Municipal Solid Waste Management
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Lecture - 13
Analysis of Collection System (Part III)

So hello students. We will continue the same collection of the solid waste module and this will be the last lecture, where we will again go for analysis of the collection system, this is part 3. So in today's lecture, as I explained in the previous lecture, we will compare the haul container system and stationary container system. But, we will start with the one problem one numerical first we will do.

And based on the numerical we will try to compare whether a haul container system is beneficial or a stationary container system. And also we will see one of the very important parameters. Based on that we can finalize whether to go for a haul container system or stationary container system.

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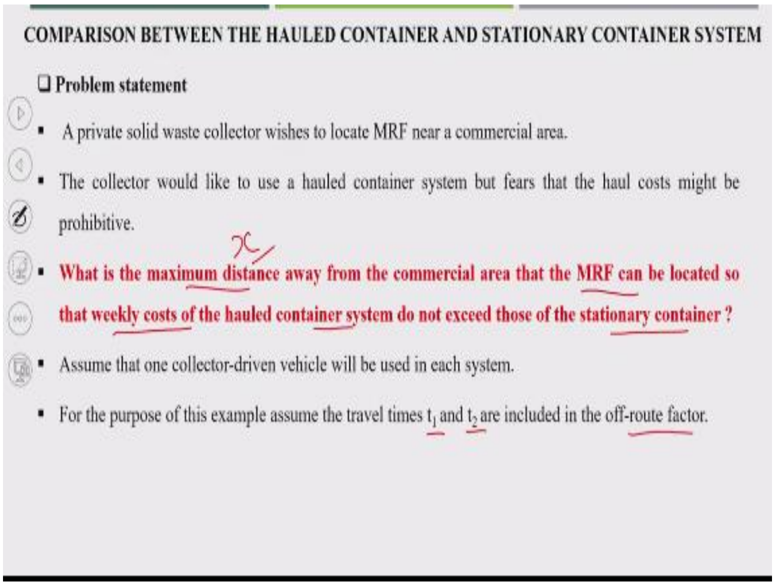

So we will directly go to the problem. And the problem statement is, a private solid waste collection vehicle locate to the MRF a material recovery facility or recycling facility near a commercial area, okay, one private waste collector. And the collector would like to use haul container system but fear that the haul cost might be prohibitive.

I think as I also told because there is a lot of hauling and a lot of hauling means, for every location you need to haul the vehicle to the recycling facility or disposal facility. But if you compare with the stationary container system, where only once in a route one route has the vehicle will haul to the recycling facility or disposal facility. But what collectors fear that the haul cost might be more, okay if he uses the haul container system.

So the question is that what is the maximum distance away from the commercial area that the MRF can be located so that the weekly cost of the haul container system does not exceed those of the stationary container system. So here what has been asked we have to finalize the location of the MRF (material recovery facility) in such a way that the weekly cost of the haul container system does not exceed the stationary container system. This means we had to finalize the x value.

This is the maximum distance This is the x value that we have to calculate where round trip distance or one-way distance we have to calculate where this private collector will finalize the recycling facility or MRF center. And then what the assumption is that the one collector-driven vehicle will be used in each system and for this example, assume that t_1 and t_2 values are included in the off-route factor.

So whatever the off-route factor 0.15 which will including the time of t_1 and t_2.

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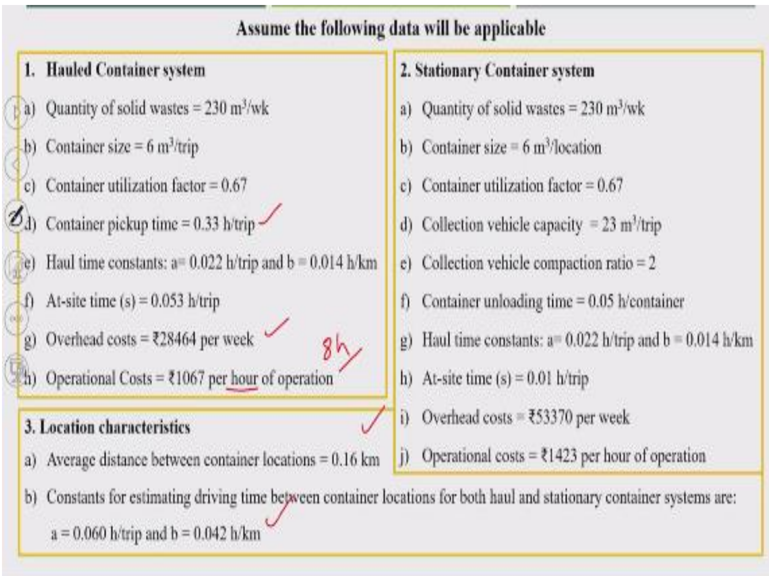

And these data are given. So this is for haul container system. So the first is the quantity of solid waste that is 230 m^3 per week. Container size, container utilization factor, pick up time. This is “pc” which is given. Haul constants a and b and at-site time, overhead cost. So overhead cost is given per week and operation cost okay. Operation costs are based on the per hour of operation.

So normally the operations will be for 8 hours okay. But the cost is given for one hour. Now for the stationary container system, the quantities are the same, container size is also the same, utilization factor is also the same. Now here the vehicle is given okay vehicle size. Collection vehicle capacity is given, the compaction ratio is given. Unloading time “uc” value is given here okay and haul constant.

Here is also a similar way operation cost is also given per hour of operation. And also for regarding the location characteristics, the “dbc” value is given, the average distance between the container location 0.16 kilometer and also constant for estimating driving between the container location a and b values are given, okay.

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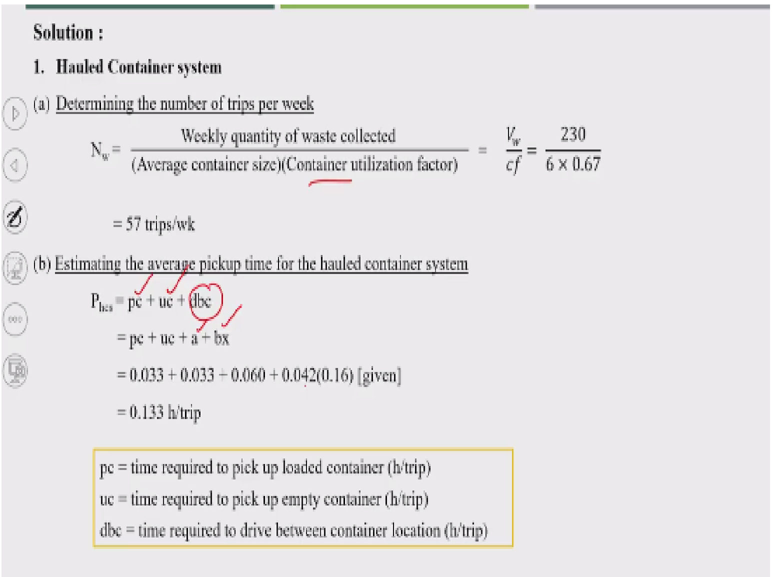

So now we will go for a solution. So first we will calculate the T w value or total time in a week that will be how many days will be required in a week. So first we will determine the number of trips per week. This we can calculate by N w into the weekly quantity of waste collected how much quantity is getting collected on a weekly basis and we will divide by average container size okay.

And this container size is multiplied by the utilization factor. In that way, we can calculate how many trips will be required in a week. So is very simple to understand. The weekly quantity collected is divided by container size. So that will be V w divided by cf. So 230 is the meter cube per week that is a quantity is given. The container size is 6 m^3 per trip and into the utilization factor. That is coming out to be 57 trips per week.

Okay, this is the number of trips per week. Now we will estimate the average pickup time for haul container system. So that is pc + uc + dbc, okay, this is already known to you people. So this pc + uc. Now here, because now for dbc, a and b constants are given, as you see in the problem for this, a and b are given. So to calculate the dbc value, we have to also use these constants.

So that will be pc + uc in dbc case a + bx okay. So here this is the constant dbc constants a and b and x is that 0.16 kilometer is given. From that P_{hcs} we can calculate 0.133. So here these unloading time is also is given. The "pc" and "uc" values are given in the problem. So pc is 0.033 and uc is 0.033 okay hour per trip is given.

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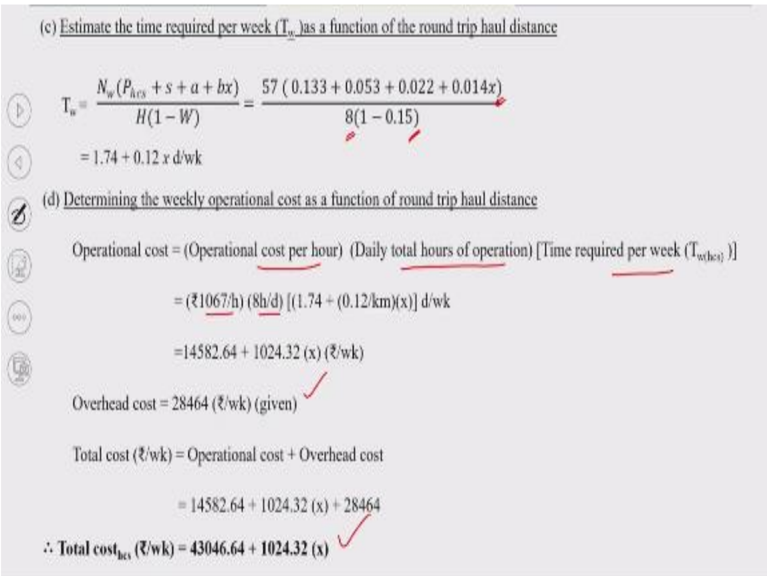

Now we will calculate the time required per week as a function of round trip haul distance. So that this is the one formula we will use-

$$T_w = \frac{N_w(P_{hcs} + s + a + bx)}{H\ (1 - W)}$$

So it is the time required per week and the unit will be the days per week. So we will put up the value. N_w we calculate 57. The remaining value is also calculated. Only we do not have the value of x okay.

And H, we already know that H is 8 hours in an operation time in a day and W is also 0.15. Suppose in the problem these values are not given like capital H and W value off-route factor, you assume. Because every time this will be an H will be the 8 hours and W will be the 0.15. So that is coming out 1.74 + 0.12x days per week, okay. Now we will calculate determine the weekly operation cost as a function of round trip haul distance.

So this operation cost we can calculate by operation costs per hour, a daily total hour of operation and time required per week that is T w value. If you multiply we can calculate the operation cost. So operation cost is given per hour operation cost. This is an 8-hour daily operation and this is the T w value we calculated. So this will be the equation that will come up with the operation cost, okay.

14582.64 + 1024.32 (x) + 28464

Now the overhead cost is already given, okay. This is given in the problem. So the total cost will be overhead cost plus operation cost, okay. So the total cost we can calculate, by summing with the overhead cost. This is finally one equation that will come up. The total cost is –

43046.64 + 1024.32 (x)

this is the total cost value, okay for haul container system.

Now we will go for the stationary container system. Similar way we will calculate the first we will calculate the T w value, the total time required per week. That will be also a function of round trip haul distance. And after that, we will calculate operation cost and finally, total cost.

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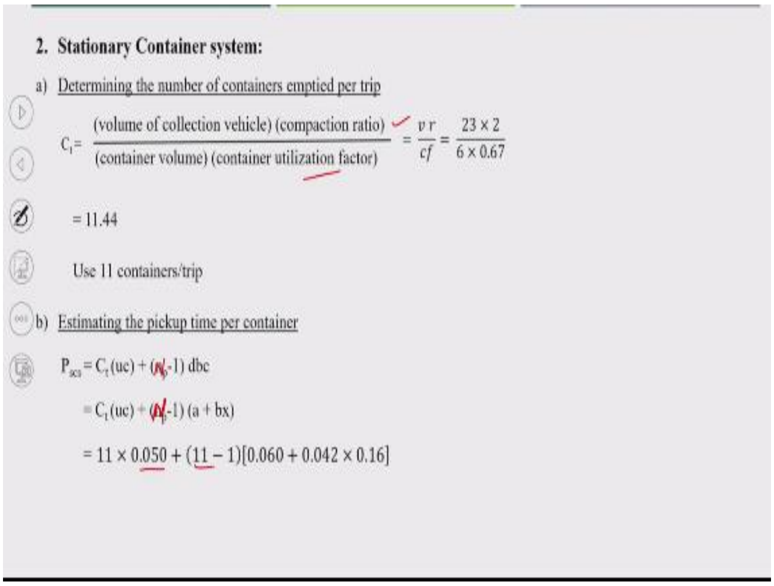

So for the stationary container system, first we determine the number of containers emptied per trip that is C t value. So this we can calculate by volume of collection vehicle divided by container volume. This is simply we can calculate the number of containers emptied per trip. If you know the volume of the collection vehicle and if you know the container volume.

So we can know how many containers could be fill up into the truck okay on a trip. So that only is a multiplying the for knowing the vehicle volume was multiplied by compaction ratio and for container volume, we are multiplying by the container utilization factor. So that is (vr) divided by (cf). So 23 m^3 per trip is a volume of the container vehicle container volume is 6 m^3, okay.

So we are getting 11.44 and we will use 11 containers per trip. If it is more than 11.5 then we could take 12 containers per trip. Now we will estimate the pickup time per operation. And we know that this equation –

$P_{scs} = C_t (uc) + (N_p - 1)\, dbc$

So here in the last class I put capital N, okay, $\{(N_p – 1) \times dbc\}$. So dbc is the same (a + bx). I will put the value "uc" which is already given.

And here also now this N_p is equal to C_t. That we assume 11. Why because the N_p value is the number of containers on each location. It was not given so we just assume only one container in one location, okay. So whatever the number of containers emptied per day, how many containers can be emptied per day, that similar will be the N_p value, okay. So this value comes as 1.22 hour per trip.

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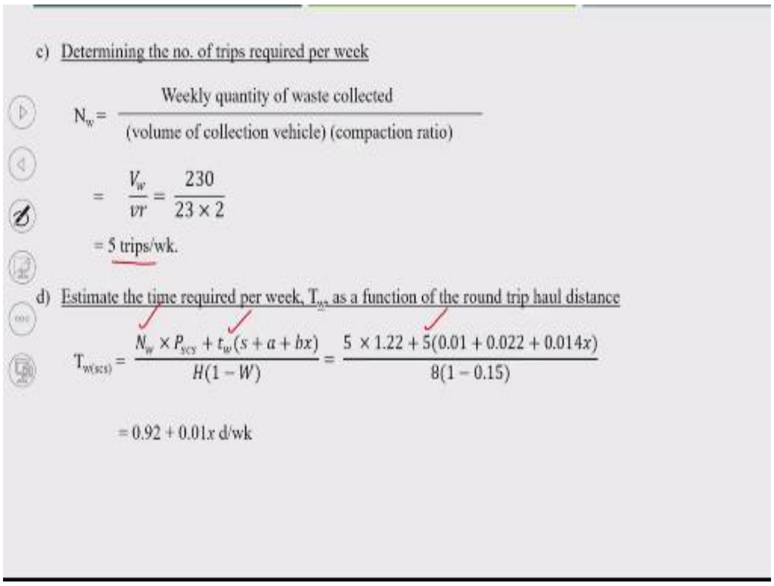

Now we will determine the number of trips per week that N_w value okay first. That we can calculate by the weekly quantity of waste collected divided by the volume of container vehicles. Is also a very simple number of trips required per week can be calculated if you know that the weekly quantity of how much quantity of waste collected is divided by the volume of the collection vehicle. Only we multiply the compaction ratio with that.

So 230 is already given m^3 per week and the collection vehicle is 23 m^3. So from that, we can calculate 5 trips per week that are the N_w value. Now we can calculate estimate the time required per week T_w as a function of round trip haul distance. So this equation we already found in the previous lecture, okay. So where is the N_w is the number of trips per week and this t_w is a round off value of N_w value.

So here since N_w is coming as 5 trips now here also we assume 5 is the round off value. If suppose this value comes to be 5.2, so we will round off by 5. If it is coming 5.8 we will round off by 6, okay. So once we put it all the data, we will get it this equation (0.92 + 0.01 x) days per week.

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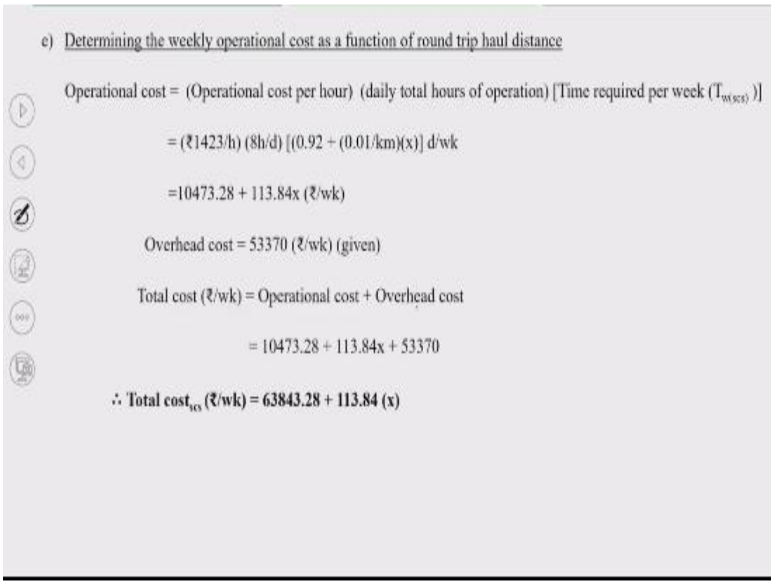

Now we will determine the weekly operation cost is a cost, which is a function of round trip haul distance. So in the same way, we can calculate the operation cost, per hour cost multiplied by the daily hour of operation and multiplied by T_w value for stationary container system. The same way it is calculated and it comes to be (10,473.28 + 113.84 x) Rs./week. So overhead cost, again the overhead cost is already given here.

And the total cost will be the sum of operation cost and overhead cost and finally is the equation will come up the total cost (63,843.28 + 113.84 x). That will be rupees per week, the total cost will be required for the total operation of the stationary container system. Now we got two equations, one for haul container system and other for the stationary container system.

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3. Comparison of the systems

- The weekly total costs for HCS and SCS have been calculated below for round trip haul distance (x) 0, 1, 5, 10, 15, 20, 25, 27

Round Trip Haul Distance (x), km	Haul Container System (₹/wk) Total $cost_{hcs}$ = 43046.64 + 1024.32 (x)	Stationary Container System (₹/wk) Total $cost_{scs}$ = 63843.28 + 113.84 (x)
0	43046.64	63843.28
1	44070.96	63957.12
5	48168.24	64412.48
10	53289.84	64981.68
15	58411.44	65550.88
20	63533.04	66120.08
25	68654.64	66689.28
27	70703.28	66916.96

Now what we will do? We will compare both the collection systems because we do not know here the x value. So what we can do x we can assume 0, 1. We will go forward 5, 10 kilometers, 15 kilometers, 20 kilometers, 25 kilometers. Likewise we will put the value in the both the equations, haul container equation and stationary container system. And we will see that how much total cost will come up.

So I already prepared that. Once we put different x values, this is the equation for haul container system and this is the equation for stationary container system. Here you see that once your haul distance is increasing the haul cost, total cost of haul container system also will increase. And similarly, initially, the stationary container system was high compared to the haul container system.

And again is rising, but that rise is not that high if you compare with the haul container system. So what we will do here we will plot the curve between x value round trip haul distance along in the x-axis and y-axis will be the total cost. And we will see how this graph will change with the round trip haul distance.

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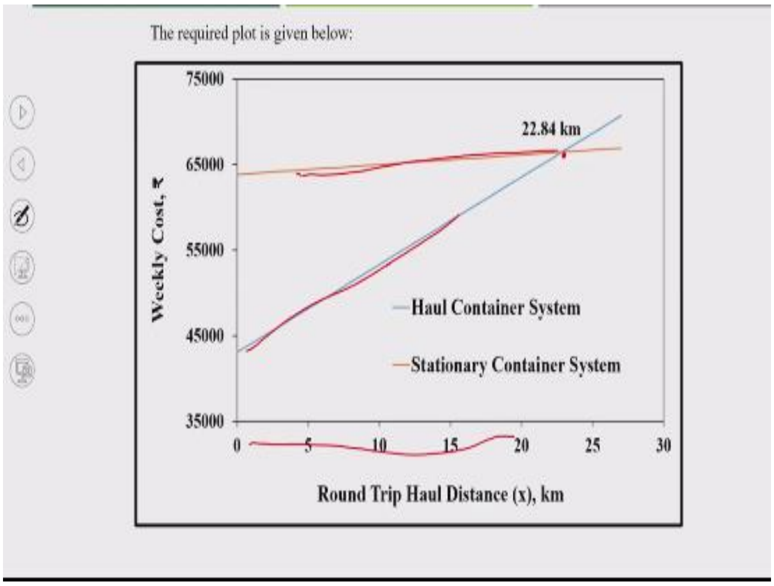

So we plotted this graph between the round trip haul distance versus weekly cost. And surprisingly you see the graph here the haul container system for initially for up to around 20 kilometers the total cost for haul container system was lower than the stationary container system and at the point, 22.84 kilometers the cost of haul container system and stationary container system will be the same cost will be required.

So that was what that private collector was looking that both the cost is similar where they can locate the MRF facility or recycling facility. Now students please understand every time we think that haul container systems are very costly systems because every location waste or vehicle has to be hauled to the disposal site.

So a lot of hauling is required, but see here in this graph for the smaller distance like for 5 kilometers, 10 kilometers even for the 20 kilometers, the cost of operation of haul container system was very low. But, it is increasing very fast. But for a smaller distance like 5 kilometers, 10 kilometers were very low.

But if you compare with the stationary container system for the smaller distance itself, it has a very high cost, but with the distance, it is not changing, okay. There is not much change. That is what most of the developing countries following whether is a stationary container system or haul container system is very difficult to finalize. But I think most of the developing countries follow the stationary container system.

Why? Because you see that whatever could be the distance whether is 5 kilometer, 2 kilometers or whether it goes to the 20 kilometers still the cost is negligible change in the cost. But when you plan for haul container system for the nearby locations always is a highly economical haul container system. But once you go for far from 20 kilometers, your cost will be very high in haul container system.

That is why I always propose for the Indian cities specially wherever possible that or the locations near to the recycling facility or locations near to the disposal facility try to go for haul container system, nearby location. And for the far locations or 20, 25 kilometers or 30 kilometers, 40 kilometers do not go for haul container system. In that case, you can plan stationary container system with the compaction facility, compactor vehicle.

Or also can be planned one transfer stations nearby so that entire waste will come to the one transfer station and from that waste is getting hauled to the disposal site. So and specially for the class 2 towns in India or specially if you take the district centers or taluka level these kinds of haul container systems are highly beneficial. So again you will say that sir, is it possible to have the haul continental system in the smaller cities because you will be required special kinds of vehicles.

So see initially in the primary collection services itself I had proposed that for the smaller cities, why not to use the auto tipper system or mechanical vehicles, smaller sized mechanical vehicles and which will directly collect the waste from the households and will go to the recycling facility or disposal facility. Need not to go for dustbins. Need not to locate the dustbin.

Smaller towns like talukas or smaller districts may neglect the dustbins in the entire city by proper waste collection facilities by the mechanical vehicle, smaller sized mechanical vehicle. And directly hauling of entire waste to the disposal site, okay.

Now I think you properly understand that when you compare the haul container system is not only a cost basis but is not only a distance basis, there are other facilities also are required or other infrastructure facilities are also required to finalize the haul container system or stationary container system. This is one way of solving our problem. So the problem your answer will be 22.84.

That is a round trip distance. So around 11.4 kilometers will be the maximum distance where the private collector will finalize the MRF center or recycling facility.

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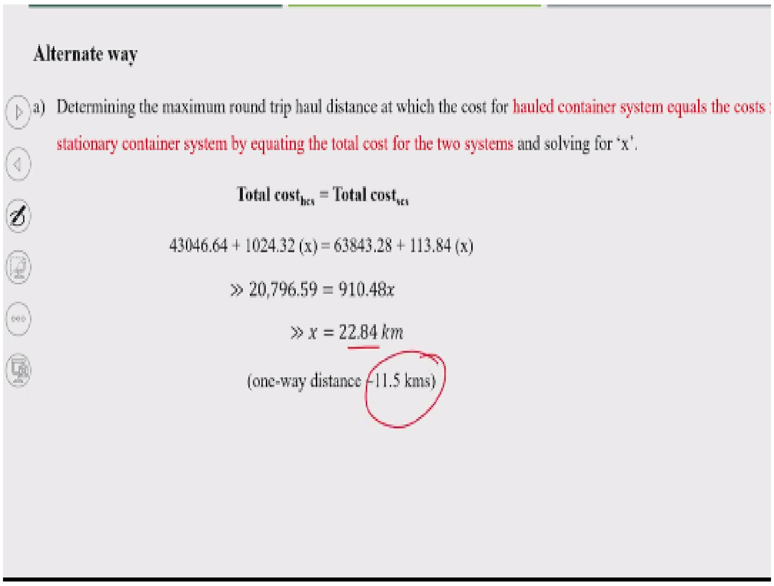

But there is an alternate way we can easily we can calculate the x value. If you put both the values the same as the total cost of the haul container system is the same as the total cost of the stationary container system. By that way we can come up with the x value; x also here the same value is coming 22.84 and that one-way distance of 11.5 kilometers is the answer to the problem.

Where private collectors can plan or can have the recycling facility or MRF facility. So need not fear that the cost of the haul container system or stationary container or stationary container system will be high. Now another very important discussion in the collection of solid waste is the collection route. This is one of the very important issues for while the collection of solid waste from the urban centers.

And there are, I think I cannot say it a is not possible to finalize so easily how to finalize the route. So what corporation also used to do based on their experiences, they are finalizing, but now is good under Swachh Bharat Mission some of the cities they started the GPS facility onto the vehicle. So we can map or we can plan their particular route.

And if suppose the routes are not economical, we can time to time we can change their route, particular vehicle route. But here, I will give a few points. At least I think we can discuss a few points while finalizing the collection route.

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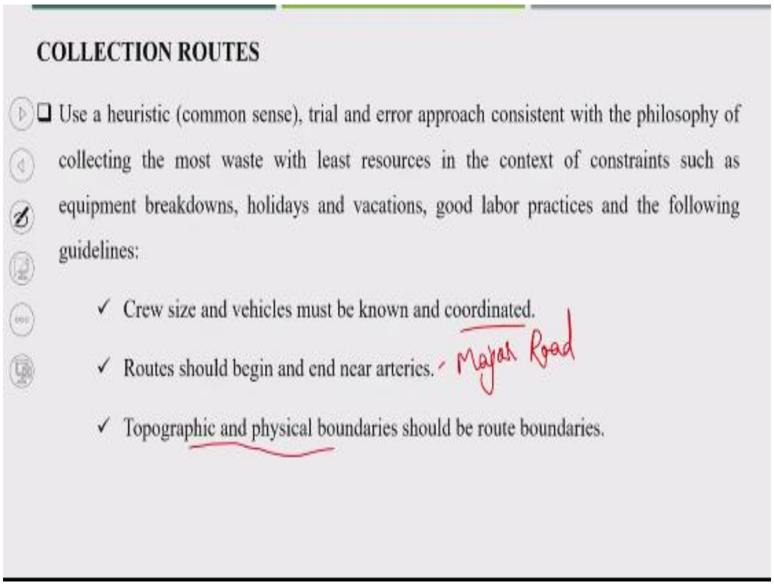

So the collection route uses a heuristic method or we can say is common sense, based on common sense. Or also can say the trial and error method, what corporations used to do. Approach with the philosophy of collecting the most waste with least resources in the context of constraints such as equipment breakdown, holidays, vacation, good labor practice, and another few more guidelines, okay.

So I think these few guidelines at least we can finalize before finalizing the collection route. So the first is crew size and the vehicle must be known and coordinated. This is a very important one, coordinated. So this coordinated means if the vehicle has the GPS facilities, anyone can locate them where the particular vehicle in the vehicle is located in the different locations.

Sometimes the vehicle is I think somewhere is more traffic and you are finding that the vehicle is going to that particular traffic area. So from the office itself, we can call the driver and ask them okay do not go on to that way we can change the location likewise. And you know that in India, India or even most of the developing countries these vehicle drivers also they are a lot of off-route times.

And especially the unnecessary off-route times they are spending. And here time is very important. So there also we can with the GPS facility, we can properly organize them. And we can locate them if they are unnecessary they are extending the off-route time. Next is the route that should begin and end near arteries or major roads. You can say arteries or major roads.

So obviously this is one of the very important points. Whatever route you are finalizing, this route has to be whether you start or whether you finish should be in the from the very near to the or very close or to the major roads. So that once the vehicle is getting filled up completely directly can go to the disposal facilities or recycling facilities. As another point is topographic and physical boundaries should be route boundaries.

This is another very important point, whatever topography of that particular area or physical boundary could be possible like it is possible that some area is covered with the one particular road or particular network could be possible. That could be route boundaries of that particular area.

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So here one photograph you can see, I think we can start from the topography so that we can start the collection from the top of the hill and work downward to the hill, okay. Once the vehicle is getting filled up, go to the download of the hill, okay.

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The last container point should be near the disposal site. I think in that case your t_2 value will be very low or otherwise, your first container could be near the disposal site so that your t 1 value could be less in that case.

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And traffic problems should be dealt with early in the morning. So this is also very important to know that whatever road we are finding the more traffic need not go such kind of vehicle and you know that in the traffic area if such kind of vehicles is going not only the odor issue but if they're some kind of leachate is coming from the vehicle that will also pollute that particular area.

So is good to have the collection system early in the morning. So some of the cities like Delhi, Mumbai even in Chennai, we found that waste collection is done at night or early in the morning like four o'clock, five o'clock they are starting so that by eight o'clock entire collection will get finished. Because from nine o'clock or after eight o'clock, schools are starting, offices are starting.

So you will find a lot of traffic in that case, at that particular timing. So is good to finish the entire collection early in the morning.

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An extremely large load should be dealt with early in the morning. This is also one important wherever I think somewhere the festivals or some particular events have been finalized where a large amount of waste has been generated. So I think that kind of large load or even construction or demolition waste should get collected early in the morning. So to avoid the traffic issue, okay.

So these are the few points and also along with that few important points like your vehicle should not be very close to the schools. Should not be very close to the hospitals. Need not to pass every time to the in front of hospitals, schools, or some civil offices or some kind of government offices. It is not good to travel, the waste collection vehicles in front of these kinds of locations.

So try to avoid such locations also. And these kinds of points also change city to city or urban center to center need to be changed and has to be finalized by the local authorities or local corporation. Based on their experiences can finalize and from time to time change the collection routes also. That is also a very important point. Is not to get fix only one route.

Time to the time change and see how best economically and without having a problem with the local people waste could get hauled to the recycling facility or disposal facilities. Okay, these are the few points where we can finalize the collection route. Also, I can give one module as if you know that GIS software also could possible to finalize the collection route.

So you can read something onto the GIS. You can put it into Google and you can do some Google onto the GIS or some of the books also available. This software also could be possible to finalize the collection route of your collection vehicles. But I think again, there are some physical parameters also has to again have to look. So use the software also and time to time changes along with whatever physical issues are in that particular city.

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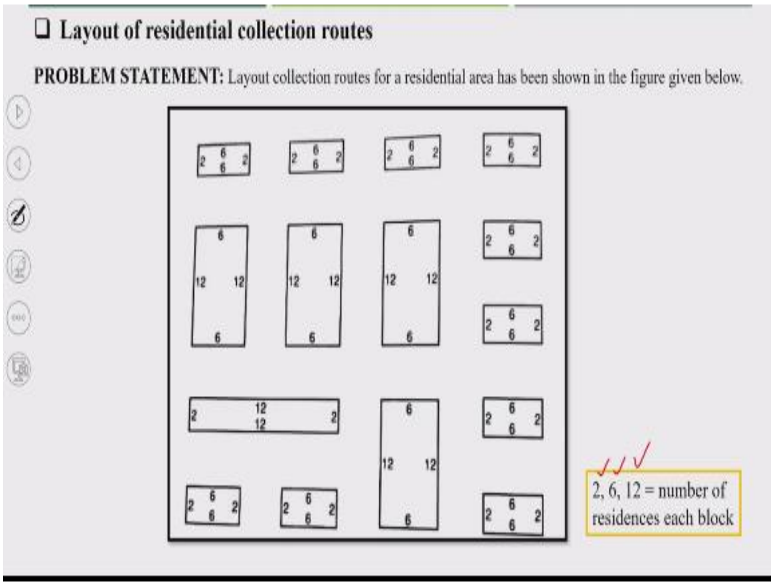

So what we will do, we will go for one problem and we will try to finalize one collection route okay. So this problem statement is, there is a layout is given of one particular residential area. So this is the layout is given okay. So here in the particular block 2, 6, and 12 number of residences each block okay. So there are different blocks are there and different residence had been given into each block.

Somewhere in 2, is 6, 12 residences are given, okay. We have to plan the collection route for this residential area.

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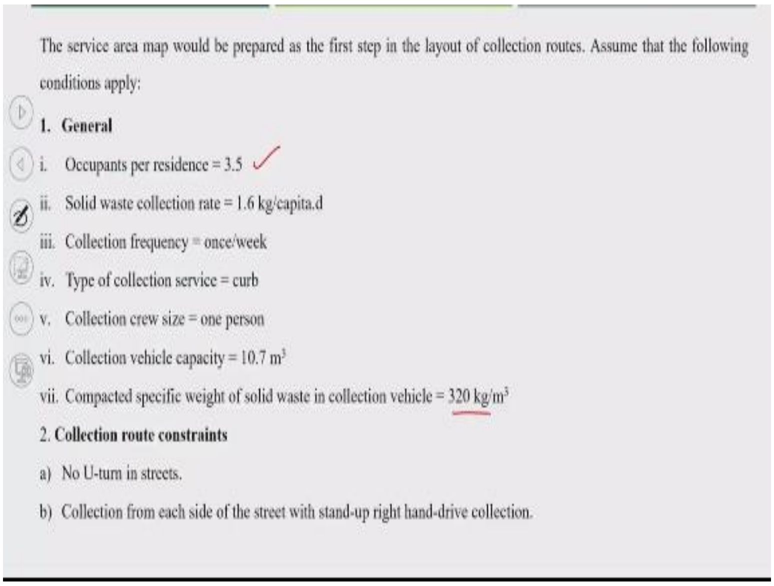

And the service area map will be prepared as the first step layout of the collection route. And assume that the following conditions apply. So the occupants per residence. So we saw that we have 2, 6, and 12 residences and for each residence, the occupants are 3.5 persons. And the collection rate 1.6 kg per capita per day. Collection frequency once per week.

The type of collection service is a curb. The collection crew size is one person. Collection vehicle capacity 10.7 m^3. And the compacted specific weight of solid waste in the collection vehicle that is density is also given 320 kg per meter cube, okay. So we will go for a solution to that. First, we will calculate how much amount of waste has to be collected and how many trips will be required.

So based on that trips, we can finalize the collection route. And few constants are given. No U-turns in the street. This is one of the important which is also needs to be discussed while finalizing the collection route. The vehicle should not have the U-turns okay. I think it is very difficult for such vehicles or large vehicles to have U-turns.

And the collection from each side of the street with a stand-up right-hand drive collection system. This is also an important one. The vehicle has a right-hand drive collection system. Only once the vehicle has the right hand from that households only the waste is getting collected. Not from the other way.

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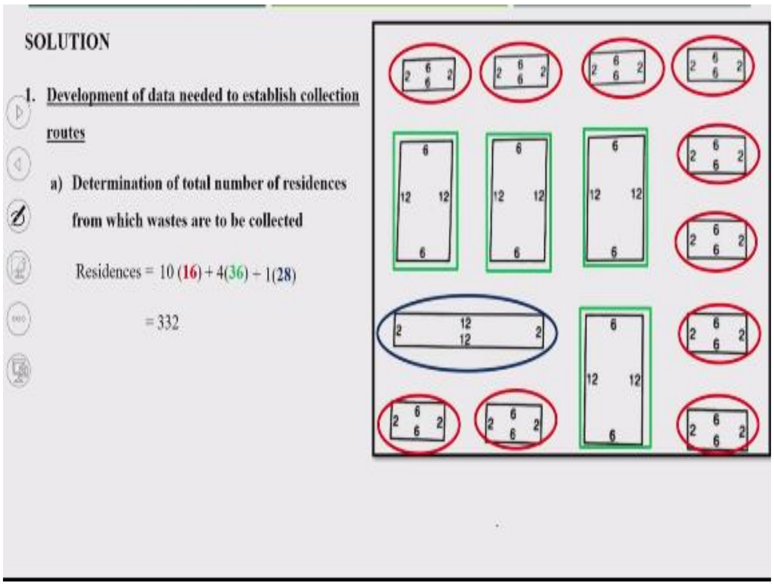

So we will go for a solution. The first development of data needed to establish the collection route. So the first is the determination of the total number of residences from which waste starts to be collected. So first we will see the residence. So we see that we have the residence of 2, 6. 2, and 6. So this is coming to be 16, okay. What are the 10 numbers, okay.

16 residence of 10 numbers and for 36 residence of four numbers and 28 residence of one number. So we can finalize the residence, 332 residence in that particular residential area.

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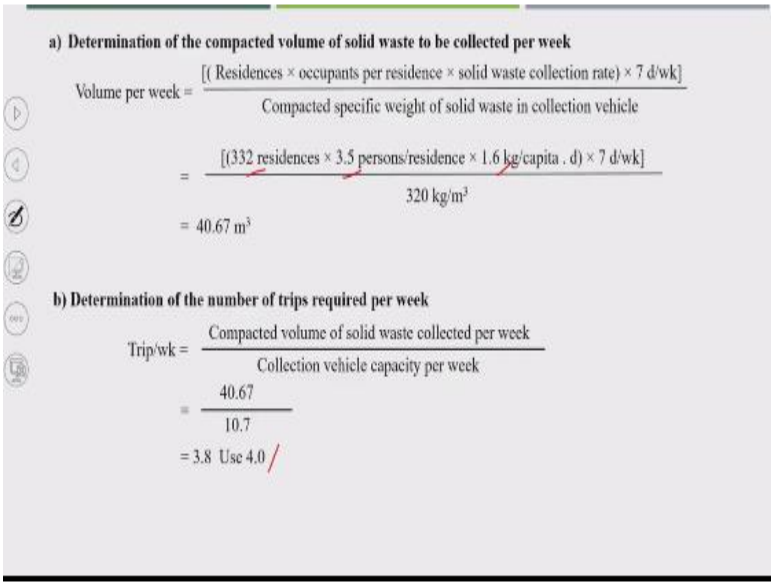

Now we will see the determination of the compacted volume of solid waste to be collected per week. So then we know that volume per week, we can calculate by residence into occupants per residence multiplied by solid waste collection rate and multiply by 7 days in a week, okay? Because once in a week collection facility. We will divide by the density or specific weight of solid waste in the collection vehicle.

In that way, we can calculate volume per week. So the residence is 332 we calculated. 3.5 persons in each residence per capita generation. And 320 is a specific weight of solid waste. So in that way, we can calculate volume per week 40.67 m^3. Now we will determine the number of trips required per trip. This we can calculate by compacted volume of solid waste collected per week divided by collection vehicle capacity, okay.

How much is the volume of waste collected per week divide by a collection of vehicle capacity you can calculate. So this we calculated the compacted volume of waste collected 40.67 and collection vehicle capacity is 10.7. It comes to be 3.8. So we will use 4 trips per week, okay.

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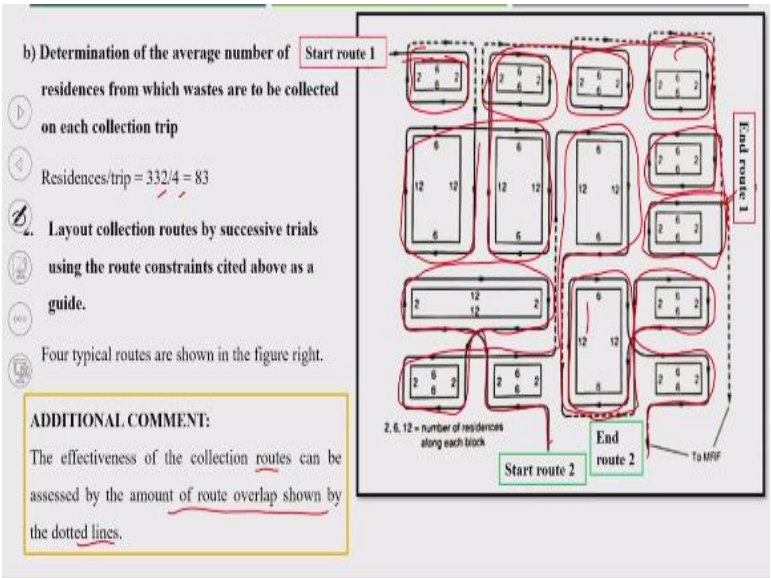

Now we will determine the average number of residence from which waste has to be collected on each collection trip. So we have a residence of 332 and the number of trips is 4. So for each trip, we will have 83 residence per trip. Now we will layout the collection route by successive trials using the route constraint cited. So 4 typical route, you can see here. So now the first is this is the start route.

So the first route started by like this. So now here see at here the waste collection by right hand only. The vehicle is traveling, waste is getting collected like this. Now, this the dotted line is saying that there is no waste collection okay the dotted line. So the vehicle will go like this, is going like this. You see it here. Likewise, the operation and you see there is no U-turn okay.

Likewise, waste is getting collected and here the route will get the end. So this is the first route. Now for the second route, it will get started like this and this will be the end of the next route. So you see here I think we plot already the routes. So the effectiveness of the collection route can be assessed by the amount of route developed by the dotted line. So in this case here you can see that there are two dotted lines.

So means I think here is very difficult. Every time the vehicles you either in the route one and route two both way that particular road has to be used multiple times. So but I think is very highly efficient this route, we can finalize it. And you see here on both routes, we avoided the U-turns. And we tried that from every location, the waste has to be collected and maximum time we tried that the vehicle has been traveled from once in once only in that particular road.

I think but I think still we have to use a few roads in the two times or three times, okay. So based on that we can finalize the different collection routes. Now here we took one example of starting a collection route and ending another collection route. So likewise, for the entire city also we can plan and every time also I propose that do not plan the entire city in one part.

So always try to decentralize even the waste collection system also could be decentralized. Some particular geographic area waste collection will be different, their routine could be different, even waste collection system could be different, whether haul container or stationary container system, some of the different topographic area of the same city, your collection system will be different, even primary collection service could be changed.

And based on that it is possible to finalize the collection route. And again is dependent upon what kind of experiences the local authority is getting. Based on those experiences they had to modify. And also is very important because the waste generation is exceeding year to year. So based on that, your infrastructure facility for the collection system or collection services also has to be improved.

I would not say need to go for a mechanical collection system only. Somewhere is very difficult to operate the mechanical system, their operation is difficult. So it should be a mix of mechanical collection systems or manual collection systems. But I think we have to try that. If you are good at the collection, then only we can go to a proper treatment facility or recycling facility, and also can we finalize the proper disposal facility.

And why I am trying to share more about that because the collection only is taking maximum funding for waste management. And if you improve the waste collection in an economical way or proper planning way, we can find some kind of money for the treatment facilities and further disposal facilities also. So with this, I will finish this module at were the end of this module.

Now from the next lecture onward we will go to the first transfer station. This is also I had shared few points onto that in my previous lectures. So the next lecture I targeted especially onto the transfer stations. Then once the entire waste is getting transported to the or collected or transported to the recycling facility or disposal facility, we can go to the treatment facility, okay. So followed by we will go for treatment and disposal, okay. Thank you.