Introduction To Multimodal Urban Transportation System
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Lecture - 46
Introduction to Intelligent Transportation Systems (ITS)

Welcome friends. Now in this section of our ongoing course, we are going to introduce you to an exciting part of transportation which incorporates totally new discipline of information communication technology in transportation, also known as intelligent transportation systems.

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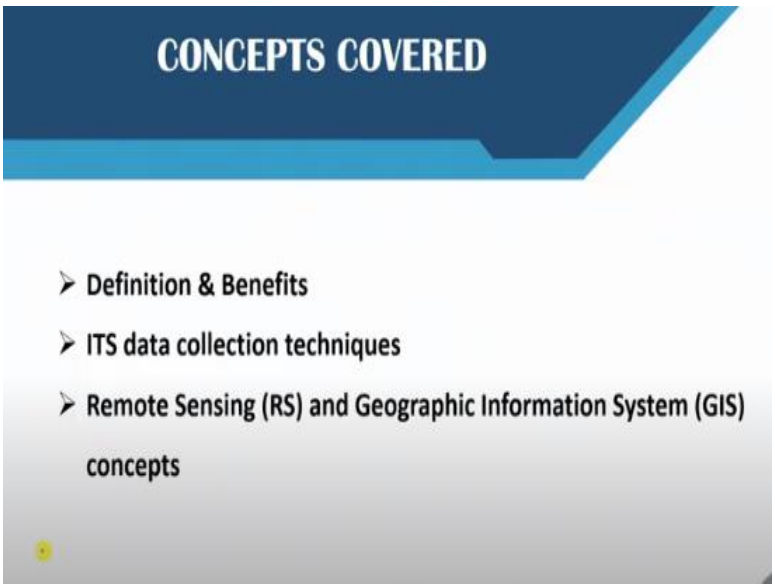

We are going to tell you in the course of this week what is intelligent transportation systems? What are its benefits? How is it used in case of transportation? And specifically, look into some of the concepts that are used. What we often do not realize is the use of information communication technology in transportation.

Specifically, in this lecture, we will be looking at remote sensing and geographic information systems which is GIS.

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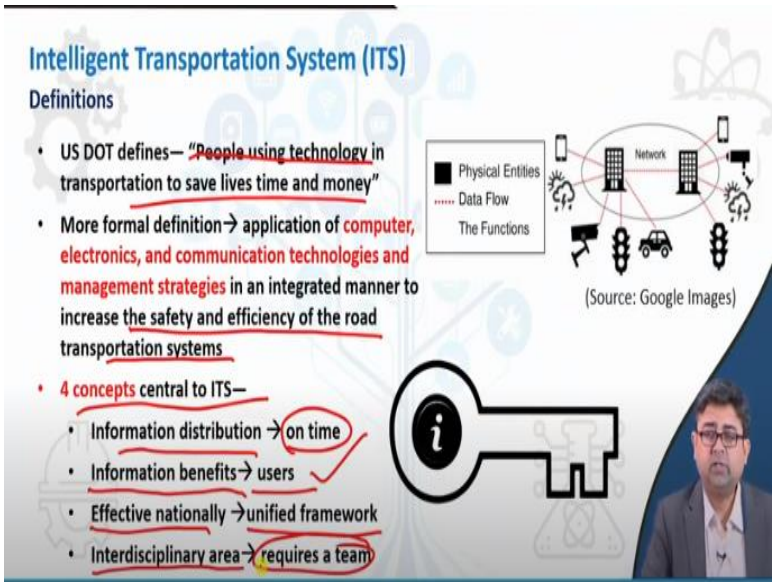

How do we define ITS? There are not any specific definitions, but different varying one. People using technology in transportation to save lives, time and money. So essentially that is the main concept of the introduction of ICT in transportation, which is to increase safety and efficiency of the road transportation systems.

So improving safety and efficiency of the road transportation systems was one of the main aim or goals of the introduction of various ITS strategies in transportation. If you look at it from a broader perspective, we were not being able to meet growing urban transportation demands of the citizens by just providing more and more facilities. So by increasing supply, we were not being able to meet the demand. As such, what was noticed was that maybe by introducing different ICT or information communication technologies into transportation, we would be able to achieve greater capacity or greater efficiency of the existing transportation system. So rather than increasing the supply, what ICT does is it increases the efficiency of the existing supply. By doing so if you increase the efficiency, we you may be able to increase the capacity of the existing supply. And hence, you may not need to provide more roads or increase the supply as such. If you look at a broader perspective, that was the main aim of introducing ICT into transportation.

The four concepts central to ITS—information distribution on time. So in today's day and age, you want to know about your transportation network more specically when you want to know about it. It is not good, that if you want to travel now, you have to wait for the information on the road so that you will have to make a decision. You

want to have that information right now, because you are traveling today. You are not traveling tomorrow or you are not traveling day after tomorrow. So you need on time traffic information, for example. Information benefits users. So this again works from the point of view of users. How can this information be beneficial to the users? It is one thing having information with the agencies. It is the other thing passing on that information to the users so that they can make sense of it. How do you pass on the information to the users? Through various devices, now that you have your mobile phone to your internet to whatever devices that you use. How do you pass on the information to the users? Effective nationally, have a unified framework. So when you move from one city to other city, you should be able to access the same system just like how you did in your home state or home city.

There is some some basic national standards associated with these ITS systems. And it is of course, interdisciplinary in nature. And hence, requires a team effort. We are civil engineers who usually specialize in transportation. We do not usually take courses in electronics or in computer science unless or until we have an interest in it.

But if you want to develop a career in intelligent transportation systems, then you have to have this interdisciplinary team, or at least have interdisciplinary knowledge. So you have to have ITS person or a computer science person on your team. Similarly, the computer science person on your team also has to have some understanding of what is transportation and what are the basics of transportation so that both of you can work in unison.

So this is a very exciting new field, in which transportation has ventured into over the last two to three decades. And we are going to give you some more information throughout the week about the different systems that are currently in place in India as well as worldwide, where different ITS strategies are being used effectively.

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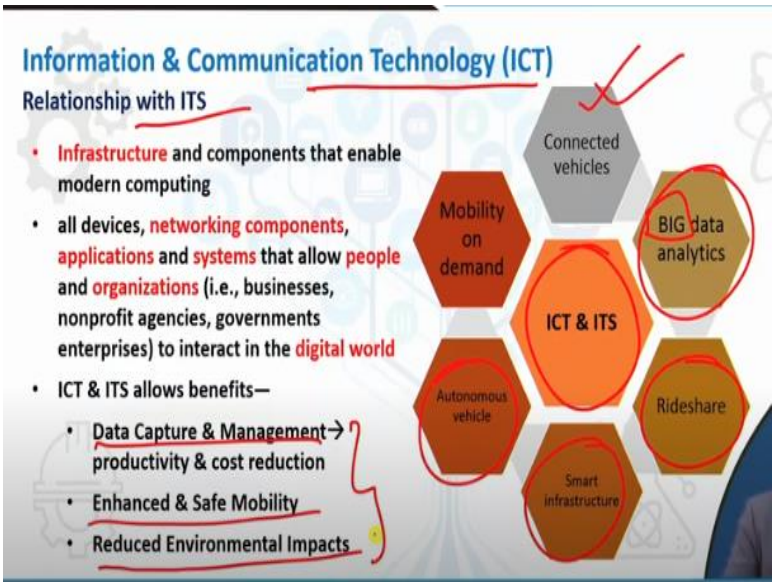

How how does ICT relate to ITS? When we talk about information communication technology and the ITS, what are we essentially talking about? This is the latest thing that you might be hearing all the time, like connected vehicles. Vehicles that can drive by themselves, how is all that possible? However, you might have already been introduced to smart infrastructure, or even to ride sharing. So all the Ola, Uber type services that are using different ICT devices to match the ride that you need. How is all that happening? That is all happening because a driver now knows that you want a ride, you are asking for a ride and all the communication is happening through the different software platforms and hardware platforms that are available. So all of this has to be integrated. We as a civil engineer, as a transportation engineer, rarely think about all of these things, but we know that ride sharing has an impact on the transportation network. Now that is the whole point of you to understand, at least have a basic understanding of how ITS works so that you can then measure its impact on the transportation network. If you do not have an idea of how ITS works, then you will never be able to keep pace with the growing impact of ICT on transportation. So you have to understand how ICT and ITS interact. Before you get into autonomous vehicles and connected vehicles, we will tell you what that is. You also may have heard about big data analytics, which allows you to now measure speed for example, using information from your mobile phones. So your mobile phone is at one instant is at this location and in the other instant is at another location. Using that distance and time information you can one can predict the average speed on a travel corridor, for example. All this are various ICT platforms and ICT devices are helping

transportation improve the efficiency of its system of its network. So it captures data in a very innovative framework. It manages, manages the data that comes in. Because big data usually means large volumes of data. We usually deal with experimental data or say perception data which is in very smaller volumes, right. But when we talk about big data, it is data that is created every second, so huge volumes of data is generated. How do you see through all of that data? How do you make sense of all of that data? That is what data capture and management refers to. At the end of the day it enhance safety and mobility for the users. And also has to reduce the environmental impact. So ICT is helping in at least these three broad different ways of improving the transportation network.

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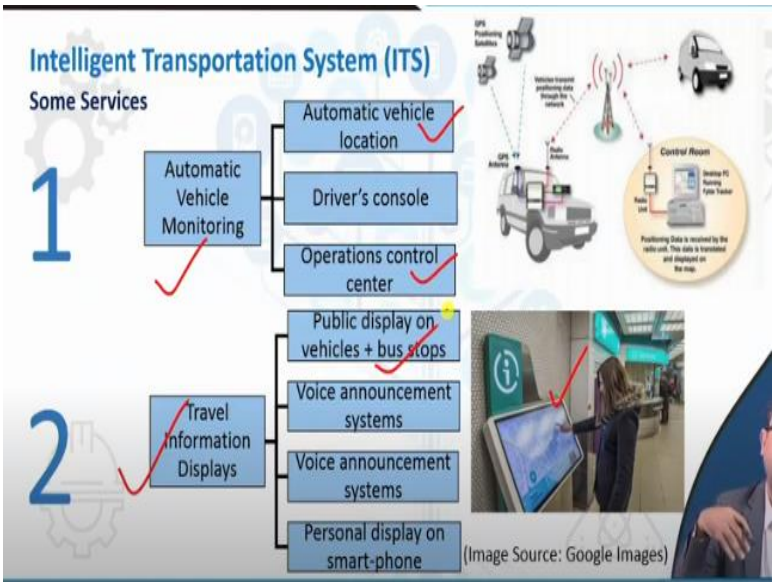

When we talk about some of the services that you might have already seen, but never really thought about it from the transportation point of view. You might have already almost always thought about it from a very technology savvy point of view, but all of these technologies are essentially helping improve the transportation network. When we talk about automatic vehicle monitoring, the modern car has so many gadgets within it, may be that is a mini computer in itself. So whenever you need your fuel is going down, you have a fuel indicator. When you want to turn right you have a right turn, left turn indicator. When a vehicle is maybe coming too close to your vehicle, there is a sensor that tells you that you are swaying too much. There are so many gadgets that are associated with your vehicle that tells you about different controls, and at tells you about where your vehicle is as well. So in order to improve the safety as a post-accident measure, there is you might have heard of a black box on an

aircraft. There are similar devices now on cars, which can communicate directly with a hospital or with an ambulance after you have been in a crash. So once you have been in an accident or a crash, this device automatically sends a message to the closest hospital or the ambulance so that care can arrive quickly rather than wait for somebody to call in about the accident or you yourself reporting the accident. This device in the car automatically can do so. So that is something called automatic vehicle monitoring. It can also indicate routine work that the tire pressure is low, that your maintenance is due and so on and so forth. It can do all kinds of things. Then there are traveler information displays. You must have now you have such kind of screens in your mobile phones. This allows you to navigate through newer areas when you are traveling or when you are in a tourist destination this helps you a whole lot. This provides you information about the city, about the various transportation modes available in the city and it makes your journey seamless. Makes your journey very easy, very smooth. It provides you information for example about maybe various bus stops, when the next bus is arriving. There may be information displayed on the bus as well as what is the next stop. If you are in a metro nowadays, every metro has automated display on the inside of their vehicles as well.

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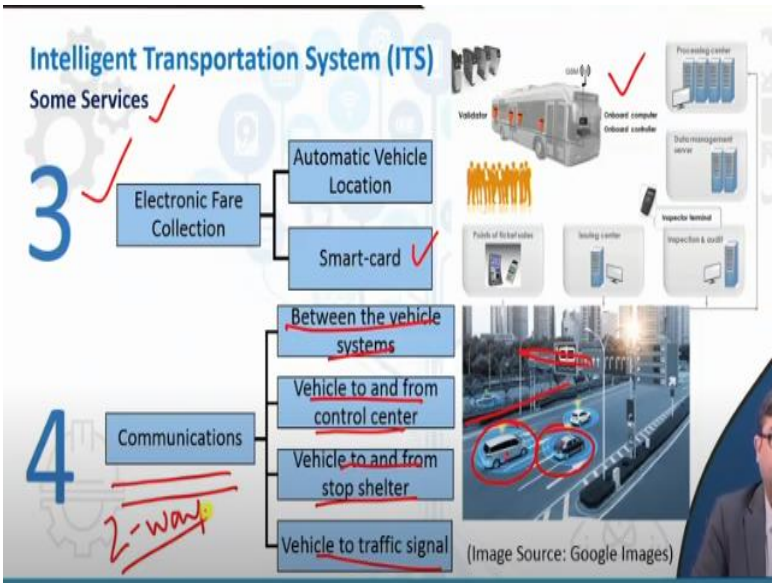

The next thing that you would have encountered if you have traveled on any of the metros is electronic fare collection. What is electronic fare collection? You have you have what is called a smart card. The smart card has a unique ID associated with it. So you use that unique ID to link it to either your bank account, your credit card or whatever it is. And every time you get on a bus, get on a metro, you just swipe the

card and you make payments. All of this is helping the helping improve the efficiency of the system, right. So now, if it was manual ticket counter from where you receive tickets, then maybe the manual ticketing counter would have been able to process 10 people every minute. But now with the electronic ticket counter or the electronic turnstiles that you have in your metro systems, every minute maybe it is able to process 20 to 25 people. So you see the efficiency of the system gets improved many fold and that is one of the primary benefits of ITS.

The next main service that ITS provide is communications. Now communications is very vital when it comes to intelligent transportation systems. Communication may be between the vehicle systems from vehicle to the control center, from vehicle to the infrastructure or the stop shelter, from vehicle to the traffic signal. Now this is how it is possible that there can be driverless vehicles. Unless something is being communicated from the vehicle to the next vehicle or from the vehicle to the infrastructure that is either above head or along the side of the road. Only when there is two way communication between systems that is when such kind of driverless cars is possible. Now you have automated signals in many of your cities in the urban areas in India right. So what are they doing usually? They are detecting cars. So it detects cars at a signal and when the queues get longer and longer, it automatically turns them into green so that they can be released. So now that is a one way detection from the infrastructure. But there can be, the other way detection for example, ambulances have that power to change the red to green wherever the ambulance is arriving at the traffic signal right. So at that time, there is a two way communication. Now the ambulance is also communicating to the signal, saying that, although you are red, please now turn to green as I have to cross. That is two way communication. All of this is usually taught in electronics and electrical engineering, but with the advent of intelligent transportation systems, many transportation engineers who are interested in this field are getting more and more knowledge of such systems.

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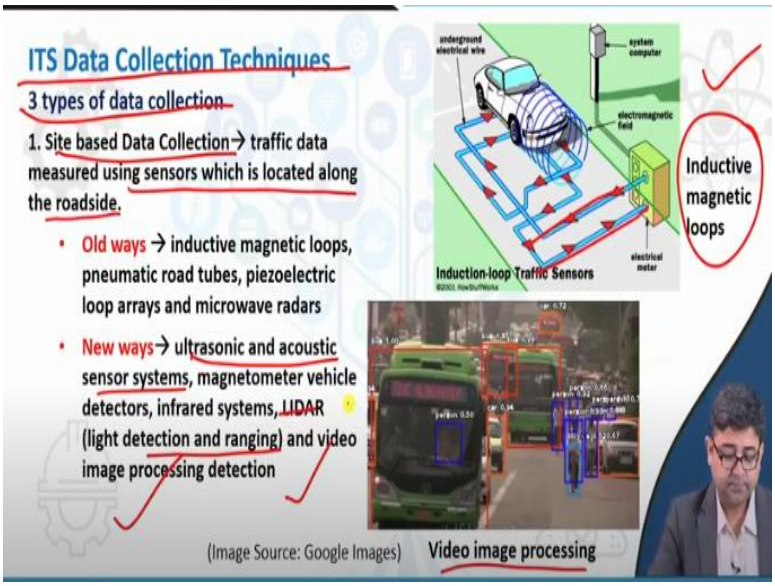

So when it comes to data collection techniques, we have to realize that manual data collection is not only too expensive, but also time consuming and also gives us a very small sample size for with which to work with. So we have to use modern technologies, we have to use newer gadgets, newer information, ICT methods to collect transportation related data. So there are three types of data collection that ITS allows you to do. One is site based data collection, which is traffic data measured using sensors that are located on the road side. So you know initially what used to happen, how a car used to be detected, through inductive loops that were present inside or embedded in the pavement. Whereas the newer ways are to have either video image processing or through LIDAR surveys or even through ultrasonic and acoustic sensors. You can now count vehicles and classify vehicles in a traffic stream. This data can be used to develop AADT. You want to know the Annual Average Daily Traffic (AADT) on your road which you used to have a permanent counter station on a highway or on an expressway and this kind of inductive loops are embedded into the pavement and they were used to continuously count vehicles. But now you can move to newer ways of data collection such as video image processing for example.

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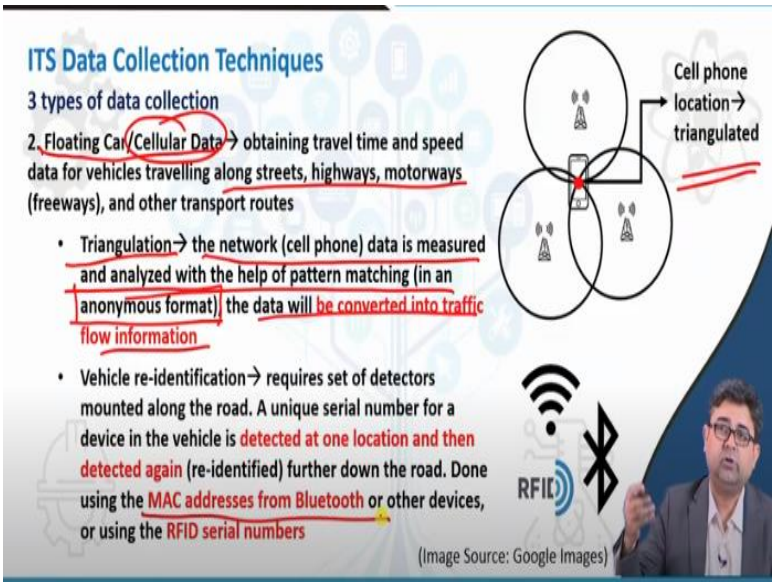

The second type of data collection is traditionally known as the floating car technique to calculate the speed of a vehicle. Whereas now you can use cellular data to measure the travel time or speed of vehicles along streets, highways or motorways. How do you use cellular data to measure speed? It is your good old geometry which is known as triangulation. The network data is measured and analyzed with the help of pattern matching in an anonymous format. The data will be converted into traffic flow information. Now with big data, anonymity is one major point. Nobody wants to give out information with their personal data embedded in it. So when we are saying that we would give you smart cards, and that would allow you to travel seamlessly on metro and bus services, we also want to assure that your we that no one will be able to trace back your smart card to you. We will have to completely anonymize the data from your personal identity. For example, you might be linking it to your bank account. Then your bank account will have your PAN number. But when we are talking about big data, there are huge volumes of this data. So when we are using these huge volumes, what we usually do is we anonymize all of this. We take out the personal identity part, falsify it, and say that we put you in a pattern. You are not an individual anymore, you are part of a pattern. So that is how we would usually try to anonymize all the data set and that is very true in all of the cases worldwide unless and until somebody really wants crime data for which they want to track you. Only it is through certain high level clearances that such kind of personal identity data can be divulged. Otherwise, for regular research and information dissemination purposes, all your personal identity is always safe. So anonymity is one of the biggest concerns

which must be alleviated, or which must be alleviated when it comes to use of IT or use of ICT in transportation. So cell phone triangulation is usually done in order to find out the location of your mobile phone. And hence can you estimate or predict at what speed you were traveling, and then can further deduce that what mode of transportation you might have been using as well. If you have traveled only at one kilometer per hour speed, it cannot be that you are traveling in a metro. Most likely it will not be that you are traveling in a metro rail or something. You might be walking maybe. So if you are traveling at 45-55 kilometers per hour, and the speed is constant, then it might be something like a dedicated mass rapid transit system on which you are. Because there is no variation in the speed while you are traveling. Whereas, if there is variation, then it might be on a surface transportation mode, which is traveling on a non-dedicated right of way. For example, a bus which may be able to achieve 35 kilometers per hour, but sometimes because of traffic it may go low as well. So ITS or cellular phone data not only allows you to measure the speed or estimate the speed, but it may further then allow you to even know that whether which mode of transport were you using at that point in time. So this is all possible because there is a unique MAC address from a Bluetooth or other devices that can be tracked. Your cell phones or mobile phones always have a unique MAC address that can be tracked. Again, the unique MAC address has to be anonymized only after which can we use this kind of information.

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The other technique is to use GPS based methods wherein some of the vehicles equipped with in-vehicle satellite navigation or GPS systems that have two way

communications with the traffic provider. This provides you readings of the vehicles location. You may not even communicating with the satellites there because your smartphone is already communicating. So there are very few vehicles that currently have in-vehicle navigation systems because they have become redundant, because of smartphone. But the smartphone based rich monitoring system is used to track speed and density very much. So when you when you have your mobile phones on, and then whenever you are traveling in your car, it is essentially transmitting a lot of data that is allowing researchers to understand the travel time on that corridor.

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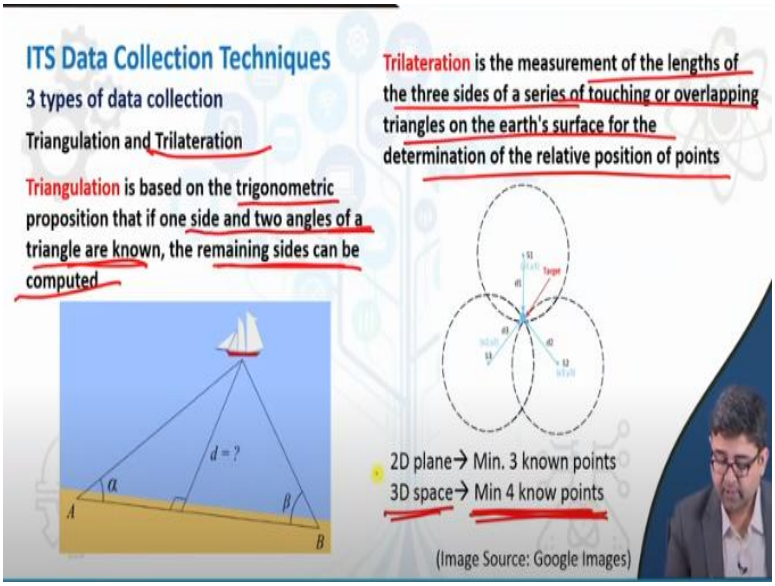

Let us give you a quick understanding of what is triangulation and trilateration. Triangulation is based on trigonometry that if one side and two angles of a triangle are known, the remaining sides can be computed. Remember your basic trigonometry if one side and two angles of a triangle are known, the remaining sides can be computed. However trilateration is the measurement of the lengths of the three sides of a series of touching or overlapping triangles on the earth surface for the determination of a relative position of points. Now what happens is in a 3D space, a minimum of four points have to be known. So if you are, if you are measuring something on the earth's surface, at least you need four points in order to find out the relative position of an object. But as in a 2D plane, you have to know only three points.

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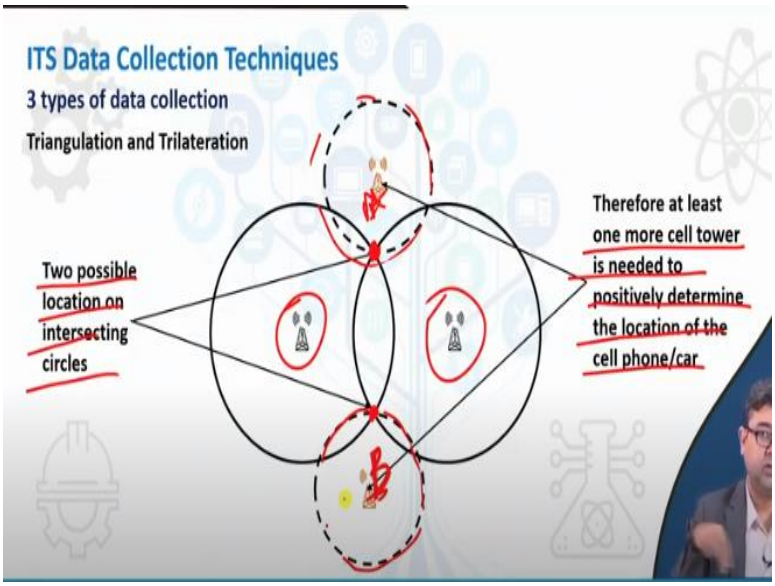

So what happens is, if there are two cell phone towers, and they are overlapping, there are now two possible positions on which you can be, right. So if there are only two cell phone towers that are tracking you, and then you can be either here at position A or position B, so you will always need another at least another cell phone tower. Therefore, at least one more cell phone tower is needed to positively determine the location of your cell phone. So now, if you have a third cell phone tower here, and that also intersects with your location here, then we can positively say you are at A or if you have a cell phone tower here and it triangulates and tells your location to be here, then you can see that you are at B. So usually two cell phone towers are not ideal. You have to have three cell phone towers to accurately determine your location.

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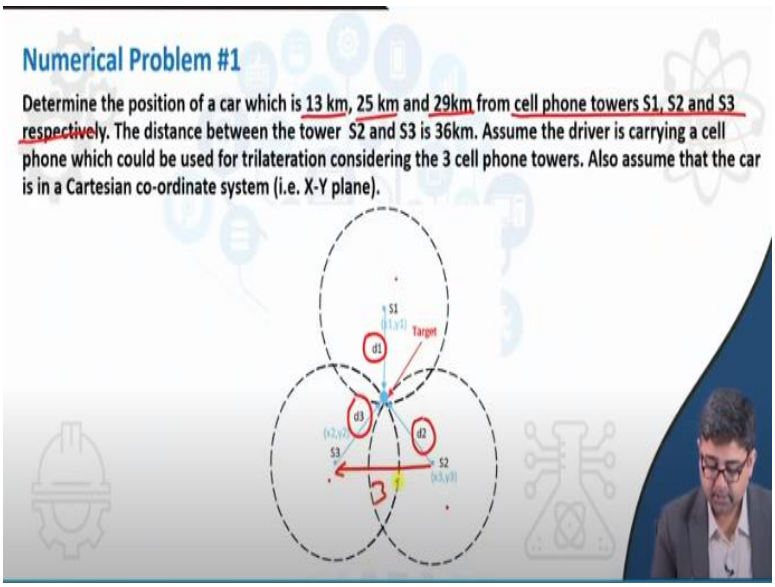

So for example, if you are told to determine the position of a car, which is 13 kilometers, 25 kilometers and 29 kilometers from cellphone towers S1, S2, and S3 respectively. So here are three cell phone towers S1, S2, S3. Determine the position of a car which is 13 kilometers from S1. So it is 13 kilometers from S1, 25 from S2, 25 from S2 and 29 from S3. The distance between two towers S2 and S3 is also given is 36. Assume that the driver is carrying a cell phone which could be used for trilateration considering the three phone towers. Also assume that the car is in a Cartesian coordinate system x-y plane, okay.

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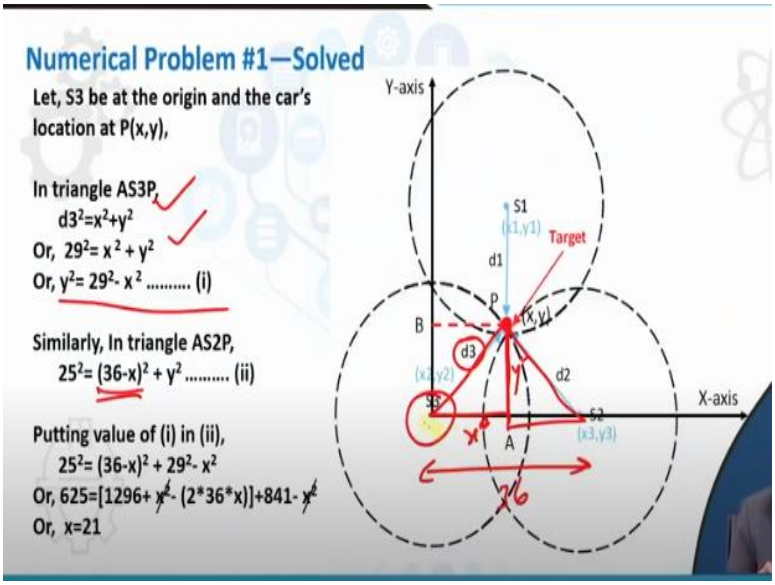

So now, if we just draw a Cartesian plane x and y axis. Let S3 be the origin and the car's location P x, y is right here. So in this triangle, first let us look at the triangle AS3P. We know that simple,

$$d3^2=x^2+y^2$$

You have already been given the distance d3; d3 is 29.

So 29 square is equal to x square plus y square. So you can convert that into a y formula.

$$y^2= 29^2- x^2$$

Similarly, in the other triangle AS2P,

$$25^2= (36-x)^2 + y^2$$

So d2 is 25. So 25 square is equal to x square plus y square. Whereas, x now you know the distance, you already know this is x and you know that this is 36. Because you have already been told that the distance between the two towers S2 and S3 is 36.

So this distance is 36. And in this you have already assumed that this is x. So this must be $(36-x)^2 + y^2$. So if you just solve these two equations, you will get x = 21.

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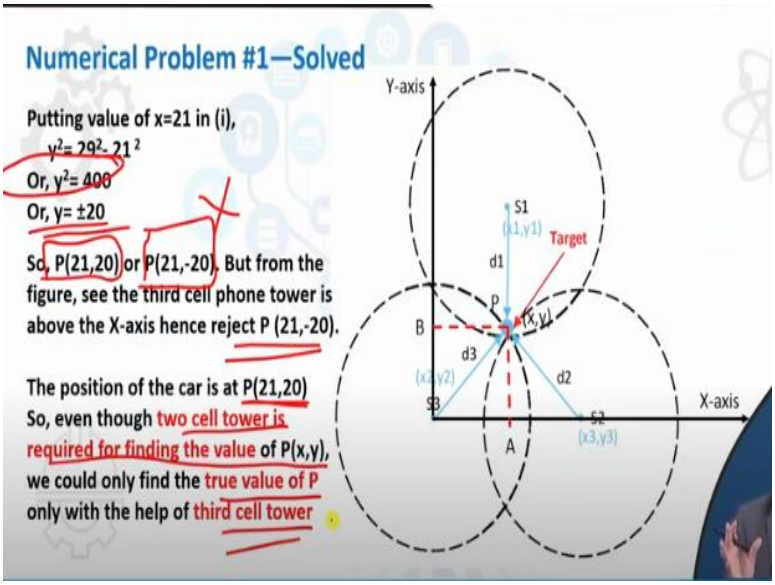

And if you put this x = 21 into one of the equations, that one you will get y square is equal to 400, or, you have two values of y now.

y could be either + 20 or - 20. So now, you have had possibly two different locations where your car could be. It could be either at an xy location 21, 20 on a Cartesian plane or it could be at location 21, - 20 on a Cartesian plane.

But from the figure, you see that the third cell phone tower is above the x axis. But we have only used information about S3 and S2, right. Only two cell phone towers so far we have used information about. But from the figure, you can see that the third cellphone tower S1, which is above the x axis. Hence, you can reject the values of the negative value of y, saying that this will not be possible.

Hence, the position of the car would be P1 is equal to 21, 20. So even though two cell phone towers is required finding the value of P (x, y), we could only find the true value of P only with the help of the third tower. So the most important point to remember is that in order to use cell phone tower information to determine where a vehicle is. We have not even gotten into measuring speed or anything, this is just locating a vehicle in an x-y plane. Just for locating it, you have to remember that there has to be at least three cell phone towers to positively identify where the vehicle is. Two cell phone towers are not good enough.

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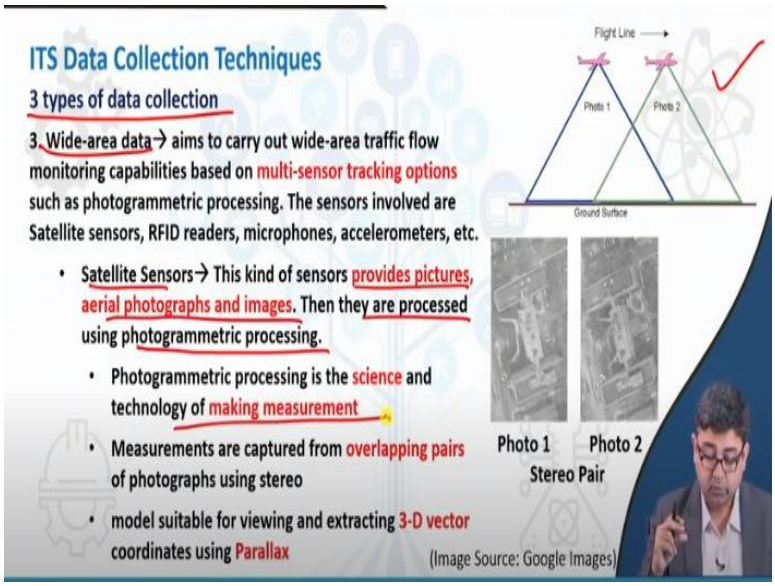

The third type of data collection that ITS technologies allow you to do is wide area data. Now the wide area data is something that is now more and more being used in India as well, because there are lot of satellites that India has specifically put in orbit that allows you to take pictures about the urban area and how the urban area is changing, where the roads are coming up, where new roads are being built. Where new roads are being widened, how the urban form is changing. So all of that information is then being used in the GIS format for display. Now we assume, we use Google all the time, but the basis of all the Google Maps and everything is geographic information systems. Lot of it is based on remotely sensed information that is coming out of sensors. It provides pictures, aerial photographs and images. They are then processed using photogrammetric processing. Photogrammetric processing is the science of technology making measurements. So just through picture, how can you convert it into a information? You have to use certain science to convert that picture into data.

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You must have also heard about RFID tags. The easiest location where you might have seen it is when you are using an airline they put a tag on your baggage and there is a barcode kind of information. Most of that is RFID technology that allows you to track your bags from point A to B to C. The RFID has been used earlier in ITS to locate vehicles as well. Now a lot of mobile phones have now replaced RFID technology. Mobile phones are ever increasing from 3G to 4G and now we are talking about 5G. So all it is doing is increasing the efficiency and hence also increasing the safety on our highways.

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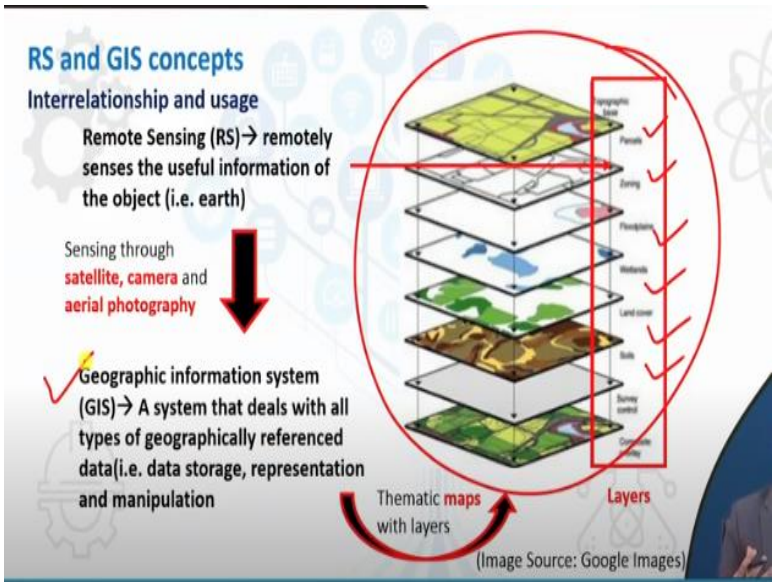

What remote sensing allows you to do is it allows you to break up a picture into different layers. Once a single picture is taken, you can now break it up into different layers, study each of those layers separately, then recombine them. So it allows you to combine information about say for example, different parcels zoning, what is the floodplains, what are the wetlands, what are the land cover, soil. So all that information which you would have had in separate different maps. Physical maps would have been there. People would have conducted surveys of floodplain. A floodplain survey map would have been there. People would have zoning maps separately. Now all of these maps could be digitized. So when people say digitizing of maps, and overlaying those two maps the information from those two maps into one single map, so what they are essentially telling you is that there is some technology that is being used to compare or to overlay those information together. So how do you do all that? That is what essentially, remote sensing and photogrammetry is all about. GIS is a tool that anybody dealing with transportation nowadays has to know about. Otherwise, spatial data analysis is something that you would not be able to do, if you do not have an understanding of GIS. There are specialized GIS courses that you should be able to take. But in this class we are just going to tell you about different forms of ICT that is out there so that it gives you a flavor about what ITS is really about.

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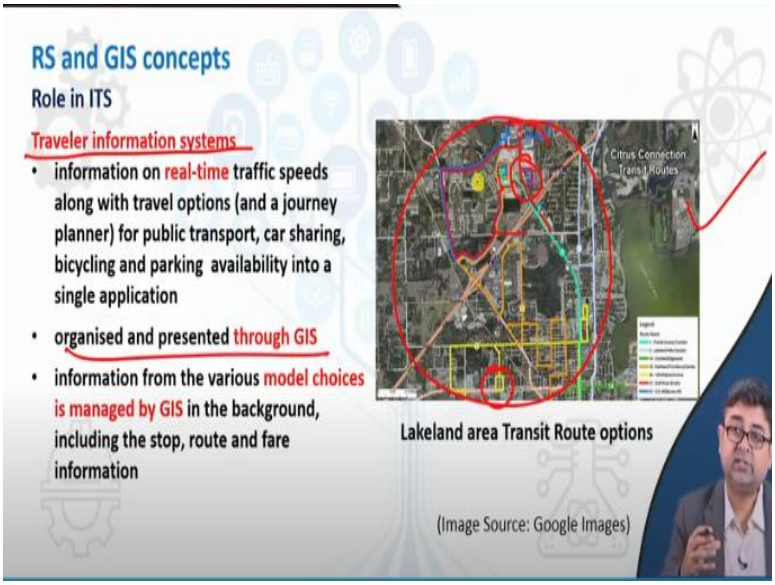

Traveler information systems. You must have seen several maps, even Google displays or this could be a map about the different bus routes in your city for example. So this is all on a GIS platform, right. It gives you information about different lines,

the different bus stops, where they are. So this is just not drawn, these are all drawn to scale. So everything, all the information here is something that can be converted into information and data. It is not a sketch as such. Organized and presented through GPS. And you could then use this to do different types of spatial analysis. For example, how many passengers are disembarking or embarking the bus on the yellow route versus how many are disembarking or embarking the bus on a red route or the blue route. So you can do different spatial analysis at different points in your city. And GIS is a tool that allows you to do that.

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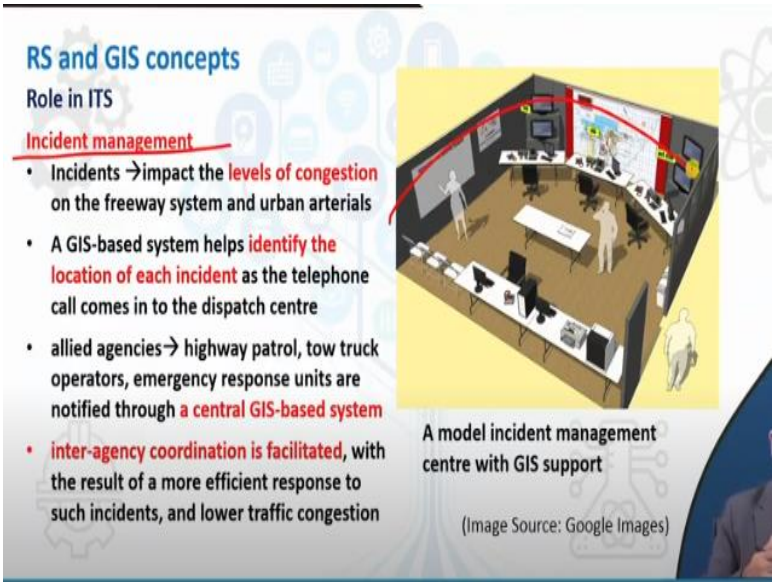

You can do better incident management. You must have heard about control centers that are there in many cities. All of your cities might have lot of CCTV cameras that are all giving all the feed to one common location that is the control center. For example, if there is an accident that happens, because of the CCTV cameras immediately an ambulance or a police car can be notified and they will reach that location so as to save lives. So this is how safety is being improved on a on our highway systems right through better incident management.

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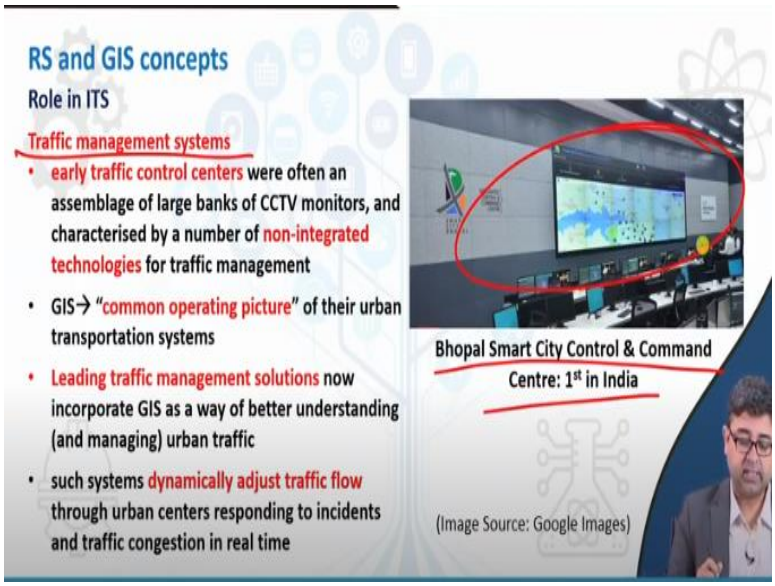

And of course, better traffic management systems as well. Not all the systems are coordinated, but at least all the system have CCTV cameras associated with them and all of that is being live monitored at a control and command center. So Bhopal Smart City for example has a control and command center that is first time in India, where you can now change the signal timing based on real time demand. Suddenly, maybe because of an accident, there is a lot of queuing that is happening at a downstream signal. So then you can change the signal timing sitting from in the control center so that the queue could be dissipated faster. You do not have to have physical police personnel on site to change the signal timings. So there could be different things that can be done based on analytics that is going on in the control center. So lot of analysis is going on in this control center that allows you to improve the traffic flow or the traffic management in your city.

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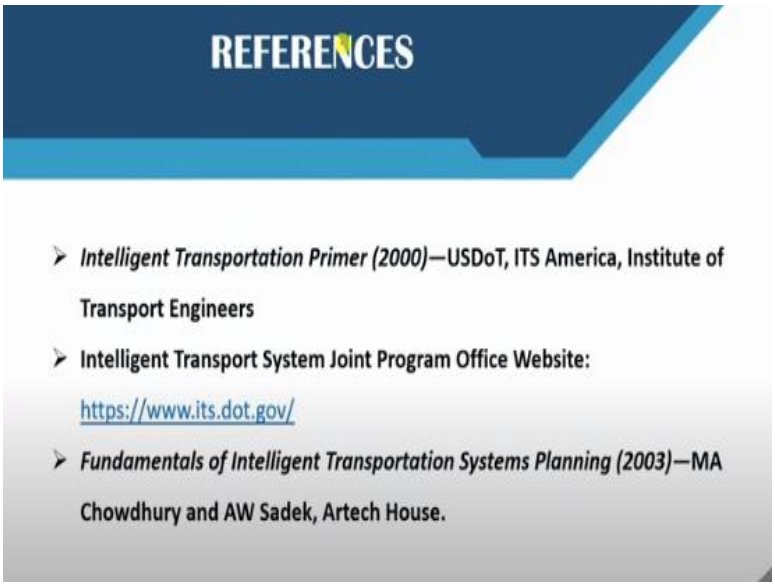

So that gives you a very basic understanding of what is ITS.

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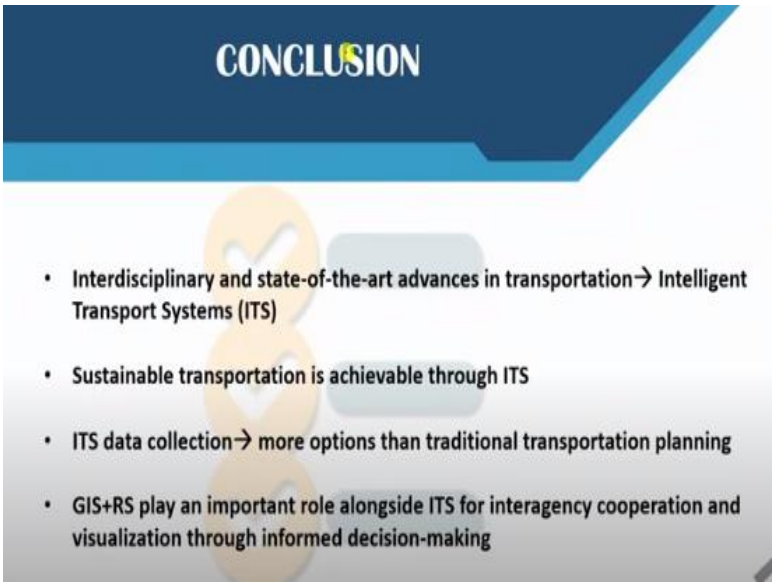

What is ITS, how it is being used in urban transportation, and how specifically GIS is playing a role in all of this. It is helping how remote sensed data is being converted or being used on the GIS platform in order to help the transportation systems. So I hope you have enjoyed the first lecture. We will have four more lectures on this as well. Thank you.