Introduction To Multimodal Urban Transportation System

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Lecture - 48

Urban Transport & Sustainability: ITS Architecture

Welcome back friends. Now that you have got a flare about what is intelligent transportation systems and how different ICT devices are used in the transportation arena to collect data, now, let us in this lecture give you an understanding of the basic ITS architecture.

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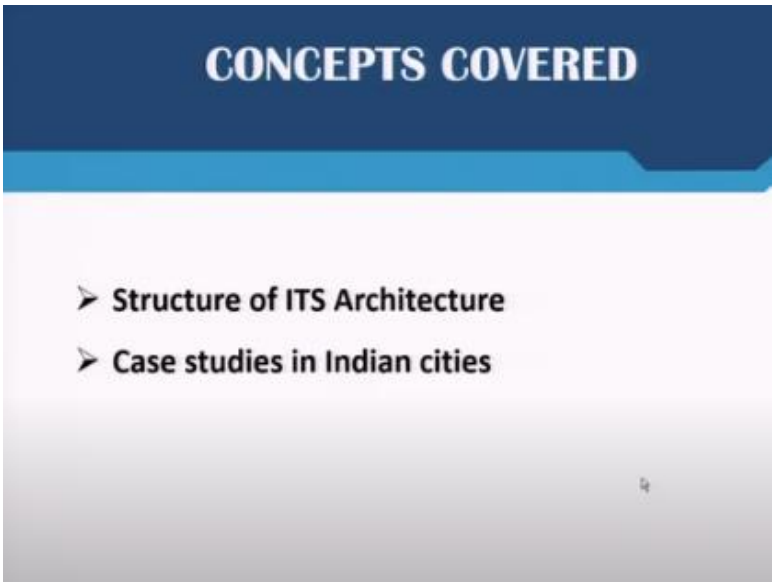

So what do we mean by architecture. We are going to show you the different structural elements in the architecture and also show you some relevant case studies of certain service packages of different ITS systems that are deployed in Indian cities.

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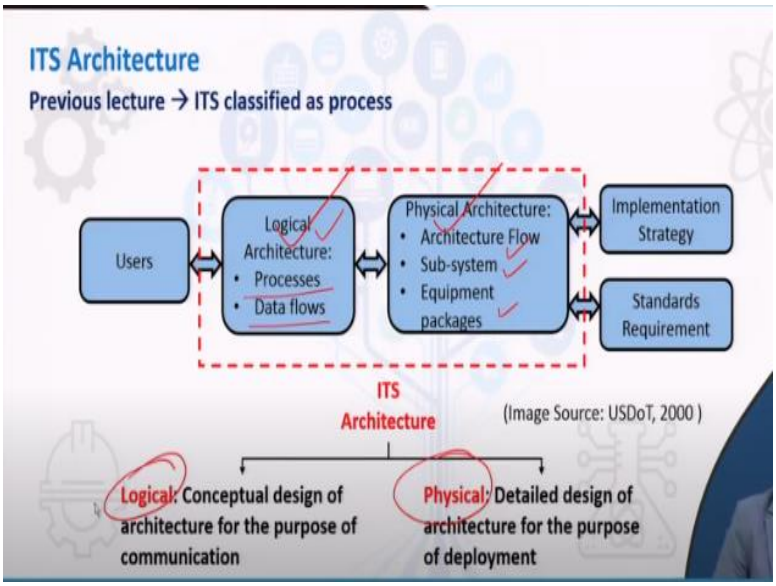

So when we talk about ITS architecture, what we mean is basically the central two blocks in this picture. One is the physical architecture whereas, the other is the logical architecture. So just as in the civil engineering and architectural field we have to basically draw a design and show all the components in the design. Similarly, in the IT world, you also have to have a digital architecture of the system. You have to understand all the hardware components that are involved in the design of the system. What are all the communication devices that are needed in order for data to flow between the different systems and subsystems. Combination of these entire physical systems, communication systems, subsystems all of these put together is the ITS architecture. When we talk about physical architecture, we will show you the different architectural flows, the subsystems and the different equipment packages that are involved in developing each of the systems. Whereas, when we are talking about logical architecture, you will be understanding about the architecture from the point of view of the different processes and the data flows. It is easier to understand the concept while looking at the physical architecture than the logical architecture. But still you have to understand both of them to kind of get an idea about the ITS architecture as a whole.

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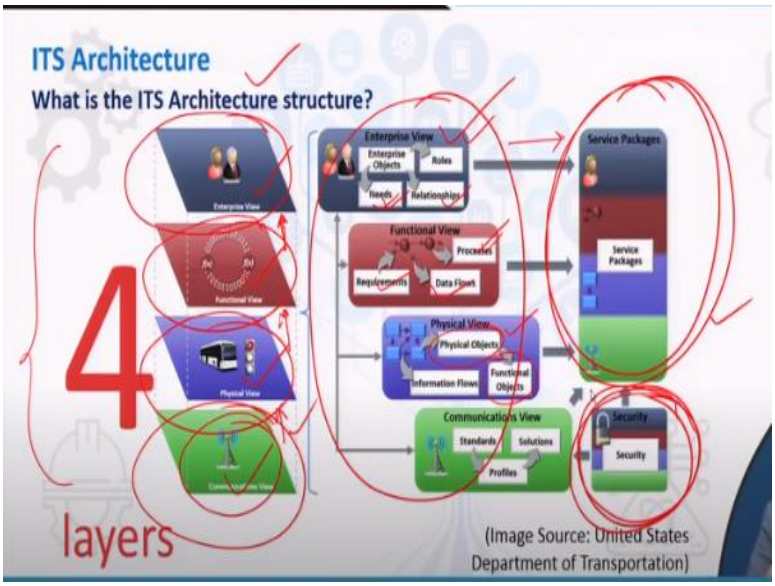

So when you look at the ITS architecture structure, you will see that it consists of four different layers. And these are in order from top to bottom or bottom to top. The top most layer is what is called the enterprise view. The next one is the functional view. Next one is the physical view and the final layer is the communication view. So you have to look at it in that hierarchy. What it essentially tells you is that, the ITS systems that you deploy in your city has to have all of these four different layers. The top layer is the enterprise view where you have to define all the roles and the relationships. And the needs of that system that has to be defined there. In the functional view, you have to outline all the processes, all the data flows and all its requirements has to be outlined in the functional view. In the physical view, you have to have the actual objects, physical objects as well as functional objects that are needed in order for all the processes to take care and all the needs to be satisfied. So each of these views have to satisfy the layer on top of it. The communication view is the basis for the ITS architecture. The stronger and the more detailed the communication layer is the better is the ITS system. It can be two way communication, one way communication, wired communication, wireless communication, whatever it maybe, is dependent upon you as a system integrator. But the communications are the base layer, upon which everything builds on. The communication view has to satisfy all the three views on top of it. The physical view has to satisfy the functional view as well as the enterprise view. Whereas the functional view has to only satisfy the enterprise view. So it builds on layer after layer. And all of this in turn is then associated with different types of service

packages. These service packages are nothing but various ITS interventions that are bundled together to be used for specific for specific locations, functions and so on and so forth. Rather than you getting a switchboard and wire and a three-pin plug and so on and so forth, it is better that you always get all of these assembled together in the form of an extension cord. So this extension cord or this extension wire, if you extrapolate it to an ITS system, that is what is called a service package. So you get everything built in for a certain type of functionality, for a certain type of use. And each of those service packages again have the enterprise view. They have some sort of functional view, physical view as well as communication view. And all of these service packages and each of these layers are again intertwined with security systems. Everything has to be secure otherwise, if your top roles and responsibilities are compromised, and are not secured, then your ITS systems will not function. So an ITS system architecture, and ITS architecture should have four different layers. Enterprise view, functional view, physical view and communication view. Each of those views are associated with certain number of any single or multiple service packages and in turn the service packages and these four views are connected to some sort of a security system. So that in a nutshell, in an overview is what an ITS architecture looks like.

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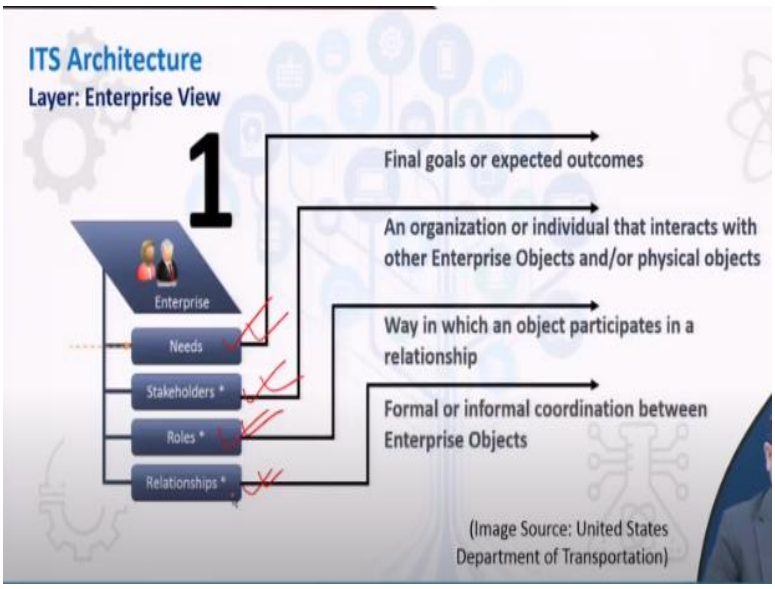

If you go into each of these views, one by one, starting from the top you will look at the enterprise view which defines the needs of the system. You have to define why a certain system to be put in place. Otherwise, if there is no strong need for it, then most likely, it is not going to help you in fulfilling what you are trying to achieve. So it has

to outline what are the needs, who are the stakeholders, who are the people that will be for example, receiving information, who will be giving information, who will be actually using this information for certain purposes. So all the stakeholders should be involved and should be identified in the enterprise view. Each of the stakeholders roles, and the relationship between each of the stakeholders should be clearly outlined. So that is the basic functionality of this enterprise view. And you can go that is what is shown here in each of these arrows.

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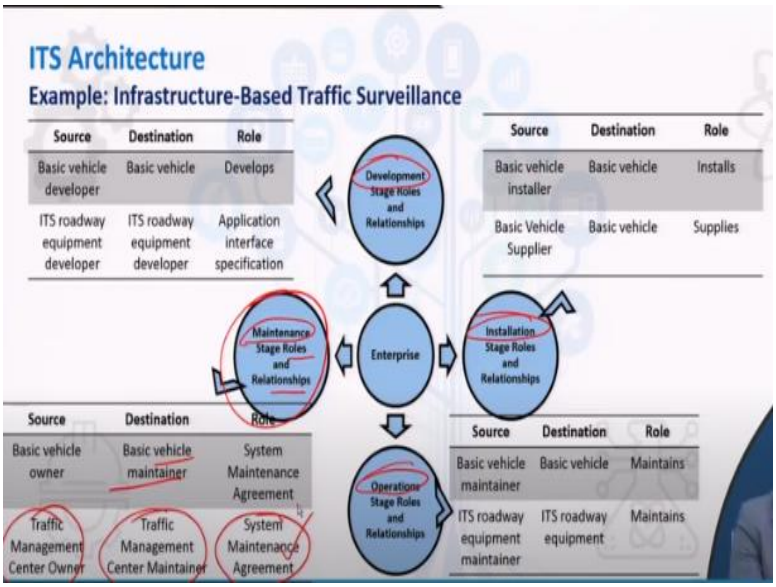

So for example, let us say that you want to you want to develop a maintenance system, which will automatically tell you when your roadway requires some maintenance. What you want to identify first is is the system's maintenance agreement that is currently in place. So for example, what is the rutting level after which you are going to do a routine maintenance? You have to first understand what the system maintenance agreement is. Who is going to do all this? The traffic management center maintenance. You have to you have to identify the person. For example, somebody at the TMC will have to be identified as the person who is in charge of maintenance and the traffic management center owner in itself is going to be the person who is going to be responsible for this. So at the TMC level, you have to have somebody who is going to monitor each and every roadway segment. Monitor the existing maintenance agreements and the existing conditions of the roadways and then this TMC owner has to then decide as to when and at what locations maintenance agreements have to be or maintenance has to be carried out. Such are the roles and responsibilities that has to be assigned at this enterprise level. So when we say roles

and responsibilities, this is what we actually mean. Such kind of roles and responsibilities can not only be assigned during the maintenance stage and it can be also assigned during the development stage, the installation stage and during the operation stage as well. If you want to deploy an ITS system for any one of these four stages, and you want to know what should constitute the enterprise view, this is an example of what should constitute the enterprise view. So this is just the first view that we are talking about, and this example gives you the enterprise view for any one of the four stages of a road development project for example.

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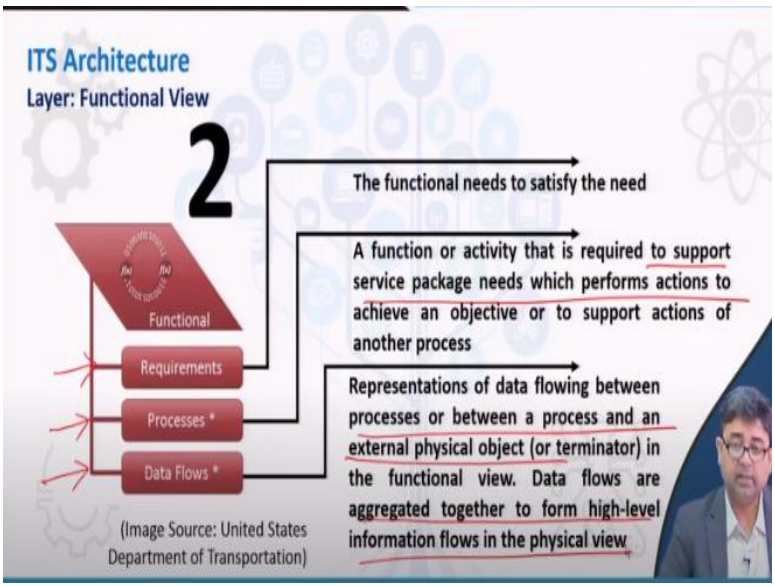

So now, if we move on to the next view, which is the functional view. So what the functional view tells you is three basic things. It tells you about the requirements. What are needed, say what is required in order to carry out the function that you want to carry out. We should outline, much defined processes in order to meet those requirements. The processes should be well defined, and also it should tell you about the data flows, where data should flow from between the system and subsystems. Could be unidirectional, bidirectional, so on and so forth. The functional needs to satisfy, the functional requirements in order to satisfy the need processes, or functional activity that is required to support the service package needs. And finally data flows flowing between processes or between a process and an external object in the functional view. So data flows are aggregated together to form high level information flows in the physical view. So you can in the physical view, aggregate the data flows for better understanding. I told you physical view is an easier view to

understand rather than the logical view, but you have to understand all of these. So let us again see an example of what do we mean when we when we tell you about the functional views.

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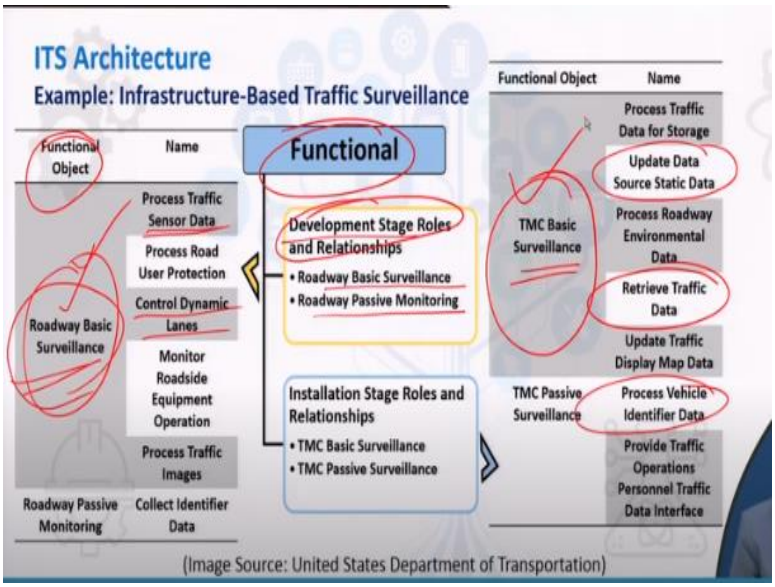

So for example, let us say that at the development stage, the roles and responsibilities would be roadway basic surveillance and roadway passive monitoring. So for these two types of roles and responsibilities at the development stage, what kind of functional objects would you need? When you say functional objects, so maybe you need a roadway basic surveillance object. You have to have sensor data that is going to tell you the volume of traffic that is going on a road. So for example, so you will need actually those different kinds of sensors. It is very easy to say that you will need the sensors, but these sensors should not only count maybe the number of vehicles that are moving, but also maybe they have to classify the vehicles into different types. Trucks, buses, cars, two wheelers. In case of India, we have so many different types of vehicles moving. So can they classify between different kinds of vehicles. For example, in the development stage, you want to know whether there will be a lot of heavy traffic on this road, whether there will be light traffic, whether there will be goods vehicle moving, a high proportion of goods vehicle moving or not. So all of this has to be understood. So for example, in your functional object called roadway basic surveillance, maybe you have to have sensor data, maybe you have to have control dynamic lanes, maybe there are specific lanes for heavy vehicles, like some of the roads in India, are being envisioned as truck only lanes. There will be lanes along

which there will be only trucks moving and nothing else. So can we have such kind of monitoring system that can that can happen? So these are all the functional objects. Again, for example, you can have at the TMC level. Now, this is at the roadway level, right. So similarly, you can have functional objects at the TMC level. TMC level, meaning the traffic management center level, you want to update the data from all these static sources that you are getting. You may be getting data from 100 different payment section locations. Then at the TMC level, you have to update that every 24 hours maybe, or whatever the protocol is. Once you update it you have to retrieve all the data. You have to make sense, by processing all the data. You have to analyze that data and everything happens at the TMC basic surveillance level. All the four views are interconnected with each other. Unless each of the views are performing their functions, roles and responsibilities, the entire IT system will not be functioning very smoothly. So you understand what is at the enterprise view. You understand what is at the functional view.

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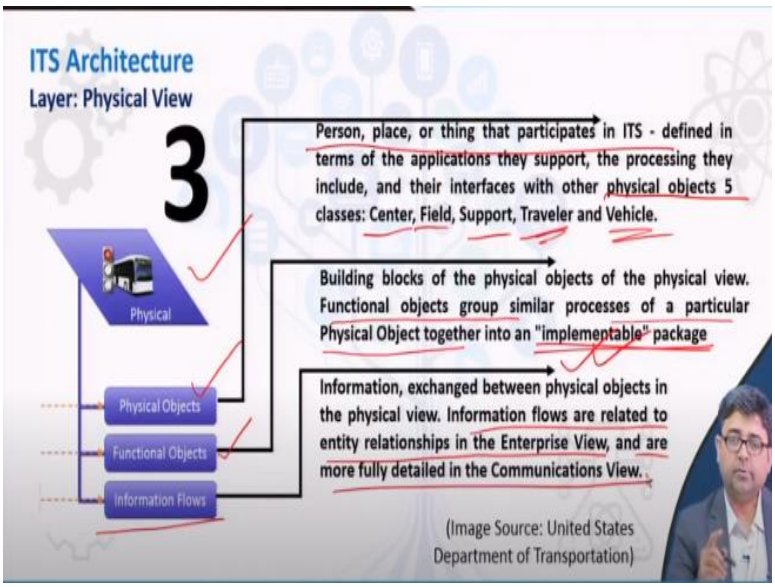

Now if you move on to the next view, which is the physical view. At this view, you would be able to identify the actual physical objects that are needed in the system in order to carry out all the functionalities and the in order to deliver all the roles and responsibilities that are outlined in the enterprise view. You will then have to identify also what are the functional objects, what is the difference between physical objects and functional objects. And then of course, the data flows that you have identified in the previous functional view. Now, you have to identify the information flows. So in the previous view maybe you have identified that data will flow from point A to point

B and not from point B back to point A. So now, in this view, you have to identify what information in that data flow should happen. Should there be information about the type of vehicle, the registration plate number, the weight, the age, or does it have to be only vehicle category type truck. That is the only information that is flowing. So that is the difference between data flow and information flow. Data flow is when, the data will flow from the vehicle to the roadside instrument and not from the roadside instrument back to the data. So that is kind of unidirectional data flow. Whereas what information is flowing is understood from the physical view. So physical objects are person, place or things that participates in ITS. Like we said it can be a TMC. The TMC is a physical object. It can be anything from the field. It can be the traveler themselves. It can be the vehicle itself. So there are different at least five different classes of physical objects. Building blocks or physical objects of the physical view. Functional object groups, similar processes or of a particular physical object together into an implementable package. So all these physical objects when they are grouped together into an implementable package that is called a functional view. So you will have different smaller physical objects. They have to be grouped together into a functional view, so that they offer a proper function and are implementable. And then of course, information has to be exchanged between objects of the physical view. And information flows are related to entity relationships in the enterprise view and are fully detailed in the communication view which is coming up next.

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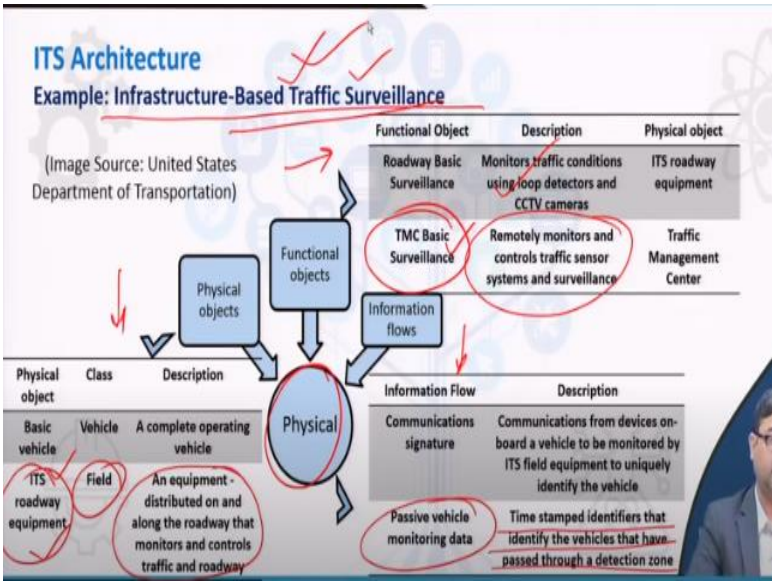

If you look at an example of an infrastructure based surveillance, traffic surveillance system. So what are all the different types of objects in the physical view, what are all

the different types of objects that you can see? You can see functional objects, you can see physical objects and also you can see information flows. First if you look at the physical objects for a traffic surveillance system, you have to have some kind of a roadway equipment which is in the field and this description is an equipment distributed on and along the roadway that monitors and controls traffic of the roadway. So this is an example of what are different types of physical objects considering an ITS roadway equipment. It may be a permanent counting station. It may be as simple as a traffic surveillance camera. It is a physical object in there. So then if you combine these different kinds of physical objects into a functional object, it brings you up to a TMC level. Now at the basic TMC level surveillance, it will remotely monitors and controls traffic sensor systems and surveillance. Now it can look at all different types of roadway equipment that are there and can perform a function. And the function that it can perform is it can either increase the green time for example at traffic signals, or reduce the red, all red phase and so on and so forth. So the basic thing to understand here is different physical objects constitute a functional object. And this functional, the basic premise of this functional object is that it is implementable. A collection of physical objects that are implementable is essentially what is called a functional object. And then, of course, information flows. In passive vehicle monitoring, data time stamped identifiers are used to identify that the vehicle have passed through a detection zone. So that is the only information that you are collecting. For example is the timestamps at which all of these vehicles are passing through that zone. So that is all the information flow that you need for your basic traffic surveillance system. So that is an example of the physical objects or the physical view, what you can see or what you can develop in a physical view of a system.

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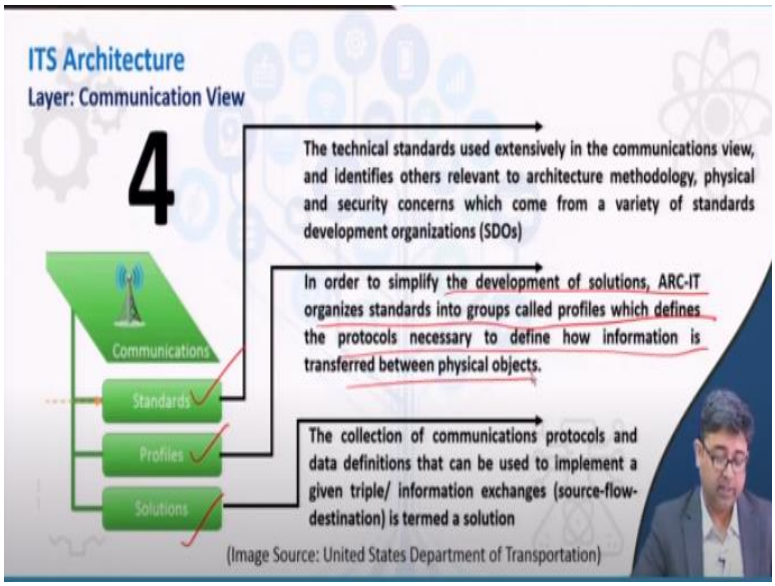

The final and the most essential view is the communication view, that tells you all the standards that are required for the different hardware and software systems involved in the ITS system, that you are trying to implement in the field. All the different types of user profiles and all the solutions or the package solutions that you are trying to provide. So in order to simplify the development of solutions, ARC-IT organizes standards into groups called profiles, which defines the protocols necessary to define how information is transferred between physical objects. So the communications layer is a very, for civil engineers or transportation engineers, it is a very difficult thing to understand at the first go. But once you look at the details of it, and really try to understand what type of or standards of communication system do you want to essentially use, that will really help you build your system. Maybe you need for your system, you need data only once a day. Once a day data is good enough for you. So you only invest in that type of communication system. Whereas you need data every second. Then you need to invest in a different type of communication system that will give you data every second. So the cost involved in building the system also changes based on your communication protocol that you want from your system that is in place or that is something that you wish to build.

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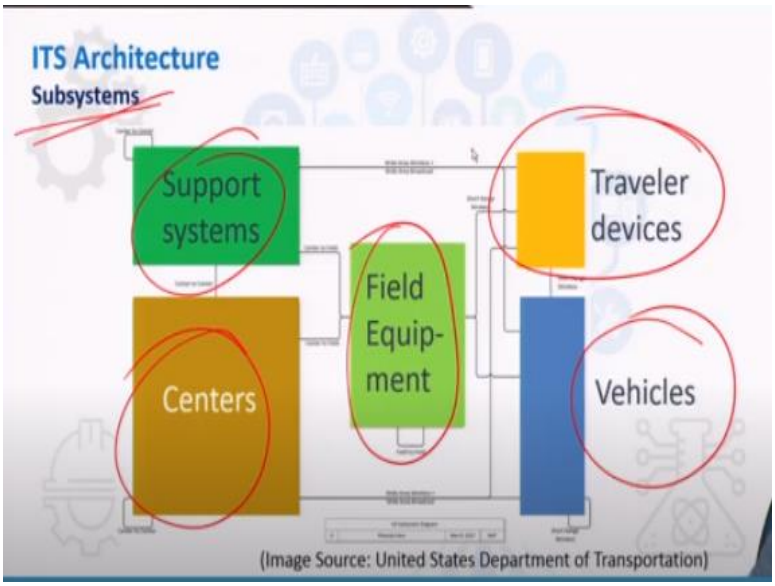

So all of these four things, all of these four views, all of these things can also be seen in the form of different subsystems if you want to see it in that in that manner. The subsystems, again like we said, consists of vehicles, centers, equipment in the field, some support systems, and obviously, the users' or the travelers' devices that are now available to you.

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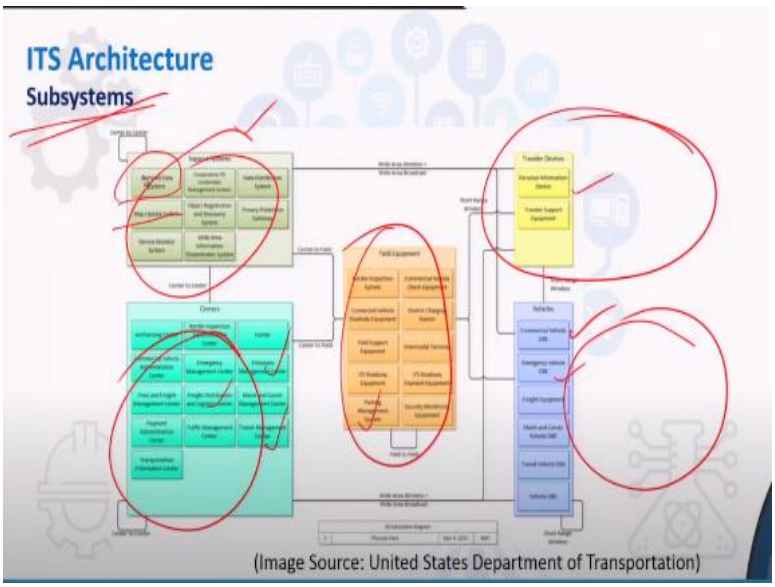

So again, if you are talking about the vehicles, you have your emergency onboard equipment, whereas if you are talking about traveler devices, you have your personal information device, your mobile phones or anything else, field equipment, you can have roadside equipment, parking management systems, all of those that are deployed in the field centers. We have already told you about TMCs. You can have emission

management centers. You can have freight distribution and logistics centers. Transit management centers happens in different cities that have large public transportation systems. And obviously, you need some support system for the centers for example, you need your maps to be updated for example. Maybe archive data has to be provided to you and so these centers have to be also supported by some other forms of data. And this is how you can look at the different subsystems in the ITS architecture.

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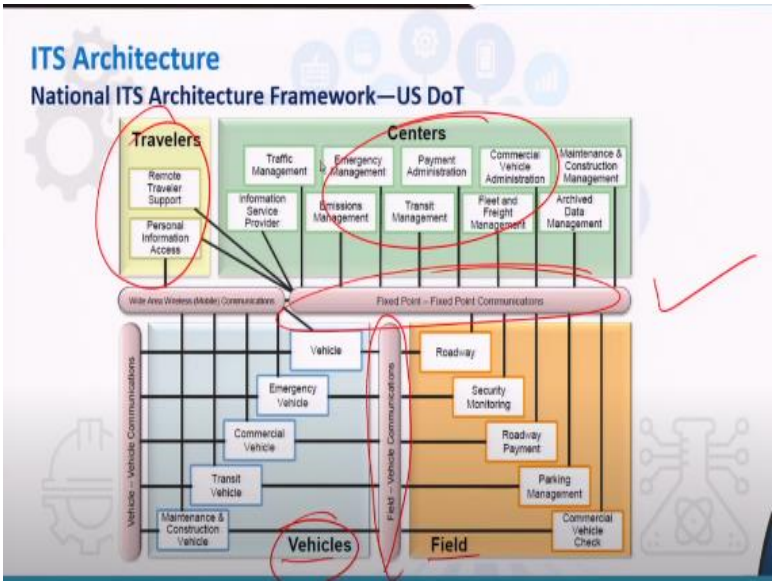

This is an older view of the same thing that we are trying to talk about here. It further shows you that what different types of communications can be used between these systems and subsystems. For example, between the vehicles and the field. What the different types of communications that are used. Fixed point communications can be used between the centers and the field. Similarly, the travelers can get information not only from the vehicles, but also from the centers themselves. The centers can directly send in information to the users via variable message signs or even through your FM radio in your car to a certain frequency, you can get direct traffic updates as well. So those are all coming from the centers. So this is overall view of how the ITS architecture looks like, what are the different elements involved, what are the data flows, and the communication channels between each of these subsystems and kind of gives you an overarching idea about what we are dealing with when we talk about ITS in or ICT in transportation, which is otherwise called intelligent transportation systems.

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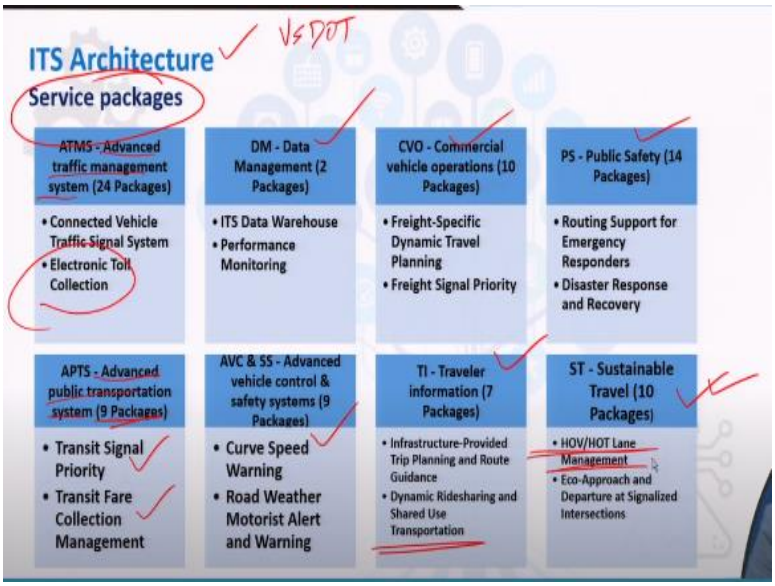

Now ITS has been there for about three decades now. It started way back in the early 90s in the United States. Then it moved to some of the other developed countries. So there are there are several packages that have been already developed. So when we call it a package, they are ready to use implementable packages that you can utilize and train for your own cities. So when we are talking about different service packages, one of them is the advanced traffic management system. (ATMS). ATMS for example, electronic toll collection, there are 24 different packages. We have already listed two here. Electronic toll collection package is already available. So there are different custom off the shelf system systems available. You can just implement it in your toll systems. There is advanced public transportation system packages, nine of them available. For example, there may be transit fare collection management systems, how can you electronically collect and manage your affairs that you receive from the users. If your transit requires priority at signalized intersections, how do you do that? So all of these service packages are already well defined and are in the ITS architecture that has been developed by the USDoT. So any of your cities could adopt or adapt that to your local conditions and start building your own package. Similarly, you can look at data management packages, commercial vehicle operation packages, public safety packages, advanced vehicle control and safety systems, traveler information packages, which is becoming more and more interesting with the ride sharing taking over in many of our cities. And also sustainable travel packages such as high occupancy vehicles (HOV) or high occupancy toll (HOT) lane

management and how do you reduce congestion on the road by the use of HOV or HOT lanes. There are different service packages that are used.

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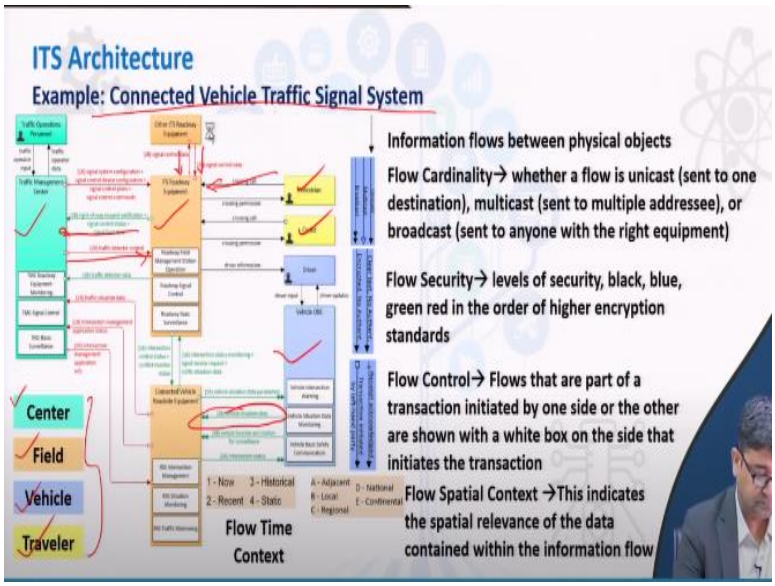

This is again a physical view of a system which is the connected vehicle traffic signal system. So if you are moving towards connected vehicles, meaning vehicle to vehicle information is being passed and you can almost drive without a driver or driverless vehicles. So how should a traffic signal in that case work? Otherwise, all these cars have drivers will break the traffic signal red. But now that the drivers are not driving and the vehicles are communicating amongst each other and to the traffic signal system. So in order for that system to be developed, how what all should you have in your ITS system. Standardized colors are used, so that it is easy for you to understand. Which function should happen at the center level, at the field level, at the vehicle level, and at the traveler level or the user level. So all of these things. Similarly, you will see that there are data flow arrows that are developed. All of these have certain meanings associated with it, which I am sure if you look into the reference packages, you will understand pretty well. Some are unidirectional in one way, some are green, unidirectional the other way. Some are black, whereas some are bidirectional both up and down. So just go through the reference materials. I understand this might be too overwhelming for a civil engineer or an urban planner to understand and start jumping into this entire ITS thing. But take it easy. Read as much as you understand. Try to take it slow. But if you really try to understand this, this will help you a lot in the future when you actually can then graduate from being only a civil engineer dealing with transport transportation systems rather than a transportation system expert who

knows both civil engineering transportation as well as the IT component as well. So take it easy, go slow, but do not lose focus. Do not think that this is not civil engineering and so we should not read this at all.

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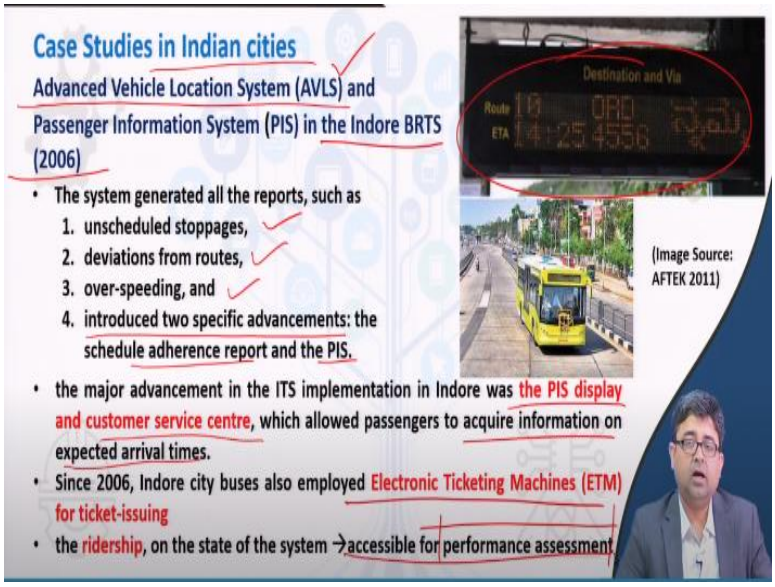

Let us look at some of the case studies in the Indian Indian cities that have implemented ITS. So for example, the Indore Bus Rapid Transit System has an ITS system deployed, which is called the advanced vehicle location system. So the system generates all reports such as unscheduled stoppages. So the bus is supposed to stop only at certain specific locations, bus stops or at signalized intersections. So if the bus makes unscheduled stoppages, this system can able to detect that deviation from route. It should move on a specific route. So if it deviates from the route, the system should has the capacity to capture that and then the driver is asked what the reason was. Again over speeding. The system knows the posted speed limit on the different routes or the different roads. The system can also read the onboard equipment on the bus. So it can correlate and understand when was the bus over speeding and then the again the driver would be questioned as to why there was over speeding. It is then introduced to specific advancements. The schedule adherence report and the Passenger Information System (PIS) is present to enhance the system. So that is what I was telling that you have to take these service packages that have been developed in other cities, but you have to tailor make it towards your own city and maybe also enhance it so that you can actually customize it for your own needs. So what they did was the PIS display at the Customer Service Center, which allowed passengers to acquire information on the expected arrival times. So this is kind of a PIS display that

was put in the bus stops based on the vehicle location. So based on the location of the bus, one would update that PIS so that the passengers waiting at the bus stop can get that information. Maybe that information could now be also provided via an app so that if you are at your home and you can then calculate the time that you have to leave in order to catch the next bus. So that is something that can be thought about. Also they employed electronic ticketing machine for ticket reissuing and the ridership of the current state is accessible for performance assessment. So all that ITS system does is it gives you the mechanism to assess the performance of the system. Now you have a large amount of data about all the workings of the system. So you can assess how well the system is functioning and make adjustments where the system may not be functioning well in order to improve its functions.

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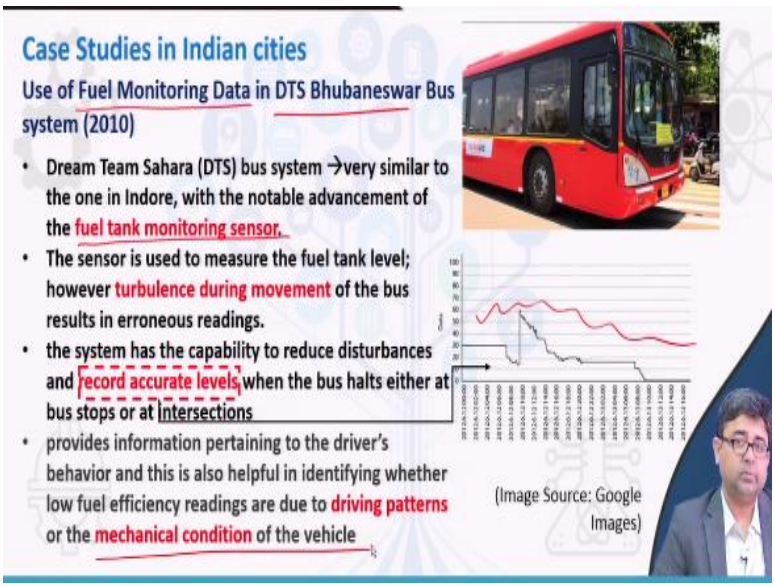

The other interesting ITS system that has been deployed is in Bhubaneswar, where a fuel monitoring data system has been deployed on the buses. So fuel tank monitoring sensors have been have been deployed, which continuously measures how fuel is been used by the individual buses. This gives an idea about whether congestion really affects the fuel usage of the buses or not. Based on that, there might be recommendations on to whether to alter the bus routes slightly in order to improve the fuel efficiency and so on and so forth. So this system has been very helpful. And it also helps you understand the mechanical condition of the vehicle as well. Maybe based on the mechanical condition, the fuel usage varies as well. Maybe schedule maintenance was not performed. Maybe the tire pressure was not significant. So all that contributes to fuel usage or fuel efficiency of the bus. So by having sensors that

measures the fuel tank or monitors the fuel tanks, this was made possible in Bhubaneswar.

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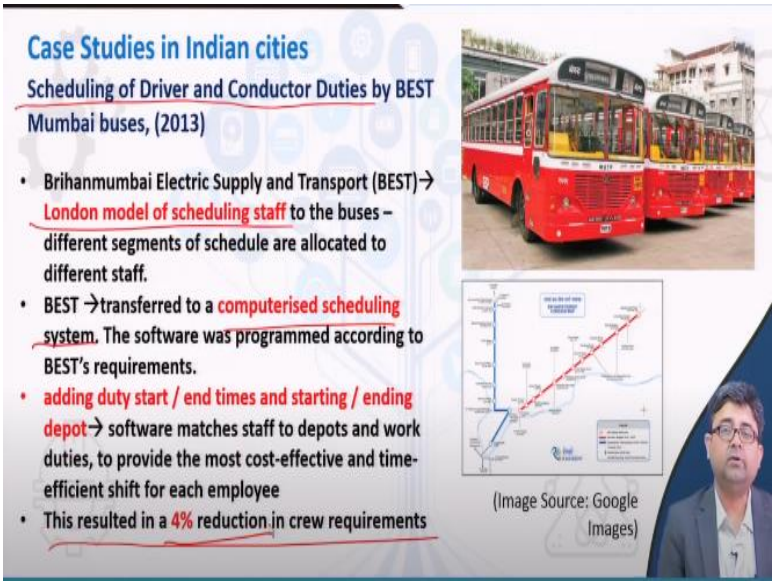

The last one that we are going to tell you today here is about the scheduling of driver and conductor duties by BEST in Mumbai. So Mumbai has several bus routes and you may be able to comprehend how complex it will be to schedule so many different drivers and conductors schedules on these buses. They have developed an ITS system through which you can easily schedule these the driver's and the conductor's routes. When do they arrive, at which location? How many routes do they work on per day? Which day do they take which route so on and so forth. All these computerized scheduling system was developed by BEST. Of course, it was based on the London model of scheduling staff of the buses. But again, it took that service package from London, adapted it to the Mumbai situation. And this has resulted in a 4% reduction in crew requirement. Maybe we thought that more and more crew is needed to run these buses. But a proper adherence to schedules actually saw that a 4% reduction in crew requirements was good enough to run an efficient system. So these are different types of systems that are actually in place in India as well, but we never look at it from the point of view of transportation. We always look at it from the point of view of being tech savvy or something some other sense.

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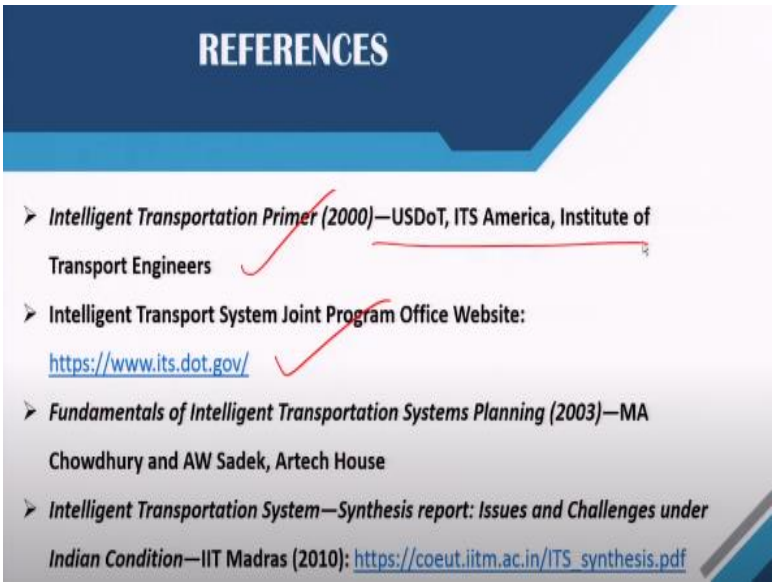

But if you look at it from the point of view of transportation, you would actually understand that all of these systems are finally leading towards improved efficiency and improved safety of our systems. So these are some of the reference materials that I have been telling you about. Please do look at them very carefully. The websites are very self-explanatory. And you should be able to follow them step by step in order to understand, get an understanding of what ITS systems are really about. Many of them are based in the US, but hopefully we will also bring about our own manual pretty soon.

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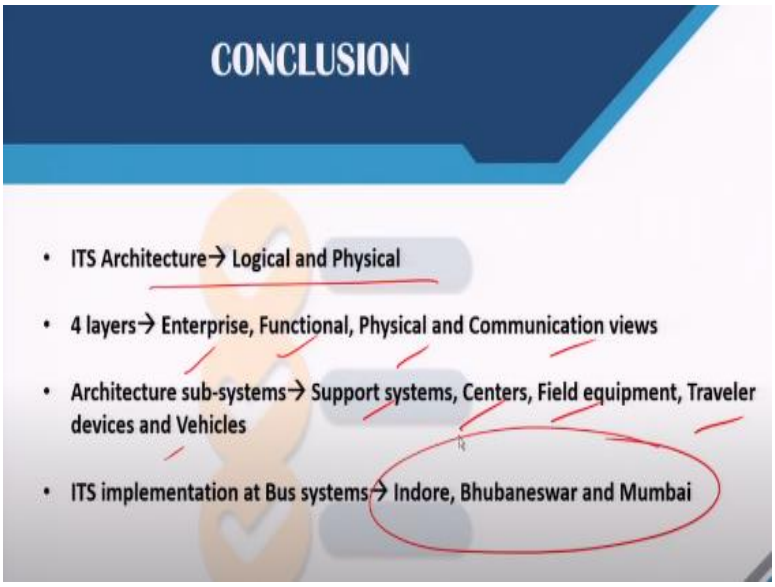

So in conclusion, what we looked at today were different types of ITS elements in ITS architecture, logical and physical. We looked at the different layers; enterprise, functional, physical and communication view. And then looked at different types of subsystems; field, field equipment, center, travelers, and support systems and gave you some understanding about how these systems work in some of the cities in India. Thank you.