Course on Integrated Waste Management for a Smart City
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Module 6
Lecture No 26
Collection System

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Okay so let's get started this is the week 6 of the program now so we have already finished week 5 and we are getting into week 6 so this is kind of at the end of this week we will be covering nearly half of the material, so I hope you are enjoying the course again I do encourage all of you to have it a two-way conversation, when I say two-way conversation means use the discussion board, use the discussion board, post your questions there you can even learn from each other.

I encourage even you to kind of if somebody raises a question on someone else of you knows the answer you answered them to it is kind of you have to wait for us to kind of give their but answer if you really sure about it so we do not want to create any confusion, of course every evening we are keeping an eye on the discussion board, every late afternoon, every evening we get that and we try to respond to any questions you have. So go ahead and use the discussion board that is the forum we are using communication and of course if needed we will be mailing you from time to time and you are getting some administrative type of email as well.

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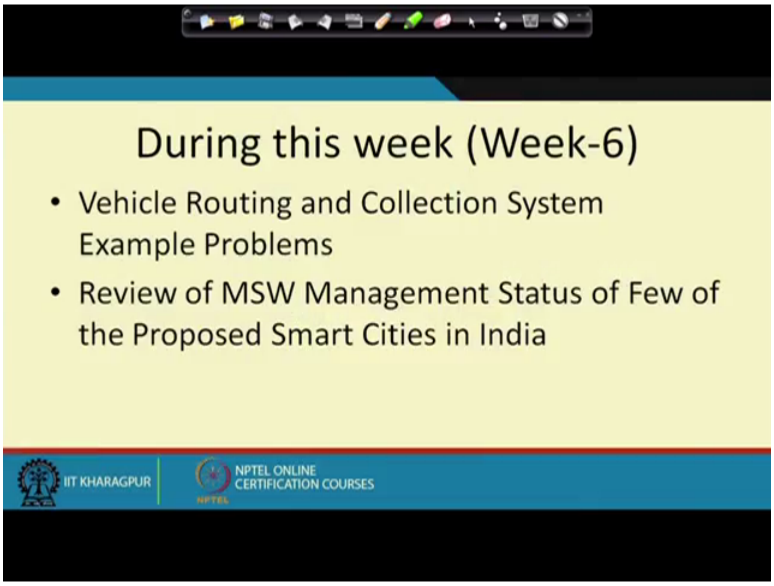

So let us get started now so we have looking if you remember the earlier week towards the end of the earlier week we were looking at lots of examples, problems trying to illustrate the concept that we have already learned or the last 5 weeks, how those concepts are applied in the real world situation, so will continue that in the first part of this the first part of this lecture will do some math on in terms of the vehicle routing and the collection system especially for the collection system will do an example problem on how to design a collection system? How to calculate all the numbers?

And then as this course as I said in the very beginning in the introductory video as well the cost is the primary focus of this course is the Indian municipal solid waste, so because it is intended for Indian audience was people from around the world can benefit from the course but is because the situation is similar in other parts of the world as well but here in the second part of this week we will be focusing on looking at the MSW management status of few of the proposed smart cities in India. So we have several around 100 smart cities out of that, 20 smart cities were in the first list, so out of those 20 we have visited few and in the month of December of 2016 and so we have visited few and then summarized out of the spaces we have visited we have summarized few of them in here, we have visited some other places as well.

So that we will go over, what they are doing right now? What are the challenges they are facing? How they can go about having a better integrated waste management framework and if time permits we will start getting into the little part of this week into biological treatments, so that is how what you will be learning in this particular week, so if you get the vehicle routing you have talked about this little bit earlier, vehicle routing is how see we are talking about the collection system, collection system is another most not the collection system is the most expensive part of waste management plan.

So when we try to design the route is how the vehicle will move around, how will the vehicle move around and collect the garbage from different collection points. In big cities in old cities it would be mostly from the primary collection centre, it cannot be from individual houses especially since our lanes are very narrow we cannot have this trucks kind of go around, so here we have those trolleys and you will see the pictures of that as we have some trolleys where people are using those trolleys to go to individual houses and there are big apartment complexes it is being collected and just at the gate of the apartment complex, so whenever possible will like to take smaller vehicles, trucks, trolleys.

So whatever you talk about is always we have to plan a route and this planning of the route for waste management I think I have said that earlier as well there is very similar to what the planning would be for say Flipkart or Amazon or Snapdeal and others stuff because essentially you are moving certain material from one point to another point whether it is your new laptop coming through Amazon or new cellphone mobile coming from Flipkart or your moving garbage with city of Kolkata or within city of Delhi from point A to point B all has the same basic concept, so it is basically optimization of the route and there are some companies totally specializing on that where they do some route optimization.

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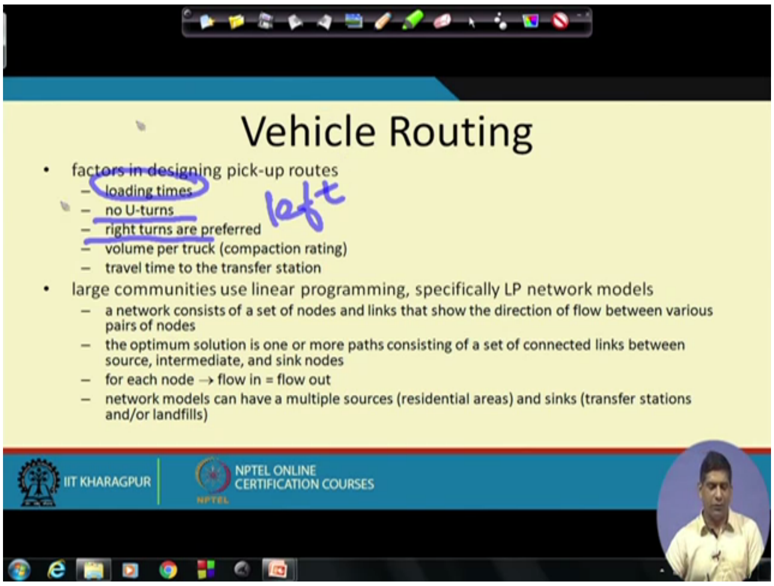

So in terms of the vehicle routing there are software is now which take cares of that but all show you what exactly goes in those software, so but in terms of factors that is required that it has to go and collect waste from each and every location, so when it goes to each and every location there is this loading time it is critical, so they have to have this loading time and some of the stuffs that you can avoid, you do not want to have a U-turn because if you take a U-turn your essentially killing sometimes, so you are not very efficient if you are taking too much of U-turns.

Sometimes you cannot avoid that but many places you can avoid it and again since this is essentially coming from the Western world be mostly drive on the other side of the road, they say that the right turns are preferred, so in Indian context we will have the left turn is preferred, is not it? We like the left turn because we can do the left easily than the right turn here, so we will have the left turn is preferred in the Indian context than the other things we need to know is volume per truck. How much waste can be collected in a truck and should be compacted, how much compassion can be done?

And the travel time to the transfer station, so those are all important in terms of factoring when you trying to do this pickup route. We are assuming here that there is a transfer station, it can be transfer could travel time directed to the landfill as well, so when you design this pickup route you will have a worker working there, you will have a driver and couple of people working with him, total you are looking at something around 8 hours per week, in 8 hours per week you have to factor in the time for lunch time and some break time in between, for the washroom break people have to go to the bathroom and tea breaks.

So while factoring those things in there depending on what kind of practices they have in that particular city you will have may be around 6 to 6 and half hour of total route time that a truck can take in a day, so we have to design a route which is good for 6 and half hours, so they start in the morning they collect at certain plane then at the end of the day they take it to the transfer station or if transfer station is not there to the landfill.

If the city is small and you may design 2 routes like 3 hours 3 hours, if the city small and then if you get the garbage collected much quickly, if your truck gets filled up so you have to actually look at how many houses are there, what kind of streets are there, so these are not that easy actually. If you really want to do a scientific methodological way of doing it, it requires lots of input, so that is why computer programming comes in picture here as well.

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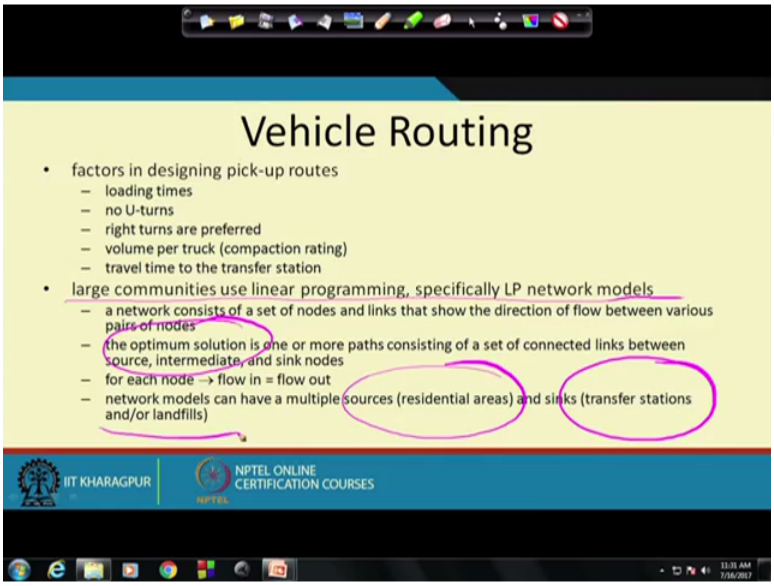

So what does the large community do, that they use linear programming, so these large communities they use some sort of linear programming specifically linear programming network models and in the next slide I will walk you through how that works, so a network what is it says, is a set of nodes showing different directions between how the materials will flow, again when I am saying material here we are talking about the waste and essentially waste is a resource as well and then we try to do some linear programming and you do some optimization of that.

So you come up with the optimum solution and this optimum solution is where one or more path you have several sort of connected nodes, intermediates, sink nodes and all that and for each node there is a flow in and flow out because things will come in and things will go out, so you can have multiple sources, multiple residential areas, you can have a sink is your transfer station or landfill. So those are the work you can use for going in to the input for the vehicle routing.

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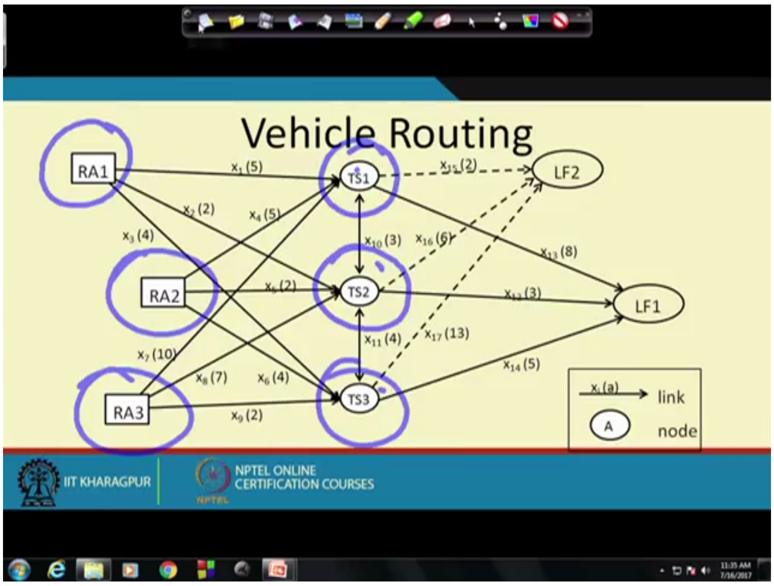

So let us look at this next slide so here it is we have as you can see over here the same thing which I said earlier in the previous slide in the form of text, your am trying to explain you in the form of a pictorial diagram, so here if you look at these areas here we have RA1, RA2 and RA3 as RA is residential area, so I am calling RA as residential area, so there is 3 we have taken and this could be many more as well but for our just have a simple example.

So see this 3 residential area RA1, RA2, RA3. Now and then we have 3 transfer stations as well TS1, TS2, TS3 it could be just one or could be 2 and then what you have, you have from RA1 things can go to transfer station 1, things can go to transfer station 2, things can go to transfer station 3. When I say things is basically waste going into these either of these transfer station. So RA1 can have things going in different transfer station, similarly for RA2 and similarly for RA3 and as you can see here different route as well X1, X2, X3, X4 and then it talks about some links in between so X1 and then in the bracket those numbers shows kind of shows different possibilities of the route different number of trucks and all those different variables are put in there.

Now from transfer station things can go to landfill one and potentially it can go to landfill 2 as well, so I am saying whether either to landfill 1 or landfill 2, sometimes it also depends on the type of waste that is being collected, so and then this all the axis are showing you the different routes which have been taken up, so what it requires is you come up with for say for the I am sitting in in Kharagpur in IIT Kharagpur campus, so if we take the whole Kharagpur town and we try to come up with… Kharagpur town if you think about those of who are familiar with Kharagpur, we have this of course IIT campus is one of the good population here then we have railway area but railway area is well spread out.

So if you can just take the railway areas closer to the railway station there is also called Bangla side or south side so if you just concentrate on that part so that could be our say KGP campus is RA1, railway near railway station area is RA2 then if you just go to Kalaikunda area just there are some other areas there as well, we have (())(11:30) but and then some there are lots of other residential areas but say if you just focus on these 3 so these are the 3 and from each of them if we have a transfer station build up at different places in Kharagpur, how the waste will flow? What will be the route? And those are showing you those X with that arrows are showing all these possible routes and then it could be different possibility as well from RA1 to TS1 it can go by different streets.

So all those things we need to take into picture, if there is a if there is a school in that area you do not want to take your garbage truck in the school hours or whenever either the school is like kids are coming in or whenever the kids are going out after the school is done so in the morning around 8 o’clock most of the schools open and then around 3 o’clock between 2 to 3 most of the schools have their closing time so we do not want this garbage truck going into those areas, so all those factors we need to take into consideration different then of course one of the important part would be how many houses we are serving? Again remember in the earliest slide we talked about vehicle capacity like how much houses can take? If it is a compactor truck how much compaction you will have it and then you have 6 and 6 and a half hours of work day, so you have to come up with lot of variables are there which all needs to be factored into come up with an optimum solution.

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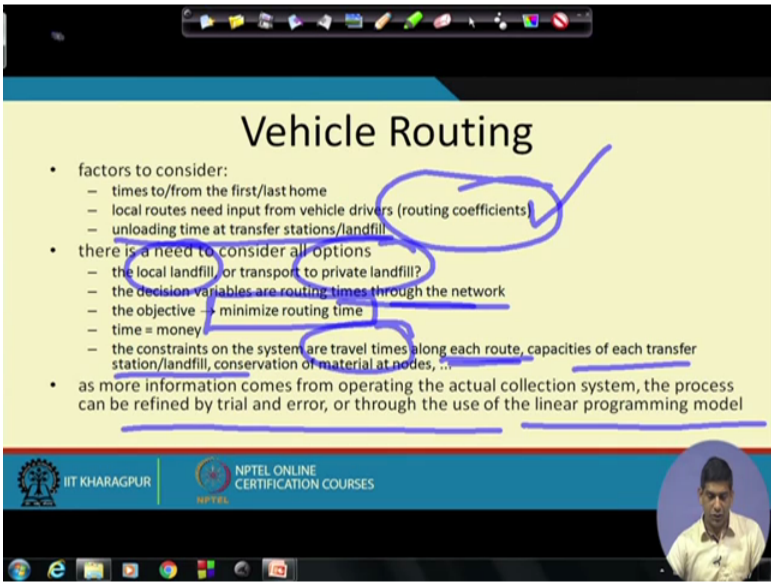

So this is what this kind of like a vehicle routing possibilities you will come up with and then you will consider several factors which is what is the time to or from the first and last home because the garage mostly this garbage trucks will be in the garage, so if its drives to a particular house in the morning, how much time does it take? That should also be part of the 6 and half hours, now local routes, how the local routes? What is the speed of the local routes? How congested they are at different times of the day?

Those inputs will come from the local people, local drivers who are driving in that area and based on that what has been a what we have this is already kind of published together for it is called routing coefficient, for most of the Western cities it is already there, for the Indian cities we need to develop that, we need to develop a routing coefficient and it is a dynamic number because things are things are changing especially in developing countries most of say you will have a narrow street then it becomes a wider street, you may have some new area developing, you may have new construction going on.

Earlier right like the traffic light was not there now traffic light is there, things may have been made one-way, so things are dynamic so for that this routing coefficient will also keep on changing but at least we need to have some sort of so what this routing coefficient are basically takes the information of the traffic, how the traffic flows and then he comes up with a number and that is how it is like if you are interested in transportation sector, you will learn more about that, so but that is how it is then we will use that number I will tell you those numbers in a minute and then there will be some time which was unloading time at the transfer station or landfill so that time needs to be counted for as well.

So all these things needs to go into the route and so there is a need to consider their will be different options, they could be local landfills, there could be a private landfill. Decision variables or routing time through the network will look at that objective is to minimise routing time, so that is the main detective we have is to minimise the routing time. Why because as you know time is money, if you can minimise the routing time you can have more houses be served by the same truck and that will mean less number of trucks that will mean saving of money, so this all kind of related with that, so constrained of course the travel time along with the each route and then capacity of the truck or transfer station as well and then try to conserve the material at the different nodes.

So as and this is kind of whatever we start doing it for one particular city or town it will be like working progress for first few years, you will not have a perfect solution on first go because you come up with one, you operate within the actual scenarios and then once you get some more information then you refine it by trial and error and through the use of linear programming model, so this is how things gets evolved over time, so as I said earlier there are actually some companies which deal with these kind of routing system for our for like waste management program waste management system for different cities, so there are companies and they are the same companies who works with railways or work with Amazon and Flipkart and all those things as well.

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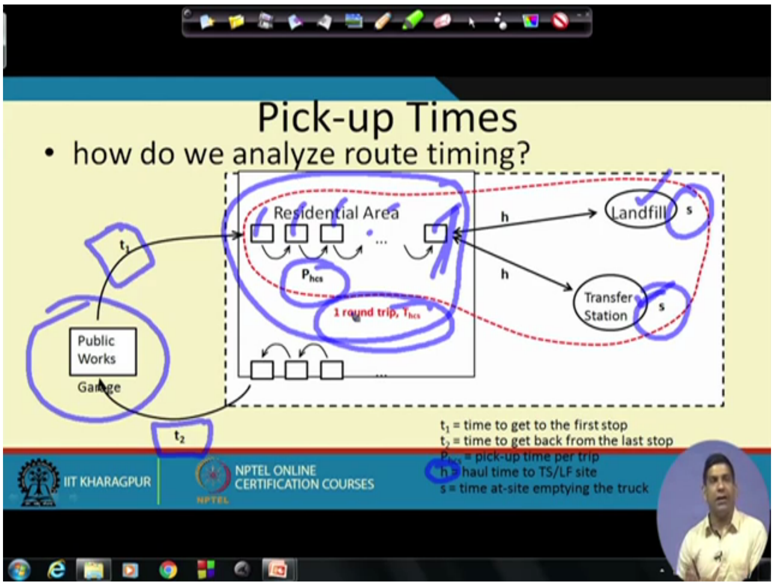

So just in another kind of whatever we talked about just kind of summarise in a pictorial way again just to goal here is to make it very clear to you that how the software works because what happens in most of the time if you are doing this work, you will be using a software and then you do not pay any attention to what the software is doing which is not at all correct as a designer, as a waste management engineer we need to know what our software does? What the inputs are and how we have to optimized things using those software.

So here in terms of the routing how it takes the route timing, the timing that it will take, so in the morning so this is the public works garage, as I was saying you earlier let us see just this is your public works garage where the truck will be in the night time so in the morning they will start driving, so from the time T1 we have to encounter that say if you have to calculate the route time we have to can play the time it will take to do one route, so from public works garage it goes to the first house, so that is the time T1 so we need to account time T1 then we need to account for time T2 is what is from the last stop after it does a thing and it wants to come back to the public garage.

So that is the time T and then the important time is pickup time per trip, pickup time is what is how much time it takes to pick up the garbage at each of the houses that it stops to pick of the garbage, so that is called Phcs, so be will be using lots of terminology here again you will have several terminology and may be the size of your problem description maybe like a big but do not worry about those do not get intimated by that, collect all the data points that you have and then you walk out the problem.

As I said earlier most of the solid waste in general, even environmental problem are pretty much straightforward as long as you break it down and do task by task like step-by-step, so here Phcs is pickup time per trip. Now what is the pickup time per trip? We will serve several houses there will be several houses that needs to be served, so all these houses each houses it was stop say at least for 30 seconds or 40 seconds or sometime even for a minute depends upon the type of the truck, how many person in the truck doing the service? So we can we have to calculate this Phcs that will be kind of pickup time at each locations multiplied by number of locations as the travel time between locations.

So many times what we do is actually the travel time between locations we club them together with the pickup time, so because this is essentially the whole time it will take for the garbage truck to get filled up. So once it filled up it can go to a transfer station or it can go to a landfill, so in both cases the time is required so that is the haul time this is the h, we call it h that halt time, what is the halt time? Basically hauling the garbage no more additional of garbage the truck, it is just holding the garbage from this last point to the transfer station or to the landfill.

So that is your that part and then S is the time that it takes at the site either at the translation or at landfill empty the truck and then again the whole process will continue again, so this is this is the one round trip and that is called Thcs, so one round trip the terminology used is Thcs so that includes the entire time, collection time at the houses, time to the landfill, time to the transfer station and the time back to the residential area to the next house, so that is your Thcs so this is how you analyse the route timing and that is will do the math using all these different terminologies in a minute.

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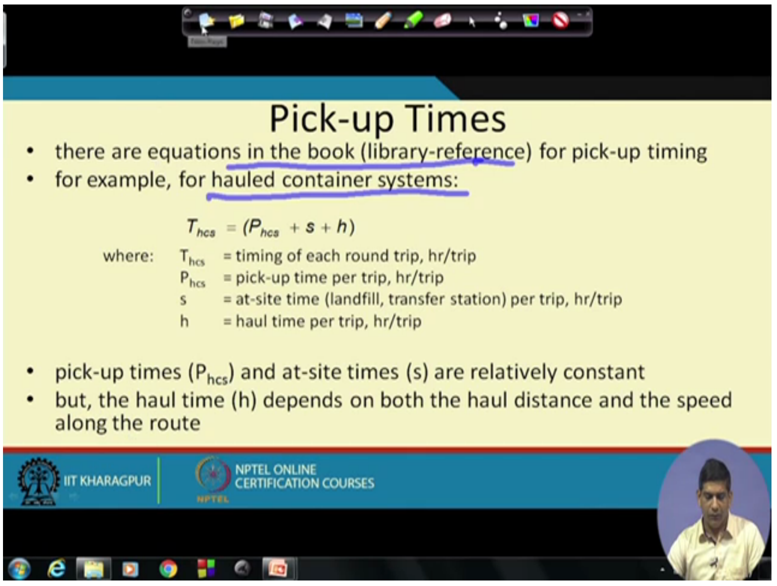

So pickup time these are the equations, these equations are available in the book you can pick up this is again I think I mentioned to you that there is a book by Tchobanoglous you can this is one of the like a bible for waste management the book is old now probably it is time for write a new book and I hope to do so in near future but it is so we can but this this you can look at that Tchobanoglous Integrated Solid Waste Management book which should be available in any library but again if you do not have access to it the most of the information have already provided here.

So these there are the equations which you can in the books so these question has been taken from the book and which is you can look at the reference or so for the pickup time for the hauled container system, this is a hauled container system so where we are hauling the final once the truck is pulled up we are taking the truck to the disposal point. So here Thcs which is a time for a round-trip, hour per trip is in combination of again it is a very simple straight math with simple if you just use your common sense.

Now the total time of the round-trip be what? It is the time for whatever time it takes the last place with the truck got filled up to the transfer station or landfill the round-trip we can take the round-trip time, so that is one time we need to account for that is what h is given in the equation, then we have S which is the time and the landfill or the transfer station depending upon the case, we have to account that time. So we have accounted for the hauling time as we have accounted for the time it takes at the landfill of the transfer station.

Now what is the time left? Is the time that it will collect garbage from each of the houses, so that time needs to be taken up as well, so that gives you the total for garbage to get filled up in the truck time gets disposed at the transfer station or a landfill, so that is one part of it then other part is the time from the garage to the first house then next other part is from the last house that is served on the day back to the garage, so that time is also there but that is that will take into factor in a minute here, here the timing for each round-trip we are talking about the round-trip for just the garbage collection.

So the pickup time Phcs and at site time are typically constant, so Phcs and S is actually factor of it is under our control, is it not? We can go from each of the houses we know kind of those residential area not too much traffic probably so we can go around each houses and we can collect the garbage and then we can make it as efficient as possible and we can do that. How much time you take at the transfer station or landfill that also pretty much is in our control.

What is not in our control is the time h because h is the haul time on the road where you are actually you are competing with the same road space with other vehicles in there and depending on what is going on in that particular city at that particular time your h will vary, so h depends on both the haul distance as well as the speed along the route like what is the speed limit and like how one of the other traffic condition that area, so all these things depends when you go for this value for H.

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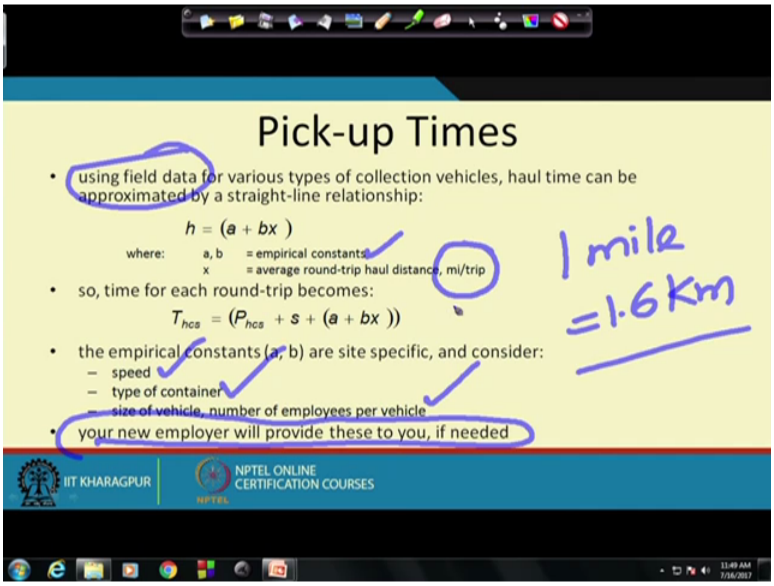

So h is calculated based on field data as I said earlier those are your what is known as coefficient, so based on the field data using the field data detect this and values of a and b. So h has been defined as a plus bx, using the field data with various type of collection vehicle, the haul time is approximated by street length relationship where a and b are empirical constants and these constants are based on the traffic conditions and if you are more interested in how these things are done, how these things are developed?

I will recommend you to read some transportation book a day do all this kind of calculation and the solid waste just believe me or just trust me on the fact that this can be linear relationship where a and b are the empirical constants based on your the traffic conditions, the way the roads are, if you have a narrow lane, single lane, double lane, 4 lane all those times things are getting factor then, so that is where a and b, x is the average round-trip haul distance in miles per trip again here remember this is in miles per trip. So we need to convert things to miles, why is it in miles per trip?

Again these are this was developed in US and US they still use miles, so they have developed it for themselves so they are using miles, so it is in miles per trip and we know one miles is 1.6 kilometers, so we can always convert that then use it for miles or as I was saying you earlier we need to actually develop our own a and b value is for the different cities in India as well. So empirical constant a and B are site-specific, it depends on the speed, it depends on the type of container, depends on the size of vehicle, number for employees per vehicle so if you are working on a company your new employer will provide these to you if needed, so you will get this values from them. So those value will be available view from the new employer from your company from the consulting company. So this is again this is the same equation the previous slide if you.

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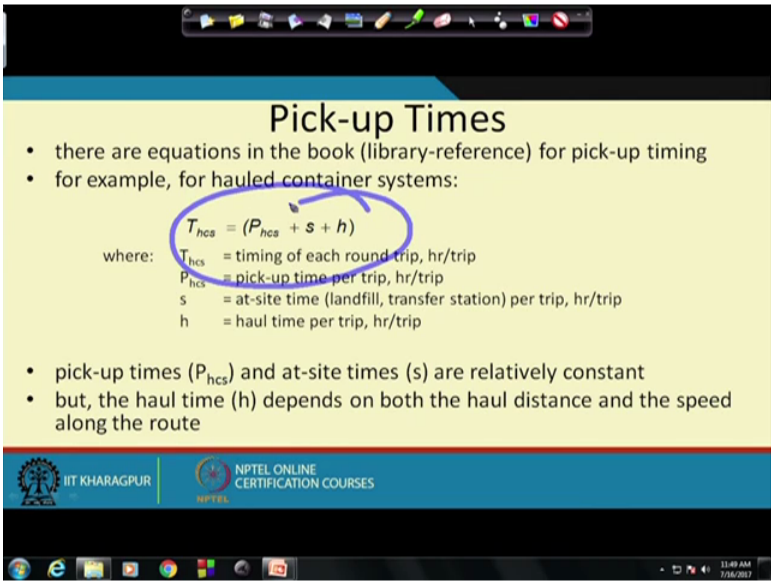

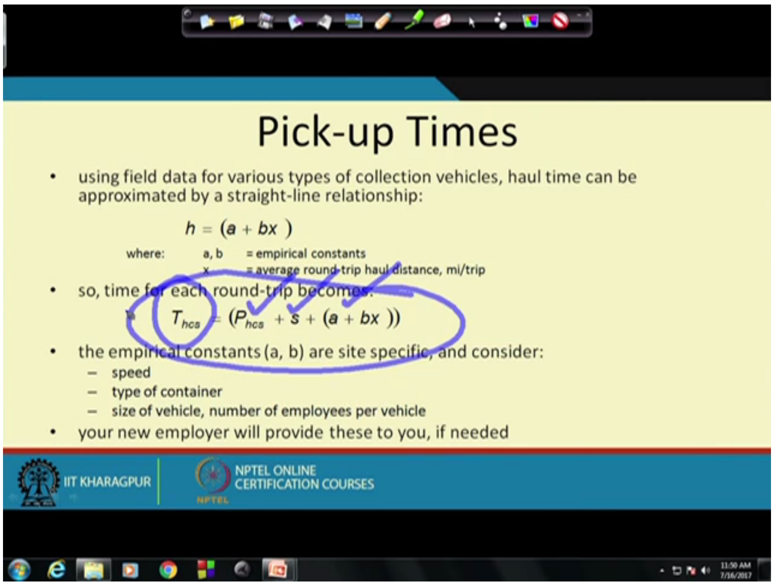

If you remember from the previous slide this was the same equation just if you go back to the previous slide for second this was P you can see this is the same equation here that you using but what we did instead of h we extended the value of h and now we have h is equal to a plus bx. So the same equation is changed to this format. So we got Thcs we can calculate Phcs, we can calculate s because we know how much time it does for each houses, we know how much time it takes and then if you have the value of a and b and we know the distance x miles per trip, we can get the value of this Thcs which is the time of collection and hauling for a truck.

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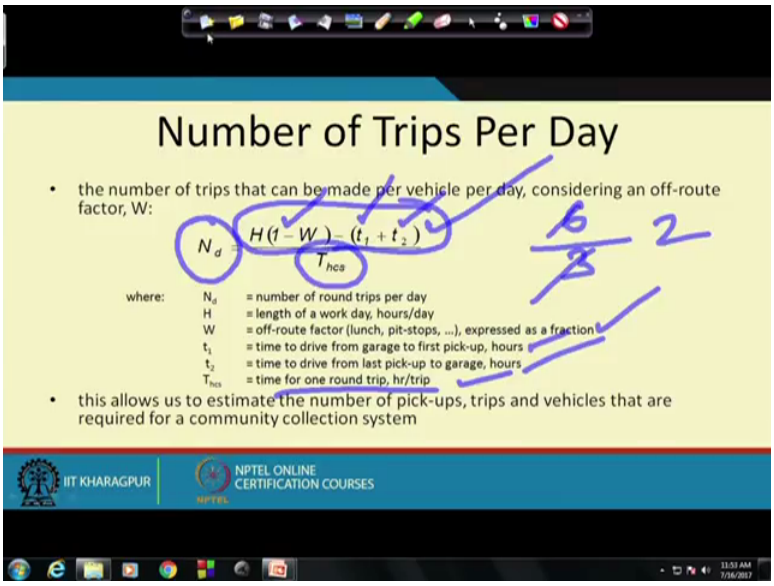

So once that number is there, we can calculate number of trips per day. How we do the number of trips per day so again you remember since is a work hour of around 8 hours per day but there will be certain off route factor for example is there will be some lunch break, there will be some bathroom breaks, they could be some tea break, cigarette break and all those kind of it is it is a fact people, the workers will take those breaks, so better you take you accommodate those times in their so that everybody is happy along that way, so you have the off route factors so that is that is there, so we take it as a fraction and T1 is a time to drive from garage we already talked about that t2 is the last one, Thcs is the time for one round-trip we already calculated how we can do this.

So if you look at the numerator here what we have? Here h is our length of work they so it is taken 8 hours a day out of 8 hours there will be certain off route factor like lunch, pit stops and all those breaks so we have to factored in that over here and so that we get total like a work time minus the time taken for garage to the first location in the morning and from the last location to garage in the evening.

So we have to take those numbers also out, so that minus this number gives the time that we have for the garbage collection at each of the houses plus taking the garbage to the transfer station or landfill and dumping the garbage over there. So those are again if you follow in a logical way these are not that difficult, it is simple common sense that whatever time you have available divided by time taken for one trip will give you the number of trip, is not it? So the number of trip that can be made vehicle per day is so that is we call it Nd is the time available, total time available which is the numerator divided by the time taken for one trip, so if it is say total time available is 6 hours and then if it takes 3 hours to do so we have it can do to trips and if it does less than 2 trips it can be 1 point 5 trips, what does that means?

That means that it will do one trip and then the next half trip it will get the garbage collected but it will not go to the transfer station or the landfill it will just take in the garage and the next day it will start again filling up the truck and one such truck fills up then it will go to landfill or the transfer station. So how this is how you calculate the number of trips, so once we have the number of trips it can based on that we can find out how many trucks we will require an based on number of trucks we require any to find out what is the man power requirement, how many people will be required to manage this truck to run this truck and all that.

So these are some of the basic calculation this is how it is done. I think I have gone over the basics of how the collection system is designed how we will get all those numbers. Now the next we will do in in the next video we will go over a math where we will all these equation that you have learned in this video will apply in the next video and you will see how the numbers are calculated.

So just to illustrate one so that you are comfortable in terms of designing again designing good collection system design is very critical for a good waste management system and that is collection is the most expensive part and as you will see in the later part of this week as well when we will talk about some of the upcoming smart cities in the country. Even though cities are even struggling for having a good collection system, so good collection system is a must for a good waste management system and for good collection system you need to do this kind of math to come up with the solutions which will really work.

So that the trucks or working optimally, the drivers are happy they know that it will take that much time of course we need to take the inputs especially when you are getting those a and b values, we should not just get an a and b values for some US cities and then just plug-in here and use it. Of course to start with we can do that but once we refined our process and we need to (())(31:46) that a and b values to make it more realistic for the Indian conditions. So with that lets close this video and then I will see you in the next video where we will continue with that example problem on this. Thank you.