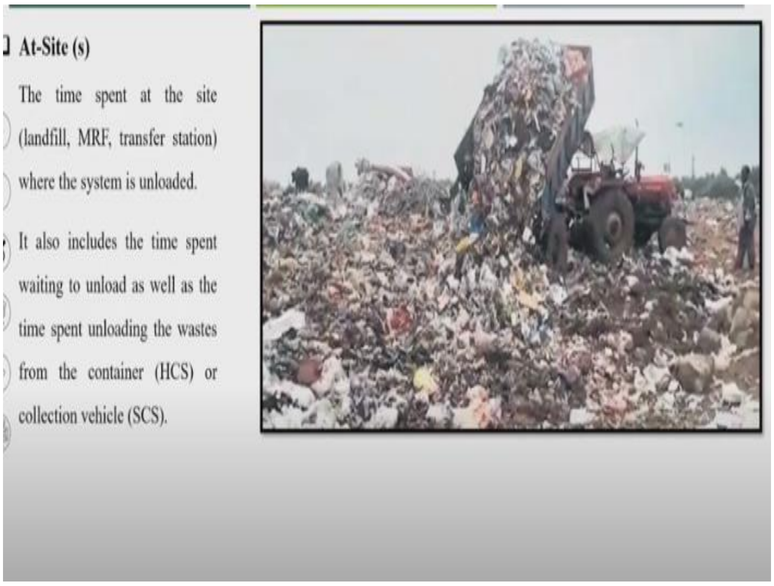

Next is the at-site time. This is the time spent at the site. That is the final place where the waste is getting disposed off. That is that could be a landfill, MRF (Material Recovery Facility), or transfer station, where the system is unloaded. So that time also includes the time spent waiting to unload as well as the time spent unloading the waste from the container or collection vehicle in both cases.

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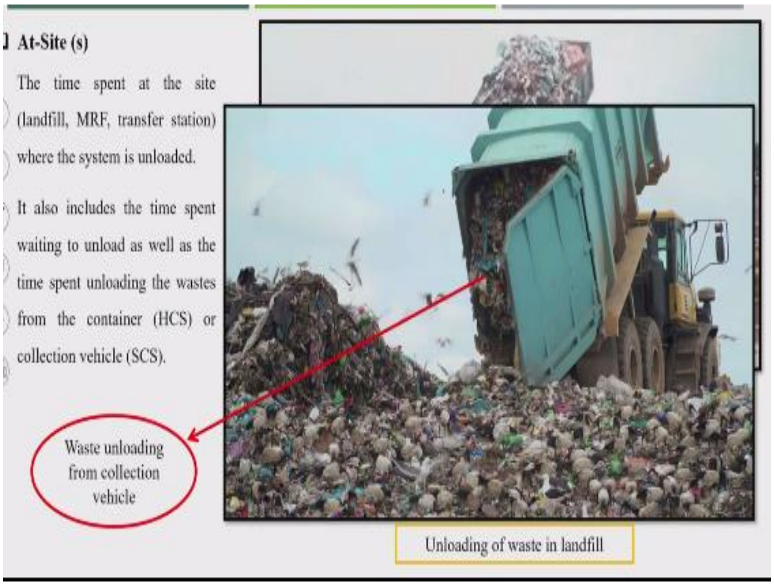

So you see here, waste unloading from the vehicle is one of the vehicle waste is getting unloaded.

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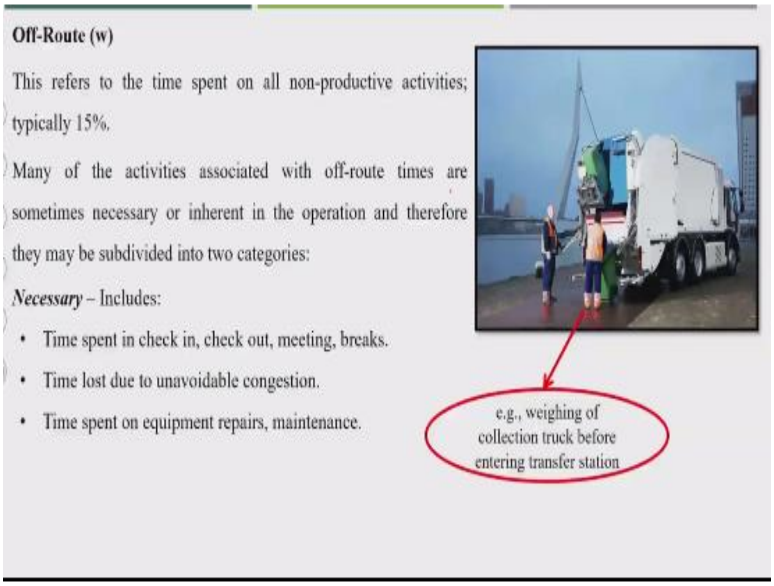

Now next is the next unit operation is an off-route. That is now in the case w. This refers to the time spent on all non-productive activities, the non-productive activities that typically used to be 15%. And what are those? Many of these activities associated with the off-route time are sometimes necessary or inherent in the operation that is very important for the necessary operation.

And something could be unnecessary also is possible. So the necessary will be include time spent in check in check out, meeting, breaks. So whenever the vehicle is reaching to the disposal site, recycling facility, it has to be check-in. Or somebody is writing or you have to wait that vehicle has to wait. Maybe there are number of vehicles which will be together. So it has to wait until their slot will come up for emptying the vehicle.

Also, time lost due to unavoidable congestion. It is also possible that maybe because of the traffic issue also is possible. And time spent on equipment repair, maintenance, that is also possible. These are all necessary activities, necessary operations during the collection. And like you see here, weighing of collection truck also wherever the vehicle is entering the recycling facility it is getting weighted.

So how much amount of waste is going inside the disposal site or recycling facility. It is also possible that one is coming out again the weight is getting measured. And many times the vehicle is also get cleaned because a lot of if suppose that vehicle is collecting biological waste has to be cleaned every trip or wherever is getting emptied. It has to be cleaned. So for there also it required time. That is a necessary time.

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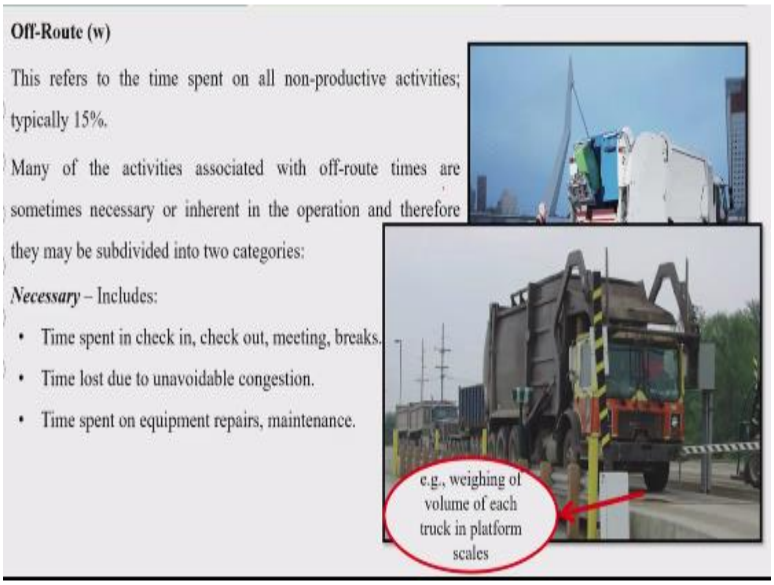

So here another photograph for the weighing of the volume of each truck on the platform scale. And there could be some unnecessary. That is time spent in the personal or it is unnecessary extending the tea times, coffee breaks. And you know that few vehicles, few drivers will always do some unnecessary time they will spend. So that is including into the off-route.

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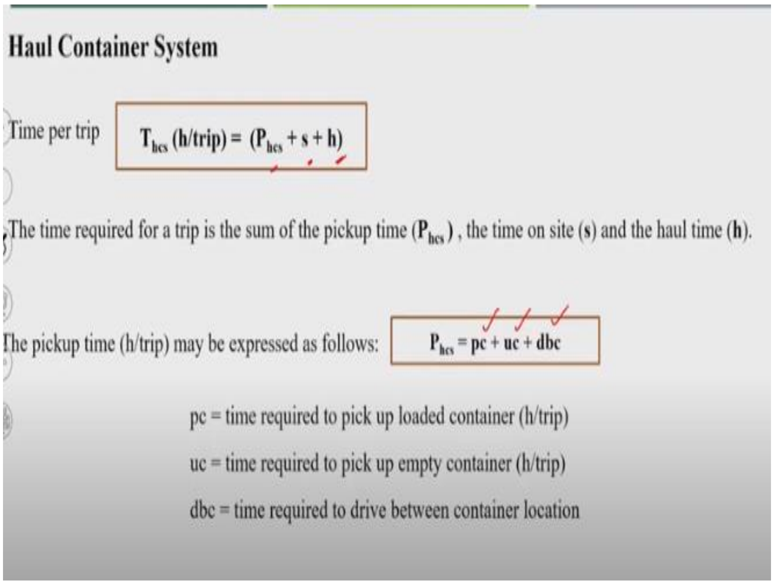

Now we will go for some equations for designing of haul container system. So the first is the time per trip. So for one trip or for one location, how much time is required? That is normally is a sum of pickup time. Sum of pickup time, at-site time and haul time. That is the total time per trip. The time required for a trip is the sum of pickup time, on site time and the haul time.

And this pickup time may be expressed again as pc + uc + dbc. That is a pickup time and that could be different for picking and different for depositing empty container time will be required, transportation from one location to another location, that could be also different.

So this is the pc which is time required to pick up loaded container, time required to pick up empty container that is uc and dbc is time required to drive between container locations. So here in this equation, the P_{hcs} we can calculate by pc + uc + dbc.

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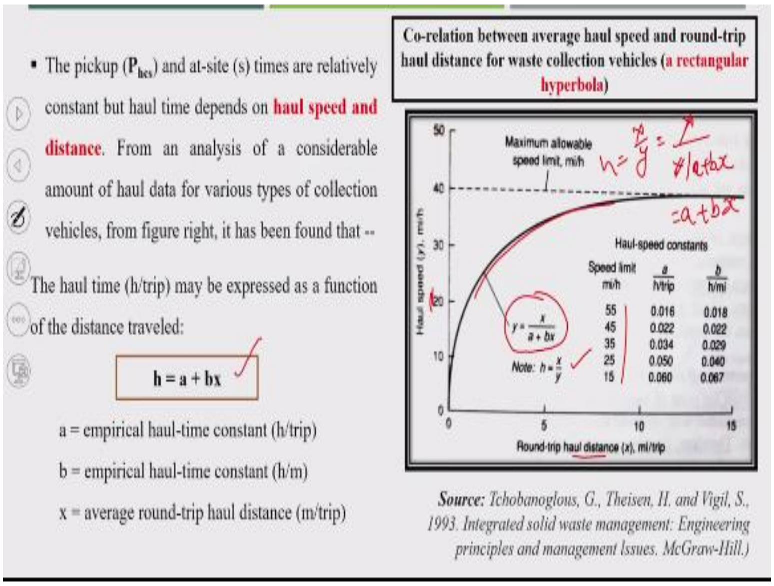

Now next is the pickup time, at-site time. Even at-site time is known how much time will be required to empty the container at the disposal site or recycling facility are relatively constant. Almost you know that how much time will be required in that case. But the haul time depends on haul speed and distance. What is the distance from that particular location from different locations, what is the distance and also the speed is also important to find out the haul time.

So that haul time maybe

expressed as a function of round trip haul distance,

h = a + bx.

If you plot a graph, between haul speed with haul distance, round trip haul distance, we will see here a rectangular parabola. See here, and here we see the speeds also, different speeds. So from this we are getting the equation as,

$$y = \frac{x}{a + bx}$$

where a and b both are haul speed constants. But you see here

$$h = \frac{x}{y}$$

That is a known thing that is time. Haul time is equal to round trip distance divided by haul speed. So if you put it here in this equation, like here I am solving here if h is equal to x by y, then this x divided by in case of y, this will be x divided by a + bx. So this x will get cut and this will be a + bx. So that is what a + bx we can find.

Now here the importance is the haul time constants a and another haul time constant b should be known.

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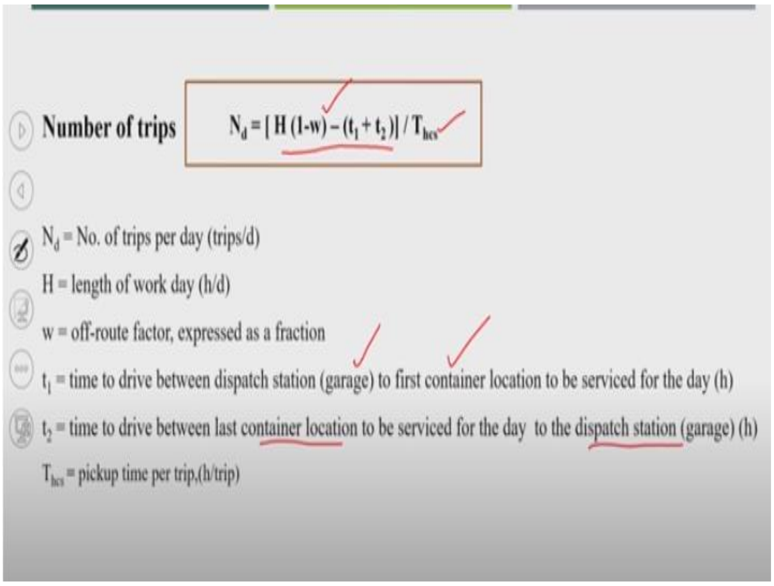

Now here another equation to calculate the number of trips, that is N_d that number of trips in a day. That normally finds how much time available in a day this is how much time available in a day and how much time is required for one trip. In that way, we can calculate the number of trips. Now here, you see here the time available in a day we calculate it like we minimize the off-route time.

We minimize that w = 15% or whatever the value is given of w. If not given we will assume that as 15% and also we minimize the t_1 and t_2, where this t_1 and t_2 are time required to drive between dispatch station from the garage to the first container that is t_1. And t_2 is time to drive between last container location to the dispatch station finally. That is t_2. It is possible that t_2 could be negligible.

Also, it is possible that because normally the first location we are finalizing, which is very close to the dispatch center. So in that case t 1 could be very low value could be possible and even t_2 also that is possible sometimes that dispatch station is very close to the disposal site. So in that case t_2 will be negligible. So by that way we can calculate number of trips.

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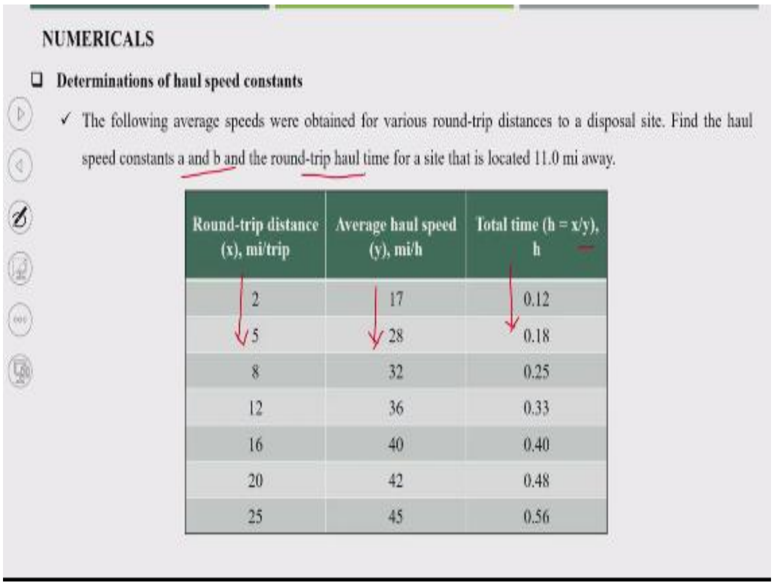

Round-trip distance (x), mi/trip	Average haul speed (y), mi/h	Total time (h = x/y), h
2	17	0.12
5	28	0.18
8	32	0.25
12	36	0.33
16	40	0.40
20	42	0.48
25	45	0.56

Now first we will go for the first numerical to determine the haul speed constants, which I told in the previous slide for calculation of a and b, how best we can calculate. The following average speeds were obtained from various round trip distance to a disposal site and find the haul speed constant a and b and round trip haul time for a site that is located 11 miles away. So this is what data is already available with us.

We know the round trip distance, different round trip distance and we also know average speed and also we know the total time is required that is x by y. We can do and easily we can find the total time. So now we have to calculate the constants a and b and round trip haul time. That also we can calculate, that is x value.

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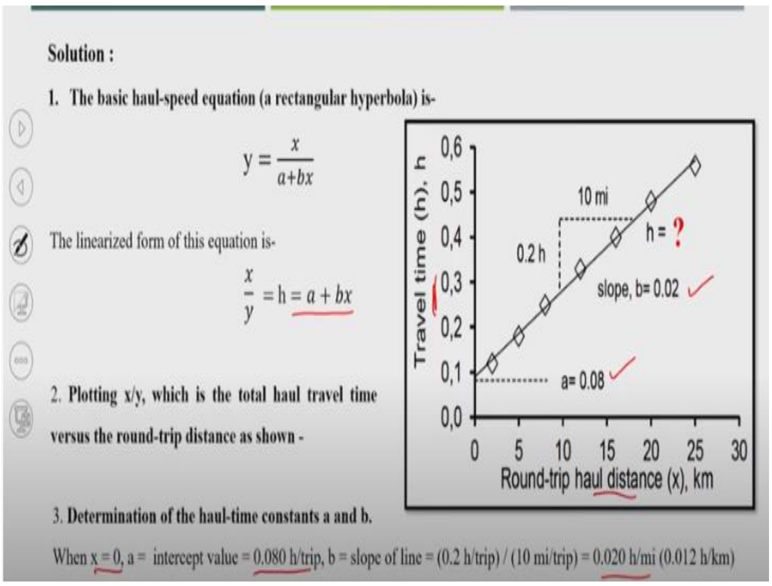

Now, we will go for the solution. The basic haul speed equation, that is we know that is a rectangular hyperbola. That is,

$$y = \frac{x}{a+bx}$$

So if you linearize this equation, we will get it h = a + bx after linearization which we have seen in the previous slide. Now if you plot whatever the data as given the x and y, which is the total haul travel time versus round trip haul distance.

So we will see the plot like this. So, the haul time is given. And this is the haul distance given. And if you plot you see here, we are getting a value that is first constant. And we get second value b that is the slope of this curve, 0.2 divided by 10. So when x = 0, a = 0.080 that we found. And slope of the line that is 0.02 hour per mile. And now we have to calculate.

Now from this graph, where we calculate the a, the constant and b constant, okay for given data by plotting the graph between total time versus round trip haul distance x value. Now we will calculate the h value.

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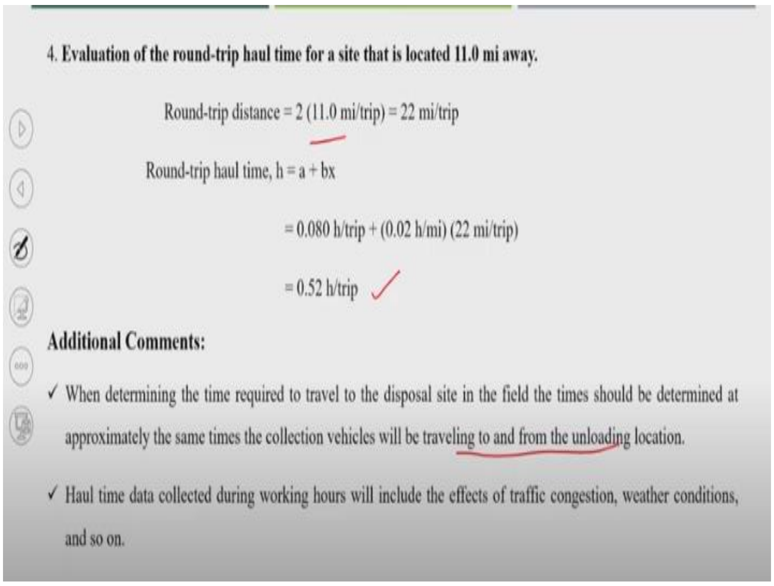

So evaluation of the round trip haul time for a site that is located 11 miles away. So first we have to calculate round trip distance i.e., x value which will be double of whatever the distance is given for the locations. So (2 x 11) = 22 miles per trip i.e., round trip distance. Now, we will calculate the round trip haul distance h = a + bx; a and b we found. And we will multiply by x.

That is finding round trip haul time is 0.52 haul per trip, okay. So there are few additional comments on that. Like first is the determine the time required to travel to the disposal side to the field time should be determined at the approximately same time the collection vehicle will be traveling to and from the unloading location. So here you see the round trip distance we multiply it by 2.

Means the thought was that simple thought was that whatever time required to travel from the location to the disposal site and whatever time required from disposal site to the same location, we thought of is the same, both will be the same. That is why we multiplied by 2. That is one important assumption. And haul time data collected during working hours will include the effects of traffic congestion, weather condition and so on.

So whatever the haul time we calculate, that includes all conditions like traffic conditions, weather conditions, or whatever the maintenance issue will come up that is included in the haul time data, okay. So from this one numerical, we found that how we can calculate the a and b constants and also based on that how best we can calculate the haul time value.

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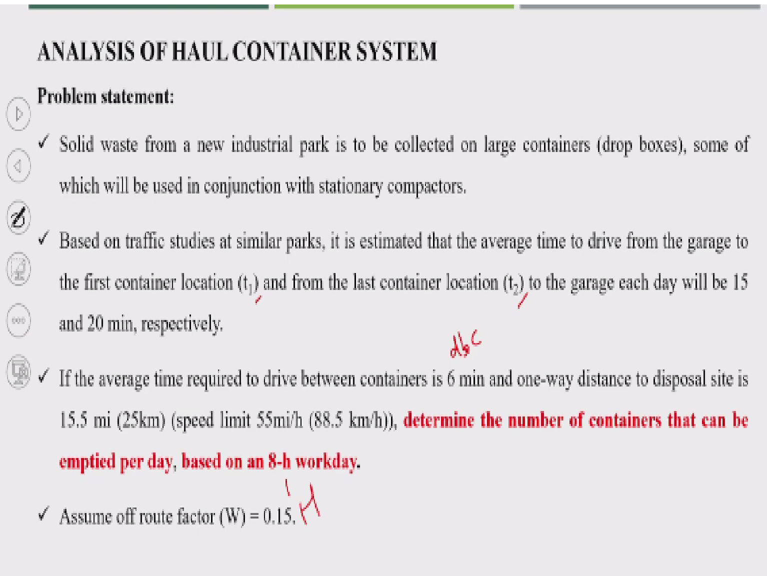

Now we will go for another numerical another problem. From that, we will try to understand how best we can design the haul container system. So the problem statement is the solid waste from a new industrial park is to be collected on large container that in the drop boxes. Some will be used in conjunction with stationary compactors. So it is a mix of haul and stationary container system.

So based on traffic studies at a similar park it is estimated that the average time to drive from the garage to the first container that is t_1 value and from the last container location to the garage that is t_2 value is given that 15 minutes and 20 minutes respectively. So t_1 is 15 minutes and t_2 is 20 minutes. And if the average time required to drive between container is 6 minutes, i.e., dbc value is 6 minutes.

And one-way distance to the disposal site is 15.5 miles or 25 kilometers. So is a one-way distance. But you remember that x is a round trip haul distance. So we have to double this value. And the speed limit is given that is 88.5 kilometers per hour or 55 miles per hour. Determine the number of containers that can be emptied per day based on 8 hour work day. This 8 hour is given that is H value.

Now we will solve the problem. And again one more value is given, assume off route factor W is 0.15. If it is not given also you assume that it is 0.15.

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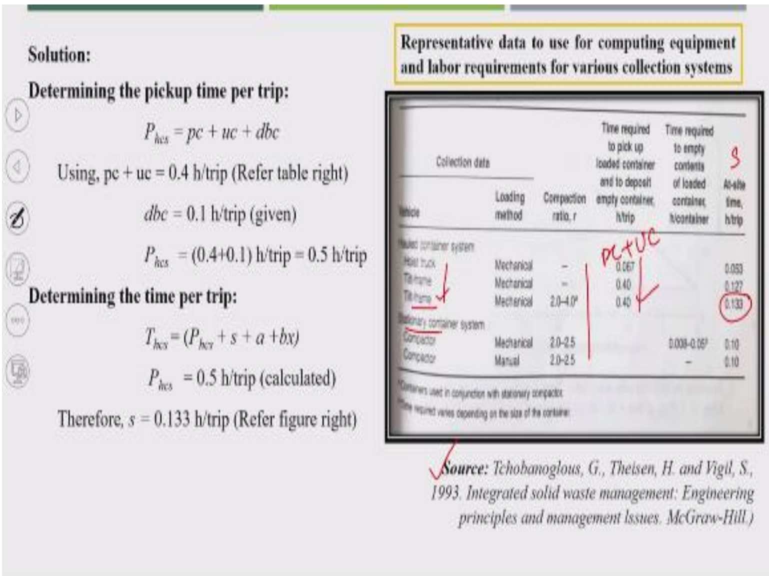

So we will go for solution. First we will determine the pickup time per trip. That is P_{hcs}.

$P_{hcs} = pc + uc + dbc$.

Now here, dbc value is given, but pc and uc are not given. This pc and uc value will be refered from one table, you try to find the source. This is a very good book and some of the notes also I took from this book. This is a very good book for reading purpose.

This book has given these data, where the different kinds of vehicles and what could be the compaction ratio, what could be the time required to pick up loaded container and to deposit empty container. So this is pc + uc value. And also at-site time i.e., s value is also given. So here in problem it is given that what kind of vehicle has been used. So here we had used the tilt-frame.

This vehicle had been used. So we took the value of pc + uc = 0.4 hours per trip and also the at-site time as 0.133, okay. So suppose in the exam this table is not given, but the value will be given. Or otherwise, this table will be given. You have to find the values based on the type of vehicles and type of collection system. Whether it is a haul container system or stationary control system.

Because this table is given for stationary container system also. So now this dbc is given i.e., 6 minutes. That we converted in hour per minute; 0.1 hours per trip. Now we calculate P_{hcs} which is the sum of pc + uc + dbc = 0.5 hours per trip. Now we determine the time per trip. That is total time required in a trip i.e., T_{hcs} that is

$T_{hcs} = P_{hcs} + s + a + bx$.

Now pickup time we know that 0.5 hour per trip we calculated already. And s we took from this table = 0.133 hour per trip.

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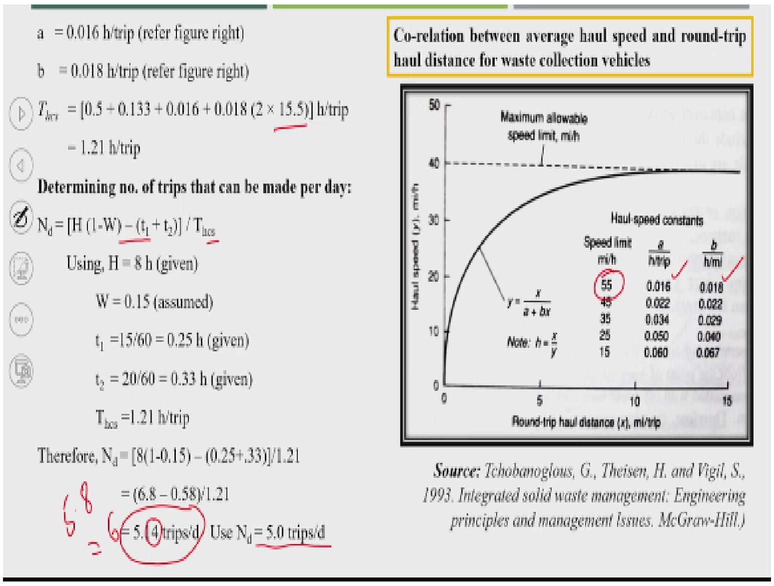

And a and b also I think yes in problem it is given time limit as 55 miles per trip. So from that we took a value as 0.016 and b value as 0.018. It is possible that in exam this graph may or may not be given. Otherwise, the value will be available in the exam itself like a and b value that has to be assumed. Now T_{hcs} we will calculate that is P_{hcs} + s + a + bx. Now here bx we know the distance as 15.5 miles.

So that multiplied by 2, that is round trip haul distance. So that is coming as 0.12 hour per trip. Now once I think two values we know that one we calculate pickup time we calculate the total time required. Now we will calculate the number of trips that can be emptied or that can be made per day. That is the total time available in a day divided by time required in a trip. That is N_d value.

So "H" is given as 8 hour work time. "W" is assumed as 0.15, t_1 and t_2 that is given, t_1 = 15 minutes, that we converted in hour as 0.25 hour, t_2 is given as 20 minutes that we converted in hour as 0.33 hour. And T_{hcs} we calculated that 1.21 hour per trip. So therefore N_d will be 5.14 trips per day. This is the answer, number of trips per day. But you see here this is not possible.

But 5.14 trips cannot be possible. So we will assume 5 trips per day that should be a single numerical value. And suppose if your solution comes as 5.8, you consider as 6, okay. It is just 5.14 so we are assuming as 5 trips per day. Now because the trips have been reduced theoretically, we found it as 5.14 but we assumed numerical value of 5.

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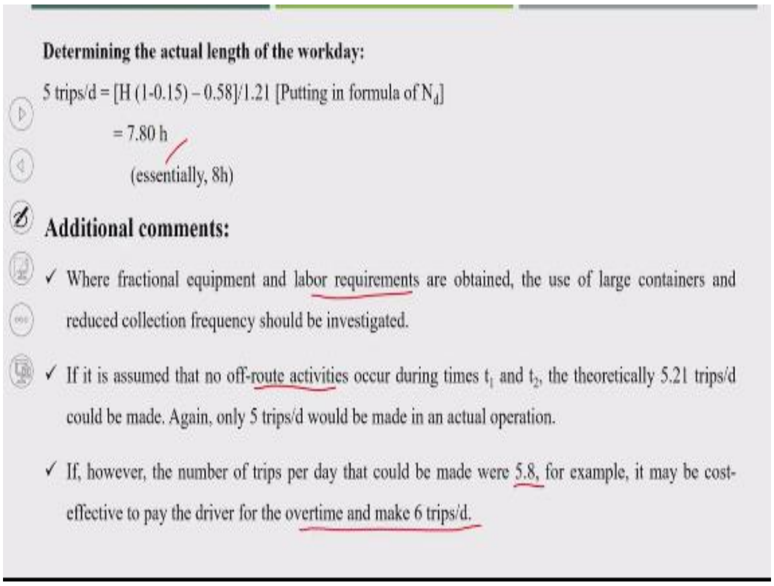

So we will again determine the actual length of workday. Because that 8 hour workday would not be possible. So how much time will be remained? So if you put it in the same equation putting in the formula of N_d same 5 trips per day and we will calculate the H value. So here H is getting 7.8 hour. But actual work time available is 8 hour. So that 0.2 hour is available. So essentially it will be 8 hour.

So, what I said in the previous slide like when it is a 5.8 the value we assume 6. So your time requirement will be more. That will be more than 8 hour. So it is possible that some manpower cab be paid extra charges for half an hour extra work or 1 hour extra work and you can get benefitted by increasing the number of trips in a day. Now what are the additional comments?

So your answer is 5 trips per day that is possible with the given data. So some additional comment for this example, where the fractional equipment or labor requirement obtain the use of large containers and reduce collection frequency should be investigated. That is also very important that the labor requirement.

That we will go for another problem; we will solve for the labor requirement or the time required in a week "T_W" value also we will calculate. And if it is assumed that no off-route activity occurred during the time t_1 and t_2 so theoretically 5.21 trips could be made.

But again 5 trips per day could be made in the actual operation, which I had already explained. And however, the number of trips per day could be made 5.8, suppose if it is possible. For example, it may be cost-effective to pay the driver for the overtime and make the 6 trips per day. That is that could be possible.

So we will finish this lecture. And in this lecture, we see that in the haul container system, how best we can calculate the haul constants a and b followed by haul time from the graph, plotted graph and also given data, how we can calculate the number of trip per day. And we can design the time period on a workday. On a workday, we can go for more than 8 hours also or we can increase the number of trips by that we can design.

These kinds of examples are for one location. Similarly, we can go to different locations and in that way, we can finalize the number of trips and how much time is required. In so next lecture, we will go for a few more examples, where we will try to calculate the labor requirement and also the vehicle type, vehicle size also how best we can calculate. So thank you.