Introduction to Multimodal Urban Transportation Systems (MUTS)
Prof. Arkopal Kishore Goswami
Department of Ranbir and Chitra Gupta School of Infrastructure Design and Management
Indian Institute of Technology – Kharagpur

Module No # 02
Lecture No # 07
Public Transportation: Basic operation elements of public transportation

Hello friends. Welcome back to the next lecture. In the previous lecture on public transportation we got some introduction about it and learnt about some benefits and what are the issues facing public transportation in India. So today we are going to take it forward and move to the next step where we are going to introduce you to the basic operating elements in public transportation.

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The concepts to be covered in this lecture include some basic definitions and formulas for eg. line, stops and networks, how do you define transit right of way? What is a vehicle? What is a transit unit? And some operational factors of public transportation including a headway, frequency, capacity and utilization. These are very specific terminologies that have to be remembered in case of public transportation.

As we move forward we will be solving some problem and so on and so forth, so good deal of attention is to be paid to these terminologies.

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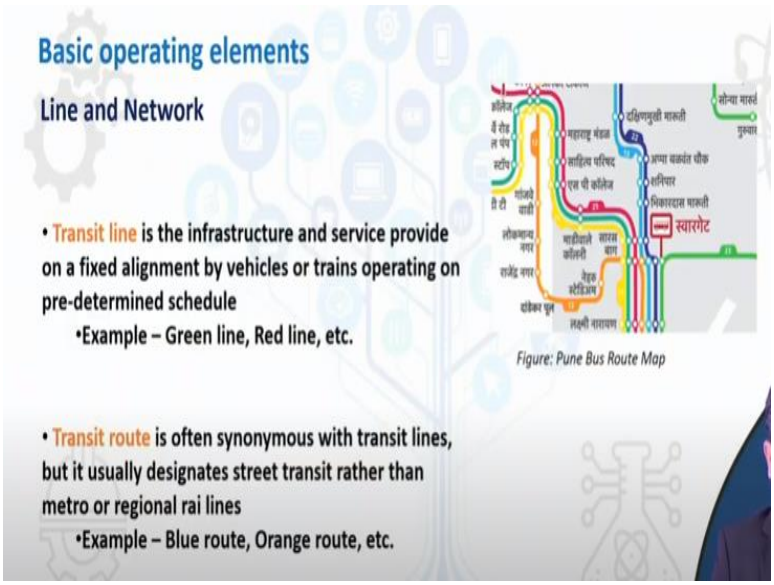

So let us begin the first and the basic terminology in any public transportation system is what is called as transit line. We all have taken several public transportation systems, maybe across different cities, and we always know that there is a public transportation line which we need to take. So how do we define a public transportation line? It is the infrastructure and service provided on a fixed alignment by vehicles or trains operating on pre-determined schedules.

These are vehicles or trains operating on pre-determined schedules and on fixed alignment. So usually what happens is, we can see in the picture given on your right side, that there are several different lines that you can take to go from point A to point B, such as yellow line, green line red line, so on and so forth. This is an example from the Pune bus route map. So if you have to go from Point A to point B you would pick a line or the other, given the characteristics of that line.

So that is basically what we call as a transit line. Sometimes transit line and transit route are synonymous to each other. The term transit route usually designates street transit rather than metro or regional rail lines. So street transit meaning, they operate along with other transportation modes such as cars and auto rickshaws and so on and so forth, then they are called street transits.

So when it comes to street transit we call it transit route rather than a transit line. So in the same example, if it is a bus route, ,we will call it a blue route or orange route, and so on and so forth.

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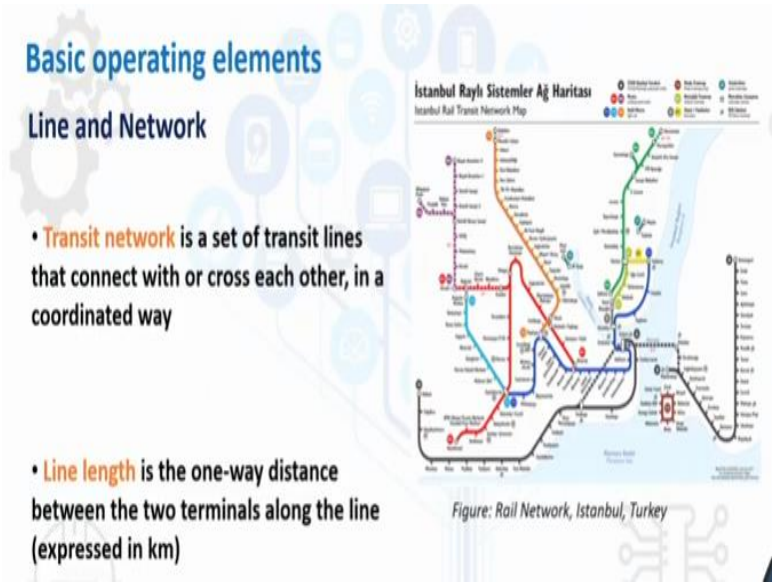

The next terminology to remember is a transit network. There may be different lines, there may be different routes in a public transportation system, and what a transit network says is that it is a set of transit lines that connect with or cross each other in coordinated way. So the transit network comprises of several transit lines or transit routes. So here you would see again a map of rail transit network in Istanbul in Turkey.

So you would see that there are several transit lines; some of the lines run parallel to each other whereas some crisscross. So the crisscross is by design, it is not accidental or due to different alignments coming to meet at one point, but they are actually designed in such a way that people can move efficiently from one point to the other in the city. So that is what a transit network is. All of these lines collectively would represent a transit network.

Then the next terminology to remember is line length. When we have so many transit lines we have to remember what the length of a particular line is? So line length is defined as the one-way distance between the 2 terminals along the line, usually expressed in kilometers or miles or whatever the unit it is. So if you look at this map you would see a black line at the bottom of the map which runs from a point in the western most point to eastern most point and vice versa.

So you can calculate the line length of the black line from the terminal, that is in the eastern most side, to the terminal at the western most side. So between the 2 terminals the entire length of the line is called the line length. These are called operational terminologies that help in scheduling a

bus service or rail service. Once you know that your transit line is 10 kilometers long and you have S number of stations in between, so you can then schedule your transit line accordingly.

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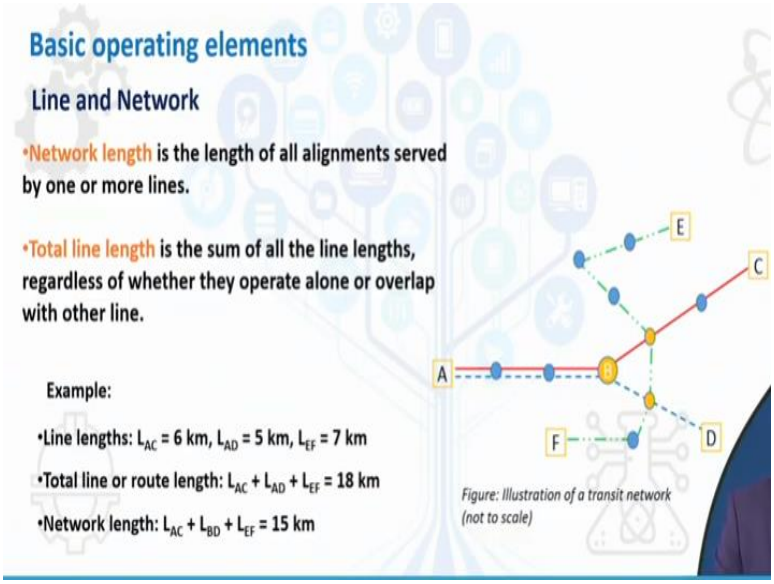

So moving on, next is what is called the network length. So now you know the line length, so in similar way you have to now determine what is the entire length of your network that is within the city? So the network length is intuitive and easy to define – it is the length of all alignments served by one or more lines. If you have multiple lines, then the length of all of those lines added together is the network length

A similar sort of a terminology is called a total line length and we will see how it is different from a network length in the example that is following this definition. So total line length is the sum of all the line length regardless of if they operate alone or overlap with each other. So there may be some overlapping lines, however when we calculate the total line length we will calculate all those overlapping lengths as well.

Whereas when we look at network length we usually do not consider the overlapping length. So that is the subtle difference between a network length and total line length. So here in this example you would see that there is a red line going from terminal A to terminal C, there is a green line going from terminal E to terminal F, and then there is another blue line that also starts from terminal A but goes from terminal D.

So there are these essentially 3 lines but they are crisscrossing at different points. So if you are to calculate the line length the individual line lengths then you would say that line length A C for the red line the line length would be 6 kilometers given that every station is equally spaced and it is 1 kilometer each. So if you see then you could calculate that the alignment AC 6 kilometer similarly the line length AD, which is the blue line which is 5 kilometers and the line length EF is 7 kilometers.

So now when we want to determine the total line length or the route length what we do is we add up all of these line lengths individually. So irrespective of whether these 2 lines which is the red line and the blue line that are over lapping for one stretch between A and B, we still add all those lines up and say that the total line length or the route length is 18 kilometer. Whereas when we look at the network length, you would see that we would adding AC we are adding EF but now we are not adding AD but we are only adding BD.

So we are neglecting or we are not adding the overlapping section and we are only adding the section that is not overlapped. So then we get a network length of 15 kilometers. Hopefully that is clear now, we move ahead.

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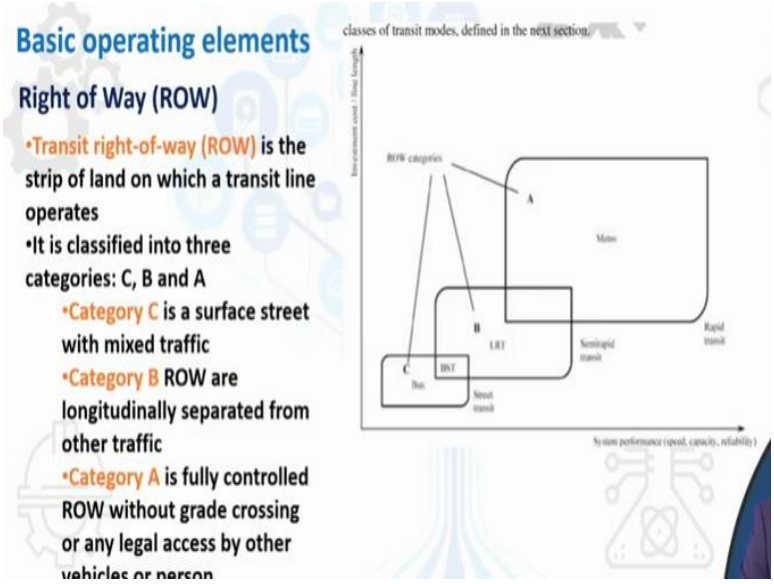

Now when it comes to right of ways, we define transit right of way as a strip of land on which the transit line operates. That is simple enough however it can be classified into 3 other sub categories. So category C, B and A, so what you essentially see is that category C is a type of

right of way where a surface street with mixed traffic exist and the transit runs on that surface street itself.

So, category C is a surface street with mixed traffic. If there is that kind of right of way, then we say that this is a category C right of way. Whereas when the right of way is longitudinal separated from other traffic we call them as category B. So what do we mean by longitudinal separated -- maybe there is a median on which public transportation line runs. So the median is separated from the adjacent vehicular traffic by some sort of tree line or some sort of different pavement type.

They are still running on the surface, so such type of right of ways are categorized as category B right of ways. Whereas category A right of ways is fully controlled right of way without any at-grade crossing or any legal access by other vehicles or person. So when we see the metro line, usually that are over ground or above ground, such kind of right of way for the transit or public transportation is categorized as category A public transportation so category A right of ways.

Now if you look at this chart, and we would not go in detail in this chart, which we would do it later, you would see that the X axis has the system performance whereas the Y axis has the investment cost per line length of any system. So you would see that if it is category C type of right of way you would see that the cost is very low, the investment cost is very low, but the system performance is low as well.

In other words, we can say that so introduce a bus transportation in any city it may cost very less but at the same time the system performance would also be very less. What do we mean by system performance? Schedule, or staying on schedule, i.e. staying on time, all of those things and we will look at it in much more detail later on. So similarly now if you move on to right of way B the cost increases a little bit as well as the performance also increases.

However, when you finally move on to right of way category A, it has the largest cost and the best system performance as well. And the breadth of the box is the range in the system performance; i.e. range in the cost. So that is that; kind of gives you an idea of how the right of ways are categorized.

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If I wanted to show it in pictures you would see that the first picture on your left is the right of way category C where the bus is travelling along with all the other vehicles on the street. If you move clock wise to category B that is the picture of tram which has its own right of way. So it has its rails, that is its own right of way, but the rails are at grade with the other modes of transport.

So although it has its own right of way but it is running with mixed traffic. Whereas when it comes to category A right of way they are usually the metro system and subway systems across various cities in the world, that have category A right of way.

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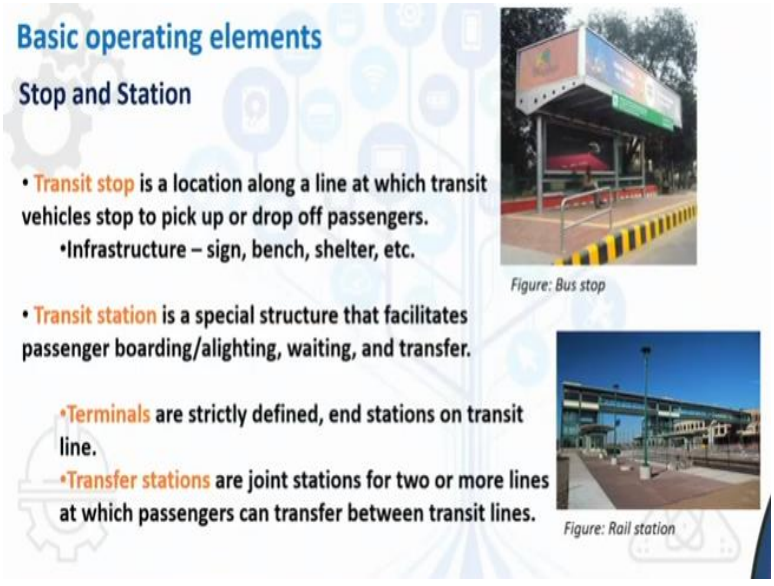

Now let us move on to the other types of operating elements that are involved in public transportation and which you have to know. The first thing is a transit stop. We all go to a designated place on the road to avail any type of public transportation. So transit stop is a location along a line where transit vehicle stops to pick up or drop of passengers. This can be easily identified by various infrastructure that are in place at this location such as sign, benches, shelters etc., and a picture on the top is illustrating the same.

A transit stop and a transit station are synonymous to each other in the way that both of these are the locations where transit vehicles pick up or drop of passengers. But a transit station is a special structure that facilitates passengers for boarding, alighting, waiting and transfer. So whereas a transit stop could be point in a line whereas, the transit station could be a linear feature along their line.

It has some more sitting facilities, it has various information available, it requires a little bit more infrastructure to actually accommodate the public transportation vehicles. Usually we call those, if they are rail public transport systems, stops as transit stations whereas if it is for rubber-tired, i.e. bus type of public transportation system, we call those kind of stops as transit stops.

So both of them are similar, but just a little bit of difference in terminologies. Now when we look at transit stations there may be 2 different types, one is a terminal station and one is a transfer station. So terminal stations are strictly defined as end stations on the transit line. So, like we looked at the map earlier of the rail transportation network in Istanbul, Turkey, so along the black transit line, we saw 2 terminals one on the east and one on the west.

So those 2 terminals, those 2 stations or stops are called as terminal stations; whereas there may be other stations where people could transfer from the black line, for example to the other green or blue lines, so such stations are called transfer stations. tThey are common stations for 2 or more lines at which passengers can transfer between transit lines. So a transit station could have 2 different classifications as well.

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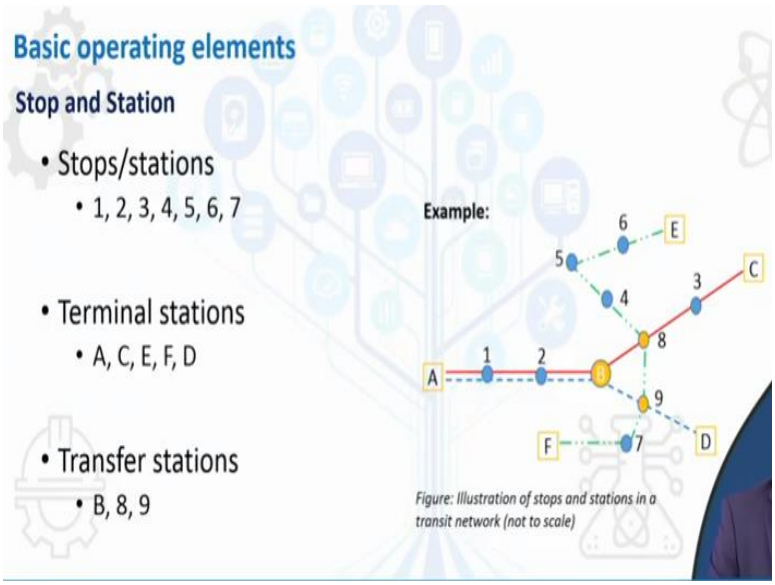

So if you go back to our sketch of the transit route network we would see that stops or stations number 1, 2, 3, 4, 5, 6 and 7 could be called stops or stations. So all the blue dots could be called as stops or stations, whereas the terminal stations are the once noted in square and has an alphabet inside the square.

So, A, C, E, F, D are the terminal stations. You will see that they are the end of any particular line whereas the transfer stations are the ones where people could transfer from one line to the other. For example, the station B is a transfer station, the station 8 is a transfer station, the station 9 is the transfer station, and so on. At station 8, one could transfer from the green line to the red line, whereas at station 9 one could transfer from the green line to the blue line.

And at station B one could transfer from either the red line or the blue line or vice versa. So that is the graphical example of what do we mean by different types of stops and stations.

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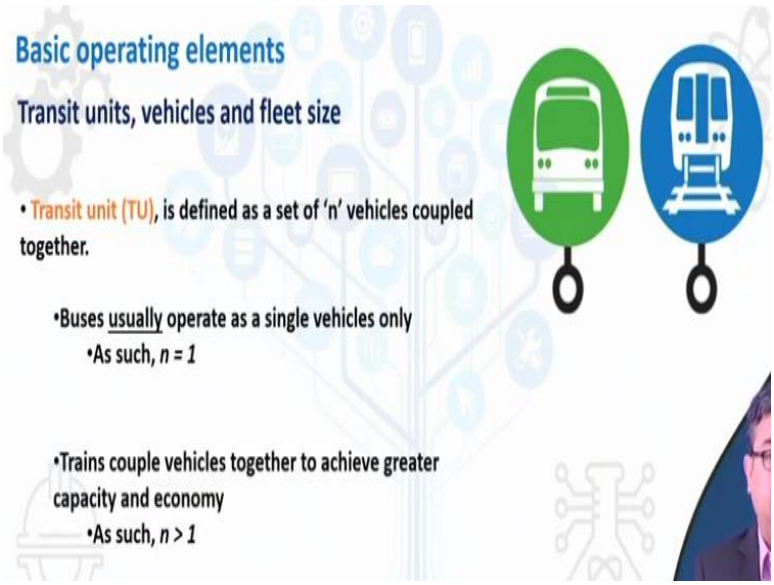

Now the next thing to know is about the vehicles and the transit units and the fleet size. So transit unit is defined as a set of N vehicles coupled together. This is the basic unit when we talk about any public transportation system. It is called TU in short. So transit unit is defined as set of n vehicles coupled together. Now buses usually operate as a single vehicle so in this case n will be 1, whereas in trains, units as coupled together to achieve greater capacity and economy, and in that case n is greater than 1.

So now you understand what is the transit unit. Now there are newer buses that are called articulated buses that may have 2 coaches that are combined with each other. In that case n would be equal to 2 that is why here we have underlined that buses usually operate at single vehicles. Nowadays we have newer buses that may have 2 coaches.

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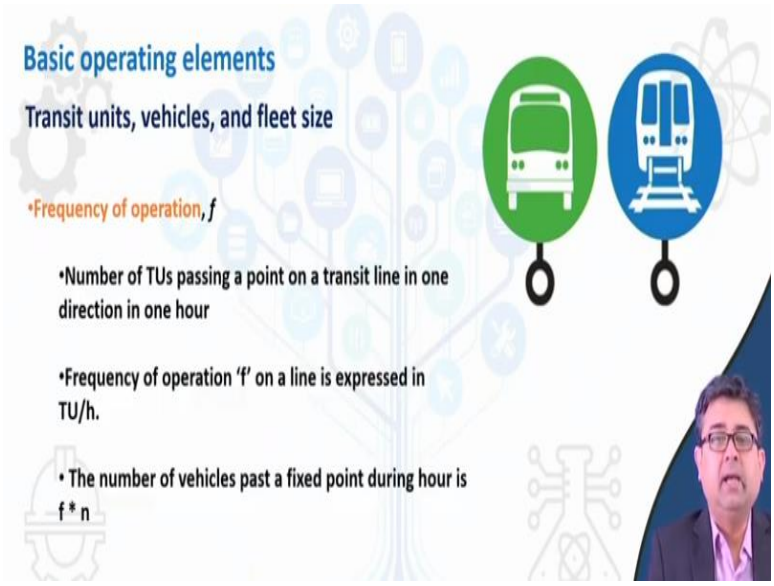

Next is to understand the frequency of operation. Now we as passengers are always interested in this frequency. We always want to know when the next bus is coming or when the next metro rail is coming. So how do we operationally define frequency. It is defined as the number as transit units passing a point on a transit line in one direction in one hour. So it is the number of transit units passing a point on a transit line in one direction in one hour.

The frequency of operation of a transit line is usually expressed in terms of TU per hour. And similarly if you just want to calculate the number of vehicles passing a fixed point, it is f times n. So that is the frequency of operation.

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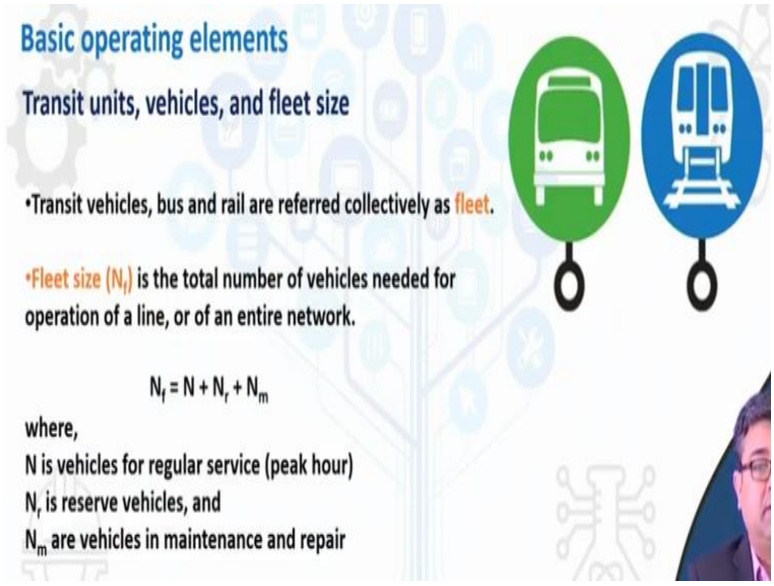

Now when we say fleet, what do we usually mean? Fleet is nothing but a collection of the transit vehicles, i.e. buses and rails together. So a particular city may have different types of vehicles, or types of public transportation, so you may have buses, you may have, some cases in cities like Kolkata you have different types of buses, i.e. mini buses, air conditioned buses, many of the cities also have air conditioned buses now.

So all of those vehicles and buses put together along with the rail, you would collectively call them as fleet. So when we are taking about how efficient is the public transportation network in a city, we usually see what is the fleet size. So all of these vehicles put together is the size of the fleet. So the fleet size can also be now calculated as the total number of vehicles needed for operation of a line or of an entire network.

So we have to have a minimum number of fleet size otherwise we may not be able to meet the demands of the people residing in the city. So the fleet size now consists of 3 different elements one is N, which is the vehicles for regular service; so during morning and peak hours morning and evening peak hours you need N number of vehicles you meet the demand of your citizens in the city.

Then comes Nf or Nr, or N sub r, which is the reserve vehicles. We always have to have some vehicles reserved in your fleet, so that if some other vehicle brakes down or if we need additional vehicles to meet additional demand on certain days, you always can use these reserve vehicles. And then there are vehicles which are classified as N sub m, they are vehicles in maintenance or repair. So, sometimes when the units brake down, there are different vehicles that go into maintenance and repair.

So all of these 3 types of vehicle's collectively can be called as fleet size or collectively determine the fleet size.

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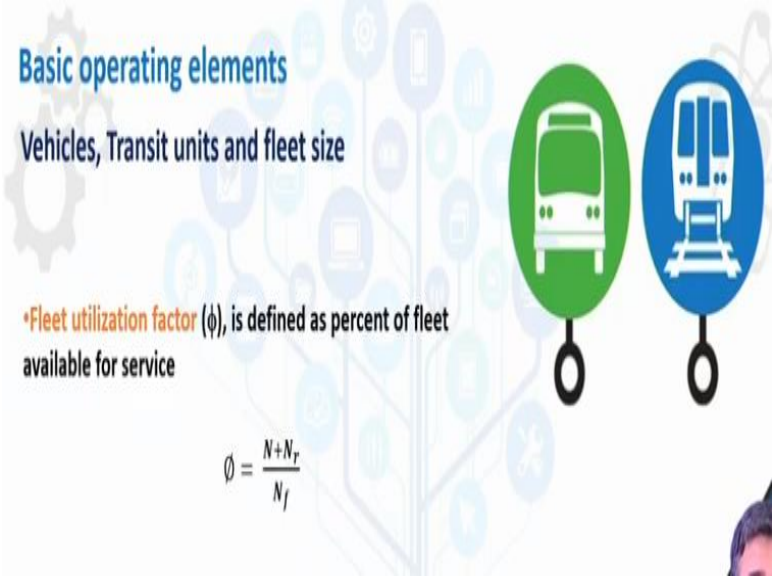

Now there is a terminology called fleet utilization factor, which is usually used by the transit operators, and it is defined as the percentage of fleet available for service. Like we saw in the earlier slide there may be a lot of vehicles that are in maintenance, i.e. that are being repaired. So they will not be available for service. And so, utilization factor is defined as nothing but the summation of N which are the normal vehicle in service during peak hour + Nr there is a vehicles divided by Nf which is the fleet size.

So, how many vehicles, i.e. fleet size that you have would be in the denominator and the numerator would have your regular fleet, i.e. your regular fleet for peak hour travel and as well as the reserved vehicles. So that ratio of that gives you the utilization factor.

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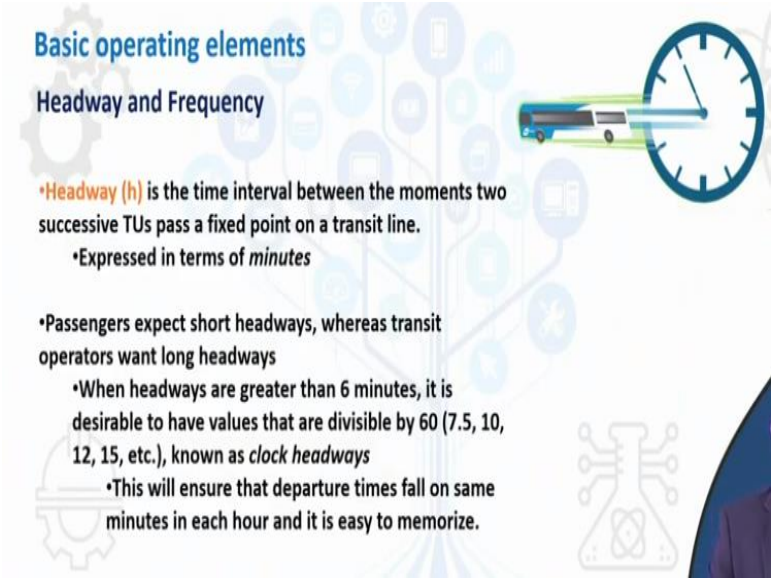

The other important terminology to remember in public transportation is headway. Now headway is the time interval between the moments two successive transit units passing a fixed point on a transit line. So sometimes we interchangeably use headway and frequency, which have to be carefully looked at, as they are related to each other. But when we interchangeably use it we may not be doing to correct way.

So headway is, so again the definition is, it is the time interval between the moments 2 successive transit units passes fixed point on a transit line. Say there is a transit line, it will have lot of vehicles, when one vehicle passes a point, the point could be a bus stop, and when the next vehicle passes same point on the same line, so the same bus stop on the same line,then the distance between those 2, or the interval between those 2, not the distance, headway is usually expressed in terms of minutes, so this we will give you the headway. Passengers expect short headways whereas transit operators want to have long headways. We always want the next bus to come very quickly, right? So we expect shorter headways, whereas it is very difficult operationally, or very expensive operationally, to have lot of vehicles coming in. So usually transit operators want longer headways; so there is always a give and take, and an optimal headway value is usually fixed.

Usually you would see that if the headways are greater than 6 minutes then it is desirable to have values that are can be divided by 60 because an hour has 60 minutes and then you can always remember when the next bus comes. So this is a usually called clock headways and it is easy to

memorize because you divide by 6. So you can say that the bus comes at 7 minutes past 7; and half minutes past the hour; 10 minutes past an hour; 12 minutes past an hours 15 minutes past, etc. So these are usually easy to memorize headways.

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There is something called policy headway, which ensures that the longest headway scheduled is determined based on the minimum level of service provided. Now since the operator wants longer headways and user always wants shorter headways, so there is always something called a policy headway that ensures that the users are not disgruntled, and at the same time the operators do not face excessive cost in running the transit operations.

So there is a headway which is an intermediary point, and it is called as policy headway, which has to be met so that the level of service is maintained. What is level of service, we will look later on. And then the minimum headway of a line is determined by characteristics of the line, like boarding and alighting rate, etc. Now there is also a minimum headway that has to be met, and what do you mean by boarding / alighting rate.

If there are lot of passengers boarding or alighting from a majority of the stops on the line, then it actually effects how quickly a vehicle can come and leave that stop. So that will affect the headways, so there has to be a minimum value that we have to keep in mind.

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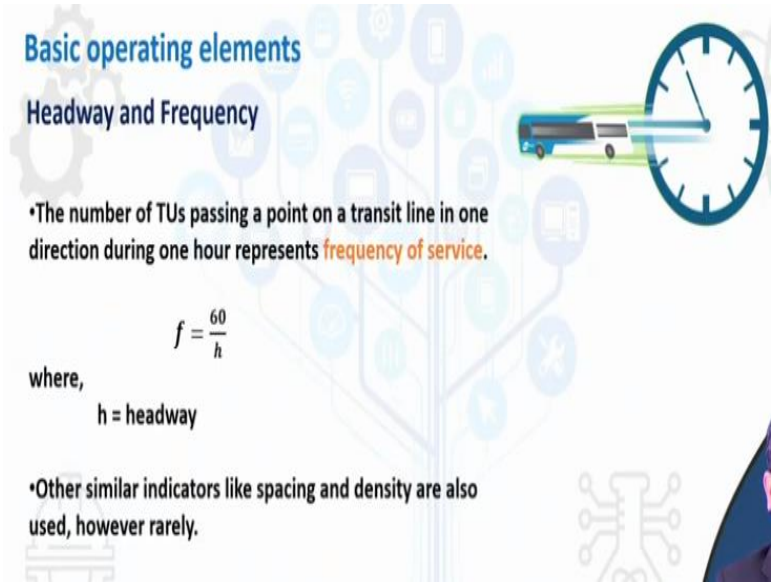

We have already looked at frequency, but let us look at how frequency and headway are related. So frequency as we know is the number of TU that is passing a point on a transit line in one direction in hour. And here is how frequency and headway are related -- frequency and headway are just inverse of each other; it is 60 divided by h, where h is the headway. Sometimes we alternatively use other indicators instead of frequency.

We say spacing or density, but frequency is mostly what is used, along with headway. But we have to remember the subtle difference between frequency and headway.

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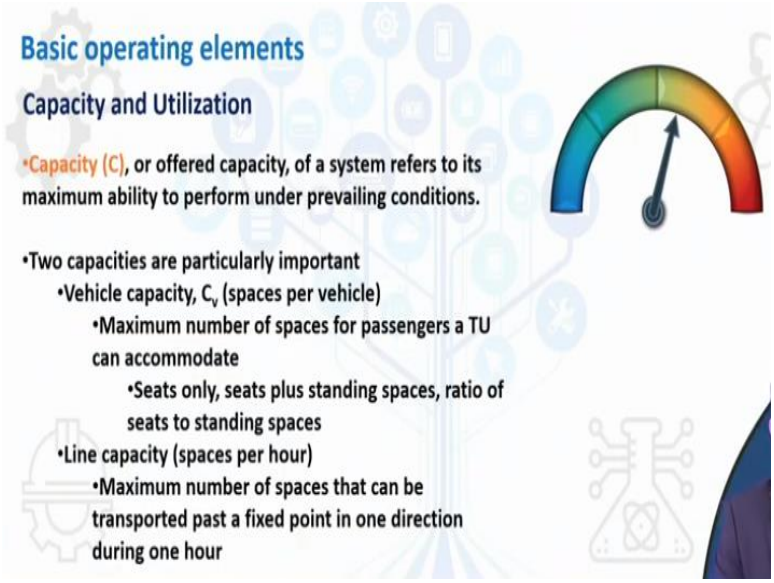

The last 2 elements to remember in this lecture is capacity and utilization. The capacity or offered capacity of a system refers to its maximum ability to perform under prevailing conditions. So any transit line would have a capacity. It has a capacity to operate N number of TUs, or it has a capacity to move N number of people from point A to point B. So that is essentially what is called offered capacity.

So there are 2 types of capacity, one is vehicle capacity and the other is line capacity. The vehicle capacity is the vehicle that is running on that line -- how many spaces are available within that vehicle okay. So the maximum number of spaces for passengers a TU can accommodate. So sometimes we count only the seats but sometimes we also count the seats plus standing spaces.

Sometimes we say the ratio of the seats to standing spaces determine what is the vehicle capacity. Whereas, the line capacity is the maximum number of spaces that can be transported past a fix point in one direction during an hour. So when we add up all these different types of vehicle capacities then we can calculate the line capacity.

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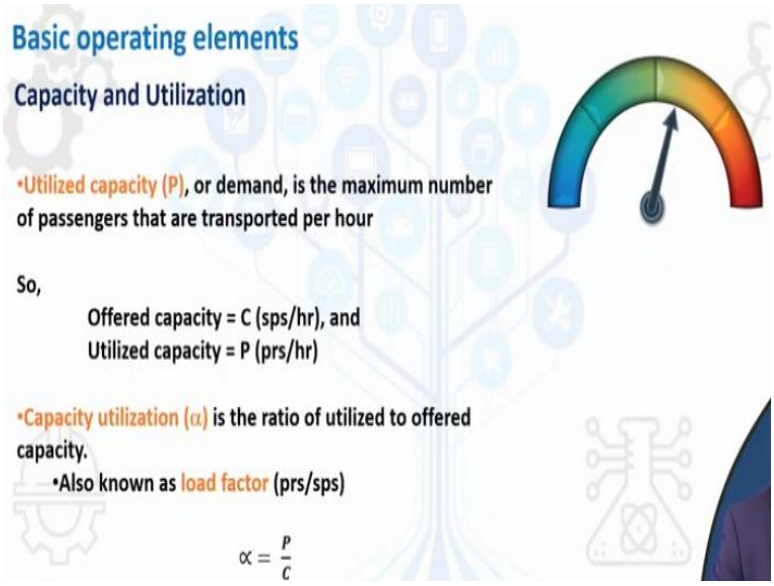

And then you utilize these two are offered capacities. Now what is utilized capacity? Utilized capacity is nothing but the demand, which is the maximum number of passengers that are actually transported per hour. So there is always a difference between what is offered capacity

and what is utilized capacity, or in other sense, there is a difference, but we also want to keep them close to each other.

So we want to keep that ratio, also known as the load factor, or the capacity utilization, very close to one. If it is very close to one, then we are operating at optimal level of service. Whereas if the offered capacity is very high whereas the utilized capacity is very low then the load factor is low. So we understand the difference between offered capacity, utilized capacity, and how both of them are related, i.e. to capacity utilization, which is the ratio of utilized to offered capacity.

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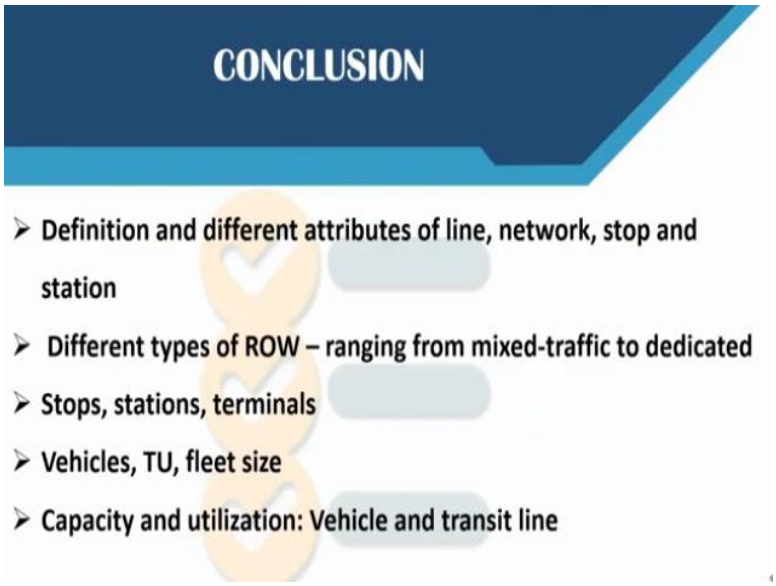

So in conclusion, we looked at the different types of lines, network, stops, and stations. We also distinguished between the different types of right of ways, which will allow you to understand how different types of public transportations operate. We looked at what is the difference between stops and stations? How the stations differ, between when they are terminal or when they are transfer stations. We looked at the basic unit of transit which is transit unit, TU; looked at fleet size, different vehicles, and finally look at capacity and utilization.

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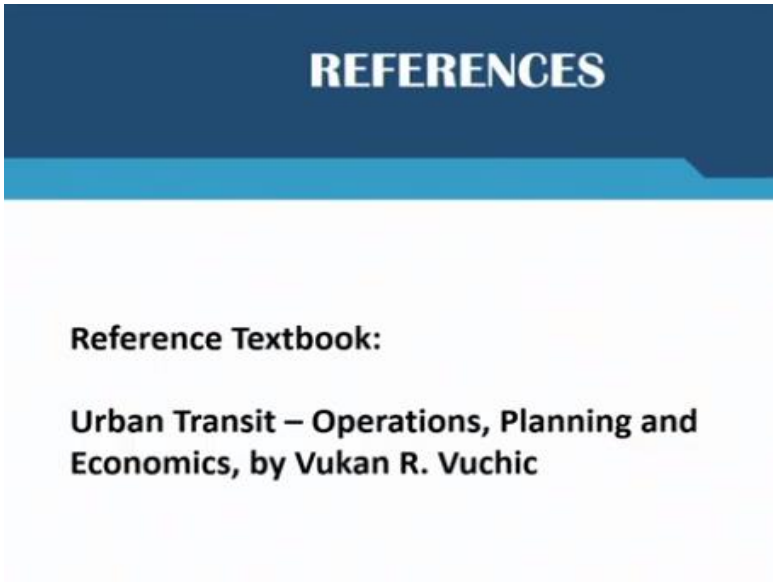

So now I would like to refer you to this text book, called urban transit operations planning and economics by Vukan Vuchic. This would be primarily the textbook that will be used for all the lectures on public transportation and you would find lot of reading materials in this textbook. So I would request you all to get it. Thank you.