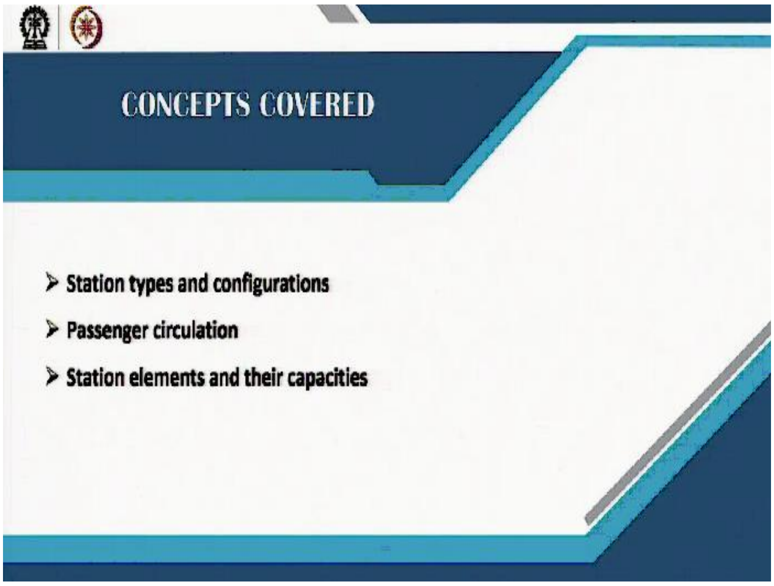
Introduction to Multimodal Urban Transportation System
Prof. Arkopal Kishore Goswami
Department of Ranbir and Chitra Gupta School of Infrastructure Design and Management
Indian Institute of Technology - Kharagpur

Lecture – 19
Public Transportation: Station Capacity

Welcome back friends, in the previous lectures we have looked at how to calculate capacity of your bus and rail transit lines. In this lecture what we will be looking at is another entity in any kind of public transportation that is the station and how to calculate the station capacity.

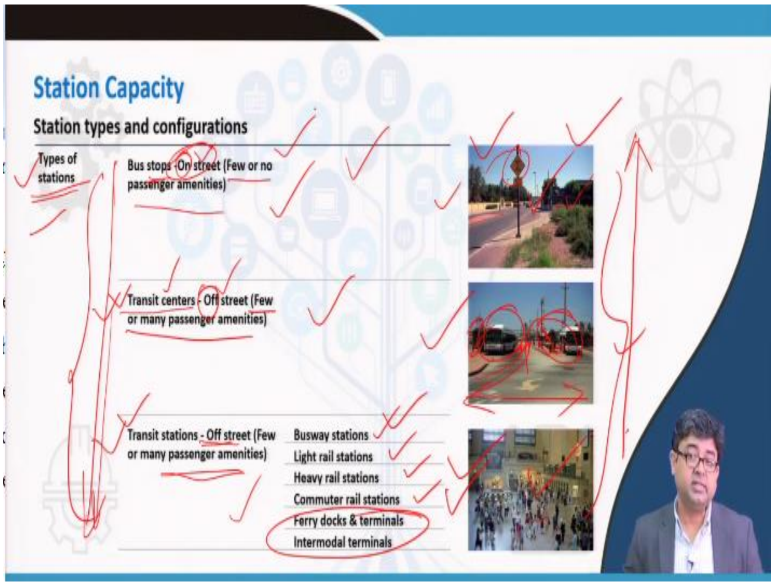
(Refer Slide Time: 00:40)



So, the main concepts that will be covered here are what are the different station types and how they are differently configured. Look at passenger circulation at these stations and what are the station elements and their capacities. So, your transit line is as good as your stations because these are primarily the places where people get on and off your transit lines.

Unless you have enough capacity for people to board or alight from your bus or transit lines at the stations, people are not going to use the public transportation lines as much. So, the stations or what we like to call them as nodes in our entire network are very crucial and the design of these stations are very crucial in facilitating a good public transportation system for your city.

(Refer Slide Time: 01:41)



So, let us look one by one to give you an understanding of what are the different types of station typologies that are available, or you might have encountered in your city or town. So, when you look at the station types, there are 3 different categories of stations, one is called stops. So, bus stops, they may be on-street bus stops. They may be just a signpost, sign mounted on a light post or something like that. And that is also a station where people board, get on and off a bus. So that is one type of station, which is an on-street station where few or no passenger amenities may be available. There may not be even a bench or there may be some lighting that is available, but there is no cover from rain or anything like that.

There is no shelter, there is no bench, it is just a basic bus stop. The next one could be what is called a transit center. These may be off-street, where there are buses that can queue one behind the other and people can get on and off the buses from platforms that have been developed, which are very basic platforms there. They may have some passenger amenities few or many, but usually a little bit more than what a bus stop has.

So, they may have few passenger amenities, but the other thing to remember is they are off-street, as opposed to these bus stops which are on the street itself. So, hence the number of buses that can be accommodated at this transit centers are a little bit higher. So, these may be termed as transit center. Now, the next one, is what is called a transit station.

Now, this of course is off-street, but it may have many passenger amenities. This is a full-blown station which can be either for bus or light rail for heavy rail, commuter rail. You may have seen all these different types of stations and you might have seen terminals that are either for ferries or for intermodal, intermodal freight transport. Those may be also called as terminals and they may also have these station areas.

So, usually you will see that the station areas has a building complex, it may have multiple amenities inside them such as eateries, drinking water, certainly chairs and benches, some may be air conditioned, some may have fans and televisions. So, there are different amenities within that station that allows people to access different bus routes, different railway lines, different metro lines, so on and so forth. So, broadly these are the 3 different types of stations that you may come across.

So, if you look at the terms of capacity of these different types of stations, the on-street station may have the lowest capacity, whereas the transit center may have a little bit higher capacity than On street bus stops. Whereas the transit stations may have largest capacity. So, these are capacities in terms of not only the number of passengers each bus can handle but also the number of passengers per bus that can be handled at the stations.

They may also be in terms of just purely the number of passengers that this facility can handle as well. So, the number of people that facility can handle and the number of people that can get on and off a bus at these facilities. Both those capacities may be varying as you start looking in-depth. The cost also of building these stations are also quite different.

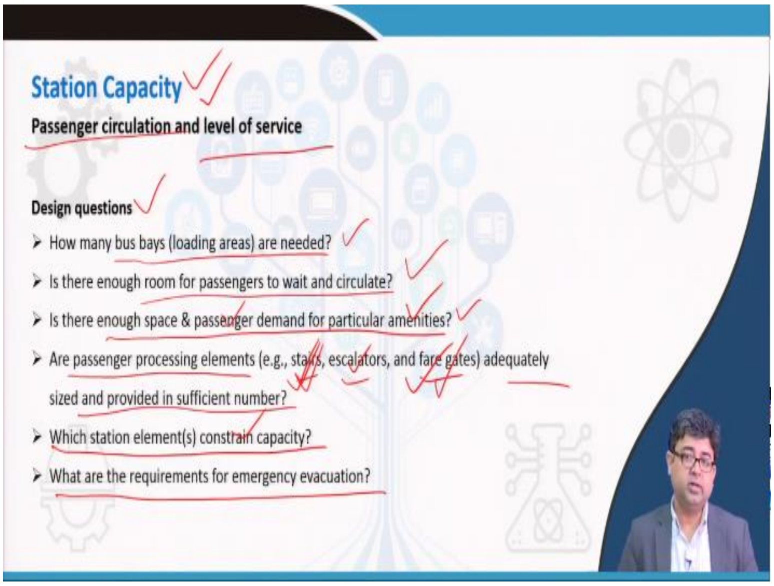
May be the easiest and cheapest bus stop to have is where you just need a sign, maybe a signpost. This needs a little bit more infrastructure because it is off-street. So maybe you must develop a pavement there, develop some loading areas, some passenger amenities, that takes a little bit more cost than this. Whereas this may be costliest one. So, when you are thinking about a which type of station, should your city have, you have to do a lot of calculation like benefit cost calculation.

So, cost and capacity calculations, simply because we have learned this cost and capacity, these 2 terminologies. So, what are the cost that goes into developing this versus what is the capacity of buses that it can handle, if yours is a small town and your bus route does not require a large capacity, maybe you should have frequent bus stops, you should just design them as bus stops rather than having transit stations.

Whereas, maybe your town does require at least 2 transit centers, one at each end of the line, because now there are multiple lines that are operating, so they may need some time to change from one line to the other line. Maybe the bus drivers need some layover time. So, all of that requires at least a transit center, at least 2 transit centers, one on each side of the line, maybe that is a requirement for your city, whereas the intermediate stops could be all bus stops.

So, I am just giving you an example for visualizing how you can pick and choose which type of station or stop or transit center to have in your towns or cities transit lines.

(Refer Slide Time: 08:23)



So, when we talk about station capacity, what we are essentially dealing with is passenger circulation and its level of service. So, essentially what we want to know is how easily passengers can circulate in the station when they are boarding or alighting from the transit line or when they are waiting to get on the transit line. So, circulation is the parameter on which the station capacity depends upon. Now what is passenger circulation? So here are some concepts that you need to know.

You need to answer how many bus bays or loading areas are needed, you already looked at the loading area capacity for buses. Is there enough room for passengers to wait and circulate? This is a question for which you must develop an answer. And based on that answer, your station will be designed or stop will be designed. Is there enough space and passenger demand for amenities?

Are there a lot of elderly people that access a stop? If there are elderly people, then maybe you had need to put a bus shelter and benches even though it may not be required otherwise. The capacity or the line capacity may require you to put in a bus stop or put in a seat in the shelter, but the demand of the passengers may want that you put in a bus shelter. So you have to answer the question of what is the passenger demand for particular amenities, and amenities meaning the needed water fountain at the bus stop, do they need a shed at the bus stop?

So that is what the amenities are. Next is passenger processing elements, for example, stairs, escalators, adequately sized fare gates are provided in sufficient manner. When you are talking about a station, are there enough escalators? Should there be escalators, or should there be only stairs? Are there enough fare gates? So, when people get in, they must punch their tickets.

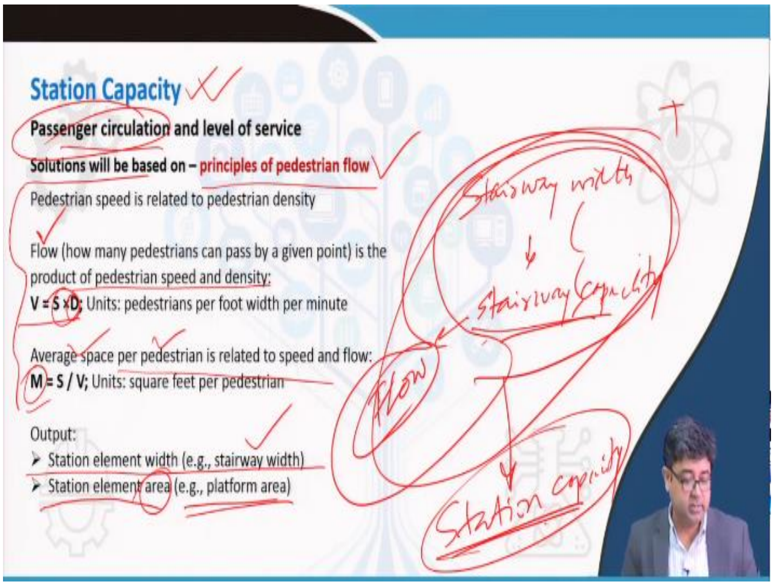
So, are there enough fare gates, especially while traveling during the peak time? So, through these questions, you can get an understanding of what the elements in the station areas are and what are their capacities. So, you must calculate the capacities of these. For example, capacity of stairs may be how many people per hour can a staircase accommodate.

How many people per minute can go through automatic fare gates? So, these capacities will in turn affect the passenger circulation in the station area. The passenger circulation will eventually affect the level of service and the station area capacity. So, these questions are designed in such a way that they allow you to think from ground up.

And then get to how to calculate the station areas. Which stationary elements constraints the capacity? Are there any elements which you must have in the station, but they are obstructing people's circulation and, hence reducing the capacity? So what are such elements that are obstructing or constraining the capacity and what are the requirements for emergency evacuation that is something always you have to keep in mind especially if you have a terminal or other station or a platform.

And for an elaborate station you need to have an emergency evacuation plan because that is the time when the load is maximum and maximum number of people are trying to get out of the station area. For example, your stairs should not be designed in such a manner that they would not be able to handle that capacity in emergency situations. You may have seen or heard about some incidents where there have been stampedes at stations or when people have been trying to get out of a station in emergency times. So, if you have not designed your stairway in such a way then that may lead to such disasters during emergency. So, keep all of these in mind when you are designing your station capacity.

(Refer Slide Time: 13:13)



So, the solutions for station capacity and passenger circulation will depend on the principles of pedestrian flow, which we have already covered when we were looking at the pedestrian transport part of this class. We have looked at pedestrian flow, you know that flow is the product of pedestrian speed and density. And density is nothing but the inverse of pedestrian space, where pedestrian space is number of the average space per pedestrian.

So, we have already gone through all of this in our pedestrian transport segment of the class. Those are the principles that are involved here in determining the station capacity because again, station capacity depends upon passenger circulation and its level of service. If you know all these, what you want to essentially know is station width.

For example, width of the stairways will determine the capacity of the stairways, which will determine how passenger circulation is happening and will be measured in terms of pedestrian flow. So, you get the relationship between all of this you know the pedestrian flow of the station if you know the stairway capacity.

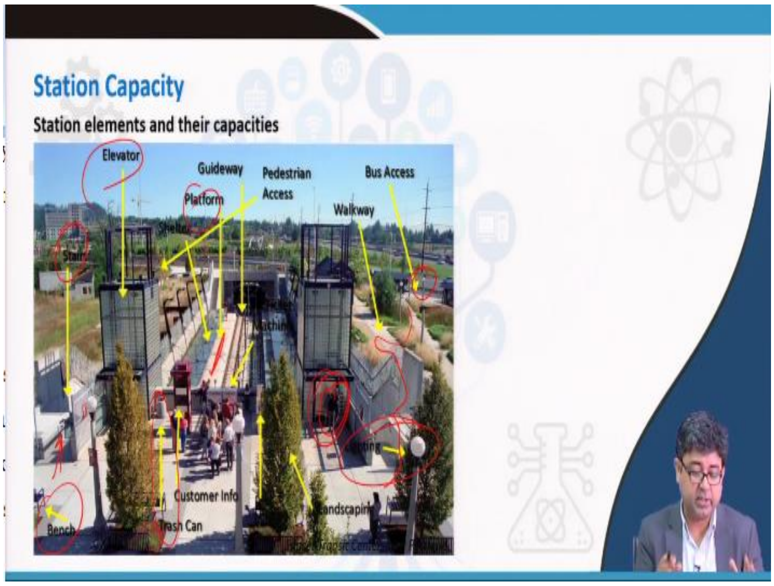
Then if you know the stairway width that will tell you the station capacity. So that is how these things are all aligned with each other. Similarly, if you want to know the station element area also can be calculated. For example, a platform area if you know the width, you can calculate the stairway width, then you can calculate the platform width as well and you can calculate the platform area as well.

So, if I were to draw the hierarchy of what are the things you must know. So, you would say that I first will have to know say for example, the stairway width that will give you the stairway capacity. The stairway capacity is in terms of passenger flow, and all these things together will give you the station capacity. So, with stairway capacity in terms of flow, you know the stairway capacity as well.

So, this is one element. So, similar to stairs, then you have to calculate the capacity of the elevators. So, you know the capacity of the elevators, you add this capacity to that capacity or you say which has the maximum capacity or which has the minimum capacity and that will give you the station capacity. So, conceptually you now understand there are different elements within a station for each element you must do a capacity calculation.

All those independent elements' capacity calculations will lead you to the development of the station capacity calculation. But all these things are based on the principles of pedestrian flow because it is essentially the people that are circulating in the station.

(Refer Slide Time: 16:47)

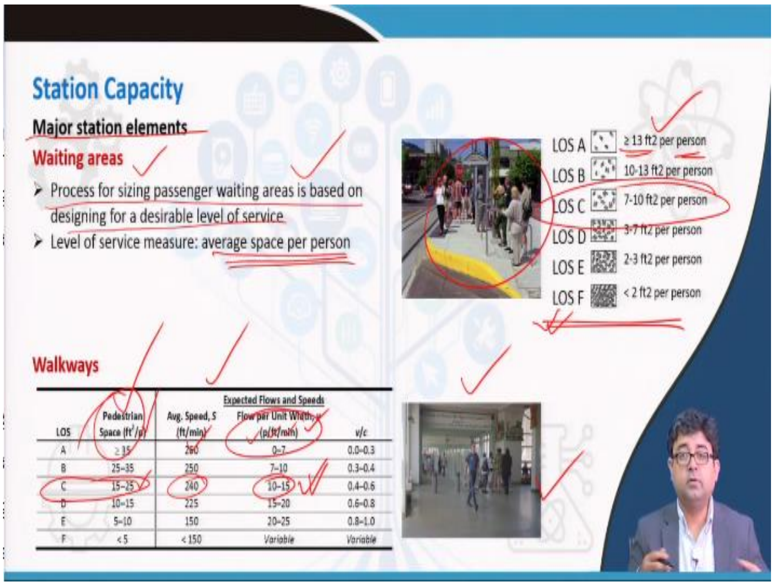


So, if you look at the depiction of a station area, it looks like a metro station. So, you get off the bus here, you get on the walkway, and you are accessing the station from here, there are lifts, the station is one floor, underneath. So, there are lifts here or there are escalators, for example, the stairs are here. These are elevators or lifts, here is the platform area.

There are benches, there are trash cans. So, these trash cans and benches are what I was talking about there. They are necessary objects that must be there, but they are impeding the capacity or impeding the flow of their area. They are acting as an obstacle, but they must be there. Benches must be there. Water fountains maybe have to be there, but they are impeding. So, you have to know those constraints when you are designing for a station area.

Maybe since this is an outdoor station area it does not need lighting, indoors may also need lighting. So, these gives you a holistic picture of what are the different elements in designing a station.

(Refer Slide Time: 18:10)



Now, let us look at some of the major station elements for which you must know the level of service or what level of service means. What is the capacity of each of those elements? So, for example, the first element may be waiting area. So, this may be a waiting area and sizing passenger waiting area is based on designing of a desirable level of service. So, average space per person tells you the desirable level of service. So, level of service A meaning there is more than 13 square foot per person.

So, in this waiting area, if there is more than 13 square feet for one person, then you are at a level service A. So that is a good capacity or an ideal capacity maybe. Whereas if they have less than 2 square feet per person, so everybody's kind of squished against each other, then there is a bad level of service. So usually what we usually see is for any kind of scale, designers design it at the level of service which seem to be the middle range of the scale.

So, if there is anywhere between 7 to 10 square feet per person, that is a good design of a waiting area. Similarly, walkways. Now you must have maybe walkways that connect to terminals in 2 platforms in a terminal. So, you must have certain passageway or walkway. So that passageway walkway again, depends upon the parameter of pedestrian space.

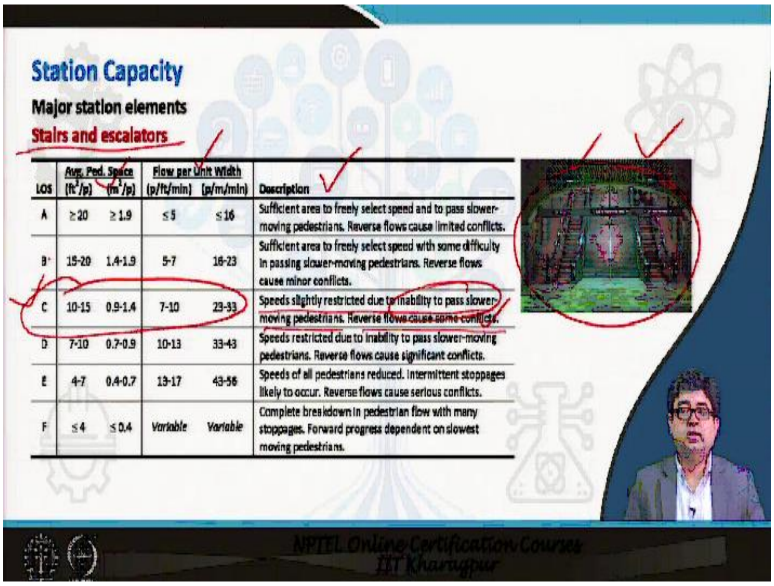
Pedestrian space is measured in terms of number of square feet per person. So, again, if you look at something that you may want to design it, so, your walkway should accommodate at least or should have at least say 20 square foot per person. So that they can walk comfortably in that and now, that may be a second element that may be a part of the level of service calculation, which may be either speed or flow.

So, for example, for a pair of walkways with a space of 15 to 25 people will be walking at 240 feet per minute or there may be a flow of 10 to 15 passengers per foot per minute. So, again if you want design it with 2 parameters in mind. Think about it as a multiple linear regression equation for example. So, what you want to have is capacity as a Y axis as your dependent variable, the independent 2 variables may be pedestrian space and pedestrian flow.

So, there has to be certain amount of pedestrian space, but there has to be certain amount of pedestrian flow as well, you may have all the space in the world, but if there are no people walking there, there is no point having that much space. So, there must be certain flow as well. So, maybe 2 parameters that can be used to design the walkway capacity and that walkway capacity will give you the level of service. So, this is an example of walkways.

So, these are again values that have been developed and these ranges have been developed based on empirical studies that have been done for different walkways around the world for the terminal areas in the terminal stations. But the main principle you must know how to do it is by pedestrian flow or pedestrian space which you already know.

(Refer Slide Time: 22:13)



The third element or the most crucial element is stairs and escalators these can be one of the most helpful elements or required elements in any transit station because most of the transit stations nowadays are either above ground or below ground and very few are at grade because of the lack of space in urban areas. So, once they are above ground or below ground, you must have escalators and stairs accompanying and these become critical elements especially in terms of evacuation.

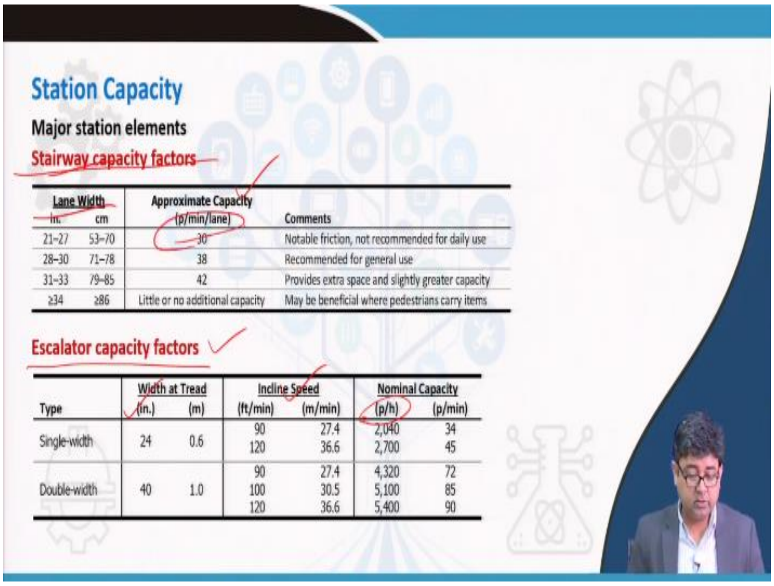
They become critical. So how to design them what is the level of service that should be provided to run daily activities smoothly. The level of service depends upon space and flow. So, in a combined system you will calculate the level of service of both together. But you can also do so separately if you just have a stairway. There is usually never a station with only escalators there always are stairways.

There may be some basic older stations when elevator technology or escalator technology was not there they may have designed with only stairs. That type of capacity can also be calculated with only stairs. But more modern stations have both stairs and escalators. So, the capacity of them can be calculated together as well. Descriptions of each of those levels of service are given here.

So, for example level of service C means, speed slightly restricted due to the inability to pass slower moving pedestrians. Reverse flow causes some conflict that is the realistic situation there may be a reverse flow people may be trying to go up majority of the people may be trying to exit the station maybe this is a destination station during a peak hour. So, majority people will be exiting the station to go to the destination but there are still some people who will be trying to access that station.

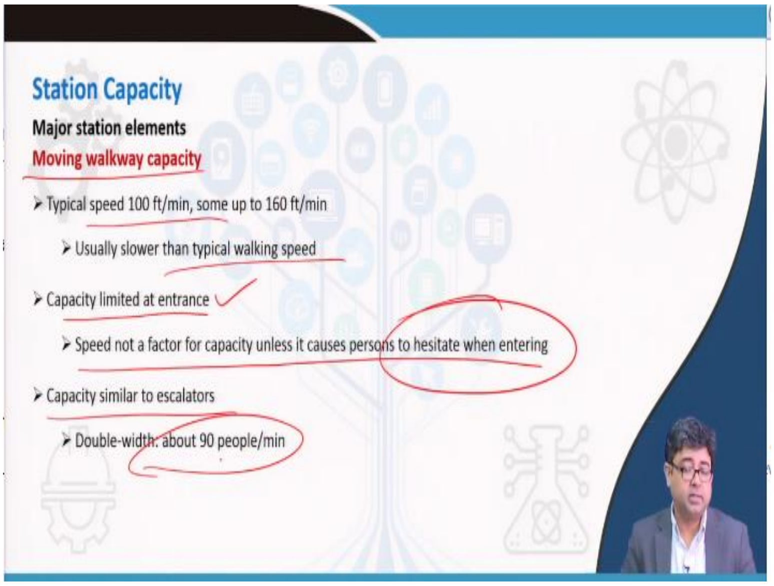
So, there will be some reverse flow and there may be inability to pass slower moving pedestrians that means that maybe people who are trying to exit but one person may be trying to exit at a very fast pace whereas the other person maybe tried to exit at a slower pace. But due to high pedestrian volume or high pedestrian flow, the slower person may not be able to cross the faster, the quicker person may not be able to pass the slower person, that is a realistic situation. That is why I said that level of service C is usually the capacity at which these are designed.

(Refer Slide Time: 25:19)



Now, say if you want to do it separately, you can have the stairway capacity factor separately, escalated capacity factor separately. So, when it comes to escalators, it not only depends upon the width, but also the inclined speed and that will tell you how many passengers per hour these things can accommodate. Stairway capacity is dependent upon the width and the flow again. So, you know what the flow is.

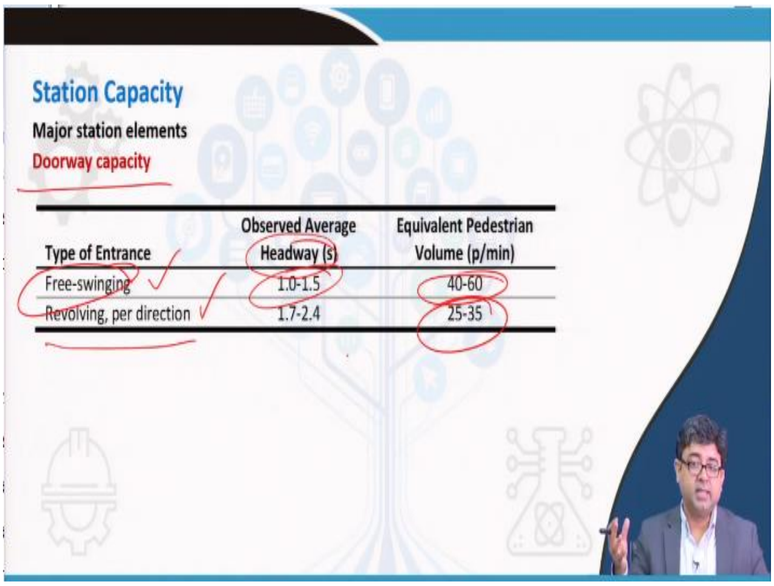
(Refer Slide Time: 25:51)



Sometimes you have at certain stations, you have moving walkways nowadays that are that have typically a speed of 100 feet per minute, which is slower than the walking speed. So, you will see that if you walk alongside a moving walkway, you will be walking faster. In India, these are usually there at some of the airports, which you can also think as large fancy stations. They are also terminal stations, if you may in terms of public transport, so the capacity is limited at its entrance.

You have suddenly in a walkway, which is maybe 100 feet wide. The moving walkway, maybe only 12 feet wide. So, the capacity is constrained at the entrance. Speed, not a factor for people who hesitate when entering; you will see that people who are not used to using moving walkway, they kind of slow down people behind them. So that is the capacity constraint there. The capacity is like escalators. However, it is designed to carry 90 people per minute which is the same or similar to escalator capacity.

(Refer Slide Time: 27:17)



On the other hands are doorways. Now you will have different doorways through which people have to enter and exit a station area. So, if there are different types of doorways available, what has been observed is that the headway between 2 people is the parameter that governs the doorway capacity. If it is a free-swinging door, so that means you open the door and it swings freely closes and opens freely, that time the headways between the people is about 1 to 1.5 seconds and the volume of pedestrians maybe equal to 40 to 60 per minute. Whereas if it is a revolving door per direction, there will be very low volume of people that it can accommodate, rolling door doorway, revolving doorway, are only in one direction. So that is the type of elements that you must keep in mind while you have designing your station. And each of these you are seeing each of these elements have different capacities that it can accommodate.

So while you want develop a station area, while you want to develop a station with a certain capacity, you have to know that there are different elements in there that may have different capacities. So, when you have to accommodate these elements into the design of the entire station.

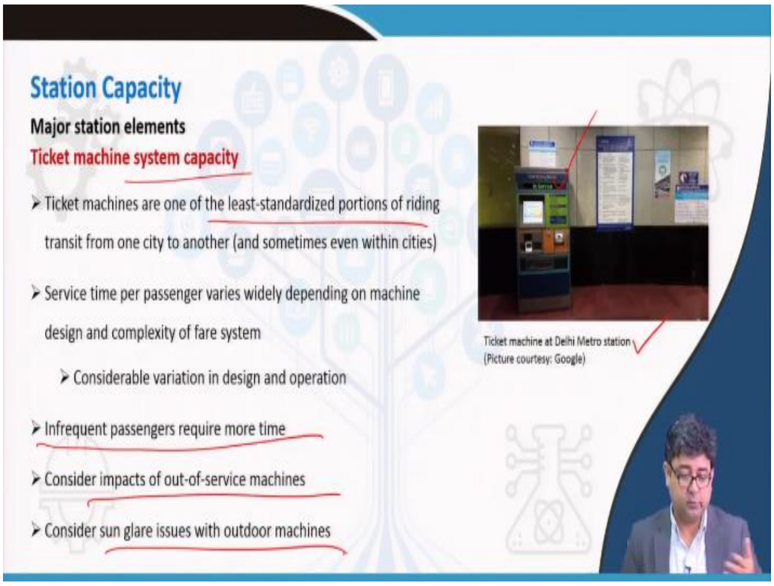
(Refer Slide Time: 28:56)

Similarly, the next element could be the fare control system. All these metro stations have these fare control systems, but you know that the during peak hours inevitably you see queuing happening at these stations. Even not during non-peak hours you may see queuing happening at the station. So, how many of these should you have at your station, automatic fare control is something everybody is moving over to.

How many of them should you have again? The capacity and the volume of people that each of these can process depends upon the headway, and headway in turn depends upon the type of system you have. If it is only a free admission barrier only then the headways are small. Whereas if you have a double slot coin operated system, 2 slot coin operated system then the headways become longer.

And the headways become longer meaning that volume of people processed per minute goes down. So that is what that says there are some examples from all over the world what they use and what their headways are your exit gates. Different size or width of exit gates will also give you different kinds of headways and equivalent pedestrian volume.

(Refer Slide Time: 30:30)

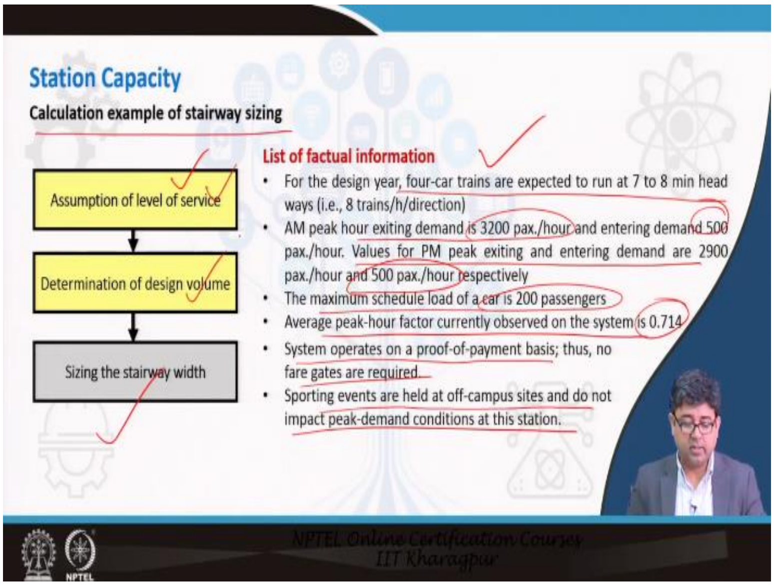


Similarly, now you see automatic vending machines, ticket machine system, they also have certain capacity because now people are installing these at say for example, this is at the Delhi metro station. Instead of having a person at a booth they are having many of these automatic kiosks, so they also have a certain capacity. These are the least standardized ones because they are different. Systems differ from one transit in one city versus another metro in another city for example.

So, 2 metro systems, we have different types of vending machines and they have not yet standardized. So, their capacities vary a whole lot. Infrequent passengers require more time, if you are not familiar with it you require a little more time and if you require more time then queuing starts to happen and then drops the capacity. There is a lot of impact of out of service machines, if a machine is not working and the capacity goes down. Sometime sun glare from outside affect the machines.

So, there factors that have not yet been standardized, values have not yet been developed for many of these factors, or newer elements in a station design. One of those is this ticket machine system.

(Refer Slide Time: 31:51)

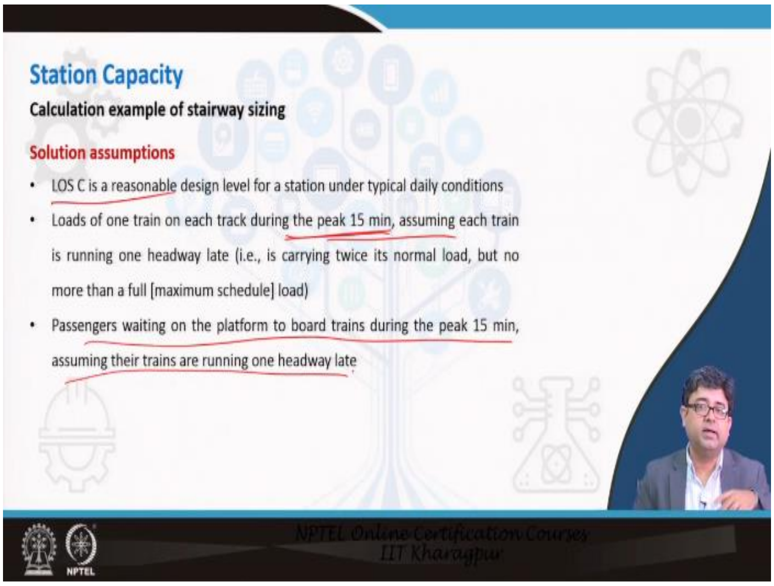


What you want to do here is again, just an example of how to develop a capacity of a stairway. So, a lot of information is given here regarding the design year, so, there are 4 train cars that are expected to run at a headway of 7 to 8 minutes. 8 trains in one direction. AM peak hour demand is this many passengers entering, this many value of PM peak entering and exiting and entering as that with the maximum hourly of this, maximum scheduled load of car is 200 passengers.

So, one passenger or one boarding, if you will think of it in our metro line can take 200 passengers scheduled load then average peak hour factor is 0.7. System operates on a proof of payment basis thus no fare gates are required, there are no fare gates in the system. sporting events are held at off campus sites and do not impact the peak demand conditions at the station. So, these are the inputs that are available for your station, what size of stairway should you design for this type of scenario.

So in order to do that, we just start by assuming a certain level of service for which you want to design and see if you are getting the same as the standards for assumed level of service. If not, then adjust your level of service because remember, the level of service has a range. So, if you start off with one end of the range and you do not get the width, then you start changing, shifting to the middle of the range or maybe the end of the range. So, you assume level of service, you determine the design volume and determine the sizing.

(Refer Slide Time: 33:47)

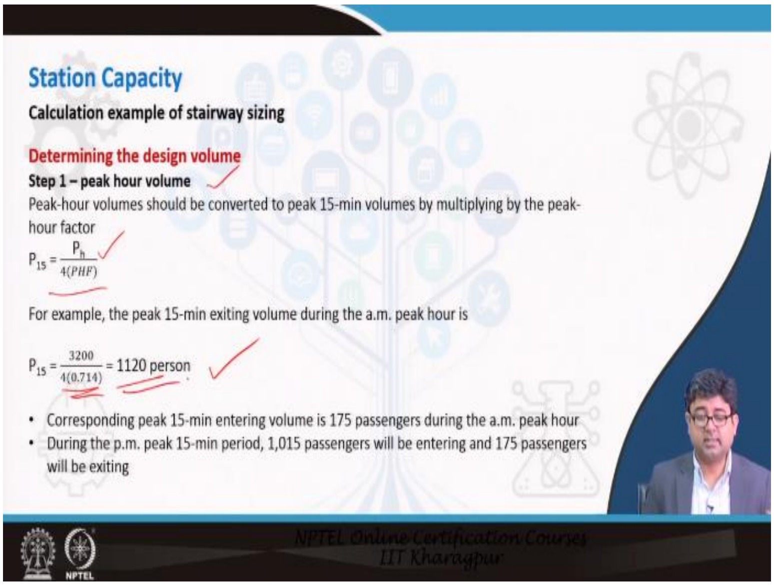


So, say level of service C is reasonable to assume loads of 10-15-minute peak. So, you always design for the peak hour. We have looked at this in the previous lectures, in other calculations also, i.e. calculations of level of service of pedestrians and bicycles that we have looked at always calculated for the peak hours because of the peak hour, your system has to hold up to the volume or the flow of people coming there.

If it holds up to that maximum volume or flow, then it will be able to easily hold off on lower volumes and lower flows during the nonpeak hours. So, you always must design for the peak hour, but with considerations for the emergency also which is even higher than the peak hour. So, always keep that in mind. And if you design that keeping that 15 min peak in mind, then you will be safe and passengers waiting on a platform to board during the 15 min assuming that the trains are running one headway late.

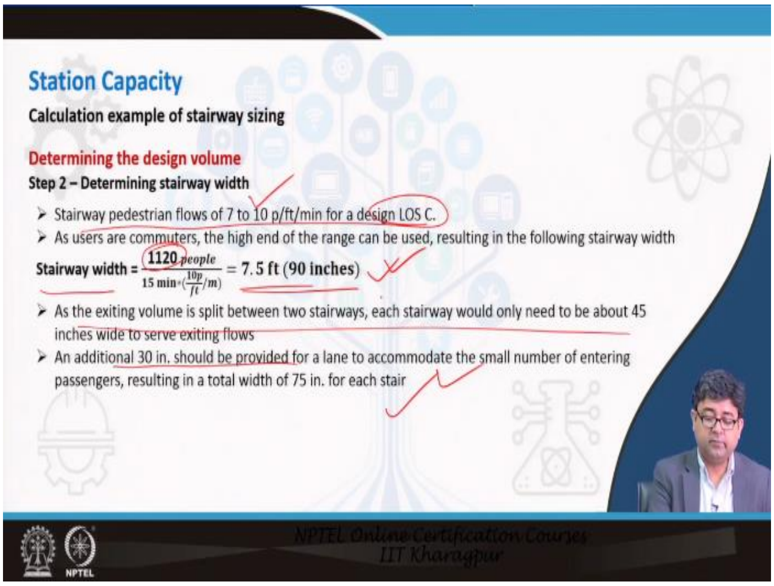
Always assume that to be on the safe side, always assume that the trains are running late by one headway, so that there are passengers that are waiting on the platform. If all the passengers get on the train and there is nobody left, that means it is where the trains are running on proper headways and everybody's getting on the train, there is no excess volume. But to develop the stairway width capacity always be on the safer or conservative side and think that there is one headway delay in the running of the trains.

(Refer Slide Time: 35:32)



So, you know how to develop the peak hour volume, if you are given peak hour flows, you just divided by 4 times peak hour factor, peak hour factor was given as 0.714. So, you now know that in peak 15 minutes there will be 1120 passengers trying to access your stairway.

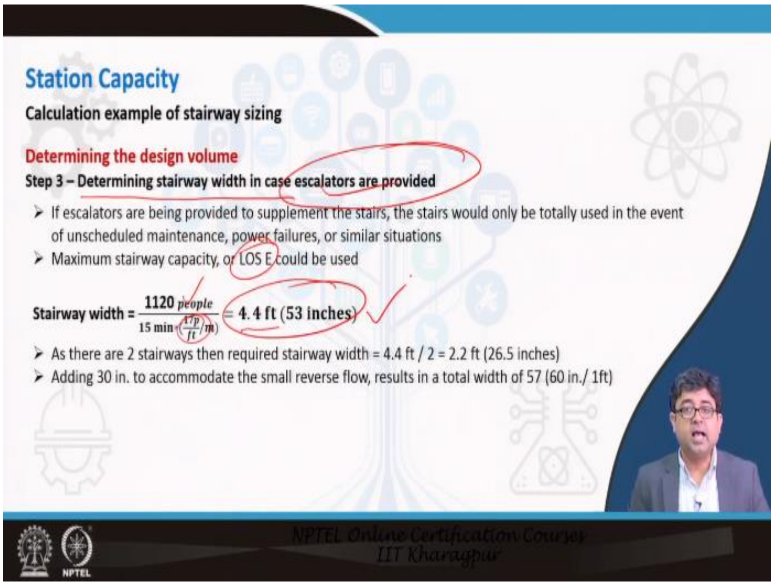
(Refer Slide Time: 35:55)



So, if you assume that the stairway pedestrian flow is again level of service C, which means 7 to 8 passengers per feet per minute, then your stairway width must be sufficient in order to accommodate 1120. Your stairway width must be 90 inches at least. So you have 90 inches wide, or 7.5 feet wide stairways you will need, then you can divide up into how many inches you need for people going up versus going down, you may put a railing in between the width in order to segregate those 2 flows.

You give an additional buffer of 30 inches maybe. So, these are all calculations that differ from station to station based on actual observations. But if you get an understanding of what your station needs should be, then you can make those adjustments based on your individual calculations at your individual stations.

(Refer Slide Time: 37:01)

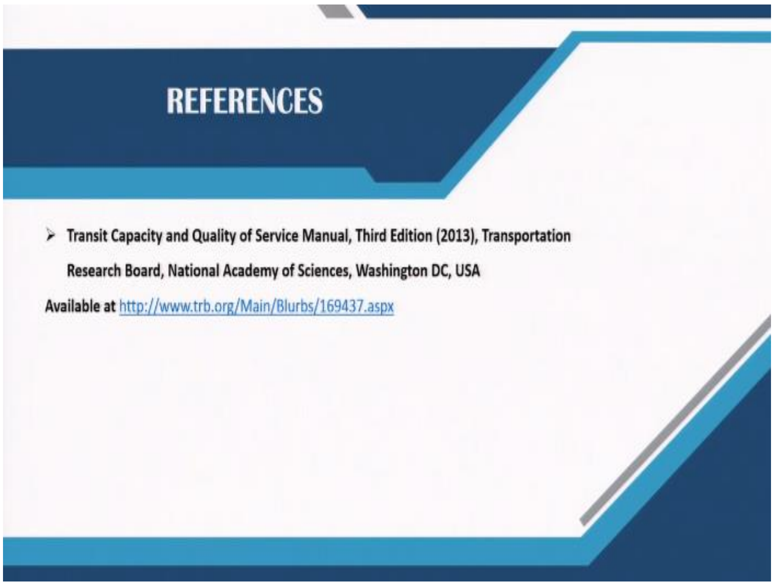


Similarly, if you want to determine the stairway width in case escalators are already provided, then you will see that if escalators are provided, then the calculations are similar. But what happens is you do not have to have so much flow, i.e. not such a high flow of passengers using the stairway, because if there are escalators, people are more inclined to using the escalators than the stairways.

So, your stairway width can go down a little bit, so for example, now, if there were escalators provided, then your stairway width can now be only 4.4 feet. Whereas, if there is no escalator provided then it must be 7.5 feet. The only thing that changes here again is that we assumed level of service C that is 7 to 10 passengers per feet per minute. Whereas here we assume a level of service E which is 17 passengers per feet per minute because that much load it will not take, the load will be shifted to the escalators.

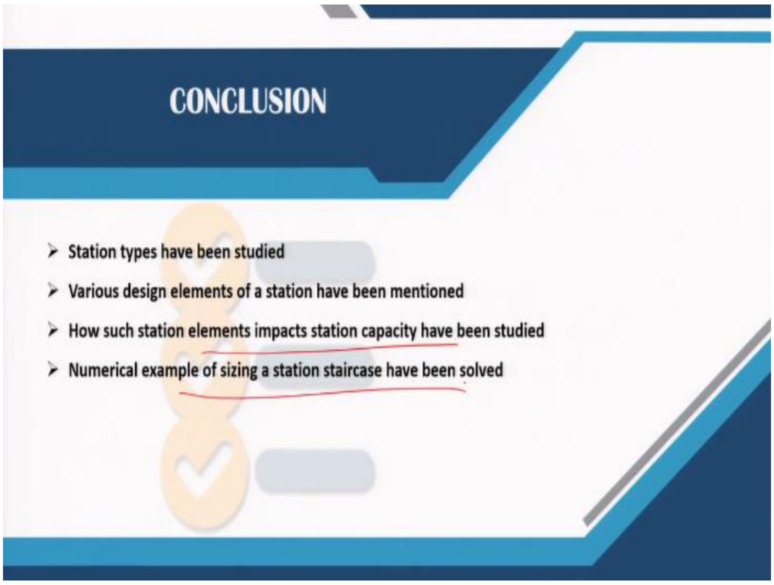
So, there you get understanding of how to develop the capacity or how to develop the width of a stairway assuming a certain capacity or a level of service.

(Refer Slide Time: 38:20)



So that again brings us to the end of this lecture. Again, it is the same reference that I provided to you in the previous lectures as well. All these solved examples are available there. So please download, this is available for free, download and you will be able to follow through when you read through this reference.

(Refer Slide Time: 38:49)



So, in conclusion, we showed you today about the different station types, the various design elements of the station, how much station elements impact station capacity. Remember there are different elements within the station that will impact. So, you must understand how different capacities of these different elements are. And we give you an example of how to measure the capacity of one of such elements which is the staircase. Thank you very much for your attention.