Integrated Waste Management for a Smart City.
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Lecture-27.
Collection system (Continued).

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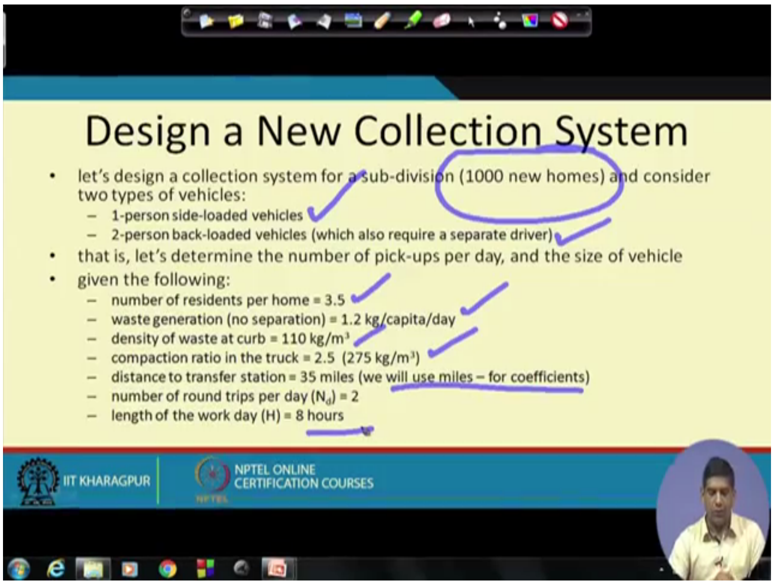

Okay, so let us, we will continue and look at the example problem that I mentioned to you towards the end of the last video. So this is the example problem, so we will design a new collection system for a subdivision. So I have taken a very small small kind of an area just to illustrate those concepts and those equations, how those equations are used, for a real study, things will be much more complex. And we cannot, but the basic concepts will be the same, the equations will be the same, you have to go around doing the same thing but of course what you can think about is a real city will be several multiples of this problem, so rather than may be 10 of, 10 of those, 20 of those, 30 of those, depending on how big is the city is.

So let us get target on this particular problem here. So we are looking at an area of 1000 new homes, so 1000 new homes, not small, it is pretty decent size. So 1000 new homes and then they are looking at 2 types of vehicles, the municipality is thinking should they take a one-person side loaded vehicle where the person will get down and do the or the two-person backloaded vehicle which also requires a separate driver. So you have one-person vehicle where the person who is driving is also bring the collection and the 2nd one is your 2 persons vehicles which also requires a separate driver. Again those are also the different scenarios you may have to evaluate because depending on whether you go for one person or 2 persons, 2 persons which also have a driver, so essentially 3 persons.

Your there labour cost will differ. So we need to look at which one is good for the city. So let us determine the number of pickups per day and the size of vehicles. So we have been given the number of residents per home, the average is 3.5, waste generation with no separation is 1.2 KG per capita per day, so it is waste generation without doing any separation going on. Then we have densities of waste at the curbside, it is on 110 KG per metre cube, that is the density of the garbage. Why we need the data, so that we can find out how much, how quickly the garbage will fill up in the truck and so how many trucks will require and how many houses the can service for doing the one trip. So compaction ratio in the truck, so garbage, in the garbage can is around 110 KG per metre cube, it is compacted around 2.5 times, so we have 275 KG per metre cube.

Now the distance to transfer station is 35 miles, why I have put miles, because for the coefficients, remember A and B values are based on miles visit was developed in US. So we will use miles for, that is why we are using miles here and I told you in the earlier video that one-mile is 1.6 kilometres, so you can do that can version as well. So number of round trips per day is 2, we have taken number of 2 round trips can possibly be done in a day and let us see and the length of the work day is 8 hours. So this is what data has been provided to us and based on that let us start do some maths calculation.

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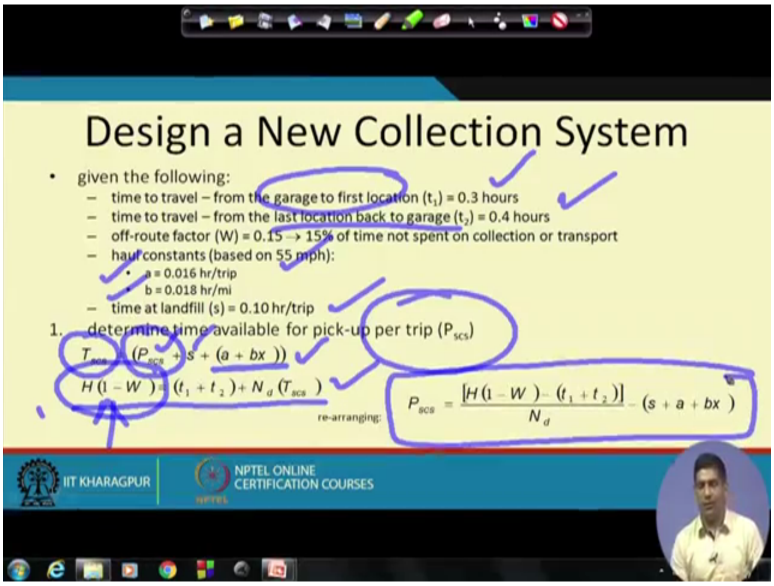

And there are some other, sorry I and B values are not given, not given in the previous slide, so we need to that as well, so we have some more data here. Where time such as T1, time from the garage to the 1st location, remember, we talked about that and from the last location to the garage, so T1 and T2 is given, 0.3 hours and 0.4 hours, then off-route, W is at 15 percent, not bad, 15 percent of the time not spent on collection transport because see people are working for 8 hours a day, 15 percent is around what , said around 1.4 hours. So with that includes lunch break, bathroom break, tea break, cigarette break and also breaks together, that is not bad actually.

15 percent time not spent on collection or transport, so that is the off-route factor, so we have to take that into consideration and then A and B values are given to us, 0.016 and 0.018 and these are the empirical numbers and they are based on hours per trip and then it is based on 55 miles per hour, 55 miles again multiplied by 1.6, you can get how much kilometres per hour. And then the S value is given as, S is the time at the landfill or at the transfer station, so that is 0.1 hour per trip. Now we have to find out what is the time available for pickup time, for the pickup so that the garbage can be picked up, how many houses it can serve.

So this again, remember these equations of the previous video, you had TSCS which is the time for the trip is how much is the pickup time per trip plus S which is it has been given to us, 0.1 hour, then A plus BX is also given to us because the distance is given in 35 miles, A is given, B is given, so we can calculate. So S is provided, S is known, A plus BX is known , so let us see in this equation what is not known is T SCS, so that is what we need to find out. And similarly we will be using the 2nd equation which was based on what is the number of trips that it can do, so number of trips, Nd, just to rearrange the equation that we had earlier, so if you do that, you will get this relationship where the work day multiplied by the off-route factor is equal to T1 plus T2 which is the time to travel to garage and back plus number of trips times TSCS.

Which is see if you just think about logically, you do not even have to memorise these equations actually. And do not try to arrive them, try to understand them, because if you understand them, you will remember it lifetime, if you try to memorise them, you will forget after this class is over. And there will be in the exams, you may have to use these equations which and of course that is why you do not want, do not try to memorise, just go by simple logical steps. So if you go, even if you look at the 1st equation, it is the time for the trip, time for the trip will be what? Time taken to calling the garbage as individual, individual houses, like how many houses that it is serving.

So that is plus the time at the disposal point or the transfer station plus the time for the hauling which is, so we have talked about that, gives us the total time for the trip. Now, in a workplace you have, workday minus the off-route factor is the total time is available for the working, for collecting garbage, for driving the truck from the garage, back and all that, so that should be what, that should be T1 plus T2 because the time from the garage and back, that should be there because that will be the work time as well plus whatever is the number of trips because here is the time per trip, so number of trips that it can do multiplied by time but trip in that particular day, that time plus the time to and fro garage is the total work hours.

Just think in a simple logic way, say if you are working 8 hours per day, you take some off time because lunch and other things has to be done as well to work efficiently operated 15 percent, sorry minus that over here. So H - 1 minus W, H times 1 minus W, so that is total work time like work time and that work time will be needed to drive a truck from the garage to the 1st location and at the end of the day from the last location to the garage, so that is T1 plus T2 plus it is going to each of the houses, collecting garbage and then taking it to the landfill or the transfer station, so that is your T SCS.

And depending on how, if it is ND is 1 with the number of trips is one, it should be one, if it is 2, we have been given that the 2 trips which is being done. So that is, these 2 equations that we have, if we rearrange these 2 equations and we can get this equation. I like to do it, I have they showed and it should not be difficult. Because if you just look at here, you can T SCS can be substituted by the equation number 1 and then you rearrange this, make this P SCS on one particular side and you will get this particular relationship. So once you have this particular relationship, here everything else is known , H is known, W is given, T1 and T2 is given, ND is given, we know S, we know A plus Bx, so you just plug those numbers and you will get P SCS, certain that simple and straightforward.

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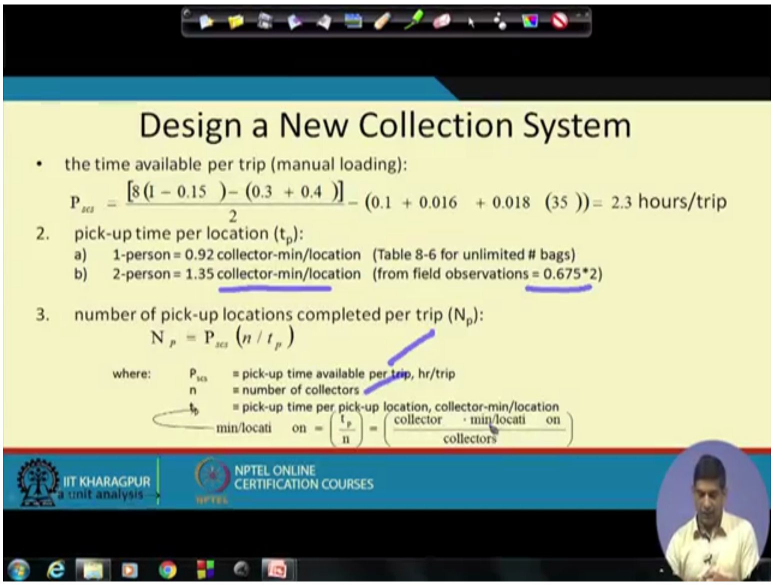

Again do not try to memorise, if you try to memorise this equation, you will definitely make a mistake. So just go logically and derive this equation, it is not that , it is not difficult to do it. So that is like the way how we can calculate, so now if you will get those numbers or if you start taking the numbers from this slide and 1st 2 slides in this particular video, you plug these numbers in your and then you get 2.3 hours per trip. It takes 2.3 hours per trip to get to do P SCS for the manual loading, or the time available per trip for manual loading is 2.3 hours, it is, that it can do. Now for 1 percent truck, it takes around 0.92 collector minute per location.

So it is table 8.6 for unlimited number of bags for the for the 2 persons trucks it takes 1.35 collector minute per location. Now it may seem like why, how come for two-person it is taking more time. Here it is, actually not it is two-person is taking more time, here it is data has been given per collector minutes. So actual value for each person is actually 0.675, so 0.675 multiplied by 2, because there are 2 people. So that is why you would see the numbers is higher. Because logically if you think if you have 2 people working, the time taken should be less but there are 2 people working, so you have to account for the time taken by both the persons.

So it is not that for one person it is 0.92, for 2 people the numbers will come down to half of this 0.9, it does not happen that way, because sometimes which is needed anyway. So you have 1.35, which is although it has come down, 0.9 to 0.675, so that is a good nearly one 3rd reduction but since there are 2 people, you multiply by 2 and that you get 1.35 collector minutes. So now number of pickup locations, so how many pickups it can do, pickup time it can do for per trip. So here PSCS, we already calculated 2.3 hours, so that is the pickup time available per trip and then and could be the number of collectors.

So pickup time pickup time per pickup location in terms of collector minutes per location you have TP which is the pickup time per pickup time where it is that, pickup time per pickup location and then divided by the number of collectors. So based on that you can calculate what is collector minute required divided by the number of collectors which is available. So let us look at that particular part in terms of the numbers which will make it more clear for you. So here in terms of 2 types of, we had 2 types of collection systems.

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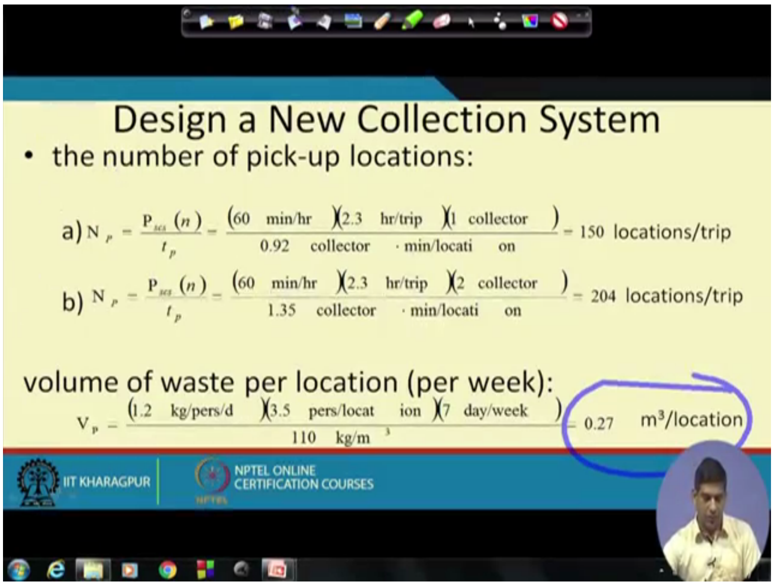

For the 1st type we have P SCS is for both the types P SCS the time available is 2.3 hours but trip, in the 1st we have one collector and for them it is the time taken is 0.92 collector minute, we already explained that in the earlier slide. So you can service 150 locations. It can do 150 locations, and then he has some conversions have been done from hours to minutes minutes because and all those things have been done. So you can serve 150 locations per trip. Now with 2 people on board where if you want, if you have to do in 2.3 hours, if 2 people are on-board, you can do this collection where you got 1.35 collector minutes and 2 collectors, so you do a 204 locations per trip.

So here we are assuming that this some other locations, the truck has already empty space to take both, so in case of 150 locations the truck will be relatively empty as compared to if we do for 204 locations. So now the volume of waste for volume of waste per location per week in terms of how much waste would be there in each of the location, it is, we will do that, we will do that based on the number of people in the house, waste generation rate multiplied by 7 days. If we are doing it for 7 days for the whole week divided by the density of the garbage, because the waste generation rate is in the mass and then but it is compacted in those garbage trend.

So that is 110 KG per metre cube, that was the density which was given to us. So based on that we see at an average, around point sorry is, at an average or seeing it on 0.23 metres cube, sorry 0.27 metre cube, so 0.27 metre cube of garbage is there in each of the locations.

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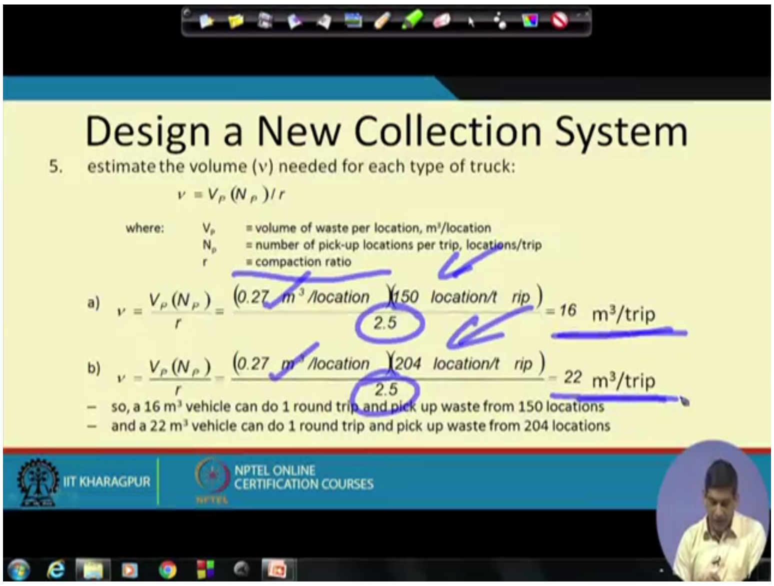

So then if you go to the next one for estimate the volume needed for each type of truck. So if you if you do 150 locations, or 250 locations, if you are kind of, we are designing it from a scratch and we are trying to order the truck, so for, the 2 options that we have for the 1st option, where the volume of the truck is, it will be volume of waste per location multiplied by number of pickup locations divided by the compaction ratio, the compression ratio is where how much compactor you can use inside the truck, so that is your compaction ratio. So for each of these the compaction ritual, we assume it 2.5 which is given to us.

For the 1st one, the, the volume of waste remains the same, 0.27, 0.27, it is the same, only thing changes here is the number of locations that can be served. So in the 1st case 150 locations can be served, in the 2nd case 204 locations can be served, so based on that we need 16 metre cube truck if we go by option A, we need 22 metre cube truck is you go by option B. So, so if we have 16 metre cube vehicle it can do one round-trip and pickup ways for 150 locations, if we have 22 metre cube, it can do one round-trip and the waste from 204 locations. So you will have to go from 16 size of the truck from 16 metre cube to 22 metre cube.

Now the question is of course the cost, how much it will cost extra to do 22 metre cube, then you have to do a economic analysis now, when you look at the cost of the truck, you have to look at in the 2nd case you have 2 people, 2 people were the garbage collectors on the truck along with the driver, so you have more labour cost and then whether the bigger vehicles can manoeuvre through the streets, through the narrow streets of the town, that is another factor you need to consider and there are, there could be some other factors as well. So based on all that we need to assume and here we are assuming that far both whether it is 16 metre cube or 22 metre cube, we are assuming the A and B, where A and B values to be the same which may not be true as well because this is a function of the size of the truck as well.

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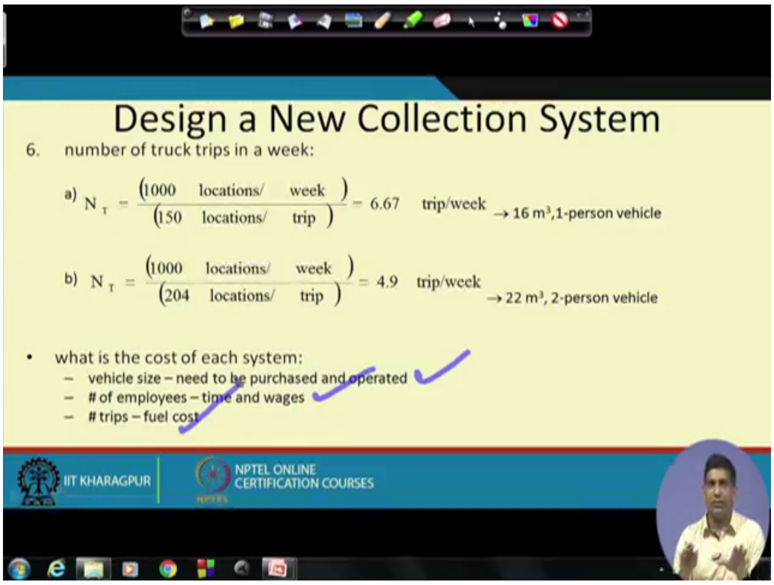

So, those things needs to be factored in. So is in terms of the, like every once you have this kind of math, and the number of trucks trips in a week. So if we have 1000 locations, remember we started 1000 locations, so how many trips will be required, if it is a weekly collection. So for the, for the 1st option you require 6.67 trips which is essentially 7 trips per week, 16 metre cube vehicle, one person. Now for the 2nd location, 2nd choice, again 1000 locations we have to serve 204 locations, so you can do 5 trips a week, 22 metre cube, two-person vehicle.

Now you have to do the as I was saying, you have to look at the cost in terms of the vehicle size, you need to purchase this vehicle size, need to be purchased and operated, the time and wages that you have to pay, number of trips that requires the fuel cost, so you need to do this whole maths in terms of detail to find out how these things will fit in terms of the budget. So again it will boil to what will work good for your city. So but here we are trying to illustrate that there are different collection systems, you can use different collection systems to, different options in the collection system and depending on what you require you can go for it.

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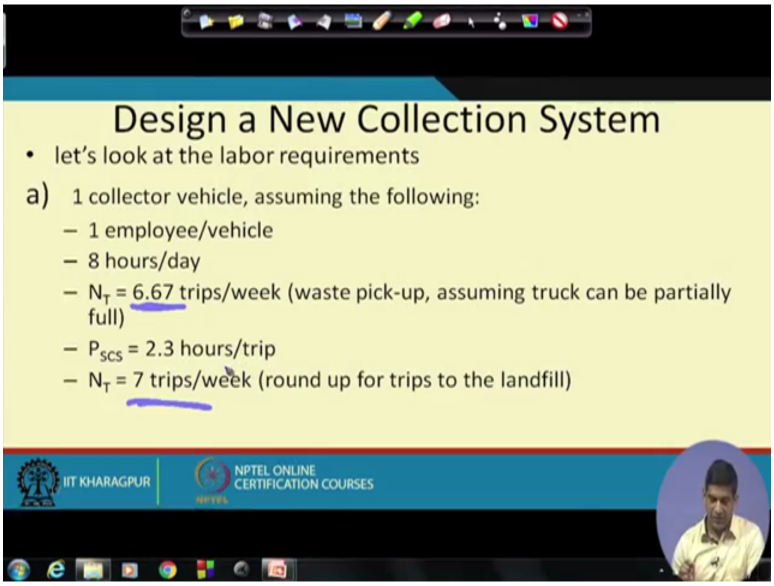

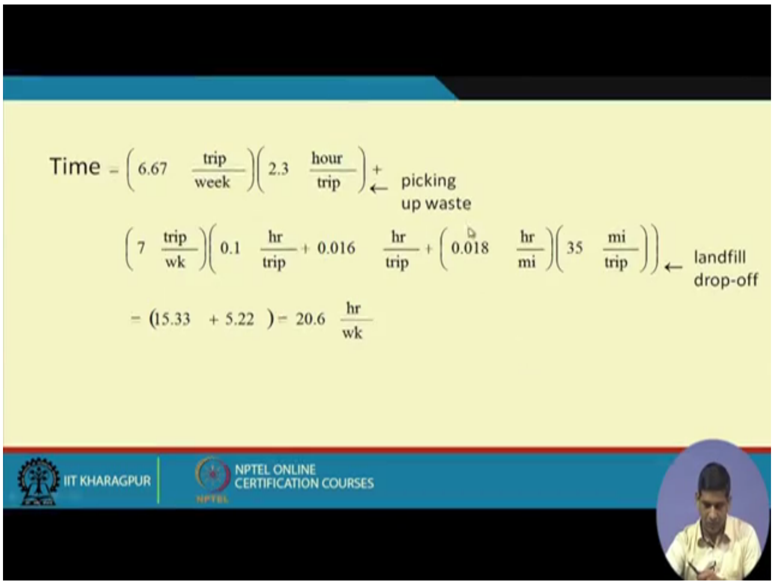

So let us say, look at the labour requirements. So with 1 collector vehicle may have one employee per vehicle, it is an eight-hour per day, so total time available in 6.6 hours, sorry 6.6 trips per week, that is the total number of trips, PS CS was 2.3 hours per trip, we talked about that as well, so essentially 6.7 cannot be, so you have actually 67 trips per week. So this is the roundup for the trips to the landfill. And, so this is the case, in the 1st case, now in the 2nd , so if you look at the time , for this, much time it goes in terms of going around and collecting the garbage.

So go back here if you have 6.67 trips per week, so it is like 7 trips per week, so it is, so there is 6.67 trips per week and 2.3 hours per trip for the garbage collection, so this is the time required for picking up the garbage. And then there are time for landfill drop off as well, so you have 7 trips per week, 0.1 hour per trip, this is S plus S, this is the S value if you remember, then A plus BX, this is S, then we have some time for T1 and T2 as well and then you have A plus BX value here, so based on that you get around 20.6 hours per week is the time, that if you add these places. So this is the hour that actually goes into the garbage collection per week, for going for the option 1.

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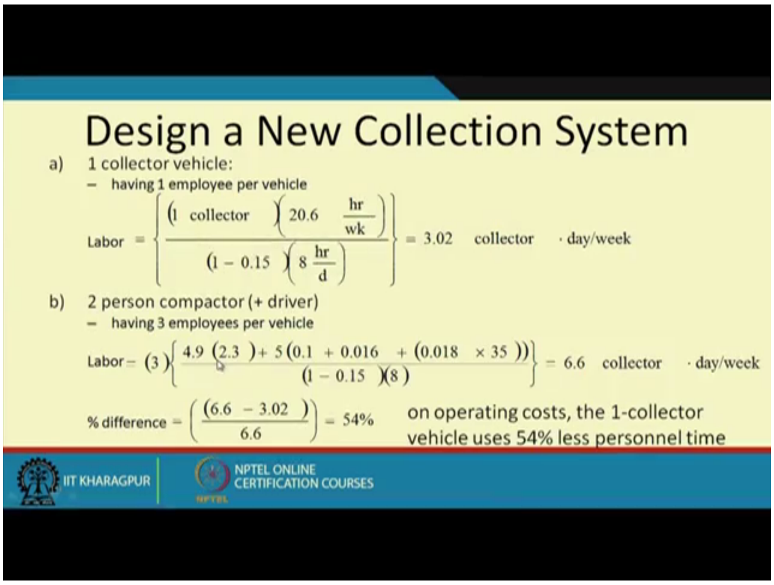

Now if you look at the option 2, okay, let us, if you go, sorry, here we have done that, okay. So this is the time required for the collection system. And if we use a 1 collector vehicle, which is the option 1, the labour required will be again 1 collector, 2.6 hours per week and this is remember it was based on 1 - 0.15 because that is the off-route factor, 8 hours per day is a workday. So you have 3.02 collector days per week. So basically you need, so this much time will go us on the garbage collection. So in terms of the 2nd option where we have 2 persons a plus the driver having 3 employees per vehicle. So we have 3 times , the time that will be required, so again we will do you will do the collection for, we will take the maths for that collection, I have done here some kind of shortcut here.

So I will encourage you to go back and do the maths for this one and because I did not show you how we got this 4.9 number, I want you to look at and do that and if you do not get it, let us know, we will, we will let you, we will explain that to you as part of the discussion board. But you should be able to do it and then 2.3 hours if the hour that it requires for the trip which we know. And then you have this T1, T2, as per A plus BX and then this is the work hour that is required, since there are 3 people, so if you multiply by 3, you get 6.6 collector days per week.

So essentially we are getting more, we need more people in the 2nd option than the 1st option. So in the 2nd option we actually have 54 percent more as opposed to with the option 1 where we are using 1 collector vehicle. So if you are using 1 collector vehicle, we use 54 percent less personnel.

So here we are to make the discussion, whether we should go for one personal vehicle or should we go for the 2 personnel, like a 1 collector vehicle or should we go for this 2 persons compactor plus the driver, because here we are having more in terms of the operation cost but the question is does it actually saving, saving that it will do in terms of number of trucks that will be required and if we, because we will go for bigger trucks, 22 metre cube and based on, says you have to buy three 16 metre cube as opposed to two 22 metre cube, which one will be cheaper. So all those things we need to decide on before we make a final decision into which one to choose.

And it will depend on the city’s budget and other stuffs as well. So that is kind of gives you an example problem in terms of a design of the collection system. So I hope that this you understood the different calculations that is needed, again if you do not understand, we are more than welcome to put your questions on the discussion board, we will be able to answer it. But I would encourage you to see, if you do not understand the 1st time, you watch the video, go ahead and, and that is the beauty of these online courses, you can re-watch the video, go over the steps again and again unless it makes sense to you. If it does not make sense, redo it, replay.

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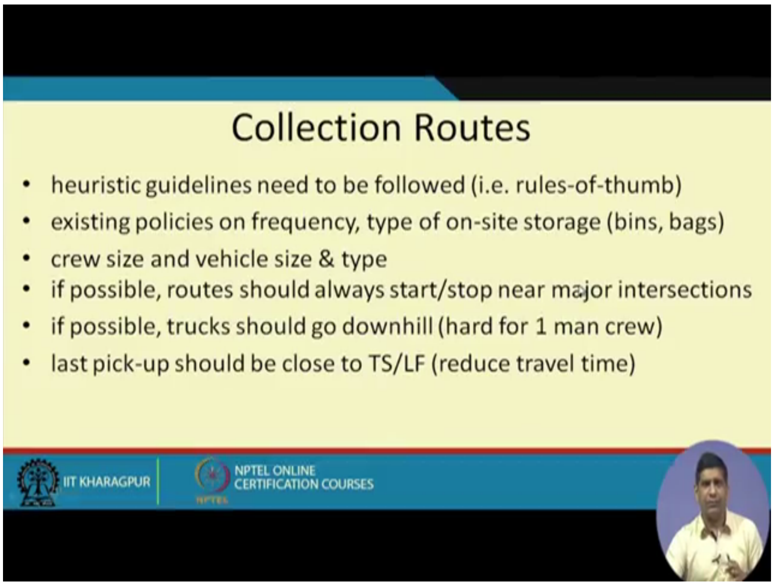

And still if you do not understand, offers we are always there for health. So that is an example of how this collection system is designed. And it is a simple example and you can take, you can basically make it in a bigger scale for a city or town. Now some general guidelines about the collection routes, I think we talked about that earlier as well. It is heuristic guideline that needs to be followed, these are available in the regulation, you can look at those regulations again, these are given here just for you to kind of see, understand and keep these in mind when you go for the collection system.

And there could be some additional requirements as well for different cities but these are some of the typical guideline which is provided in in many of these regulatory documents that you need to have what kind of like policy for the frequency, type of on-site storage, whether you go for Bean, you go for bags, what should be the crew size, what is the vehicle size, there could be certain union, unionised workers, nonunionised workers, there could be certain limitations like how you can have man-hours and all that, so those things have to be looked into. Routes should always start and end near the major intersection, so that it becomes easy for you to kind of go into a highway easily.

If possible that should go downhill , it is, truck should, if it is needed, the last pickup should be close to the transfer station or the landfill, again if it is possible, it reduces your travel time. Congested area, serve it during the low traffic time, for example do not go in the school time when in the school area. Large waste volumes picked up 1st, again it is kind of, that could be at a particular location, that at a particular location you can pick up those garbage 1st, think about the piles of bags at lowrise apartments. Use new analysis tools as they become available, use linear programming, GIS, artificial intelligence and all those things are being used these days or the route optimisation.

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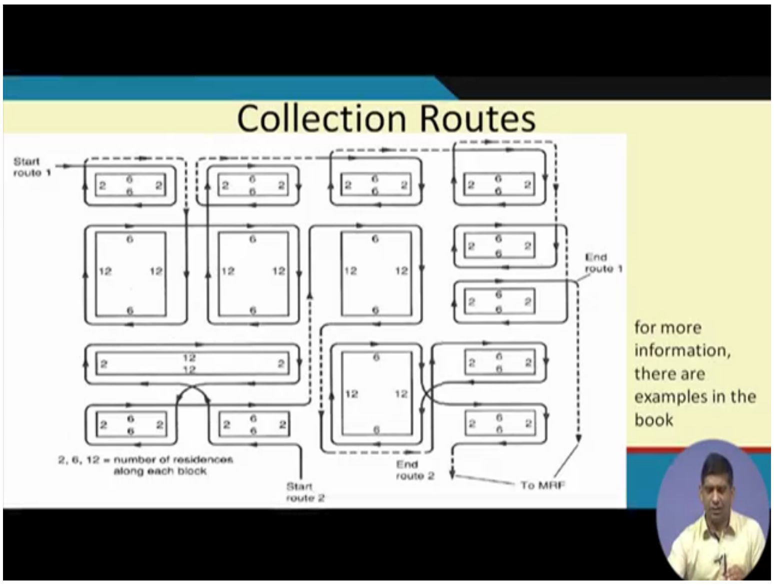

The goal again is to minimise the resource which is the time, people, vehicle and this requires trial and error, you have to do some trial and error, that is some experience associated with that and it always comes with experience. So we will look at, this is one example of a collection route and where again, this is one residential area and what we are seeing over here, so we will, it is a collection route where we have these individual boxes that you see over here, these are number of homes along this length of, so we have 2 home here, 6 homes here to homes here and 6 homes here. So here, for this particular area, you can think of it is a residential area, individual houses. So it is not in big cities, maybe a semiurban area where still you have lots of bungalows kind of places, so these are all like a 2 bungalows, at 6 bungalows, individual houses, so individual houses, individual houses that is being served.

So you see each of these boxes, as you can see here, 12 houses along this length, 12, then 6 and 6, so you have been given a certain part of a city and you have to design a route system for it. So again for the collection system of the route, the 1st thing you can come up with is you can build on that higher, heuristic rule where you have again, this is has been shown taking the right turn preferred one. So you can do a left turn preferred one as well of the same thing. And start, start with the route one and then you go around and the one you see the dotted actually you are basically going, you are going past that, not collecting garbage there because you have already collected the garbage or you are planning to collect the garbage later on.

So you start from 1, then serve this area, you come back, you start from here, you serve this area, come down, serve this area, then you basically serve all the way. Since you have already served, you just drive past, make a right, serve here, then go around, serve here, then again you are served all this, so you have a dotted line here, then you go up to this point, where you start serving this area and then you keep on going the right turn, right down and then you have the end of the route one. So you go from here to here, so if you come up with this, we have just focused on this route 1 right now, then it goes to a material recycling facility.

So it is just collecting the recyclables. So we have to find out based on all those formula that we saw, the P SCS, the T SCS, number of trips, H factor, W factor, A plus BX, so taking all those factors into consideration, what we need to do is from we start from Route 1 up to the end of route 1, what are the total time it will take and whether the rhyme is good enough for within the work day and so that we have to decide this route, of course taking those heuristic and those guidelines in mind but at the same time looking at the maths, looking at the number, what is going to really work in terms of the route timing.

So similarly then it goes to MRF and then you can have a 2nd route going around, following similar concept here as well, where you do and use of this area, you serve this area and then it goes to and fruit 2 which again goes to material recycling facility. So here essentially we are looking at the recyclables collected from these subdivisions, these neighbourhood. And this is one example, one sorry one solution, there could be different solutions of this as well. So this is one possible routing that can be done, there could be other possibilities as well for the same. So this is how, once you come up with this sketch, you can go back and do the maths and based on your maths you need to modify this sketch, again it will be back and forth, you need to do that and that is what is done using those linear programming methods.

So with that I think we will close this particular video where we have looked at this collection system and now in the next video we will try to cover what is the status of waste management system in the smart city, proposed smart cities in India and then we will start looking at the biological degradation and all those, we will start getting into treatment and disposal part of it. Okay, so I think you are enjoying the course, I hope you are and then keep on, keep us posted, if you have any questions concerned through the discussion board and I look forward to seeing you again in the next video, thank you.