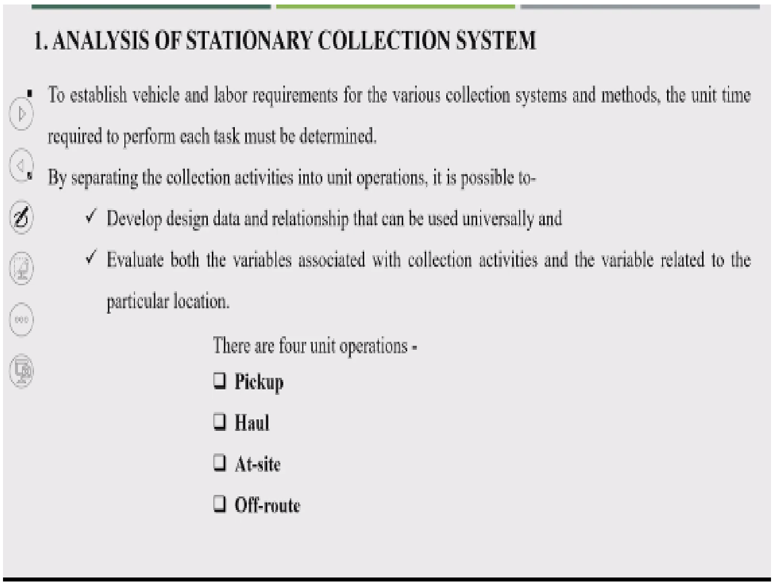
Municipal Solid Waste Management
Prof. Ajay Kalamdhad
Department of Civil Engineering
Indian Institute of Technology-Guwahati

Lecture - 12
Analysis of Collection System (Part II)

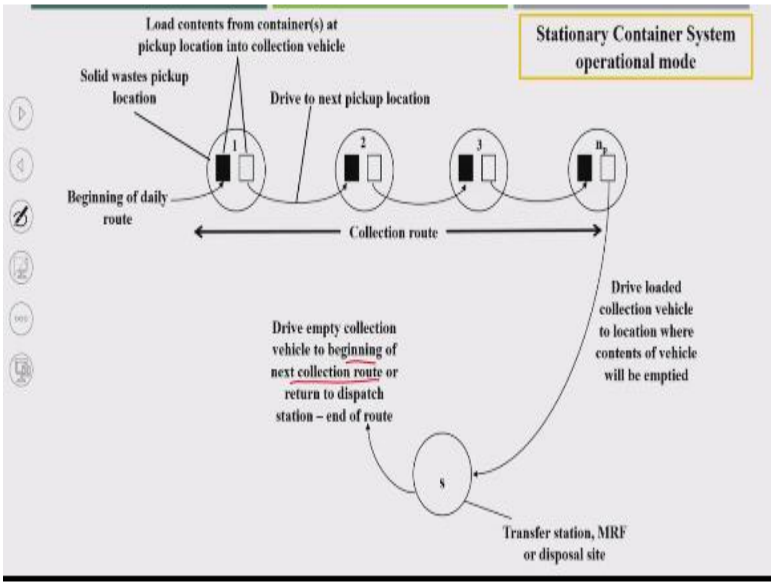
So hello students. Today we will extend our discussion on the collection of solid waste. So in the part 1, we have seen the analysis of haul container system. We found some unit operations also and we solved few numericals.

(Refer Slide Time: 00:52)



Now, this is part 2, where we will discuss the analysis of the stationary collection system, okay. So I think a few slides are similar. Why it is important to analyze the collection system because of unit time required in each task is very important. And there are different unit operations that pick up haul at site of route time. So which we will discuss during the stationary container system or collection system.

(Refer Slide Time: 01:22)

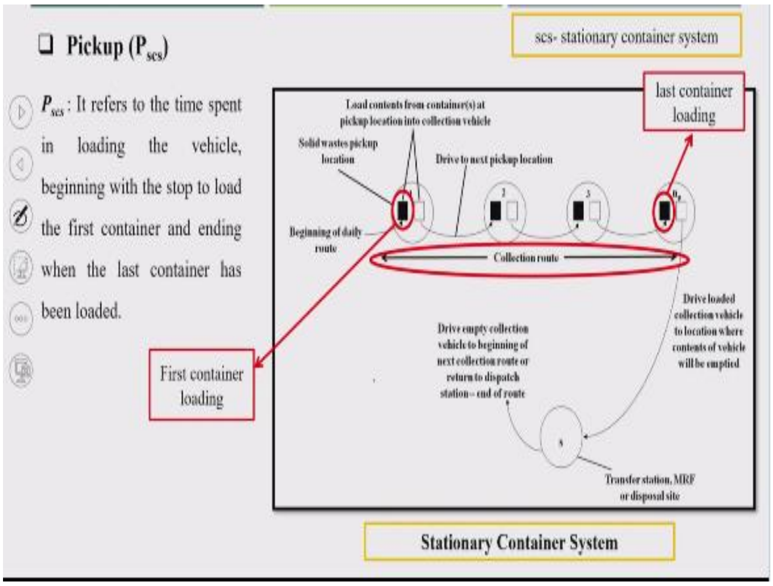


So before that we will go though one example, simple, which was initially also discussed in the previous class, how the operation of a stationary container system. So route will get start from dispatch center, wherever the vehicles are available or at night wherever they will be dispatched. It will start with the first location and it will load the content from the container, from the location so that the container will be empty.

Then it will go to the next location, the next pickup location. It will do the same way, it will load the content from the container or dustbin and you will get one empty container in the same location. Similarly, it will go to a different location or nth location. And once the vehicle will get full completely, whether is a simple vehicle or compactor vehicle and finally, it will go to the transfer station, recycling facility, or disposal site.

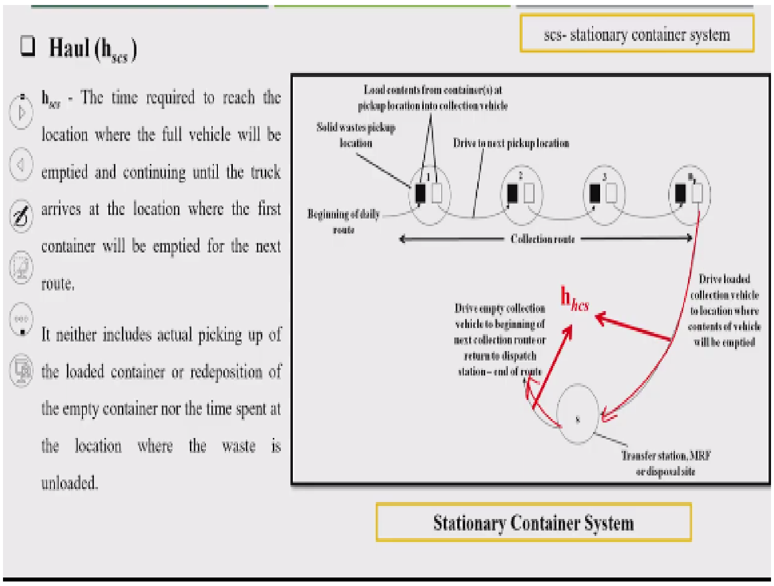
And from that, if the time available in a day is available, then it will go to it will start the next route. Suppose the time will get over 8 hours, it will go to the dispatch center finally. Or otherwise, it will start the next collection route. Like it will start the beginning. This will be the beginning of the next collection route. And this is the collection route for one trip.

(Refer Slide Time: 03:01)



So now first unit operation we will see the pickup. So in this case, in a stationary container system, pickup refers to the time spent in loading the vehicle beginning with the stop to load the first container and ending when the last container has been loaded. So it will start from the first location loading and it will go to the beginning and it will the last container loading. So this entire collection route will have the pickup time, okay.

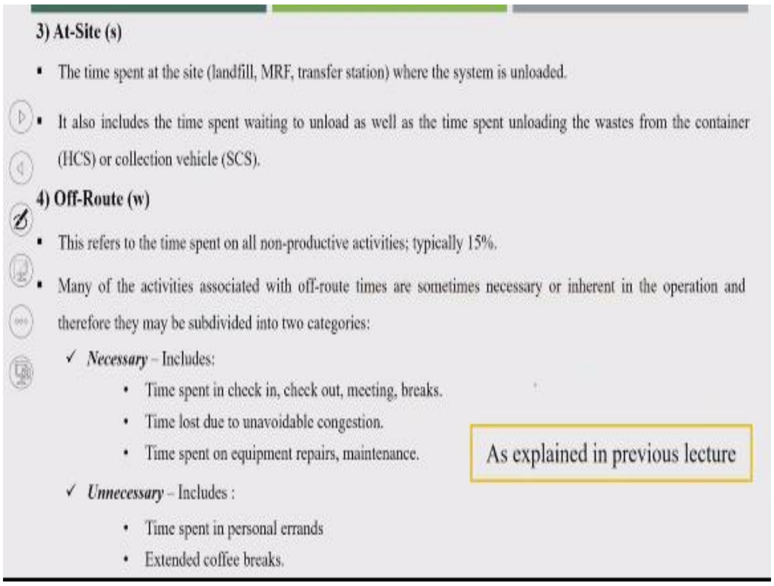
(Refer Slide Time: 03:40)



Now the next unit operation is a haul. So here haul, the time required to reach the location where the full container will be emptied, and continue until the truck arrives at the location where the first container will be emptied for the next route. So it will start from the last container location to the recycling facility or disposal facility and also it will start the time required to go to the next route or next collection route.

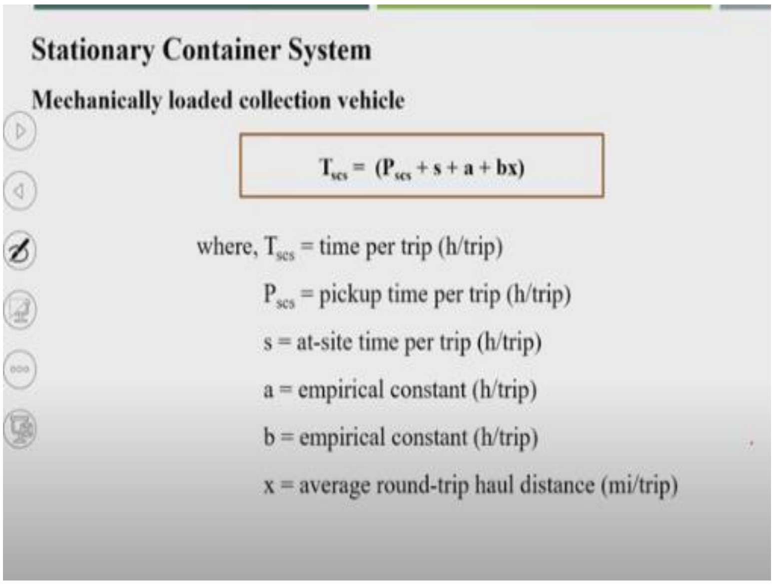
And is not including the pickup and redeposition of a container, okay. This is the same in the haul container system.

(Refer Slide Time: 04:21)



The remaining unit operations are almost similar, which was discussed in the haul container system like at-Site time and off-route factor necessary, unnecessary off-route factors.

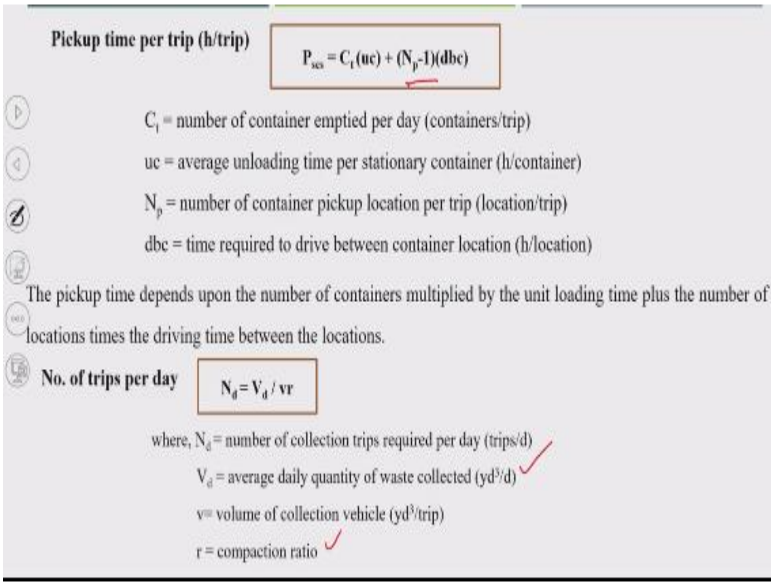
(Refer Slide Time: 04:34)



Now we will see some equations which is a stationary container system that we have seen in the haul container system. So first is because there will be a two-way stationary container system. One is the mechanically loaded container collection vehicle where mechanically container is getting loaded onto the vehicle. So their time for trips will be pick up time + s + a + bx.

It is similar to the haul container system because the entire route time is required the same in the stationary container system and the haul container system.

(Refer Slide Time: 05:18)



Now in this pickup time per trip, in the haul container system that was pc + uc + dbc. But in this case, this will be P_{scs} that is the stationary container system is

$P_{scs} = C_t (uc) + (n_p-1)(dbc)$

where C_t is the number of containers emptied per day and uc is the average unloading time per stationary container.

n_p is the number of container pickup locations per trip. Here you see that we did it here $n_p – 1$. Why, the number of container pickup locations per trip minus 1? You see here in the operation, the number of container location suppose these are four container locations. But you see the dbc is 1, 2 and 3. Means that will be 4 – 1.

That will be the dbc value. So that is why we did ($n_p – 1$) multiplied by dbc okay. And uc also has been multiplied to the number of containers emptied per day multiplied by uc value that unloading time per location. Now here has to calculate the pickup time depends upon the number of containers multiplied by the unit loading time plus the number of locations times the driving time between the locations that is ($n_p – 1$) multiplied by dbc.

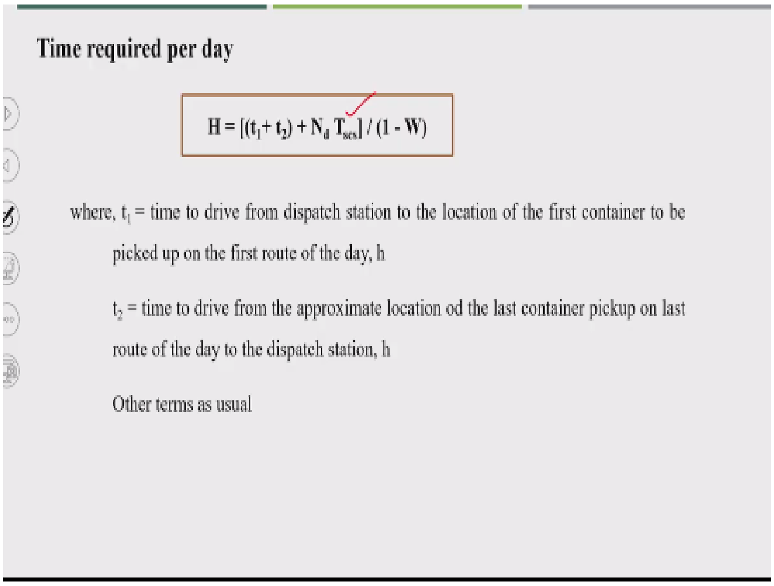
Now, the number of trips per day can be calculated as-

$N_d = V_d / vr$

Where N_d is the number of collection trips required per day. V_d is the average daily quantity of waste collected, v is the volume of collection vehicle, r is the compaction ratio. You see here it is a very simple equation, the number of trips can be finalized simply if you know the average daily quantity of waste generated and divided by the volume of the collection vehicle.

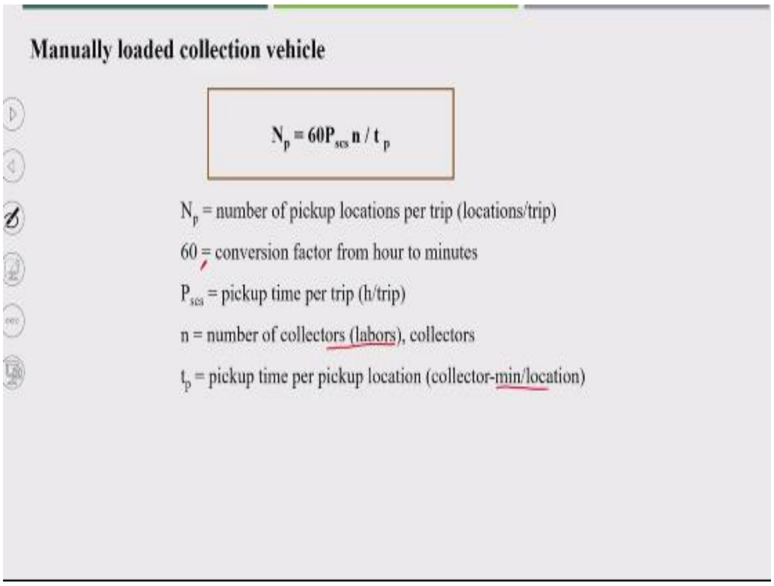
And that also volume of collection vehicle we multiply by compaction ratio and if we know the average quantity of waste generated or collected onto that particular area we can calculate the number of trips per day. This is easy way to remember these formulae.

(Refer Slide Time: 07:52)



Now time required per day, that is the H value we can calculate or is the similar equations if you done in the T_{scs} form. So remaining are other terms are usual like N_d is the number of trips, T_{scs} is the total time, t_1 is time to drive from dispatch station to the location of the first container and t_2 is time to drive from the approximate location to the last container to the next route.

(Refer Slide Time: 08:24)



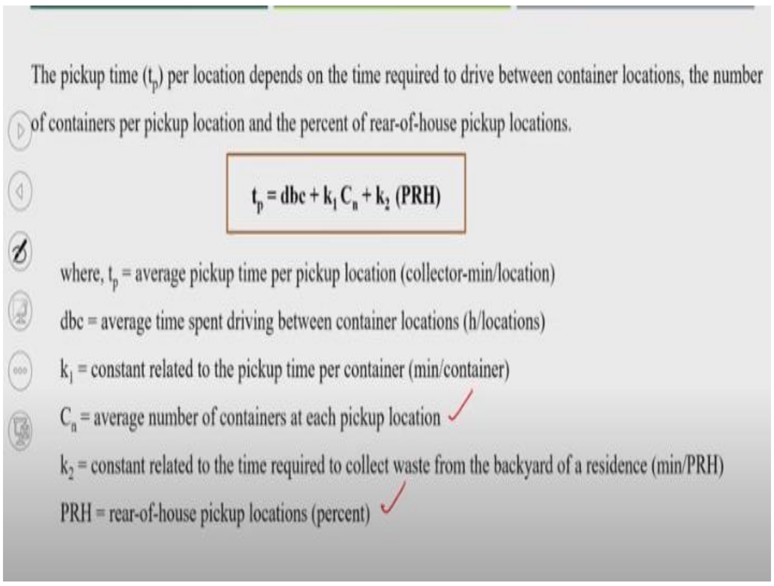
And now here are few equations for manually loaded collection vehicle. That N_p we can calculate as-

$N_p = 60P_{scs}\, n / t_p$

It is also a simple expression for N_p value, where number of pickup locations we can finalize by pickup time multiplied by number of collectors or how many labourers are working.

And if you know the t_p value like pickup time per pickup location, based on that we can calculate number of pickup locations. And this multiplication also is because if you see the unit of t_p, it is collector minute per location. That is only conversion factor from hour to minute.

(Refer Slide Time: 09:12)

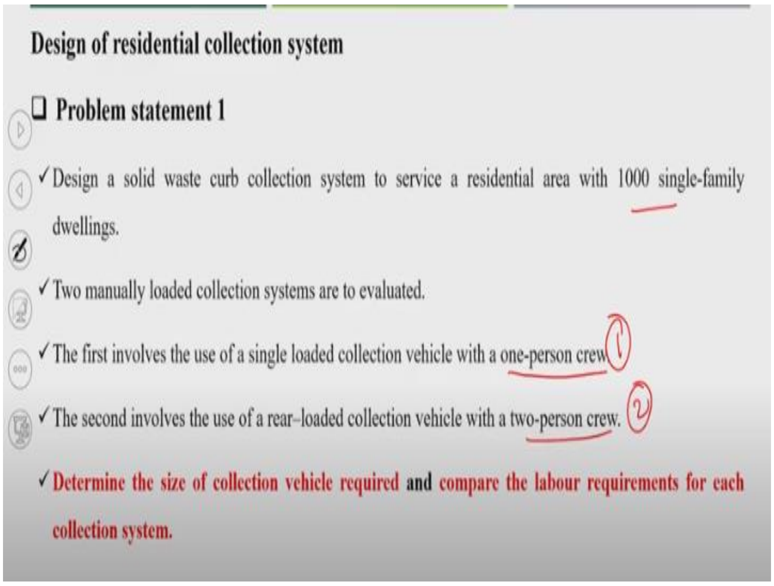


Now the t_p has to be calculated the pickup time that is t_p per location depends on the time required to drive between container location that is the one point and the number of containers per pickup location and the percent of rear-of-house pickup location. So, the formula will go as-

$t_p = dbc + k_1 C_n + k_2 (PRH)$

where, C_n is the average number of containers each pickup location and PRH is rear of house pickup location and k_1 and k_2 are constants related to the time required to collect waste from either per container or from the backyard of the residence in the PRH. So by that way we can calculate the t_p value.

(Refer Slide Time: 10:06)

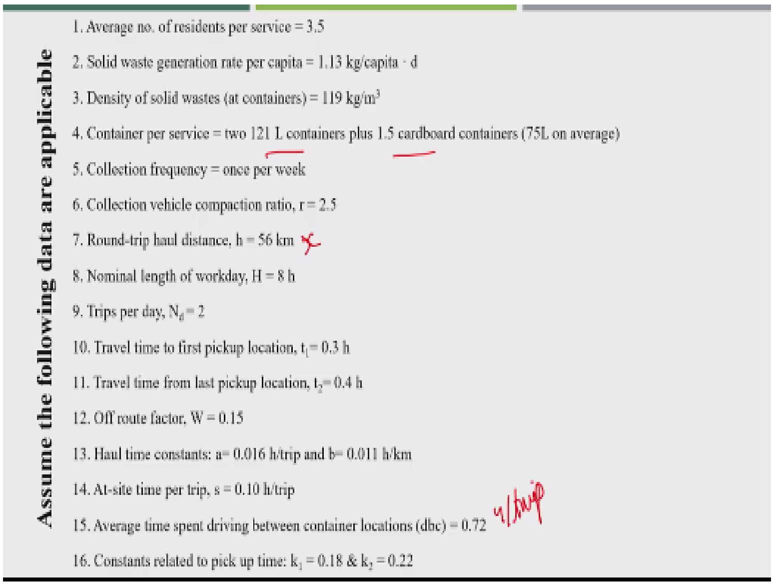


Now we will go to a problem. Here we will solve the two problems by giving different operations. So the first is a problem statement is we have to design the solid waste curb collection system to service a residential area of 1000 single-family dwellings. And two manually loaded collection systems are to evaluate. That is first to involve the use of a single-loaded collection vehicle in a one-person crew.

That is the first choice or first collection system and second is the second involves the use of rear loaded collection vehicle with a two-person crew. So we have to compare both the collection system which will be beneficial. So we have to determine the size of the collection vehicle required and compare the labor required for each collection system.

So we have to compare one person crew and a two-person crew collection system, which will be beneficial. And some data will be given in the problem.

(Refer Slide Time: 11:21)

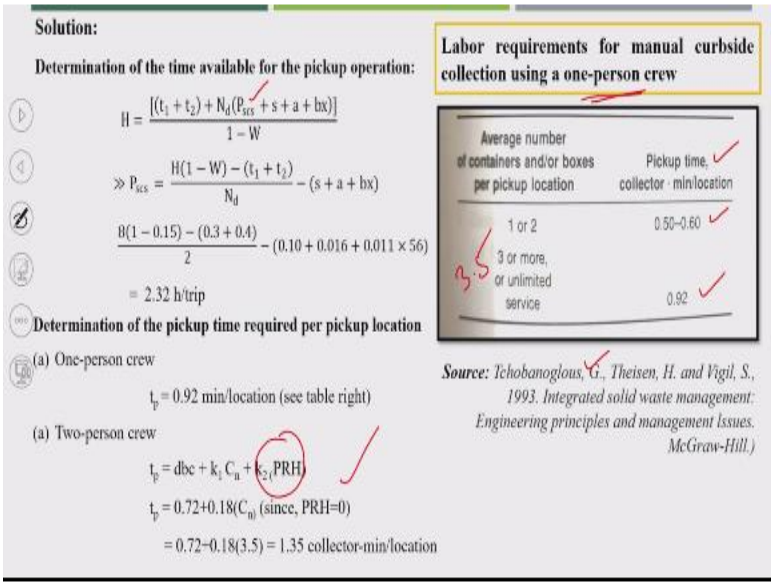


These are the data like the average number of residents per service 3.5. So the number of houses is 1000 and the average number of residents per service is 3.5. Solid waste generation rate per capita 1.13 kg per capita per day is very high. Maybe this data is from Japan or some developing countries. Density of solid waste which is very low compared to Indian waste density is 119 kg/m^3.

Container per service. So there are two containers of 121 L plus 1.5 cardboard container each of 75 L on average. So it is having 3.5 containers okay. And collection frequency once per week. Collection vehicle compaction ratio 2.5. Means the vehicle is a compactor vehicle. Round trip haul distance 56 kilometers. So x value is given here. This is the x value. The nominal length of workday H is 8 hour.

Trips per day N_d is fixed 2; t_1 value is given 0.3 hour, t_2 0.4 hour. Off-route factor is 0.15. Haul time constants are given. At-site time is given and the dbc value is given 0.72 hour per trip. This is hour per trip. And constants related to pick up k_1 and k_2 are given.

(Refer Slide Time: 13:03)



So now we will go for solution. At first we will determine the time available for the pickup location okay. So that is H. By this formula, we can calculate, where we know the N d value, but we do not know the P_{scs} value. So from this we can calculate the pickup time for stationary container system. So the P_{scs} will come up in this way. And already the data are given like H is 8. (1 – W) is (1-0.15).

t_1 and t_2 is 0.3, 0.4; s at-site time 0.1 and these are the constant a and b and the x is given 56 and N_d is 2. So by that way we can calculate the pickup time as 2.3 hours per trip. Now we will determine the pickup time required for pickup location. So we have two different collection systems; one is one-person crew and another is two-person crew. In one-person crew, t_p we will find from this table.

So is the similar textbooks, which I propose for this course. There are two columns is given here. The average number of containers or boxes per pickup location and in that case, what will be the pickup time that collector minute per location. So in our case, number of containers on each pickup locations are 3.5. So in that case we can select the second one, three or more or unlimited services.

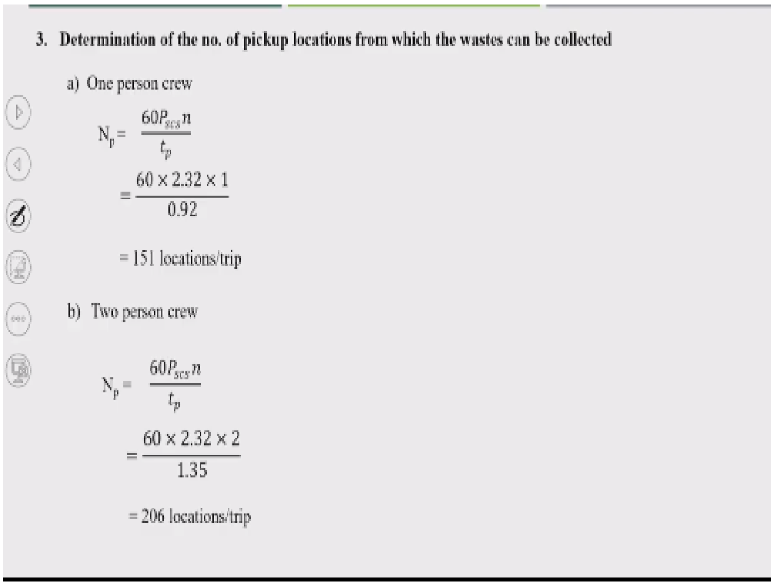
In that case, your t_p value will be 0.92 which we assume. So it is possible in the exam, these values are given in this table, are very easy to remember also. So and this labor requirement is only for one person crew. Please remember this table is only for one person crew. Now we will go for two-person crew. We will solve by the different equations. But for one-person crew need not to solve.

We can take it from the same table. And just remember that if there are more than three containers in each pickup location then in that case t_p value will be 0.92 collector minute per location and if there are only one or two locations, in that case, we can take it 0.5 or 0.6 value in between value we can take. Now for two-person crew, so we have this formula-

$t_p = dbc + k_1 C_n + k_2 (PRH)$

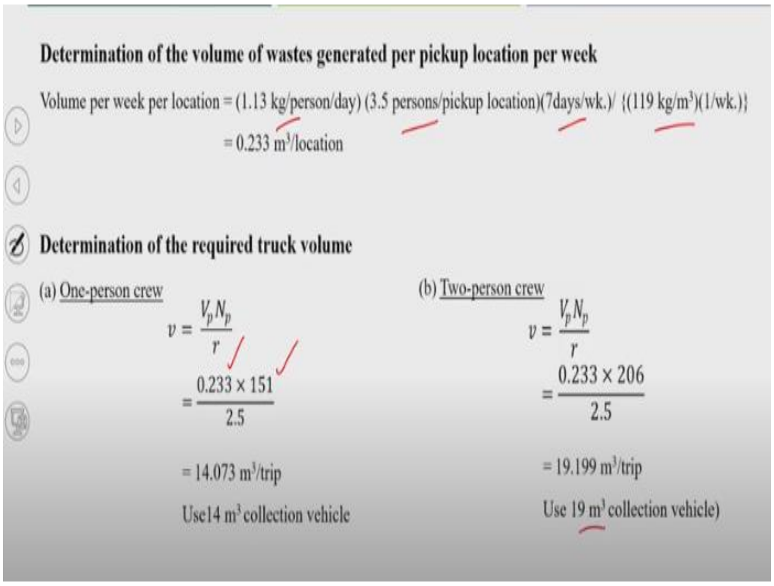
So now we will put up the value. So dbc is 0.72. Now here PRH is 0. There is no rear house locations given okay in the problem. So we will take PRH as 0. So this entire value will be 0. So from that we can calculate. So here C_n is 3.5 number of containers on each location, t_p = 0.72+0.18(3.5). So the t_p value is 1.35 collector-minute per location.

(Refer Slide Time: 16:44)



So now we calculate the number of pickup locations. So in one-person crew, the here t_p value is 0.92. And n is number of crew person, that is 1. So in that case, the value will come 151 locations per trip. And in two-person crew here n will be 2 and t_p will be for two-person crew. So in that case it will come to 106 locations per trip okay. So see here the number of pickup location in one-person crew is less than the two-person crew.

(Refer Slide Time: 17:23)



Now determine the volume of waste generated per pickup location okay to calculate the volume of the vehicle. So this volume per week locations, I think we took the per capita generation multiplied by how many people are residing in that particular location 3.5%. And because once in a week collection, so we will multiply it by 7. That is the quantity of solid waste and we divide it by density.

Density is given 119 kg per meter cube. So in that way, we can calculate the volume per week per location. Here you see that different problems the different ways the volume of waste will be given. Now in this case here, the per capita generation is given and a number of residents per location are given. So and densities are given. So sometimes it is possible that direct value is given in m^3/day.

So we have to just multiply it by the number of residents in that particular location multiplied by 7. That is days in a week. So here we got the volume per week location 0.233 m^3 per location. Now we will calculate the truck volume. So for one person crew, that is the v,

$$v = \frac{V_p x\, N_p}{r}$$

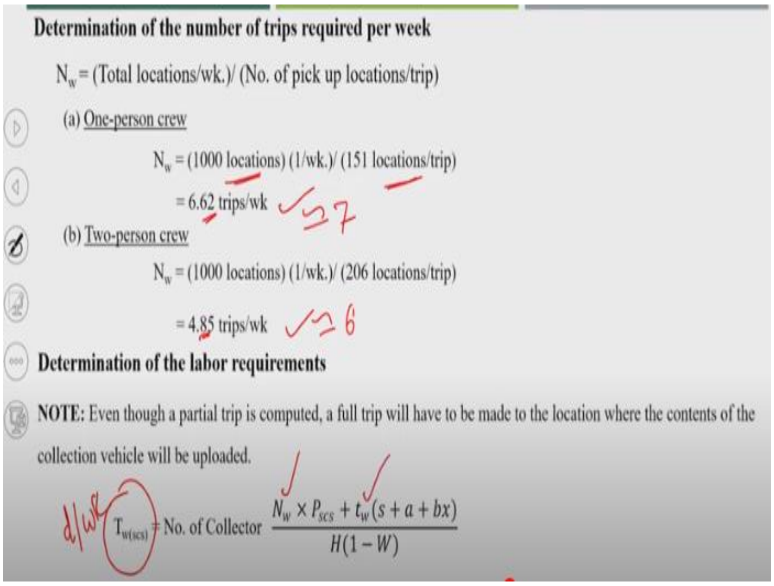
So is a truck volume we can calculate from this formula.

So here is a simple volume generated multiplied by the number of pickup locations and divided by compaction ratio 2.5. So that is coming out to be around 14 m^3 collection vehicle. So simple dumper vehicle will have almost size of 18 to 20 m^3. So if you have one vehicle, a simple dumper vehicle having 18 to 20 m^3 is feasible for this collection system.

And if you compare with the two-person crew, so in that case, it is coming out to be 19 m^3 collection vehicle. So in this case also a similar kind of dumper vehicle could be possible. And if you will use the compactor vehicle which can get it which can store or which can load around 130 to 140 m^3 so that the same vehicle can collect the waste from different locations.

Because it is a once per week collection, so that is why you are getting this much amount of waste and if you go for daily collection you need not multiply it by 7. So your volume will be very small. So in that case this value also will be a very smaller value. So is possible that the smaller vehicle or one auto tipper having size of 4 m^3, 5 m^3 is feasible for thousand households could be possible.

(Refer Slide Time: 20:42)



Now we will calculate the number of trips required per week because it is a once in a week collection. So how many trips will be required per week. So for one-person crew that we can do it by number of locations, that is 1000 locations divide by how many locations could be possible in each trip. So by that way, we can come up with the number of trips required per week.

That coming out to be 6.62 trips per week. And two-person crew that is coming out to be 4.85 trips per week. So you see here in one person crew we require more trips per week compared to the two-person crew. Now determination of the labor requirement. Means how much time will be required and here also one important note that even though the partial trip is computed, now here partial trip.

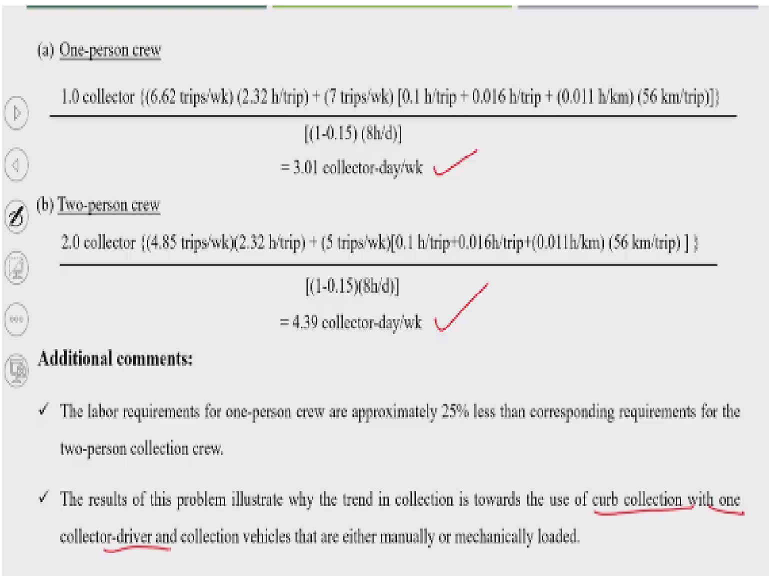
Because it is not possible to have in 0.62. This should be one single numerical value. So even though the partial trip is computed a full trip will have to be made to the location where the content of the collection vehicle will be uploaded. So it is now it is good to see that if you can get it these trips, we can assume these trips say one trip per week and in this case six trips per week.

By that way we can calculate how much is the labor requirement. So and this we can calculate this is T w is total time per week, how many days will be required and in this particular collection system and the unit will be days per week, how many days will be required in a week, that is labor requirement. That we can calculate by the number of collectors

$$T_{w(scs)} = No.of\ collector\ \frac{N_w x\ P_{SCS} + (t_w + s + a + bx)}{H\ (1 - W)}$$

Here, the N_w we already calculate. And this t_w is we can put it 7 in the one-person crew and in two-person crew 6 this value.

(Refer Slide Time: 23:01)



Now will calculate the one-person crew. It is coming out to be 3.01 collector days per week. So these many days will be required in one-person crew. And two-person crew will be required 4.39 collector days per week. So here we can easily compare that the labor requirement in a one-person crew is a low value compared to the two-person crew.

So the major comments on the solution labor required for one person crew are approximately 25% less than the corresponding requirement for the two-person crew. So that is why the result of this problem illustrates why the trend in the collection is toward the use of curb collection with a one collector driver and collection vehicle that has either manually or mechanical load. Normally we found most of the local authorities.

(Refer Slide Time: 24:07)

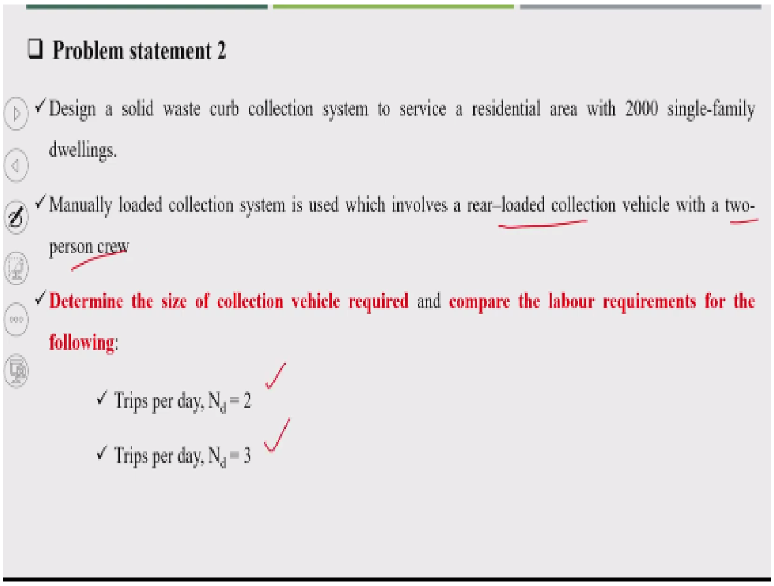
Tabulated comparison

Comparison	One-person crew	Two-person crew
Time available for the pickup operation	2.32 h/trip	
Pickup time required per pickup location	0.92 collector-min/location	1.35 collector-min/location
No. of pickup locations	151 locations/trip	206 locations/trip
Volume of wastes generated per pickup location per week	0.233 m^3/location	
Required truck volume	14 m^3	19 m^3
No. of trips required per week	6.62 trips/wk	4.85 trips/wk
Labour requirements	3.01 collector-day/wk	4.39 collector-day/wk

Now there is one more tabulated answer here, the time required for pickup location that is the same for both the case. So here t_p value, number of pickup locations. So is a very surprising number of pickup locations 151, in this case, 206. And the required volume is smaller here, required truck volume smaller compared to the two-person crew. And the number of trips is could be possible more here compared to the two-person crew.

And finally, the labor required also is very less compared to the two-person crew. So your answer is, one-person crew is more beneficial for the stationary container system, okay.

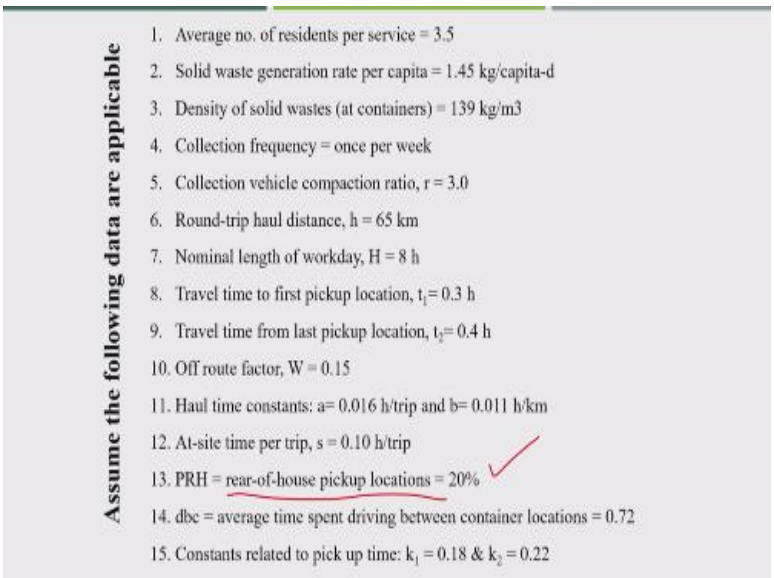
(Refer Slide Time: 24:58)



So now we will go to the next problem where we will compare the N_d value N_d =2 and 3. So the problem statement is the design of a solid waste collection system in a similar way. 1000 single-family dwellings. Is a manually loaded collection system and having a facility of rear loaded collection vehicle facility. And especially here the option is given only the two-person crew.

Only one option and we have to determine the size of the collection vehicle required and compare the labor required for the following for N_d = 2 and N_d = 3. These are the two options given okay. But remember that we have only one choice for a person crew is only two-person crew. Now we will go for a similar way problem solution.

(Refer Slide Time: 25:49)

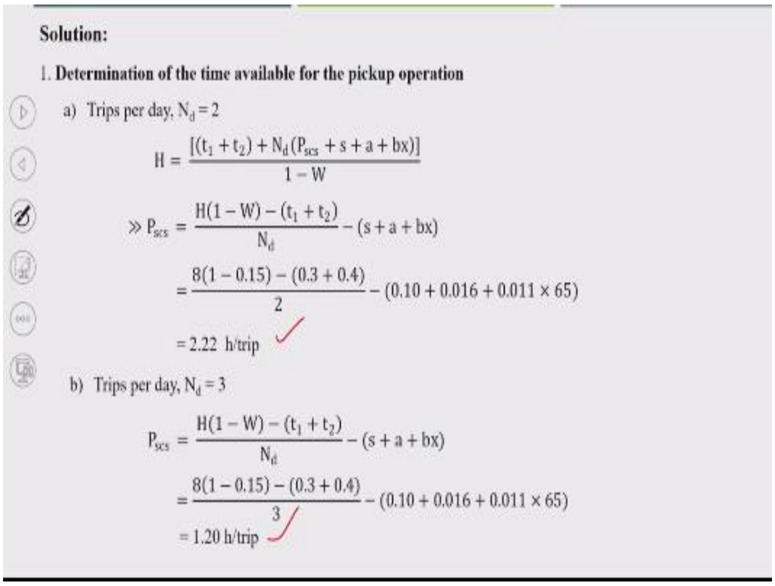


And data are given. So similar data, data are given. Now here the one different the PRH values are given okay. 20% rear of house pickup locations. So you remember that while calculation of tp value, we need to use that particular equation-

$t_p = dbc + k_1 C_n + k_2$ (PRH)

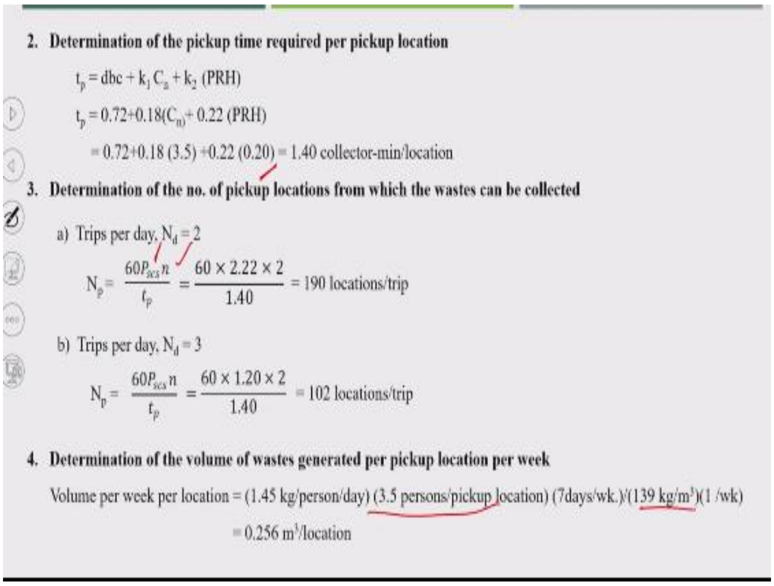
Now he has two-person crew, so we cannot take the values as given in the table from the book. So we have to analyze by this equation.

(Refer Slide Time: 26:30)



So we will start the solution. Similar way we will we can calculate the time available for pickup operation. First we will go for $N_d = 2$. So here we can calculate the P_s value and it will come up to be 2.22 hour per trip. That is for $N_d = 2$. And for $N_d = 3$ that is coming out to be 1.2 hours per trip. So you see here for number of trips per day will be required more pickup time and here pickup time is less here in $N_d = 3$. So is a very obvious answer.

(Refer Slide Time: 27:19)

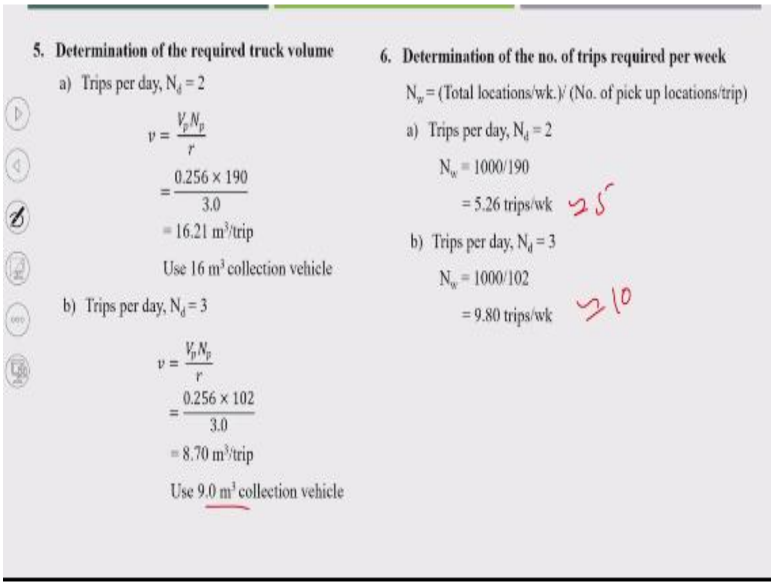


Now will calculate the pickup time required per pickup location that is t_p value. now here you see the PRH locations we took 20%. So is 0.22(PRH). So is coming out to be 1.4 collector-minute per location. Now once the t_p is known that we can calculate number of pickup locations from that is for trip per day N_p, we can calculate. Now here n is 2 okay for $N_d = 2$.

So both the cases the pickup time is different here okay P_{scs} value. So in $N_d = 2$ it will come out to be 190 locations per trip. And number of trips 3 per day. So from that we can calculate the number of pickup locations that is coming out to be 102 locations per trip. So we can calculate the similar way volume of waste generated per pickup location okay. The similar way.

The first we can calculate the quantity or waste generation divided by density. So that is coming out 0.256 m^3 per location.

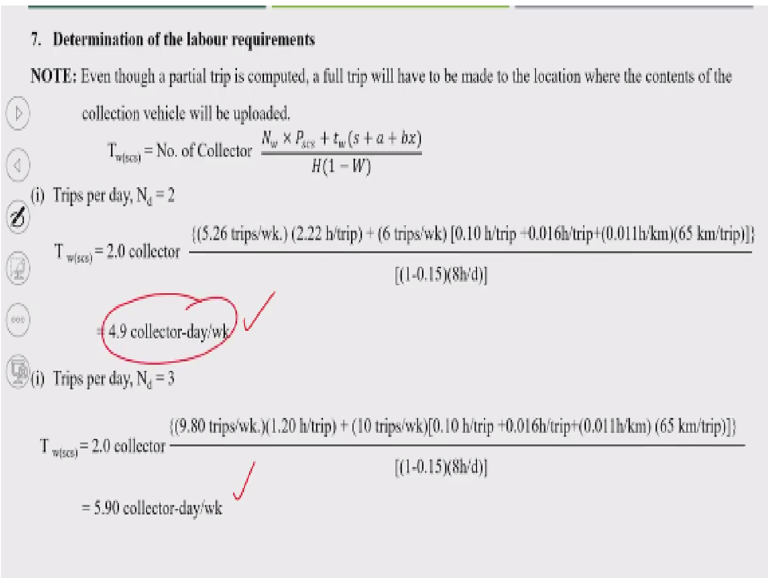
(Refer Slide Time: 29:01)



Now we will calculate the truck volume first in for N_d = 2. So we can calculate the vehicle volume is coming out to be 16 m^3 collection vehicle okay. And for N_d= 3, 8.7 m^3 per trip. We can use 9 m^3 collection vehicle. Now here you see that for N_d= 2 required larger size vehicle that is 16 m^3 size vehicle will be required.

And if you go for N_d = 3 number of trips per day 3 then, in that case, will be required smaller size collection vehicle. Now we can calculate the number of trips required per week that is N_w value. So the total locations per week and the number of pickup locations. For N_d = 2, 5.26 trips per week is coming out and for N_d = 3, 9.8 trips per week.

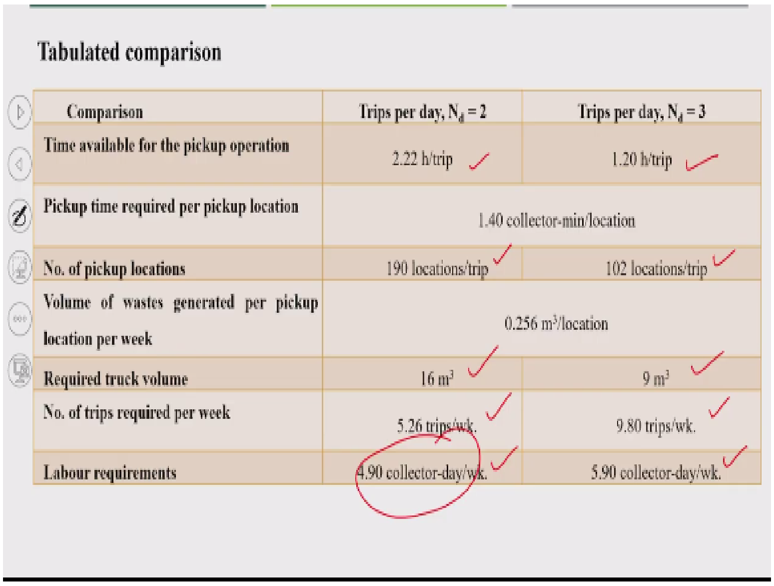
(Refer Slide Time: 30:26)



So from that we can calculate the labor requirement. In that case, we can take this value 5 and this we can take 10. So the same way the full trip has to be made in the location. So we can calculate by the similar formula for N_d = 2 is coming out to be 4.9 collector days per week and for N_d =3 is coming out to 5.9 days per week. So here you see for N_d = 2 will be required 4.9 days per week and for N_d = 3 5.9 days per week.

So your answer will be the N_d =2 so in that case. So lower time is required as compared to the N_d = 3.

(Refer Slide Time: 31:33)



Tabulated comparison

Comparison	Trips per day, N_d = 2	Trips per day, N_d = 3
Time available for the pickup operation	2.22 h/trip	1.20 h/trip
Pickup time required per pickup location	1.40 collector-min/location	
No. of pickup locations	190 locations/trip	102 locations/trip
Volume of wastes generated per pickup location per week	0.256 m^3/location	
Required truck volume	16 m^3	9 m^3
No. of trips required per week	5.26 trips/wk.	9.80 trips/wk.
Labour requirements	4.90 collector-day/wk.	5.90 collector-day/wk.

So we will go for a tabulated comparison. So in that case you see here, pickup operation requires different values. So the large value in the N_d =2 and number of pickup locations are more here in N_d =2 compared to N_d =3. And finally, here your vehicle size is large compared to in N_d =3 and the number of trips, but lower here compared to the N_d =3. But if you see the labor requirement or time required in a week that is low compared to the N_d =3.

So here the answer is now N_d =2 is your answer okay. So **so** during this class, we understood how to solve the problem related to stationary container system. Here we took two different examples, one example was given the two alternates one-person crew and two-person crew. And next problem the second problem was given where two alternate was given N_d =2 and N_d =3.

Similarly, it is possible that and we can compare the different alternatives. And based on that, we can finalize the more beneficial solution by comparing it with the vehicle volume and labor requirement. Based on that we can select one particular option or particular alternates. So now next lecture we will again compare because nowhere, what we have done from the last two lectures, the first lecture we understood the design of haul container system.

In this lecture, we understood the stationary container system, how the alternates can be compared. But we do not compare whether in the same location it is possible that haul containers could be beneficial or could be possible stationary container systems. And that is again dependent upon the x value round trip haul distance and is dependent upon the economy, the cost of both the collection system.

In so next lecture we will compare the haul container system with the stationary container system. We will solve one problem. And we will plot the one particular curve where we will compare the haul container system with the stationary container system. And also need to be discussed once any collection system is finalized whether is a haul container system or stationary container system always needs to be finalized the collection route.

That is important. Especially this collection route is very important for the haul container system. Because there are several haulings compared to the stationary container system. So thank you for today's class.