E-Business.
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Lecture-41.
GPS and GIS in Supply Chain.

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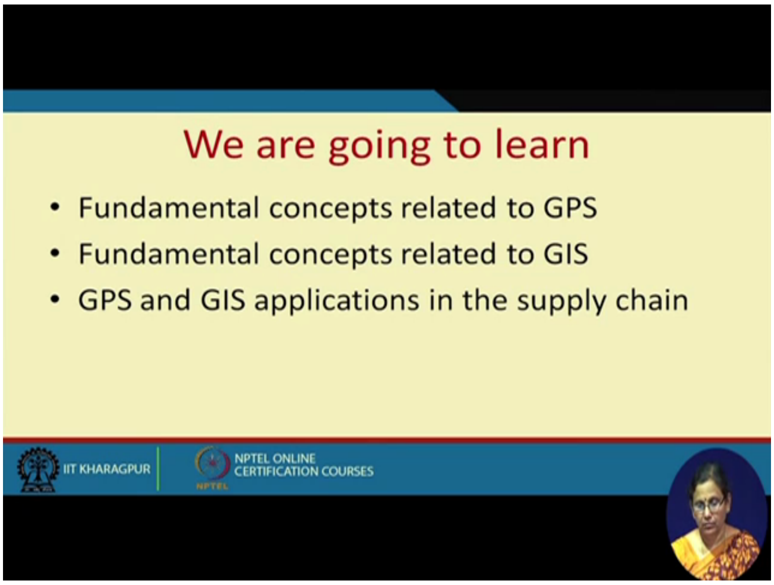

Welcome back, now in this part of the lecture we are going to learn about the technologies which can track your supply chain beyond the RFID capable areas. By RFID capable area we mean the area which is under, which is covered under the RFID reader. And we know that we really cannot track the items through this technology once it is out of the masses of a stakeholder like that of the manufacturer or the warehouse owner or the retailer. Now what happens to the item as they are out of their premises, let us say premises of the warehouse and moves along the he road.

Why road, it may be going through other mediums as well, the transport network. But as they move along the transport network, how exactly you are going to track your cargo, the corresponding technologies are your global positioning technologies and allied ones.

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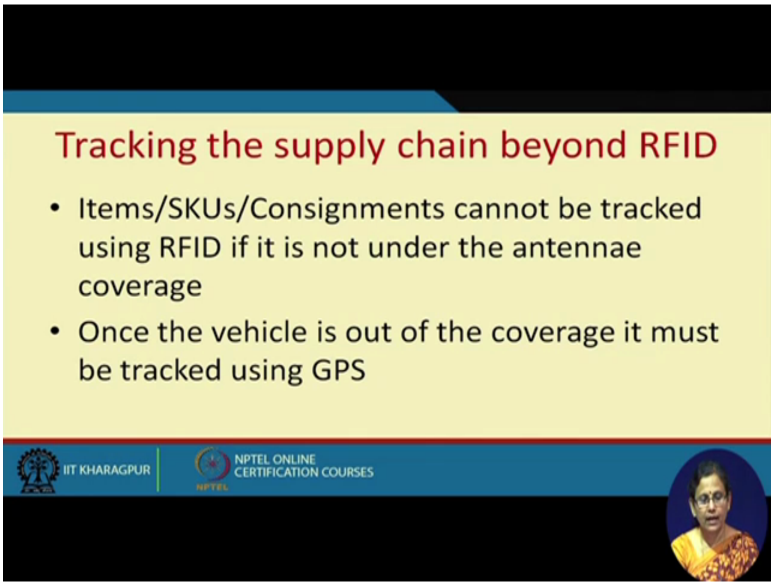

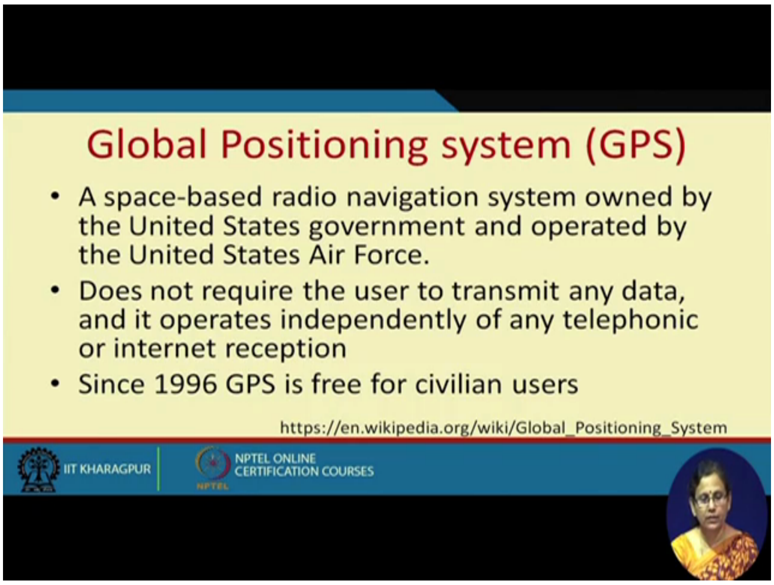

Now this is what I was telling you, once the items, SKUs and consignments out of this RFID antenna coverage, they cannot be tracked. So therefore those vehicles are to be tracked now by GPS. Now what is this GPS, this global positioning system, this is, of course all of our mobiles now have this GPS. When the book a cab, we know that position of the cab can be traced back, you can track the vehicle and you can book the vehicle and so on. Let us have little bit overview of this global positioning system. It is a space-based radio navigation system owned by the United States government and operated by the United States Air Force.

It does not require the user to transmit any data, like that of RFID, and it operates independently of any telephonic or Internet reception. Though originally it was made for military uses, now it is for civilian use. Here I would like to mention one thing as well, though we are talking about this GPS from the United States government, in fact other countries like European Union have their own GPS-like system, India also is coming up maybe in 2-3 years time it may also become commercialised. But right now whatever we are talking, it is about that United States government global positioning system.

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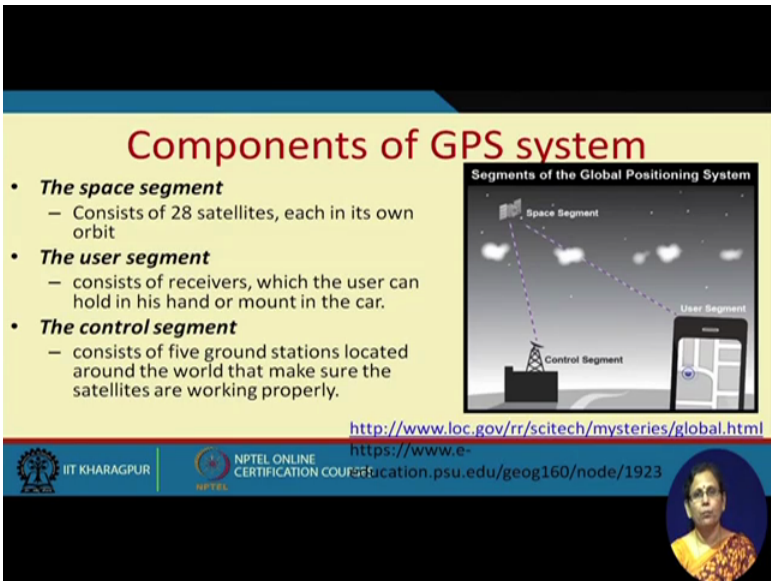

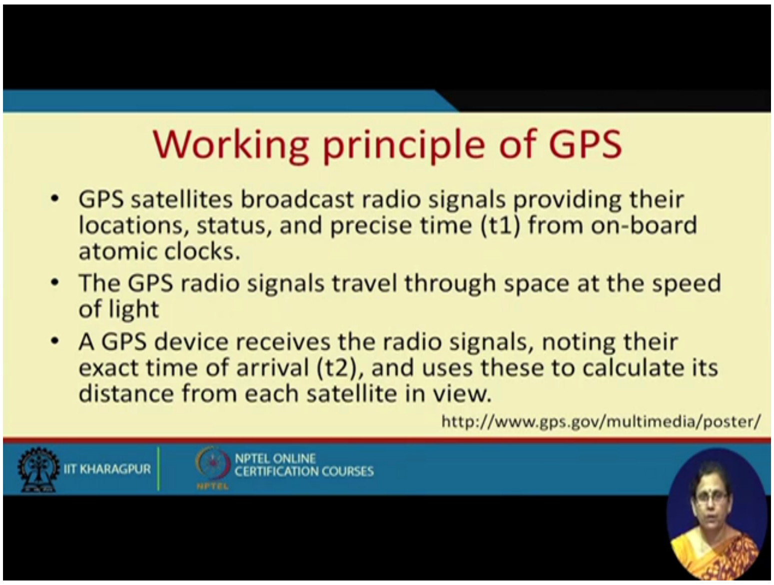

Now these are the typical components of GPS. It has 3 major components a space management component, the user segment and the control segment. The space management segment is basically a set of satellites which move around the Earth, user segment is the device, your mobile or the GPS device you put in your vehicle, those are the user segments and in order to control this space segment, to see that whether these satellites are working fine or not and instructing the satellites, you have this control segment. So this control segment consists of 5 ground stations located around the world that make sure that the satellites are working properly.

Now in order to, look, when you are using a GPS device, let us say your mobile phone, from the mobile phone or from the vehicle mount, the interface mounted on the car, you know the location of the entity who is carrying the device. So which means the device has some kind of facility to get the data from the space segment and calculate its own position. So this is how the GPS works, the GPS satellites broadcast radio signals providing their locations, whose locations, GPS's locations, status and precise time T1 from on-board atomic clocks which are there, which are mounted on the satellites.

Now this GPS radio, GPS radio signals travel through the space at the speed of light. A GPS device receives the radio signal and noting their exact time of arrival, it uses the signal to calculate its distance from the satellite in view.

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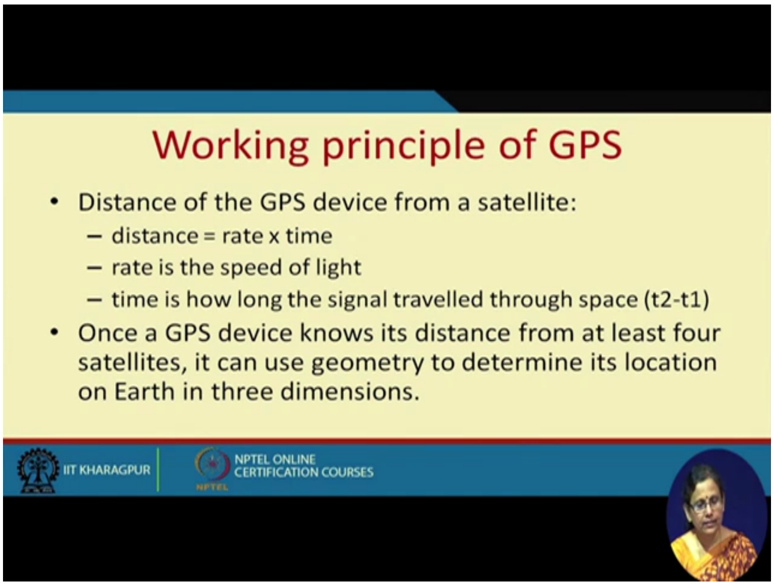

In fact after getting this, this is a sub generic of calculating that distance of the GPS device from the satellite, once it knows its position from 3 satellites, in a two-dimensional plane it knows its position on the earth. Once it is, it gets the data from 4 satellites, it knows its position not only in two-dimensional, latitude and longitude, also its height. In fact it uses a principle called triangulation to calculate this, calculate the position. But anyway that is we are not going to discuss about that. In fact to remind you while talking about the RFID location problem of locating a particular item inside a warehouse, I was talking about the same principle of triangulation.

You need in order to locate a particular SKU which is attached with the RFID tag, you need information from at least 3 antennae. Or to know its height, at what level of , at what rack of the item is placed, you need the signal from 4 antennas and using the same principle of triangulation that is used here, in case of GPS, you can calculate the position. In fact in warehouse management systems, it is not done in the similar way, in fact all the IDs, etc., they will be, their position at centre will be associated with the database and accordingly using some other method the positions are determined.

But this is again another way of determining the position using the principle of triangulation. And anyway, let us come back to GPS again. Now, once the GPS device knows its distance from at least 4 satellites, it can use the geometry that I was talking about the principle of trying relation to determine the location on the Earth in 3 dimensions.

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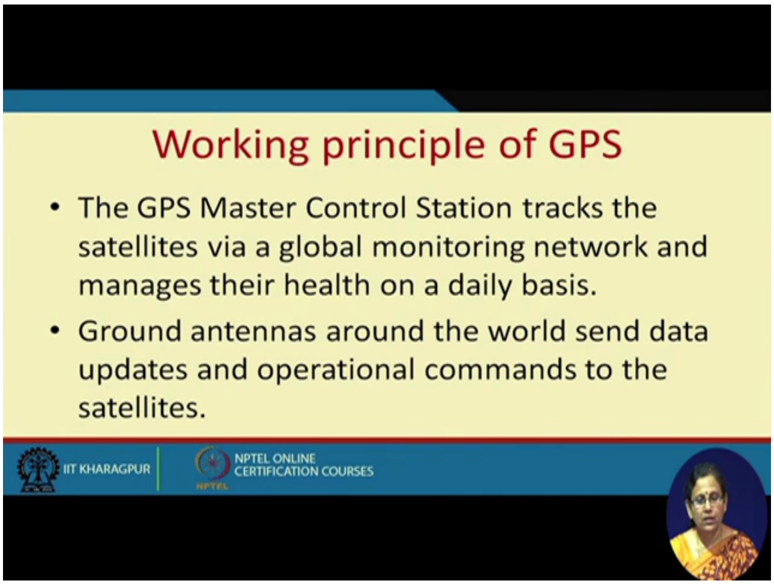

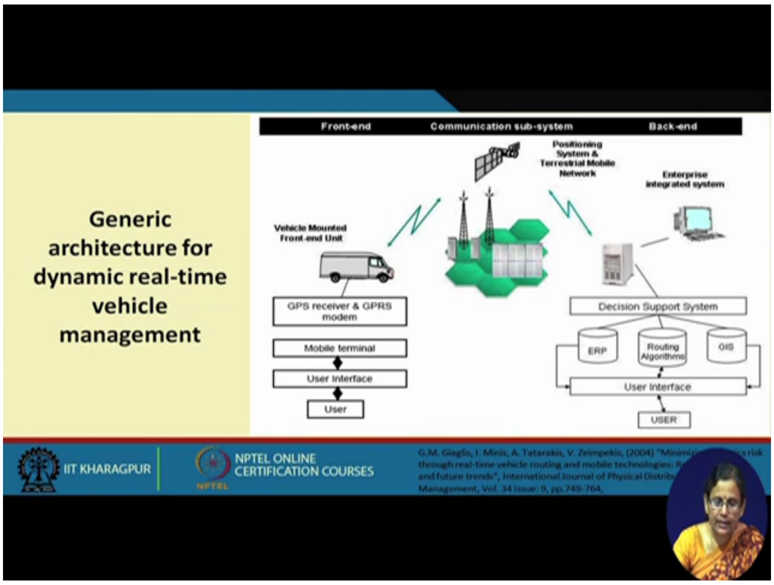

Then GPS Master Control Stations track the satellite via a global monitoring network and manage their health on a daily basis. Now ground antennas around the world send the data updates and operational commands to the satellites. Now, if you would like to use GPS for vehicle management system, for tracking your consignment, your logistics, for your logistics operation if you would like to use it, if you would like to use it, the situation is a bit different. Different in the sense, your, you will be definitely as the, if the GPS device is mounted on a truck which is carrying your items, the truck itself knows its position.

But if you would like to instruct the truck about something, this is not that way, you need the location of this truck back, as I was telling only the driver of this vehicle or the people sitting on this vehicle through the GPS device know their own position. Now the question is if you would like to give an instruction to the vehicle, the driver sitting in the vehicle, what would you do? You need to get the location data of the vehicle, GPS will not be giving you that data.

So what do you do? You have to attach some kind of GPRS Modem in the vehicle itself and that will be transmitting its own position and through the mobile network you should be getting it in your server. Now once you have this data you can run any kind of decision support module to provide instruction to the vehicle driver and send it back through this mobile network back to the driver. Driver through its user interface mounted on the vehicle will be knowing these instructions and work accordingly, we will be knowing details little bit later.

However, while making decisions at this end about the driver’s position and giving him further instructions, you may require another piece of software where you will be shown the position of the vehicle and that software should be able to give you, provide you the data access about the location details as well as help you in decision-making. So that software is called GIS, geographical information system.

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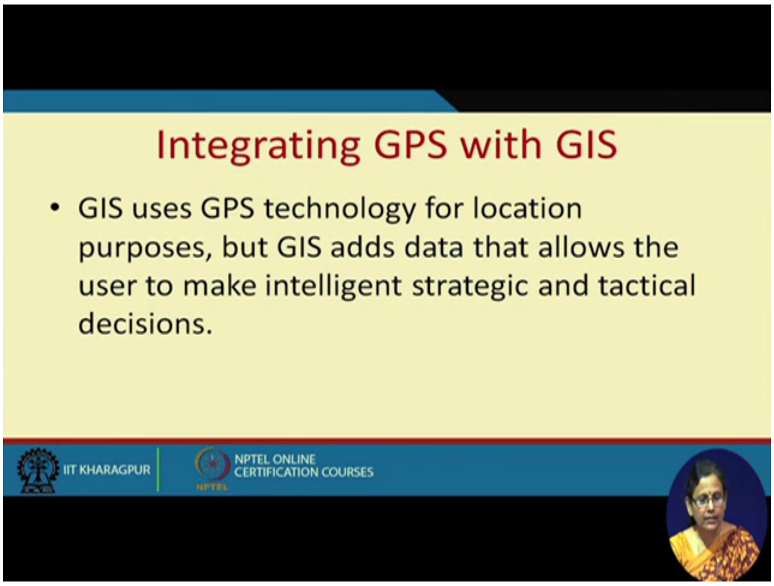

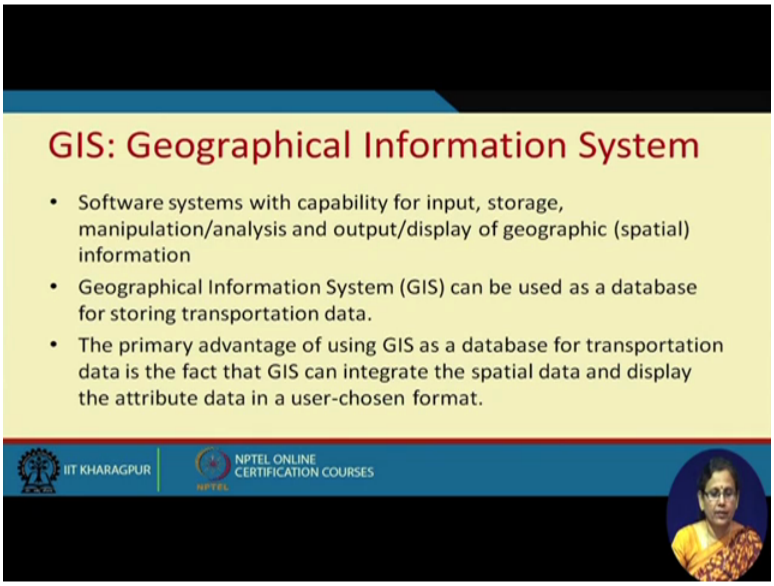

This GIS uses GPS technology for location purpose, but GIS adds data that allows the user to make intelligent and strategic , intelligent, strategic and tactical decisions. Now what is this geographical information system, these are software systems with capability for input, storage and manipulation and output of geographical spatial information. This geographic information system can be used as a database for storing the transportation data as well which helps in that fleet management. Then the primary advantage of using GIS as a database for transportation data is the fact that GIS can integrate the spatial data and display the attribute data in a user chosen format.

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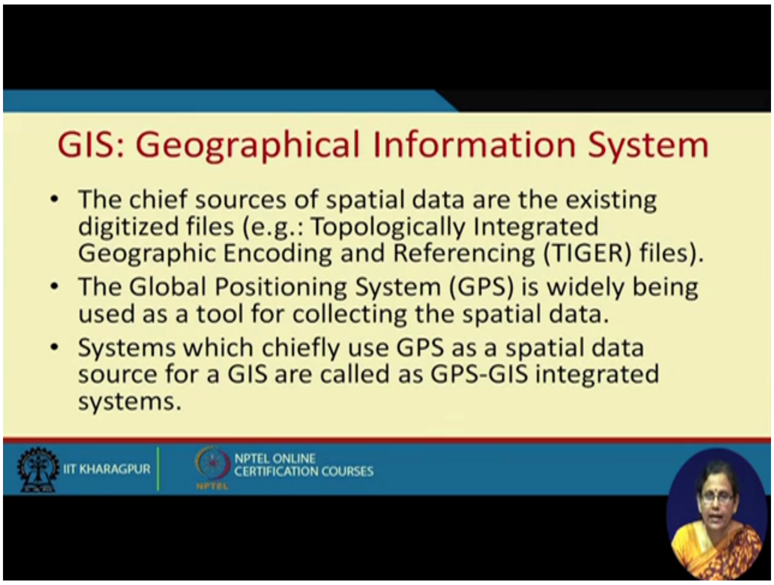

And in fact you can also integrate, you can get this data and combine it with that of your enterprise data to take better decisions. So in this GIS file, the data, it has its layered architecture, in various layers it stores the data about the spatial information and these coded files are called Topologically Integrated Geographic Encoding and Referencing (TIGER) files. Now this GPS is widely used for collecting this spatial data. Now the systems which chiefly use GPS error spatial data source for a GIS are called GPS-GIS integrated systems.

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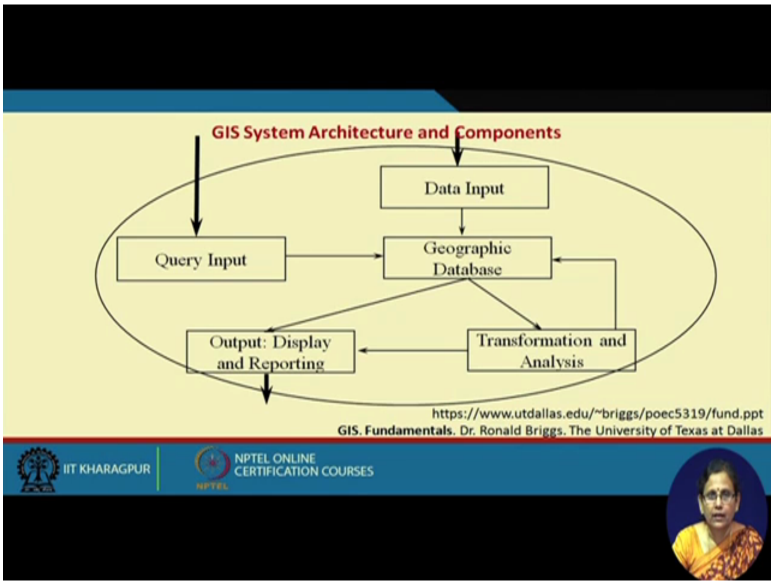

So for tracking the vehicles, tracking the consignments across the supply chain, beyond the coverage of RFID, the systems that are used are GPS-GIS integrated systems. So this GIS system, this is a schematic diagram of GIS whether data input comes from GPS and stored in the geographic database, then it can help in answering the queries of the user and generating reports and it has capability, some capability of transforming and analysis of the data.

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There are many applications of GPS-GIS integrated system in automobiles, airlines, agriculture, sports, law enforcement and so on. Out of this today we are going to look at one of the applications in little bit more detail like how, along with this data decision support can be attached to take certain, to help in taking, to help taking in certain business decisions. Now look at a typical vehicle routing problem, we are going to discuss about a dynamic vehicle routing problem and its data source which is which is coming from this GPS-GIS integrated system.

Before that let us 1st understand what is vehicle routing problem is. Look at this, we have a depot and we have many customers, now the question is what is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers, should we use one vehicle or more vehicles and once we decide the number of vehicles, how exactly we should be , we should instruct the vehicle to move around so that with minimum, minimal transportation cost all the customers are covered.

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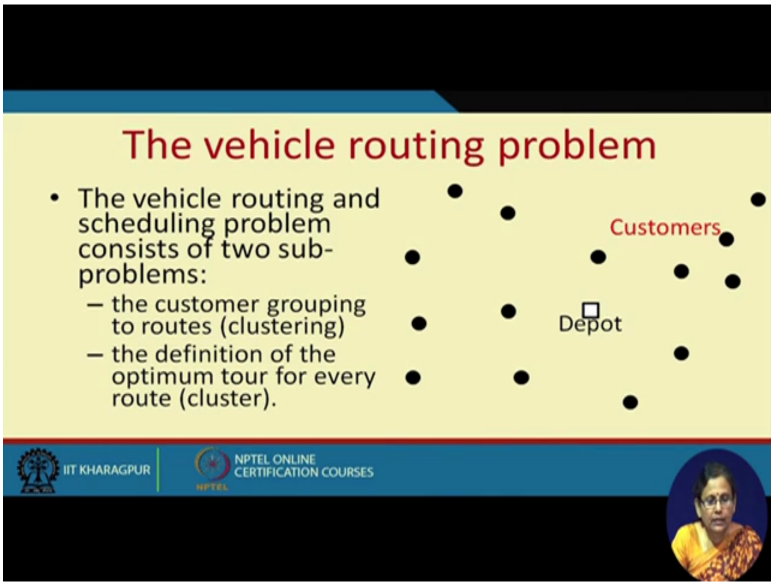

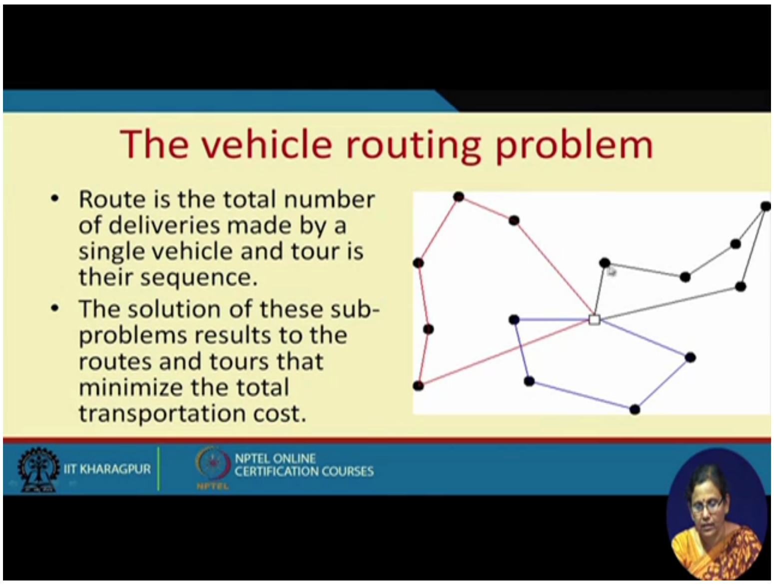

Now this vehicle routing and scheduling problem consists of 2 sub problems. 1st, depending on the number of vehicles to group the customers so that they are close enough. So 1st you have to cluster the customers and 2nd is within the cluster you have to define the optimal route to cover all the entities. Now look at this, suppose we have certain algorithm to solve this problem, the diagram that we were showing already, suppose for this one, you have now 3, now require, it appears that you require 3 vehicles and this is the optimum path data, to start from the depot and follow this path and comeback.

Start from the depot, follow this path and comeback and so on. The route is, here the route with the total number of deliveries made by a single vehicle and tour is their sequence. The solution to these problems results in the routes and tours that minimise the total transportation cost.

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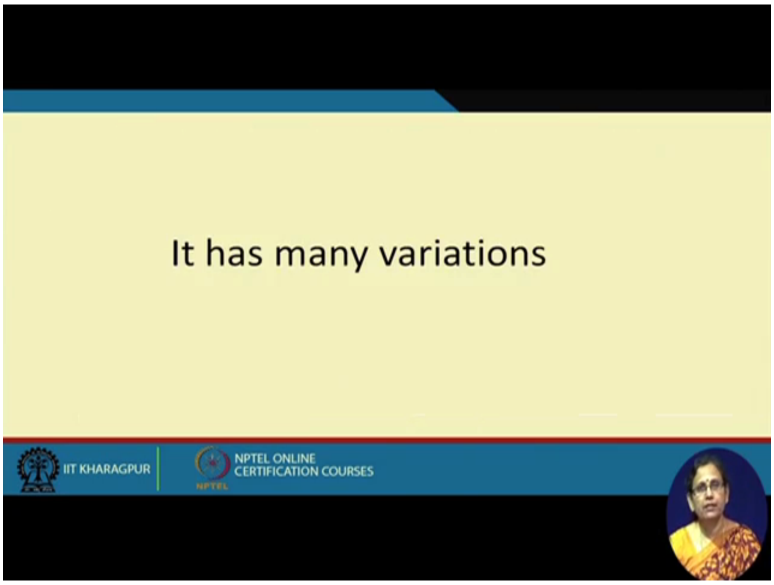
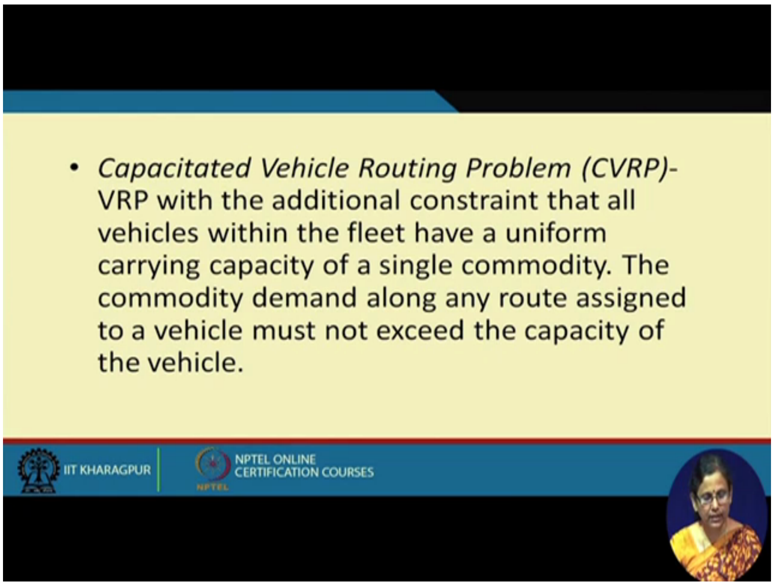
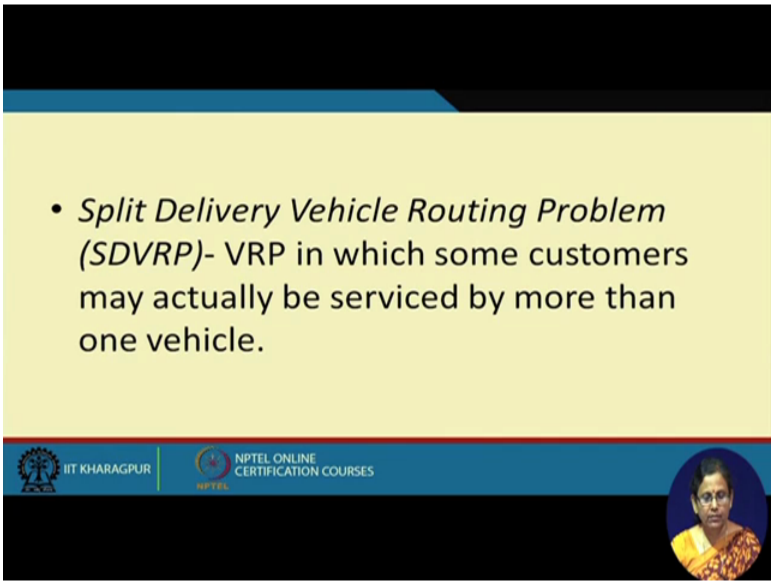


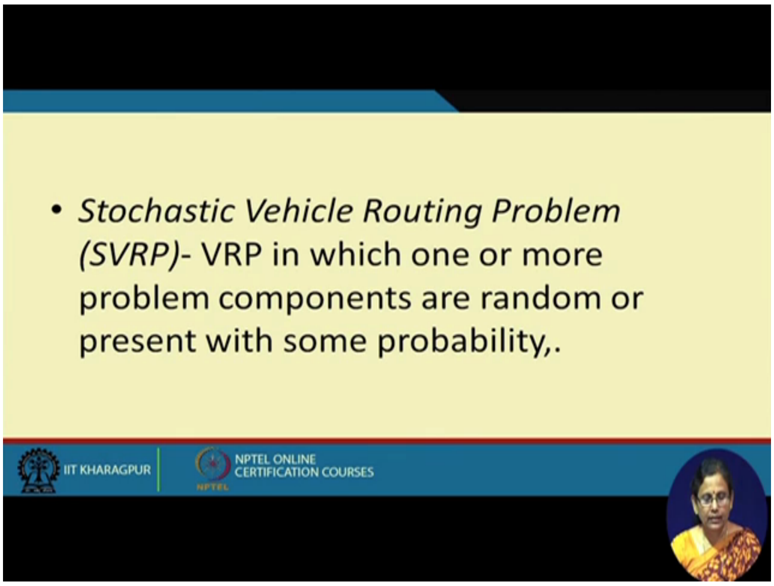


- *Capacitated Vehicle Routing Problem with Time Windows (CVRPTW)*- VRP that includes both vehicle capacities and time windows (hybrid version of the CVRP and the VRPTW).

- *Multiple Depot Vehicle Routing Problem (MDVRP)*- VRP with multiple depots and vehicle fleets. All stops must be assigned to a single depot/fleet in order to minimize service costs.

- *Periodic Vehicle Routing Problem (PVRP)*- VRP that allows service to be extended over *M* days, instead of single-day service.





This particular problem has many variations, it may have additional constraints that all the vehicles within the fleet has any form carry capacity of a single commodity and it is for single commodity. It may be additional constraints that the customers or stop has an associated fixed time interval during which pickups and deliveries must be made. It can be a capacitated vehicle routing problem that includes both vehicle capacity and the time window. It can be a VRP with multiple depots and vehicle fleets. Periodic vehicle routing problem that allows service to be extended beyond M days instead of single day service.

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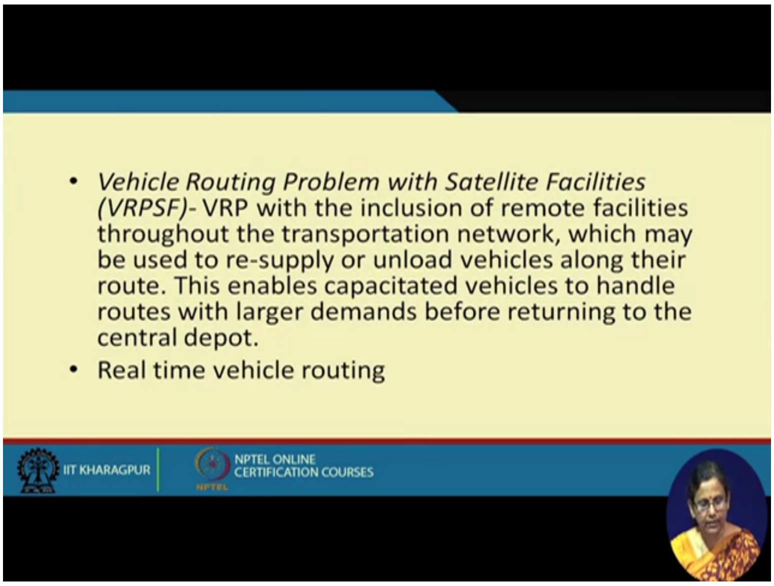

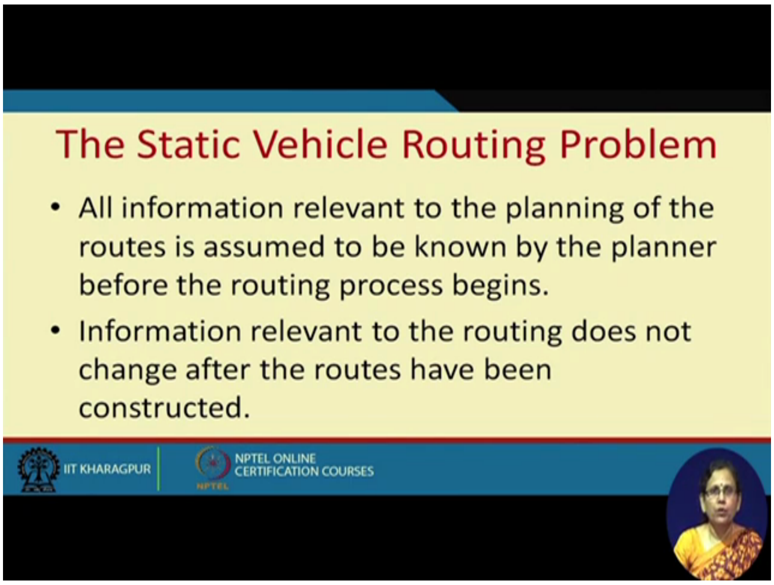

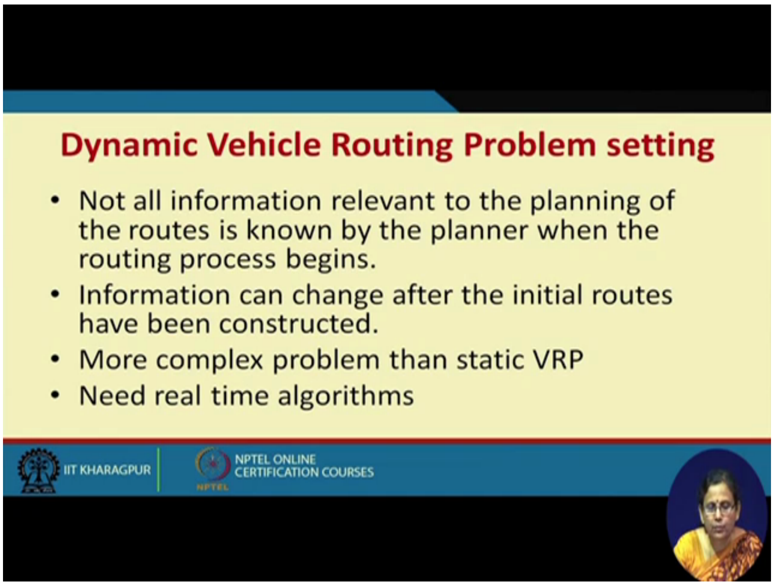

Split vehicle routing problem in which some customers may actually be serviced by more than one vehicle. It can be stochastic vehicle routing problem in which more, one or more problem components are random and present with some probability. It can be vehicle routing problem with satellite facility where the transportation network may be remotely monitored, real-time vehicles it can be called. Now again in a broad classification, these vehicle routing problems, all these vehicle routing problems, either it can be a static vehicle routing problem or it can be a dynamic vehicle routing problem.

The static vehicle routing problem is the one where all information relevant to the planning of the routes is assumed to be known by the planner before the routing process begins. Now information relevant to the routing does not change after the routes have been constructed. But in fact in reality this is hardly the case. So we have the dynamic vehicle routing problem, where not all the information relevant to the planning of the routes is known by the planner when the routing process begins.

The information can change after the initial routes have been constructed. More complex, it is a, see as such vehicle routing problem is a very, is a combinatorial problem, it is a NPR problem, it is a combinatorial and NPR problem, and anyway we are not going to discuss any algorithm details of that but NPR problems are very complex problems. And as the size of the problem grow, here the size, in this context the size is number of customers, or number of vehicles as well, as they grow, the problems become more complex.

The time increases, solving the problem increases exponentially in fact. Now, this dynamic vehicle routing problems are even more complex than that of static VRP and they need real-time algorithm, by means, by means of real-time algorithm we mean the algorithm which are, which solves the problem within a short time in a reasonable way, they cannot be giving you the optimal solution as getting the optimal solution itself requires a lot of time. But they will be solving in a quite reasonable way so that within a specific time they can get the result and effectively instruct the corresponding vehicle for any additional, except for any additional details.

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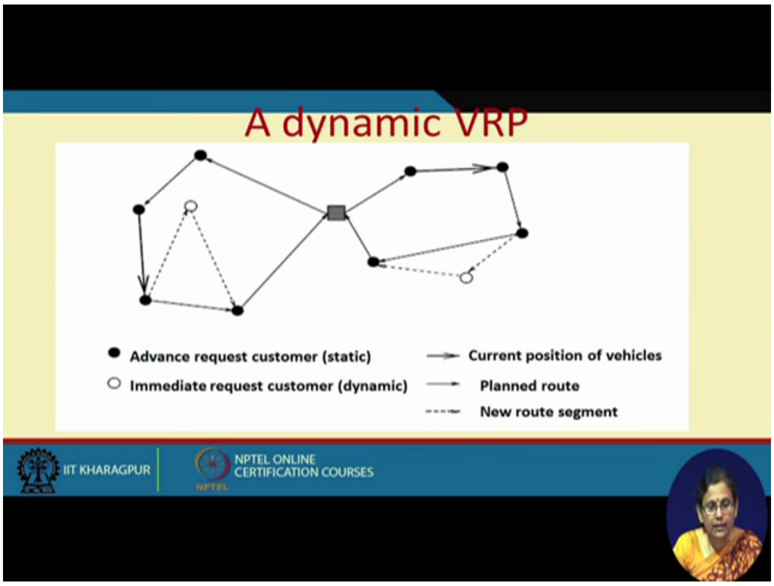

So in a vehicle routing problem, let us again we have the depot and the customers. There are some static customers whose demand is already known but in between some dynamic customers also come in who immediately request and their request is important enough to be resolved immediately as well as if it is resolved, it also decreases your cost. So depending on the current position of the vehicle it need to be now instructed. In fact you can see it is quite analogous with the with the material equipment movement that we were discussing with their warehouse management system in one of the earlier lectures.

In fact core of all this is your travelling salesman problem which is about covering the nodes with minimum time in the right sequence so that you do not unnecessarily repeat any path. So these are some real-life examples of dynamic vehicle routing problem. Dynamic fleet management where, here the situation means several large-scale trucking operations require real-time despatching of vehicles for the purpose of collecting or delivering sequences. This is important, savings can be achieved by optimising these operations.

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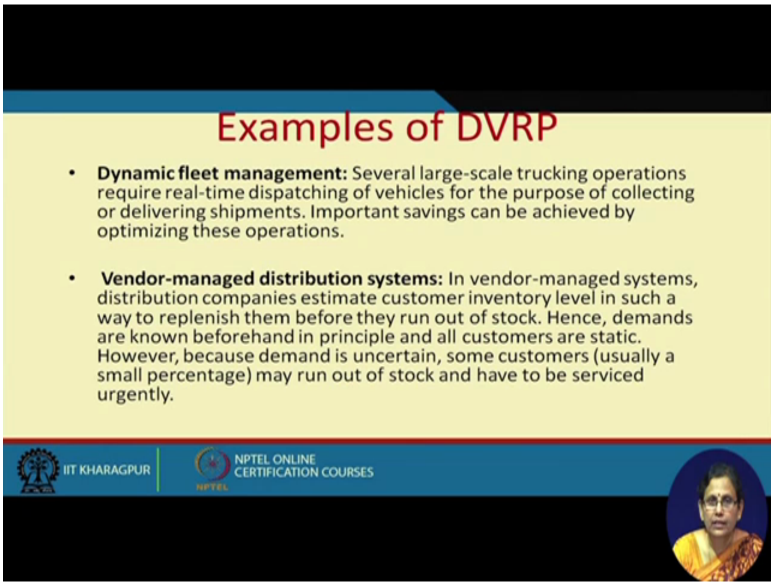

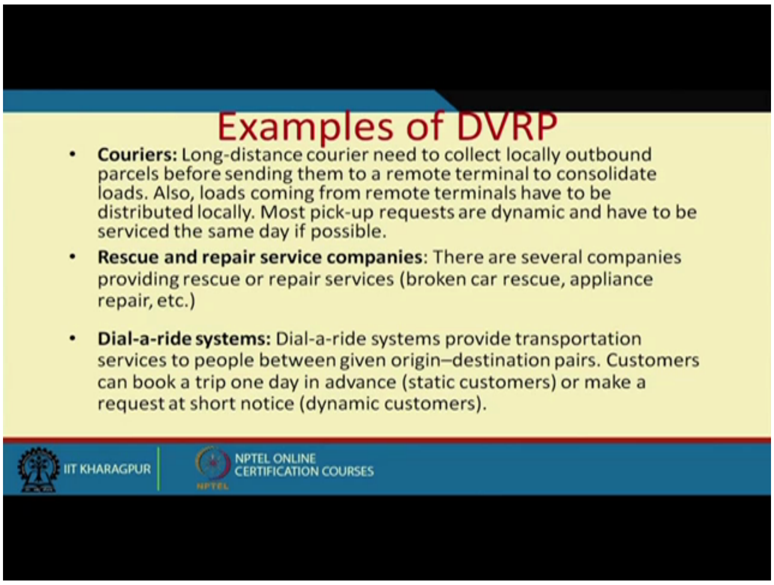

Then is your vendor management distribution system. In fact in vendor managed inventory systems we have already discussed in one of the earlier classes. In vendor managed system, the distribution companies estimate customer inventory level in which in level in which, in such a way to replenish them before they run out of stock. Hence, demands are known beforehand in principal and all customers are static. However because the demand is uncertain, some customers, may be a small percentage, can run out of stock and have to be serviced urgently because it is the responsibility of the supply to replenish the inventory.

So in that case the supplier, the supplier's truck which is already carrying some items from some other retailers can be instructed, in fact should be instructed to to immediately fulfil the demand for the retailer buy the stock is , I mean where there is immediate need of stock replacement. There are more examples of DVRP as well. Courier services, this long-distance courier needs to collect the locally outbound parcels before sending them to remote terminals to consolidate. Also the loads coming from the remote terminals have to be distributed locally. Most pickup requests are dynamic and have to be serviced at the same day if possible.

Then rescue and repair companies, there are several companies providing rescue and repair services like broken car, etc. and they get their requests in real-time. Dial-A-ride systems like your booking taxi etc., they can provide transportation services to people between given origin-destination pair. The customers can book a trip one day advance or make a request at a short notice. In fact we have seen while booking online these taxes, we find out the, we can actually on the map see, on the map we can see which is the nearby taxi and we can call it, we can book it. So this is also an example of a dynamic vehicle routing problem.

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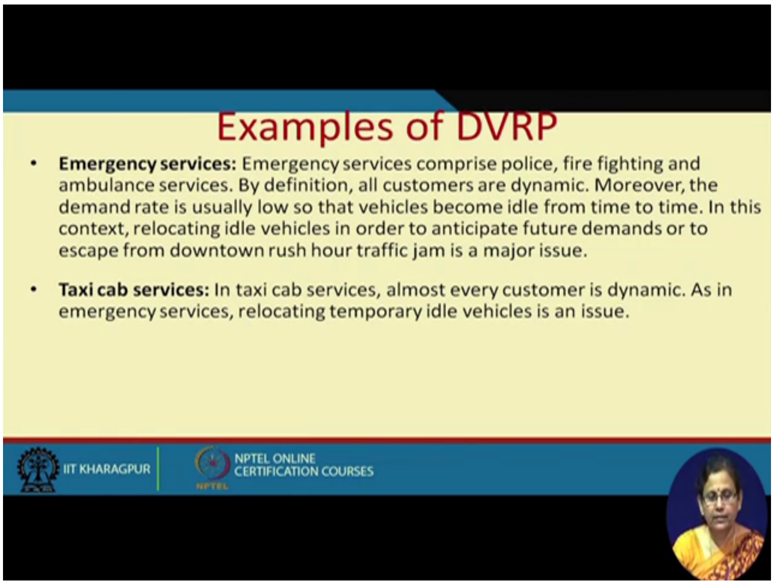

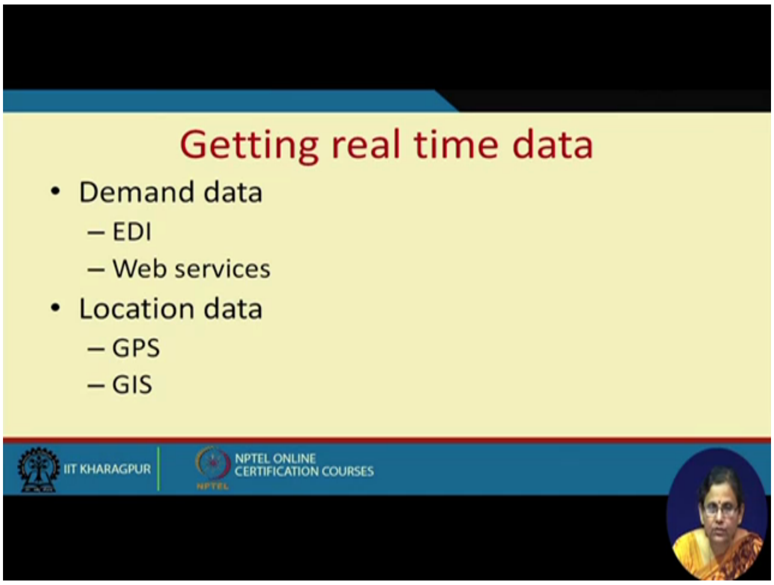

Emergency services which comprises of police, fire fighting, ambulance services, etc. they also belong to this category, including the Tab and cab services. Now solving this, we have been discussing so far about the vehicle routing problem, then dynamic vehicle routing problem. Okay, it is a problem and it needs a solution and that solution should give you optimal or at least near optimal solution so that your total transportation costs and other stocks are, your cost is basically minimised.

Now if in such systems invariably there are 2 data sources, 1st the location data which comes from GPS and the network that we saw, and the 2nd is the demand data. Consider about the vendor managed inventory system, the demand data will be coming from the interface system which collect the data , which connects to the other enterprise systems through EDI or web services, these things we have already discussed, these technologies.

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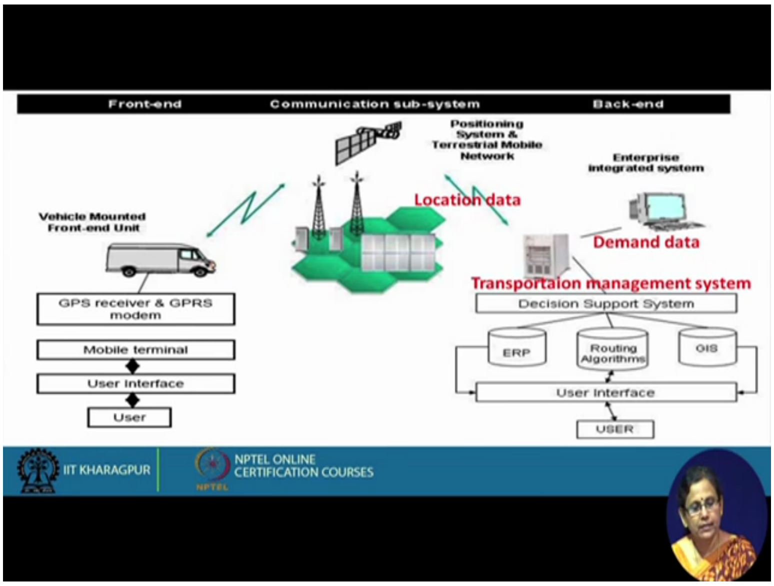

And in fact your transportation management system which will, which is looking after managing this, tracking these vehicles should be getting this location data from GPS-GIS integrated systems and getting the demand data. Either there will be a decision support system with routing algorithms etc. and GIS which helps in taking the decision and show it to the user through the user interface and transmit back to the truck for further instructions.

In fact we said this routing algorithm, if you have GIS in hand, as I told you these algorithms are very complex and all the constraints that are supposed to be considered due to increasing complexity, they may not be handled. So the solutions and algorithms are also not exact. So therefore in order to, the solution that you get out of these algorithms may be little bit adjusted manually and your GIS system which provides you a lot more details and about the geographic positions of, the spatial positions of the entities to be serviced, to be provided service with can now be adjusted little bit by the decisionmaker.

And the solution of that should be sent back through a mobile network back to the truck, so that truck should be in a dynamic manner should be able to service the stakeholders. Thank you very much.