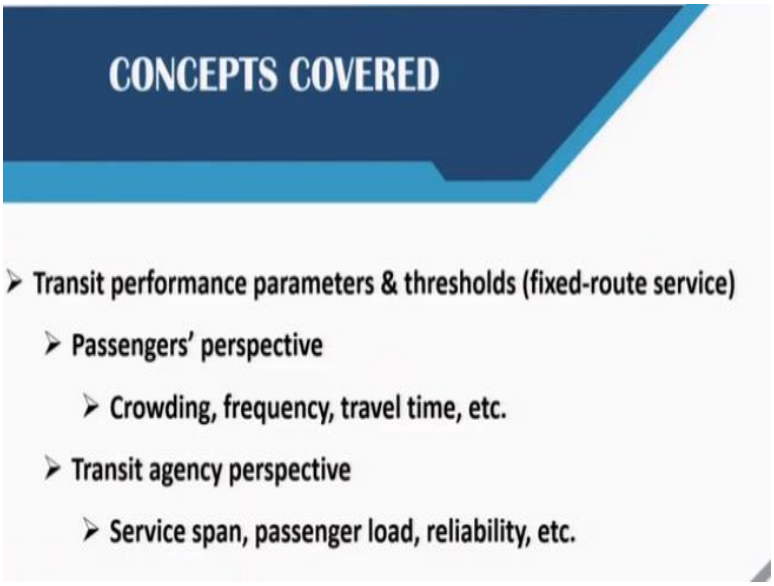
Introduction to Multimodal Urban Transportation Systems (MUTS)
Prof. Arkopal Kishore Goswami
Department of Ranbir and Chitra Gupta School of Infrastructure Design and Management
Indian Institute of Technology – Kharagpur

Module No # 03
Lecture No # 15
Public Transportation: Measuring performance of transit systems

Welcome back friends. Now that you have learnt about the different types of public transportation systems, i.e. the bus, rapid rail, mono rail, and also looked at some financing and marketing opportunities, and we also introduced you to some intermediate public transportation systems, in this lecture what are going to look at is how you measure the performance of transit systems.

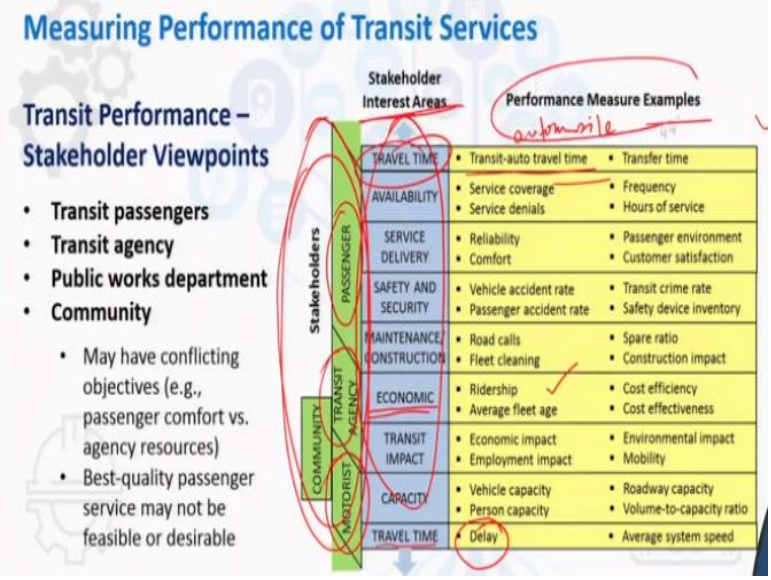
(Refer Slide Time: 00:48)



So you have all these various types of public transportation systems on your city network, but how do you measure how well they are performing; what are some of the parameters that you use to measure the efficiency, how to measure the performance of these public transportation systems? Here we will give you an overview of how you can select these parameters based on passenger's perspective as well as transit agency perspective.

And these performance parameters are related to fixed route services, so any public transportation system that is running on a fixed route and not on a flexible or demand responsive route.

(Refer Slide Time: 01:33)



So when we look at the entire spectrum of transit performance, there are 4 different viewpoints that are usually indicated, and those viewpoints are of 4 different stakeholders of public transportation. It starts with the passengers who use it, the transit agencies who operate it, the public works department which has to maintain the roads or structures on which these public transportation systems run, and also the community at large.

So it is a very fine balancing act that has to be carried out in order to ensure that viewpoints of all of the stakeholders are taken into account when you are measuring the performance of any system. Otherwise if one of the stakeholders viewpoints are not taken into account then it becomes a skewed analysis if you only look at it from the point of view of, for example, the transit agency and do not consider the passengers point of view.

Or also it may become too onerous on the transit agency to implement certain measures if you look at it only from the perspective of the transit passengers. So shown here in this table are the different stakeholders, their different interest areas and also examples of corresponding performance measures. For example, if you look at the transit passenger, they are always wanting travel times that should be minimized during their travel.

So what is a performance measure that can tell you how well the public transportation system doing? It is the transit to auto travel time ratio, auto meaning your automobile private

automotive. So if you know that in comparison to your private automobile what is the travel time on transit, then based on that ratio you can make some decisions as to how well your public transportation system is working.

Similarly, if you look at the transit agency as a stakeholder, they are always interested in the economics, of how well the public transportation is doing. So one of the performance measures could be ridership, how many people are riding on the transit service. Similarly, for the regular motorist on the highways, if these public transportation systems are sharing the roads space, then the motorist, i.e. the other motorists, also becomes a stakeholder.

So what are their concerns? Their concerns may be because of public transportation system they may be facing some delay in the travel time. For e.g., the large buses which often are obstructing the traffic flow because of several reasons, viz. may be the location of bus stops, may be the turning time require to turn on to narrow streets, and so on and so forth. So there is always delay to the motorist. So you see all of these stakeholders interest have to be taken into account while you are selecting the appropriate performance measure.

(Refer Slide Time: 05:00)

So here in this lecture, we will be looking at 2 such perspectives -- one is the passengers perspective and the other is the transit agency perspective. So when you look at the passenger's perspective, you are essentially finding out what is the quality of the service that is being

provided. Because the passenger is always perceiving the qualitative aspects of the public transportation system.

They can be broadly grouped into 2 categories, i.e. one is the service availability and the other is comfort and convenience. As a public transport user we are always worried about -- where is my bus? We are always worried if there is a service that is available at that time when we want to travel. If it is a late night or late evening travel, is the bus frequency good enough for me to get hold of a next bus available. The other thing is comfort and convenience.

We never want to encounter such a situation where the metro is overcrowded, the people are hanging out of the metro, or even the buses are overcrowded. So we are always concerned about the comfort and the convenience when take a public transportation system. So if you include parameters that would also judge the comfort and convenience, then we could determine the quality of the service from the passenger perspective and hence evaluate the public transportation system performance.

So we can say, a public transportation system from the point of view of the users is performing well, if there is less crowding, for example, i.e. if it as high frequency, so that all the passengers can avail on the public transportation system. So typical factors or typical parameters include frequency, wait time, reliability, etc. We always want to reach our destination on time every time; want the service to be close to home or the destination, crowding to be less, and also fare to be reasonable, and driver behavior and driver friendly should be good.

So these are some of the factors that are always helpful in understanding the passengers' perspective while you are measuring the performance of our public transportation system.

(Refer Slide Time: 07:31)

So if you start looking into each of these parameters one by one -- so the factors that will impact service availability include spatial availability, temporal availability, information availability as well as capacity availability. We want the bus or we want that transit system to be available spatially. Spatially meaning it should be available close my home or to my destination, so that when I reach my destination or when I disembark from the transit station, my destination should not be far away.

Similarly, when I get on a bus or to reach the nearest bus station, the distance should not be very large. So this kind of diagram shows you a classic example of how if the different transit stops are optimally located then it kind of creates a system of stops and this ensures that the transit usage is very high. So accessibility and transit usage can be linked in such a manner where you are locating the bus stops optimally. If the bus stops are farther away, then the accessibility to the metro stations or the bus stops is less, i.e. the accessibility is less.

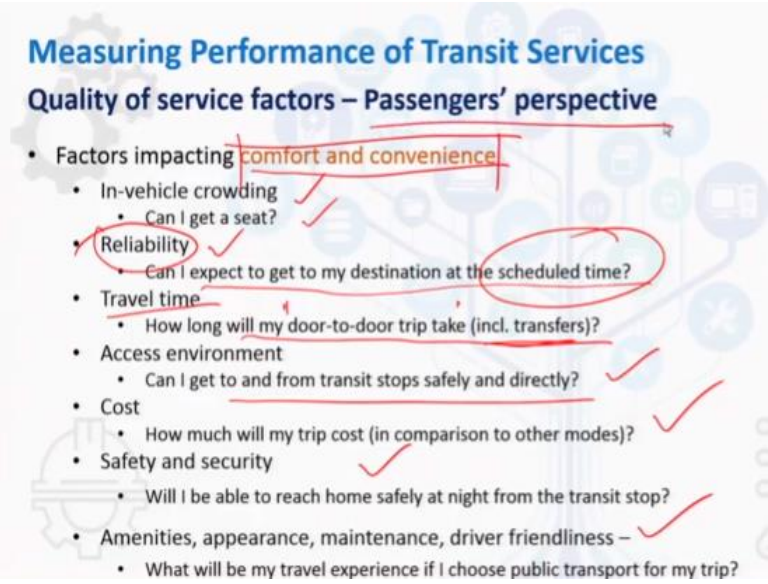
If the accessibility is low, then the usage probability is also low. Similarly, we also want temporal availability, i.e. time of the day availability. We want public transportation systems to be available almost if not 24 x 7. We want at late night, we want it early in the morning, we want it in the middle of the day. One of the things that is always requested is night services. Many of us work late in the night or work night shifts, for all of such people night services or owl services, they may be referred to as, you must have heard of that terminology, many of them referred to the owl services, and that becomes very important.

Next we would also want information availability. Nowadays information is not only available at the bus stops or at the transit or at the metro stop, but are also available online. If you have online schedules, if you have real time data about where the next vehicle is, everything can be tracked online. So, the more information availability the better is the perception of the passengers about the quality of service that is being provided by the public transportation system. Also last but not the least, we also want to know the capacity availability.

We want to know it, but unfortunately we don't always know that whether the next bus that is coming, or whether the next metro rail that is coming, would have a seat for me or not. We cannot reserve a seat in urban public transportation just as you can reserve a seat in intercity public transportation. However, this kind of situation is to be avoided, and so if you know what capacity is free, whether you will be able to comfortably stand, that is also good information to have.

Because many people do not mind standing as long as there is comfortable space, i.e. comfortable maneuverability within the bus or the metro systems. So those are the factors that are usually looked at when we are trying to identify service availability.

(Refer Slide Time: 11:17)



Similarly, if you next go to the factors that impact comfort and convenience, these are very intuitive factors as many of us think about every time we plan to take public transportation or

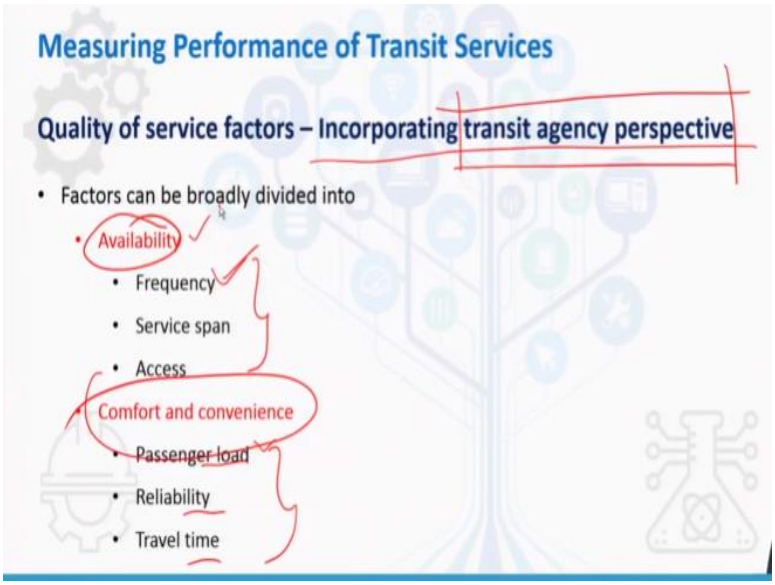
taking public transportation. One is, in-vehicle crowding, we are always worried if I can get a seat; next is reliability of the public transportation system, can I expect to get to my destination to my scheduled time or should I give myself a buffer.

We always think if I have to reach a destination at 9.30 in the morning should I take a bus that leaves a home at 8.30 reaches there are 8.45, giving me a 15 minute buffer? So that buffer time is always calculated in our head in order to make sure that if the bus is not reliably on time, then I still have some extra time available to me to reach my destination. Travel time of course, we always look for comparable travel times on public transportation versus private transportation. This is one of the drawbacks public transportation always has had.

Especially public transportation modes that share the right of way with other vehicles, people are always skeptical that they always take longer time to take you to the same destination as compared to your private automobile. Here again door to door trip is very important because when we are talking about the travel time on public transportation it is not only the time that is spent in the vehicle but also the time spent waiting for the vehicle to come.

And in case there are transfers, i.e. you have to transfer for one vehicle to the other, then the time taken in the transfers is also to be added on to the in-vehicle travel time. So the total travel time is to be calculated. Similarly, the access environment, i.e. do I have good access to the transit stops, can I easily reach there, is the, for example, is the sidewalk network good, or is there enough parking available so that I can park my vehicle, what is the cost, i.e. the out of pocket cost, safety, security, and amenities, driver friendliness etc., So these are kind of the factors that affect the comfort and convenience from the point of view of passengers.

(Refer Slide Time: 13:50)



Finally, now if you start looking at the factors and incorporate the transit agency perspective then you will again see that the broad 2 factors kind of remain the same, i.e. availability and comfort and convenience. But now you start looking at individual factors such as frequency, service span, access, and also passenger load reliability, and travel time from the point of view of the transit agency as well.

So when we talk about frequency, we are talking about essentially how many vehicles, or how many transit vehicles are arriving at a particular stop or a location within a time span of say, 1 minute or 10 minutes or half an hour or 1 hour, whatever it is. So we want to know how frequent is the service from the passenger's perspective. We want higher and higher frequency but from a transit agency perspective, higher frequency meaning lot more number of buses for it to operate and higher operational charges.

So how do we balance these things? Transit agency would not want to incur higher operating charges, whereas from the users' point of view, from the passengers' point of view, I want high frequency services. So that is where you have to balance the transit agency perspective as well. So let us look at each of them again individually, starting with availability and the 3 factors frequency, service span and access.

(Refer Slide Time: 15:32)

So when we talk about frequency, like you said ridership increases as frequency increases, i.e. more frequent is the bus service or the metro service, more number of people are actually using it. But frequency effects operating cost as well. Service span, i.e. long service span, services greater number of people, service span meaning just how many hours in a day does the public transportation system run for, how many hours in a day, or how many days in a month, so and so forth, so that is the service span.

So service span although if you have longer service hours it will again result in higher ridership, greater number of passengers taking it, and it will also determine how well of a market you have captured. So it can not only increase the ridership but it can also cater to new market segment. So you suddenly put in another line, i.e. a new line in another part of your city, and you capture that market as well, but again the transit agencies' perspective would be, to put in these new lines or to improve or to increase the service span during a day, operational charges goes up.

Similarly, the third one is access or service coverage. Here we are looking at how well public transportation system can be reached either by walking, bicycling or automobile access. How good the terrain connectivity and density are? Again remember, we just now showed you the location of the transit stations, or bus stops, which depends upon how dense the population is.

Most of the people who are accessing fixed route public transportation systems usually get to the stops by walking. If there is a parking available, they use automobile to access, and now there are

more and more people who are trying to bicycle. So how good is the access to the public transportation system determines how much coverage it is able to attract, how much coverage area it is able to attract.

(Refer Slide Time: 17:59)

There are several thresholds that have been developed so that you can easily quantify all of these measures. Unless you are able to quantify, i.e. if it becomes only qualitative, it becomes very subjective, then it may be difficult to, for example, develop budgets for these kinds of thing. So you always, we always, try to quantify it. When we say, when we try to quantify frequency, this is for example developed as a part of the transit capacity and quality service manual TCQSM in USA, so these may not be directly related to Indian situation, but again you have to understand how these are developed so that you can either adopt it to Indian condition or develop your own set of measures or parameters and then their ranges. So what this particular range says that if your frequencies your frequency could be of any one of these levels 1, 2, 3, 4, 5, 6 or 7. So they have quantified 7 different levels ranging from a very high frequency of less than 5 minutes to a very low frequency of greater than 60 minutes or only one vehicle per hour.

So what does this mean, so for example when you are developing such ranges you always have to try to quantify any of these. So when you are saying that your frequency is anywhere greater than 5 minutes but less than 10 minutes what we mean is that – the service is frequent service, and no need for passengers to consult schedules. So there is no need that are passengers as to

look at a bus schedule, he or she can just come at a stop and will get the next vehicle very quickly.

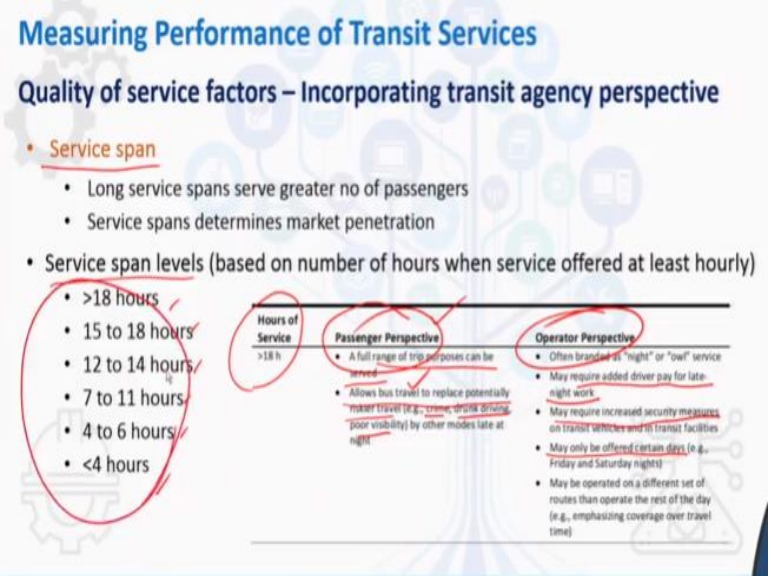
So that is kind of the scenario when the frequency is between 5 to 10 minutes; however bus bunching is possible. So then if such frequencies operate it is good for the passenger but when it comes to the transit agency they may face bus bunching. Bus bunching is where 2 or 3 buses come very close to each other or their schedules merge, so they are very close to each other, running in bunches. So that is a bad situation which can result in longer than planned wait for a bus, and more variable bus loads.

Now suddenly if 2 or 3 buses have arrived at the same time, then the next bus, to arrive, it takes a longer period of time. So when there are such high frequencies, bus bunching is possible, which should be then avoided. So from the transit agency perspective such high frequencies are only feasible on high density corridors with bus or rail service where routes converge to serve a major activity center.

So for such kind of services, i.e. if you planning such kind of services, you have to look for major activities centers that are connected,. So I mean, through various examples what we are trying to let you know is all of these factors or parameters have both a transit agency perspective as well as a passenger perspective, and they can be then converted into different scales that will allow you to then measure the performance of your transit service.

Remember we talked about levels of service earlier, so this is very synonymous to the level of service, but many of the transit agencies usually do not like the letter grade A to F kind of a grading, because they feel it is too academic or too much like a classroom so they do not want to give their operator is a grade. So rather than giving them a grade we have only divided them up into levels, you could have easily given this an A and this is an F, but we are not doing so right, we are not doing so.

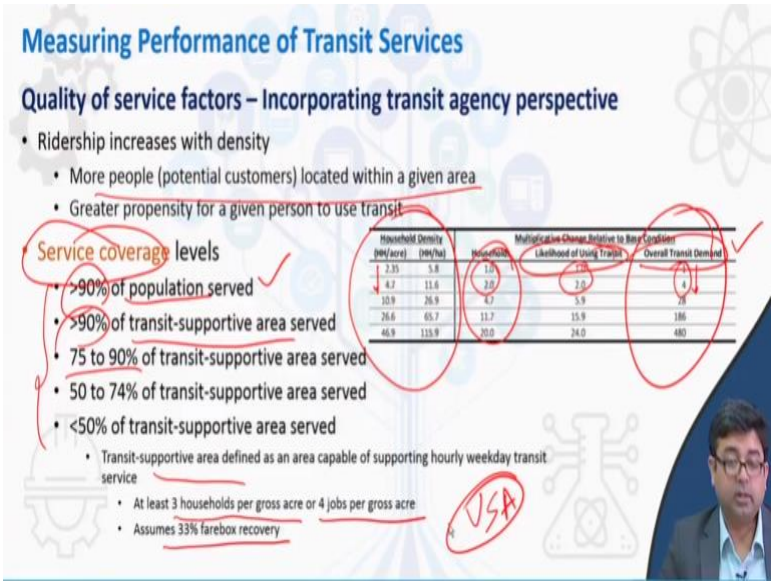
(Refer Slide Time: 22:07)



Similarly, for service span so you can break it up again into different levels 1, 2, 3, 4, 5 and 6 levels if you have service span greater than 18 hours a day so the public transportation system is available more than 18 hours a day. A full range of trip purposes can be served from the passengers' point of view, allows bus travel to replace potential risker travel. So crime, you can avoid drunk and driving, poor visibility at night can be avoided, driving in poor visibility can be avoided, and public transportation can be taken.

However, from the operators perspective this may require added driver payment for late night work that may increase the operating cost, may only be offered on certain days. So may be only on days when night services are required it may be offered. May require increased security measure especially when night travel is involved you may want to have higher security. So these are these 2 perspectives -- passenger's perspective and operators' perspective, which have to be balanced when you determine how much service span you provide.

(Refer Slide Time: 23:29)



Similarly, the next one is service coverage. Like we said the service coverage is more people located within the given area. So what is being seen is that the greater the household density along the route, the greater is the overall transit demand. So household density and transit demand go hand in hand. If for example the household density increases from 2.35 to 4.7 you see that overall transit demand increase 4 times. This overall transit demand consists of not only the number of people or number of households but also the likelihood of using transport.

So you can have higher number of households but if they are not likely to use it then you may not have such a high demand. So you have you have to have both, higher number of households or household density and that in turn will give rise to the likelihood of using public transport right. So both of them together gives you the overall transit demand. So it is also shown that 90% could be served, i.e. provide coverage for up to 90% of the population or you could provide service to 90% of the the transit supportive area. Transit supportive area again meaning around the metro station or around the bus nodes or the bus stops that kind of an area. Alternately, 75%, and so on. So you can have again different levels of this or different levels will depend upon what the transport agency can support based on their budget.

This definition of a transit support area is based on the fact that at least 3 households per gross acre or at least 4 jobs per acre is available and also 33% of the fare box collection is recovered from the services. These are assumptions that are made as per the conditions in the United States, that could be altered for our situation as well.

(Refer Slide Time: 25:49)

Similarly, now if you start looking at the comfort and the convenience part of it, we have already seen that there are 3 aspects involved passenger load, reliability, and travel time. Interestingly passengers value of time increases with the level of crowding, As soon as more than 80% of the seats are occupied people inherently start to believe that the time taken on the public transportation system will be higher than my private automobile, hence I should use my automobile because my value of time is greater.

So people always value time in terms of cost so if the time taken on public transportation system is longer, then the value of time for me goes down. I do not want to travel to in a bus that stops at every stop and it takes me longer time. Empirically it as seen that as soon as 80% the seats are occupied the person getting up on the bus immediately starts thinking that it was already crowded.

That means the road should also be crowded, that means the travel time will increase and my value of the time will increase. Cost effectiveness increases, from the point of view of the transit agency cost effectiveness increases as passenger load increases. So transit agency always wants more and more people on the bus right or bus or metro.

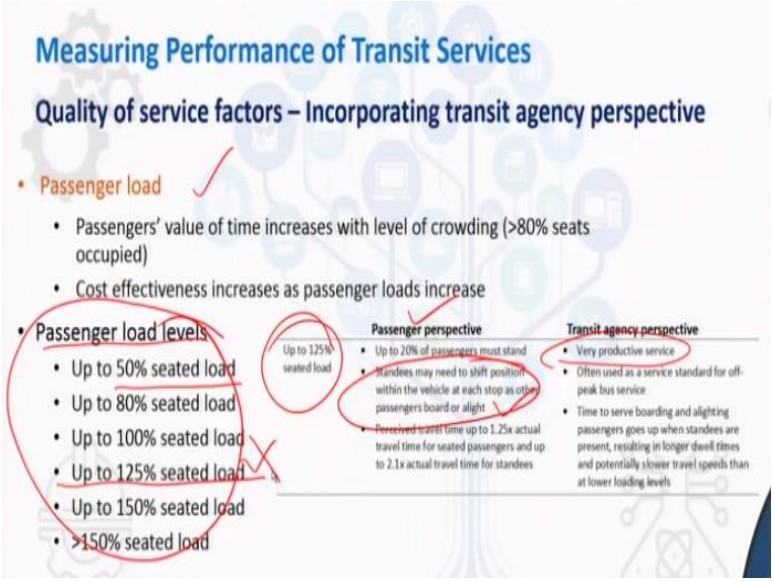
Similarly, reliability, should passengers allow extra time for the trips or not? Unreliable services, from the point of view of agency is also not good because it inserts more recovery time in to

their schedules. So at the end of the trip they have to add some recovery time and hence by adding recovery time they are not, i.e. the buses are actually not running for revenue collection, but whereas they are sitting idle and not earning any revenue.

If there are unreliable services, the recovery times are higher, which is not good for transit agencies. Similarly travel time, when it comes to transit travel time versus travel time on other modes, it is a crucial aspect in mode choice. People always make this trade off. that if I travel on my own vehicle versus on the public transport, what is the difference in travel time and if they can justify the difference, only then they take public transportation.

Operating costs are also directly involved, and are impacted by transit travel times. If there is so much congestion that the buses cannot keep on schedule, then they are actually making less runs in a day; and if they make less runs in a day, their actual revenues are lowering. So all of them again you see have the perspective of both transit as well as passenger.

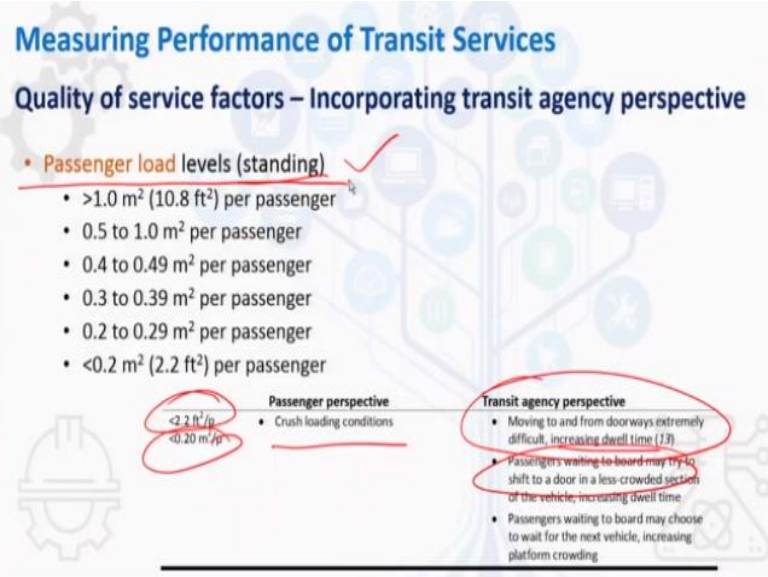
(Refer Slide Time: 29:10)



So again, individually if you look at them, there are levels that each of the services can be divided up into, so for example passenger load up to 50% of the seats are loaded ,so here the example is even of up to 125% of the seats loaded. So in this case standees may need to shift position within the vehicle at each stop as other passenger board or alight. So it is overcrowded.

So this gives you an indication, this gives you a measure for how crowded the situation is so that may not be very good for passengers but such a service may be very productive for the transit services. So how do you balance it? Should I run at 125%, or you say that no, that is causing a problem from the passenger perspective and so I should not run? So that is the kind of balancing activity that has to be carried out.

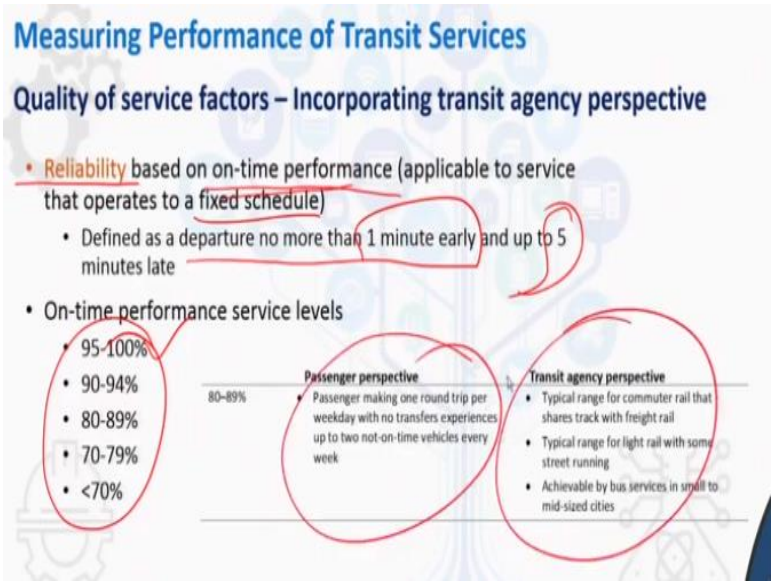
(Refer Slide Time: 30:24)



Passenger load levels -- standing levels, thresholds can be developed. For example, during crush loading, there is very less space. Either less than 2.2 square feet per person or which is less than 0.2 meter square per person, i.e. so everybody is "crushed" against each other. So there is little space standing space also available.

So even for transit agencies it becomes difficult because moving to and from doorways becomes extremely difficult, as a result the dwell time also increases.. Dwell time meaning buses that wait at a bus stop to pick up passengers also increases because now the passengers inside the bus have to be shifting to get on and off the bus. So it increases the dwell time. So passenger load level also has to be determined in order to understand how well a public transportation system is performing.

(Refer Slide Time: 31:25)



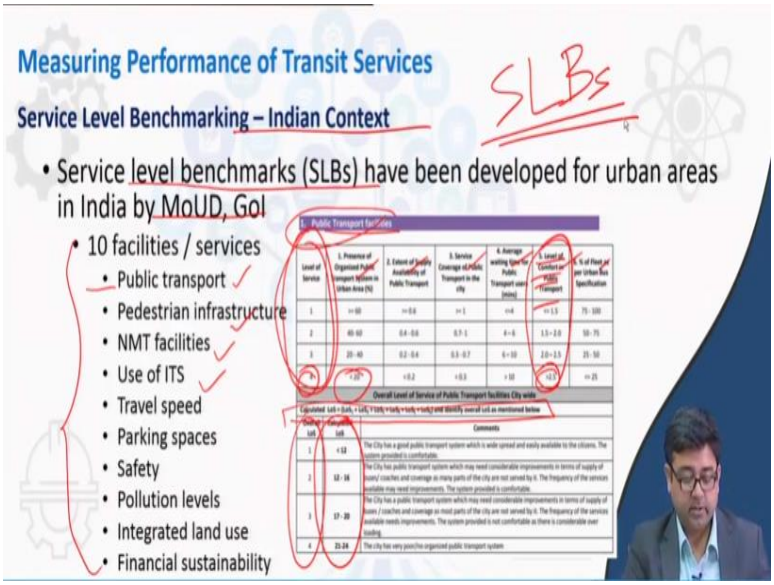
Similarly, reliability means on time performance. This is applicable to service that only operates on fixed schedule, defined as departure no more than 1 minute early and up to 5 minutes late. So if you are transit system is performing or vehicle is coming up to 1 minute early and no less than 5 minutes late, it is said to be on time. So if there are 100% of such vehicles, of all the vehicles are arriving within this time frame, then you say that their system is operating at a 95 to 100% performance. So that is how again each of them are, each of the perspectives are given in this table.

(Refer Slide Time: 32:11)

Similarly travel time, this is always measured as a ratio of transit to automobile travel time ratio. As the ratio increases it becomes tedious for all riders; nobody wants to take a public

transportation system that will take twice the amount of time, as compared to your private vehicle. So if it takes you 30 minutes on your car and if it takes 60 minutes on public transportation then obviously you are not going to take your public transportation.

(Refer Slide Time: 32:47)



Lastly, we will get into this in the coming lecture, but just to give you a glimpse of what is happening in the Indian context there are several such service level bench mark that has been developed for urban areas by the ministry. 10 such different facilities or service has been taken into account and all these levels of service have been identified for each of these 10 services or facilities.

So here is an example of the first one -- public transport facilities. So the levels of service of public transportation facilities are calculated based on 6 different parameters and the overall level of services is just the addition of all these individual levels of service, and you finally get a score, i.e. you get a score and based on a score the overall level of services are given. For example, presence of organized public transport system in the urban area. If there is no organized transport system, or only less than 20% of the urban area has organized transport system, then you get a level of service of 4.

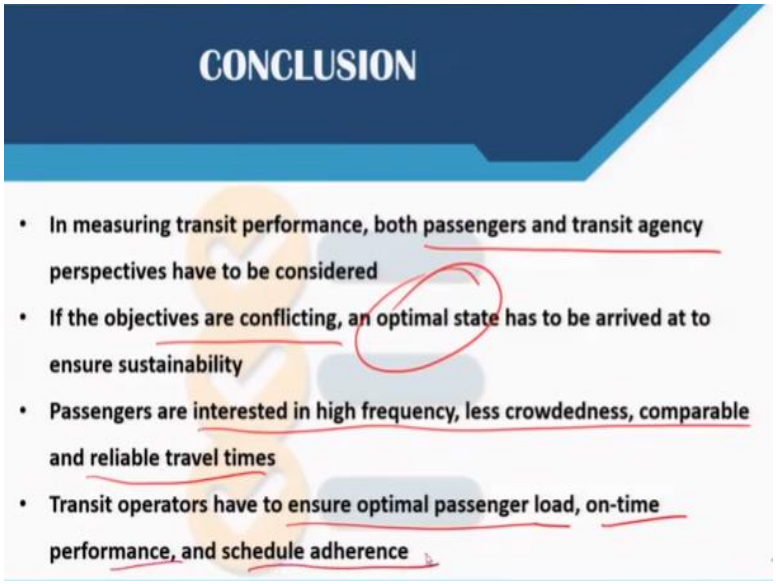
Similarly, if the level of comfort in public transport is greater than 2.5, so how do you define level of comfort, we will get into all of that; how do you calculate each of these we will let you know in the following lectures that come up. But you should know that there are such SLBs,

called service level benchmarks, that are being developed for the urban areas in India which will allow you to measure the performance of the public transportation systems.

(Refer Slide Time: 34:32)

So the references are given here. Majority of the materials have been adopted from the transit capacity and quality of service manual and it can be freely downloaded at this website. So please do look at it.

(Refer Slide Time: 34:49)



So in conclusion, in this lecture we looked at measuring the transit performance both from passengers and transit agencies point of view. If there are objectives that are conflicting, optimal situation and optimal state has to be arrive at without harming any one of the stakeholders.

Passengers are always interested in high frequency, less crowdedness, and comparable and reliable travel times. Whereas transit operators have to ensure optimal passenger load, on time performance, and schedule adherence, in order to sustain their services. Thank you very much.