Principles of Engineering System Design

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Lecture - 07
System Requirement Analysis

Hello Friends, a very good day and welcome back to another session on a Systems Engineering. Today we will discuss about the originating requirements and documentation for system development.

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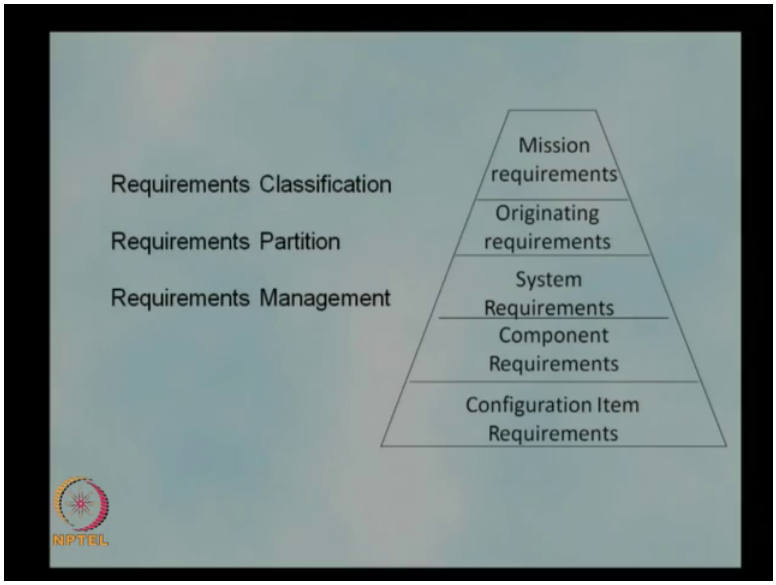

In the previous lecture we discussed about the requirements classification, then requirements partition, and then the requirements management; as we saw about the configuration item requirements, component requirements system requirements and then originating requirements and mission requirements, how do we actually classify and how do we partition them into different categories.

And today what we are going to do is to see how do we actually do a requirement and documentation which is known as originating requirements documentation. So, we will go through this process the steps involved in according the requirements.

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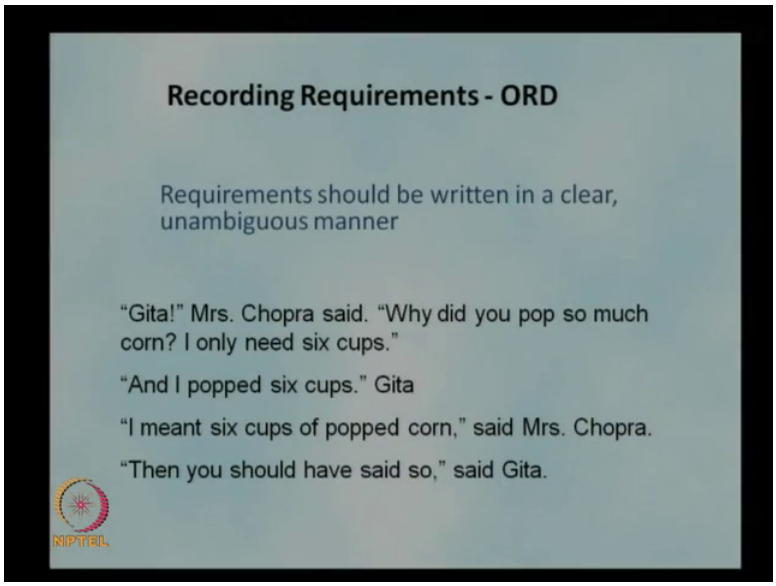

So, the basic idea is that the requirement should be written in a very clear unambiguous manner that is the requirements are going to be there throughout the process of design throughout the lifecycle of the project or the system and there will be many people using this requirements at various stages and under various circumstances. Everyone should understand the requirement in the same way as intended by the person who actually wrote the requirements.

So, it should be very clear it should be unambiguous and there is not be any confusion about what is written or it cannot be interpret in a different way. The importance of this actually we can see in our day to day life also whenever we communicate with the people we may tell something and the other person may understand it in differently. For example, you will see the dialog between Misses Chopra and Gita why did you pop. So, much corn only need 6 cups Gita says I popped only 6 cups.

I mean 6 cups of popped corn not 6 the cups popping of 6 cups said Misses Chopra then you should have said. So, that means, if you want something you should tell it properly if you give a chance for someone to interpret it in a different way then things will go in a different way and then both will have miscommunication. And, that is very important in this case of requirement analysis requirement writing also. So, we should try to tell what actually we want and we should write down in a very clear unambiguous way what is the requirement that particular requirements is another example here.

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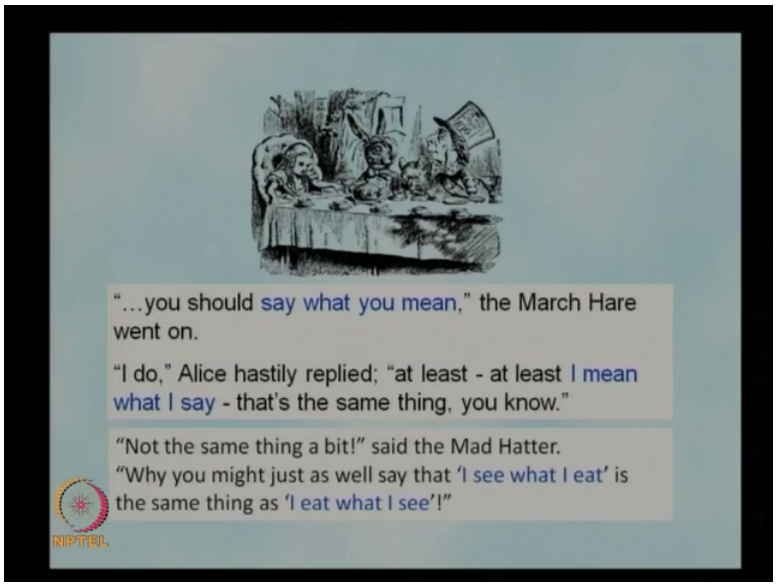

You should say what do you mean the March hare went on "I do," Alice hastily replied; "at least I mean what I say that is the same thing, you know." So, say what you mean and I mean what I say that the same that is what the argument here is, but these that true look at here "Not the same thing a bit" said the Mad Hatter. "Why you might just as well say that I eat what I see is the same thing as I eat what I see. So, you can see the difference it is not the same as what you say I see what I eat and I eat what I see are totally different.

So, we should make sure that whenever we communicate whatever we record should be properly recorded and properly written. So, that everyone understand it in the same way what we intended.

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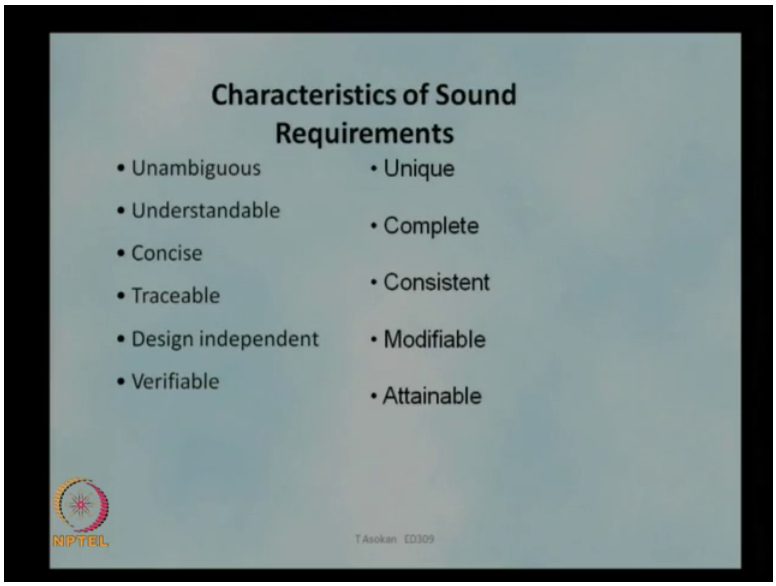

The characteristics of sound requirement so whenever we write the requirement we should make sure that they are really the proper requirement and we are writing it in a proper way.

So, I know to ensure that the requirement should be unambiguous as I mentioned it should be understandable to everyone. So, it should not be put in a very high technical way or within the very complex sentences, should make it very simple and understandable to everyone it should be very concise not be very long sentence with a lot of explanation, should be very concise statement it, should be traceable traceability is basically you should be able to go back to that requirement and find out where this requirement, but will a requirement came from and what was the origin of that requirement. So, that there is any issue at the later stage we can go back and then correct that requirement based on that origin of that requirement. So, that is why it should be traceable and it should be design independent.

So, we should not specifically say that this requirement is for this particular design. So, you should never say that there should be clear transmission between particular between 2 components, because that is becomes a design dependent. So, that requirement should not be written in the way which is depending on a particular design. So, it should be always mentioned in a design independent way and it should be verifiable. So, you should be able to verify this requirement in later stage whatever we write down as a

requirement should be a verifiable one. Otherwise there is no point in writing it because we would not be able to verify whether you are really achieving that particular requirement or not similarly it should be unique to that particular project. So, it should not be put in a very common way or should be very specific to this particular system.

It should be complete. So, the that is not be a partial statement should be a complete sentence or a complete statement of requirement, should be consistent with the other requirements also there may be many requirements in the system. So, it should be consistent with other requirements should not be a contradictory to other requirements in the overall requirement of the system it should be modifiable. So, at any time you should be able to modify that requirement depending on the situation, as a situation arises you may find that this requirement is not the one which actually you want then you should be in a position to modify this requirement similarly it should be attainable.

So, you should be able to attain that requirement or you should be able to meet that requirement through some means. So, you should not write down something which is impossible to achieve. So, the feasibility of the requirement comes into picture. So, I will face ensure that it is attainable. So, these are the good characteristics of writing a requirement.

So, every requirement should actually try to follow all these characteristics. So, that everyone can understand it nobody will interpret it in a different way and these are possible and feasible requirement for the system.

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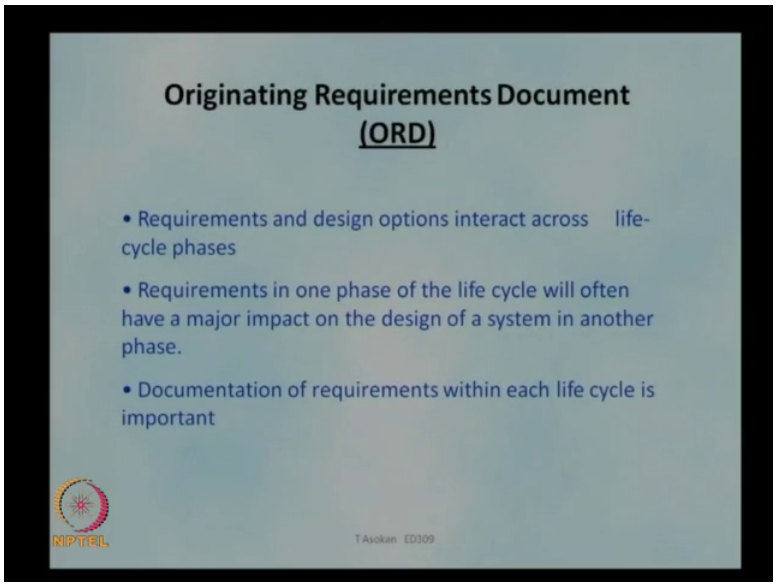

So, once you have these basic characteristics you should see how do we write the document. So, this is the document for the system development is known as originating requirements document or in short ORD. So, this is the document where actually we write down or we record all these requirements and ensure that these are feasible and they are understandable to everyone. So, the requirements and design options interact across lifecycle phases. So, this is important because across the life cycle these requirements interact.

So, that is why we need to make sure that our ORD takes of the different life cycles of the system requirements in one phase of the lifecycle will often have a major impact on the design of a system in another phase. So, as I mentioned we in the system we will look at the life cycle of the system. So, there will be an interaction of this requirement over life cycles of the system and there will be lot of impact on another life cycle.

So, the design phase requirements will be having a major impact on the manufacturing phase similarly the manufacturing phase requirement may impact the operational phase therefore, we need to make sure that this requirement what we identify are consistent and then actually their impact on other life cycles are minimal as much as possible and the documentation of requirements within each life cycle is important.

So, the requirements need to be recorded for each life cycle separately. So, as I mentioned the requirements are different for each life cycle and therefore, we need to

record these requirements for each life cycle separately the question is now how do we actually write down a good requirement?

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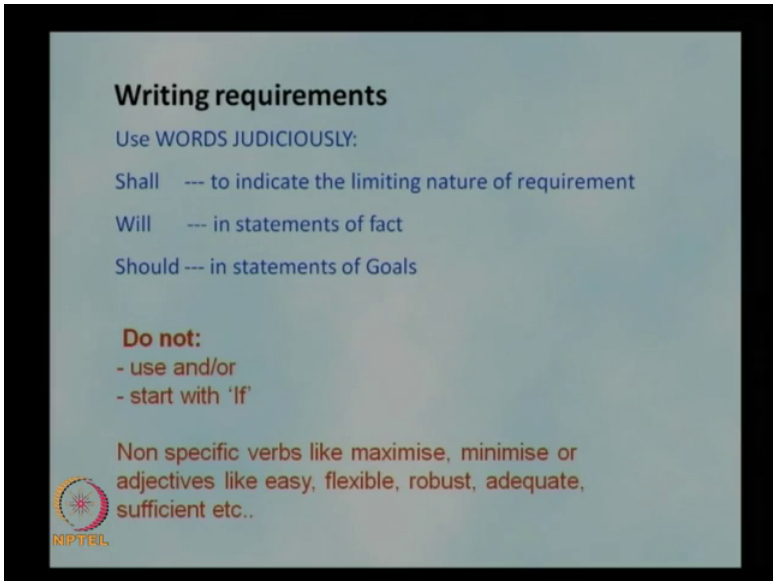

Let us see how do we do that. So, one important point here is that you should use words with judiciously do not use the words without thinking without understanding the importance of each word we use. So, we should use shall to indicate the limiting nature of a requirement. So, if you have a limiting nature of a requirement where we can have some kind of a trade off or a compromise and we should use the word shall.

We will represent the statements of fact so if you have some statements of fact which is already existing and you do not have any control over then you say it as a is a will and should will be used in statements of goals. So, if you have some particular goals to be achieved. So, you should always say you should use the word should this is basically if you have some particular safety requirements or the response that requirements then we should say the system should response to an emergency in 5 seconds or that the system should accelerate within 2 seconds. So, that type of a statement of goal should be specified using should. Then again do not use and slash or so this again a confusing statement, do not use the; and slash or so use and or in case of I mean wherever the it is needed do not put this option for a reader to interpret in a different way.

And never start with if so do not start any requirements within if, because if again we confusing to a reader at the later stage or a person who is going through the requirement.

So, he can interpret it in a different way so never use a if. Similarly nonspecific verbs like maximize, minimize, or adjectives like easy, flexible, robust, adequate, sufficient etcetera should be avoided.

Because these are all very subjective maximize minimize. So, when you say maximize. So, nobody will know what is actually maximum we want and then again the again it is subjective and depends on the situation, similarly minimize or adjectives like easy flexible robust these are all not very objective. So, we should avoid these kinds of nonspecific verbs and make sure that whatever we specify it a very objective and it is very clearly understandable to any person who is going through these requirements.

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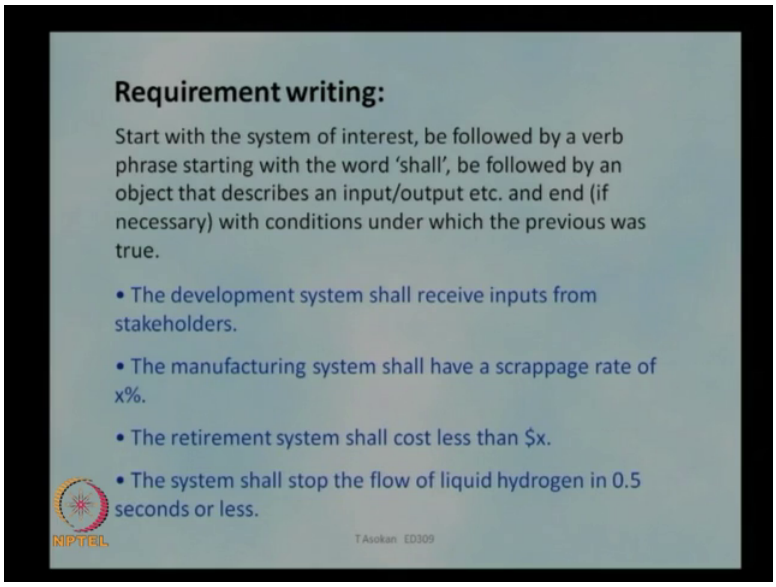

We will see some examples so whenever we write this requirement we start with the system of interest suppose if it is an elevator system or it is a mobile phone or it is a mobile network or a television system, we should start the retirement with the system of interest be followed by a verb phrase starting with the word shall or will or should depending on the situation and be followed by an object that describes an input output and end with conditions under which the previous was true. So, this is the way good requirements need to be written.

So, we start with the system of interest followed by a verb phrase starting it the word shall or will or should depending on the situation and then follow by an object that

describes the input or output what our requirement is and end with conditions under which it is true.

So, this is the way you write a requirement for example, you can see here I am writing that the development system shall receive inputs from stakeholders. So, if you have a system we are talking about a system where the development phase is being discussed and we should say this development system shall receive inputs from stakeholders. So, that is a requirement statement. So, the system should be able to receive the input from stakeholders.

So, whatever the inputs are there the system should be capable of accepting these inputs and that is the one requirement. Similarly the manufacturing system shall have a scrap page rate of x percentage or whatever the percentage 1. So, do not say that that a scrappage rate minimum scrappage rate. So, that is not acceptable you should write what is the amount that is acceptable or what is the quantity that is acceptable the manufacturing system shall have a scrappage rate of x percentage.

So, you have clearly telling that that is the acceptable range and if it is beyond that which is not acceptable, the retirement system shall cause less than particular value x dollar or x rupees whatever it is. So, the retirement system the system the cost of retirement or cost of disposing of the system should be is less than a particular value. So, it is very clear that there is no confusion over here you have to clearly telling that the cost of retirement should be less than particular value.

Similarly the system stop the flow of liquid hydrogen in 0.5 seconds or less again we are telling that 0.5 seconds is the limiting or it can go less than that, but not more than that very really clearly telling that the system, should stop the flow of liquid hydrogen in some cases you have a system for control of the liquid hydrogen then we are telling that this control system should stop the flow of liquid hydrogen in 0.5 seconds or less.

So, you can clearly see here and not using any words like maximize or minimize or other adverbs we are actually we are making some statements were actually it is not really objective. So, we do not give any a subjective evaluations or subjective values over here. It will be clearly mentioned what is the actual requirement or what is the actual expectation from the system. So, this is the way how we write the requirement for the system.

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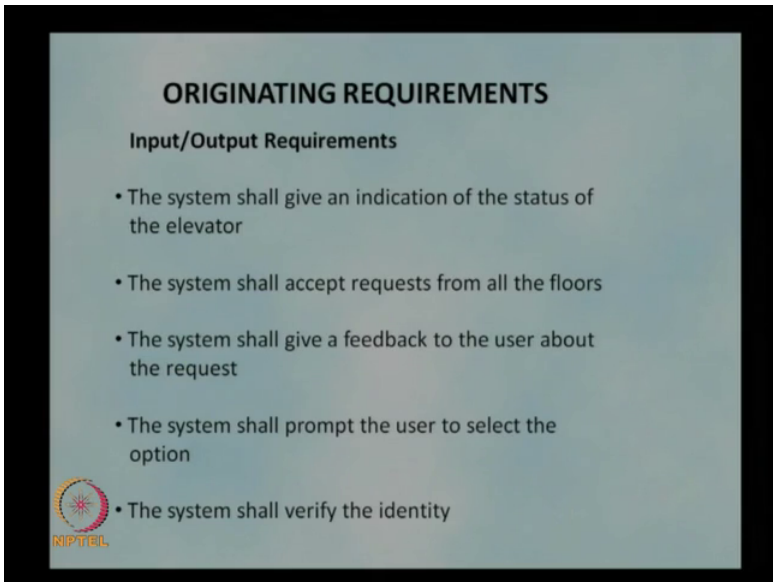

And again these originating requirements we can write down the classification as I mentioned that there are input output requirements and technology system wide requirements. So, these are all actually written in the same way of fashion or as we I mentioned in the previous slide. So, the input output requirements basically they consists of the input and output that is what is the input coming into the system and what is output going from the system. So, for the case of elevator you can say the system shall give an indication of the status of the elevator.

So, the system should have a facility to give a output indication of the status whether it is in working condition or work in which for the elevator is at present the system should be capable of giving that output. So, that is the input output requirement one of the output requirements identified the system shall accept requests from all the floors. So, again this is an input requirement the elevator system shall will accept requests from all the floors. So, all the floor should be I mean there should be a facility for the elevator to accept requests from all the floors that again a input requirement then the system shall give a feedback to the user about the request.

So, whenever user gives an input to the system and the system should be able to give an output it is actually will state; what is the status of that particular request. So, the system shall give a feedback to the user about the request the system shall prompt the user to select the option, again the system shall use the shall prompt the user to select the option

suppose there are many options and then the system should give a option or prompt the user to select the particular option for that particular situation the system shall verify the identity. So, if there is a requirement then the system shall be should be able to identify the, verify the, identity of the person or the identity of that particular requirement or the particular option given by the user.

So, these are the typical input output requirement for a system. So, we will try to identify in the previous lectures we discussed about the input output trace scenario trace scenario description and all. So, these scenarios will give us the requirements or we identify the requirement from this scenario and based on these scenarios we will try to write down these requirements as shown here. So, these are some examples of how do we write a good requirements.

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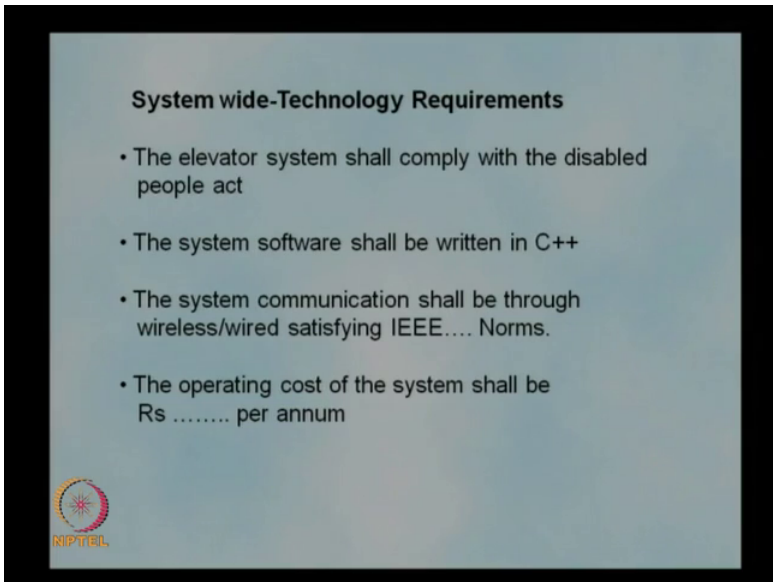

Similarly, for system wide or technology requirements in this case we will write the elevator system shall comply with the disabled people act. So, that is a technology or a system wide requirement it is not coming from the input output trace. This is coming from the technology or the system wide requirement or the context in which the system is being used. So, the system shall comply with the disabled people act, but the system software shall be written in C++ or some other languages whatever the languages whatever the software or operating system want to use.

So, that can be specified in the requirement this may be having some impact on the other life cycle. So, that is why it is written the specifically given that the requirement or the system software should be written in a particular language. Similarly the system communication shall be through wireless or wired or satisfying particular norm. So, if you have there are communications between the system and it is external system.

So, we can write down the requirement of communication what kind of protocol to be used or what kind of method to be used for communication whether it is a wide communication or a wireless communication and what is the standards what are the standards being used for communication, these things can be mentioned as a requirement. Similarly the operating cost of the system shall be a rupees dash per I know and whatever the amount. So, you will write that also the operating cost should be made less than a particular value.

So, that is a requirement of course, the depending on the further design and further development this may change that is why there is a it is not a compelling statement, but it is target what actually the designers are hoping to achieve. So, the operating cost of the system shall be a rupees x per annum. So, these are the system technology requirements for this particular case.

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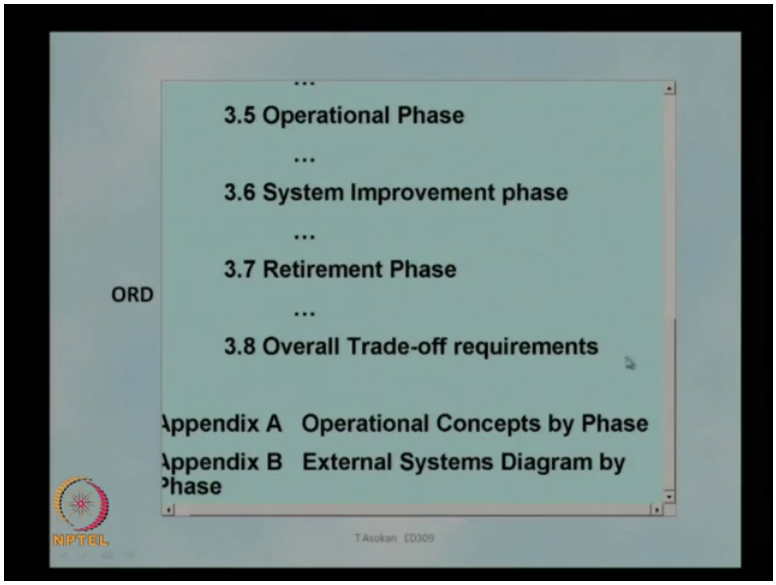

And this is how we write in ORD the standard structure of an ORD is shown here as you can see every originating requirement document it actually a as I mentioned this is a life cycle.

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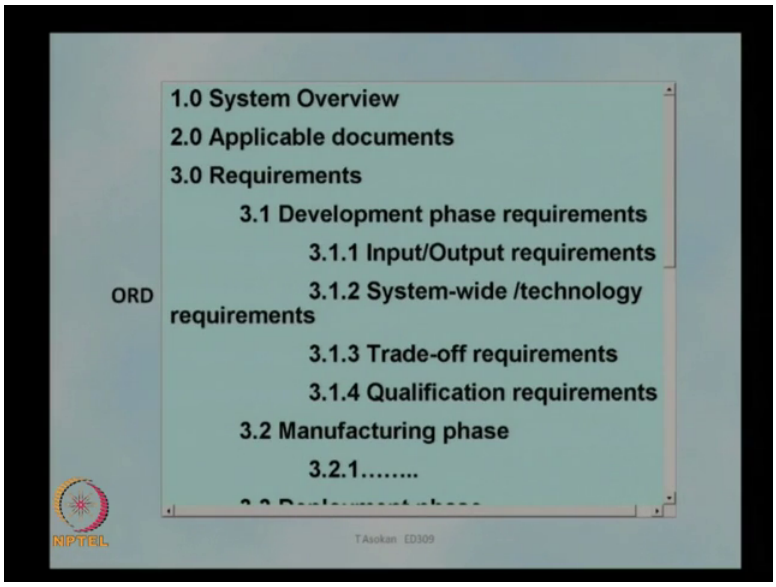

So, every life cycle will be having it is own requirements. So, the originating requirement document will actually record all these requirement throughout the life cycle of the system. So, the ORD start with a introduction or system overview. So, what the system is what actually it is meant for what are the basic concepts or operational concept the designers are planning to use and that actually we will tell you the give the a system overview of the system. So, anyone who is going through this require this document.

Will you understand what the system is for and what are the what is the basic operating concept designers are planning to implement that is the system overview and then I will give the applicable documents what are the different documents applicable to this particular requirement there may be many standards there may be this disability act or the building standards or safety norms there are international standards and the national standards. So, those documents which are applicable to this particular design will be mentioned in the applicable document section and then we will start writing down the requirements.

So, as I mentioned the requirements are written for different phases. So, we start with the development phase requirements. So, that a development phase requirement itself can be

classified into Input Output requirement, System-wide technology requirement, Trade-off requirements, and Qualification requirements, these are the 4 categories of requirements for development phase.

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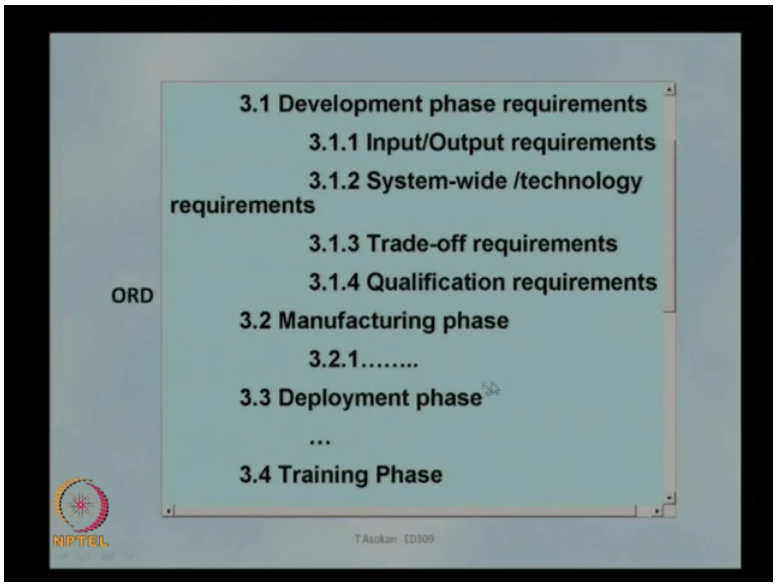

So, under the section requirements we start with the development phase requirements and then we go for the manufacturing phase requirement and deployment phase training phase and all the other lifecycle identified for this particular system it write down the requirement, again for the manufacturing phase also you try to find out what is the input output requirement, what is the system wide and technology requirement, trade off requirements and qualification requirements.

So, these 4 will be therefore all the other lifecycles also. So, we will start with the development phase requirement and then manufacturing phase again we will write down 3.2.1 as input output requirement 3.2.2 to a system wide and technology requirement, then 3.2.3 as trade off requirements and then depending on those requirement there may be subclasses or subdivisions again we will give the numbering as per the requirements identified over here. So, this is the general structure of a ORD.

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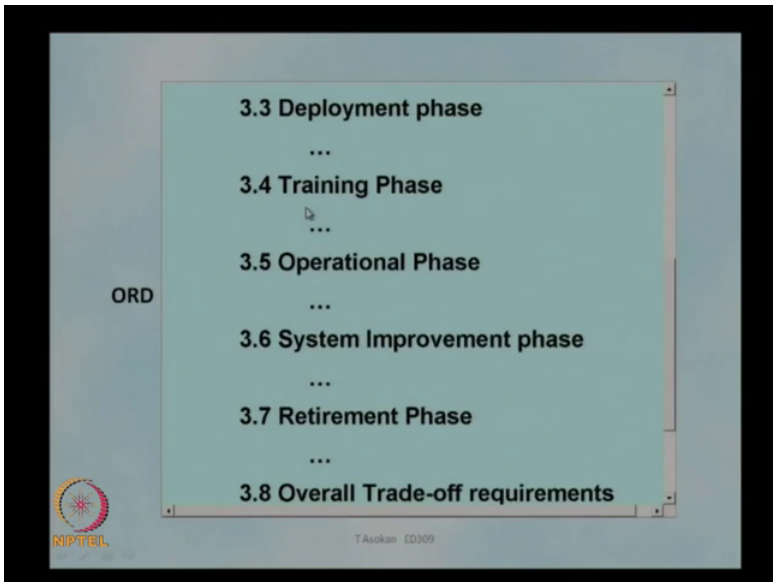

So, as you can see that there are different phases the training phase operational phase, system improvement phase, retirement phase, and then an overall trade off requirements also then overall trade-off requirement will be the identified by the designers.

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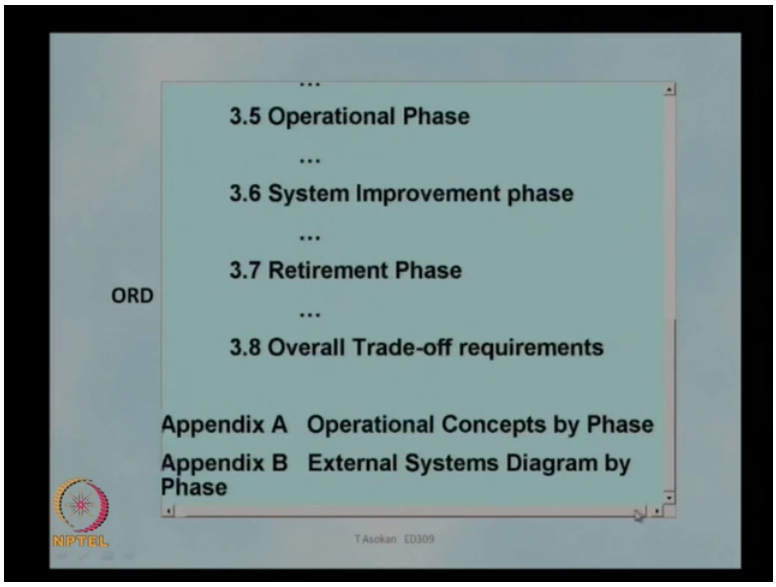

So, depending on the course depending on the performance or they are identify overall trade off requirement which may be applicable to all the life cycles. So, this is the structure and again we will be having other appendix a operational concepts by phase. So, different operational concepts by phase it is develop during the development phase

and then the external system diagram by phase or if different phases there will be different external system diagram because the interaction may be different. So, therefore, you will identify the external system diagram also and put it the all these are under the appendixes.

So, this is the general structure of an op originating requirements document. So, the first part of the design which is basically the development phase or identifying the problem and system level design problem and did this the final output is a operate originating requirements document. As I mentioned in the previous lectures we start with the stakeholders inputs, then we go through different stages; like concept development, input output trace operation scenarios, trade-off requirements and go through the requirement analysis then requirement management and requirement documentation. And at the end of this phase will be getting the originating requirements document as the output of this particular phase of development. So, system level design problem will be getting ORD as the output of this particular phase.

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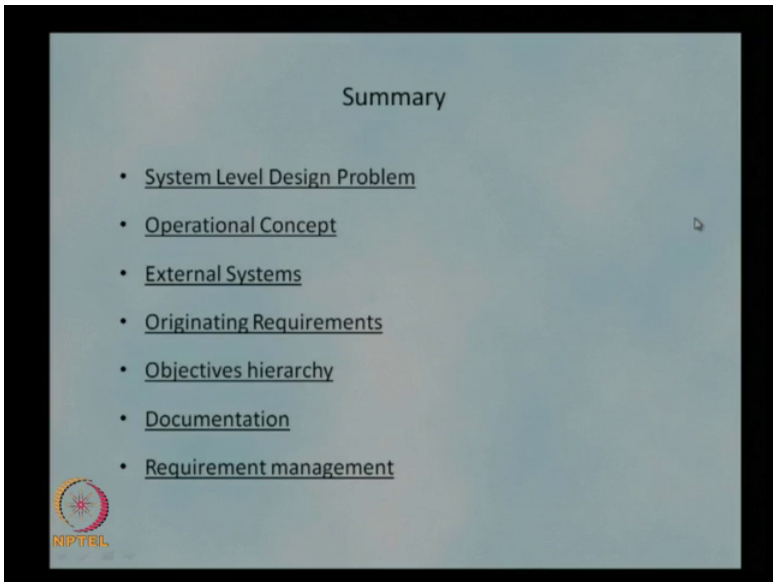

So, to summarize whatever we discussed in the last two lectures basically we discussed about the system level design problem as the initial first function of the design process we discussed that there are 6 functions.

And the first one is the system level design problem and then under this we discussed about the operational concepts how do you develop a very preliminary operational

concepts and then how do we identify the external systems, how do we look at the originating requirements, how do we look at the objectives hierarchy and then how do we document and manage the requirements.

So, these are the topics we covered under the system level design problem, but do now is to take few examples and explain how we actually go through these phases and develop the ORD for the particular case. So, to do that let me go to the a particular example which we already discussed in what about this I will go to the same elevator design and then go through the different operation scenarios and operational requirement and then we see how do we actually write down the requirement for this particular system.

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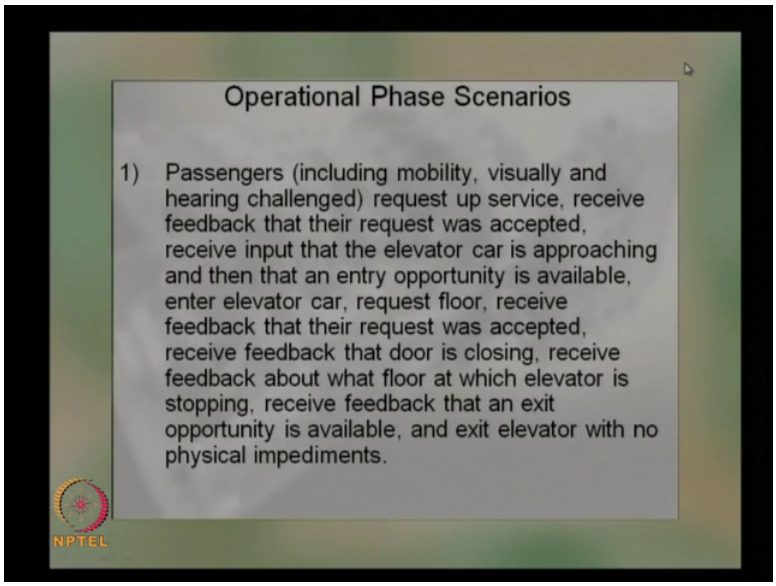

As you know the operational phase scenarios so that is the first step in identifying the requirements. So, we have different scenarios. So, one of the scenarios we already discussed about this how the passengers use the system. So, we clearly write down the steps involved in using the system by a user the passenger.

So, we say passengers including mobility visually and hearing challenge request up service receive feedback that the request was accepted, receive input that the elevator car is approaching and then that an entry opportunity is available, enter elevator car, request floor, receive feedback that the request was accepted, receive feedback that the door is closing, receive feedback about what floor at which elevator is stopping, and receive

feedback that an exit opportunity is available, and exit elevator with no physical impediment.

So, we have clearly explaining all the steps involved in using an elevator by a passenger and that actually includes the mobility or visually or hearing challenged people also. Now once we have this scenario we will make an input output trace to find out what kind of interactions what kind of feedbacks are happening between these 2 the system and it is a external systems.

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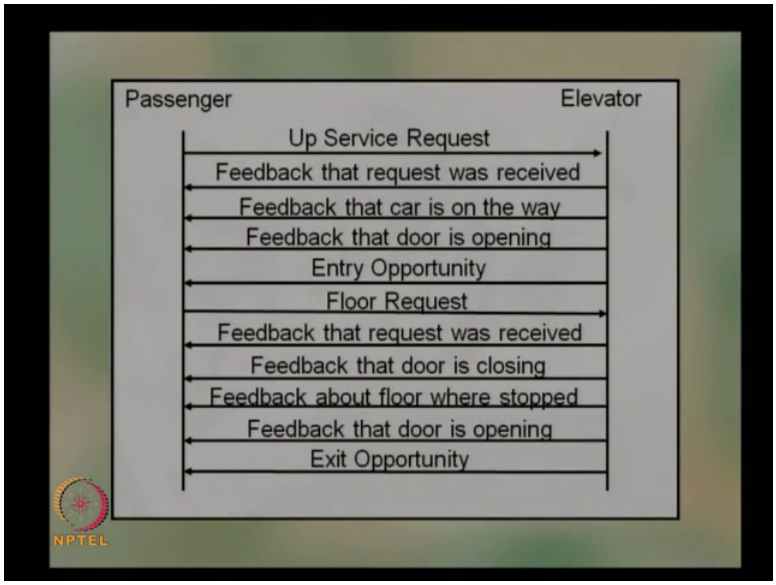

So, here we are identified elevator as a system and passenger as a external system. So, if the passenger will ask for an up service request and then there are many feedback from the elevator feedback request was received, feedback that car is on the way, feedback that door is opening, and then an entry opportunity is provided. So, this actually shows that there are 4 types of feedback going from the elevator and this actually identify the requirements also the output requirement from the elevator.

So, this was an input requirement for the elevator that an up service request it you need to be accepted and these 4 actually tells the output requirements from the elevator, that is or the elevator should give these kind of output to the passenger. And then there will be another input from the passenger or the external system that there flour request or required floor request is given to the elevator.

So, this request uses another requirements basically the passenger should be there should be an option for a or the passenger to give the inputs and there should be a facility to accept that input and then to process that input at a later stage by the elevator. And then once you have the input is received that by the elevator then the feedback to be given there are 2 feedbacks here sorry more than 2 there is a feedback that request was received, there is a feedback that door is closing, there is a feedback about where the which for the elevator stopped, and feedback that the door is opening after reaching that particular floor and there is an exit opportunity provided.

So, all these are the output from the elevator. So, the elevator system and we designed this elevator we should identify these are the output requirement from the elevator. So, you can see that using this diagram the input output trace you can actually see; what are the input requirement and what are the output requirements for this particular scenario. Like this we can identify many other scenarios and try to identify all the requirements.

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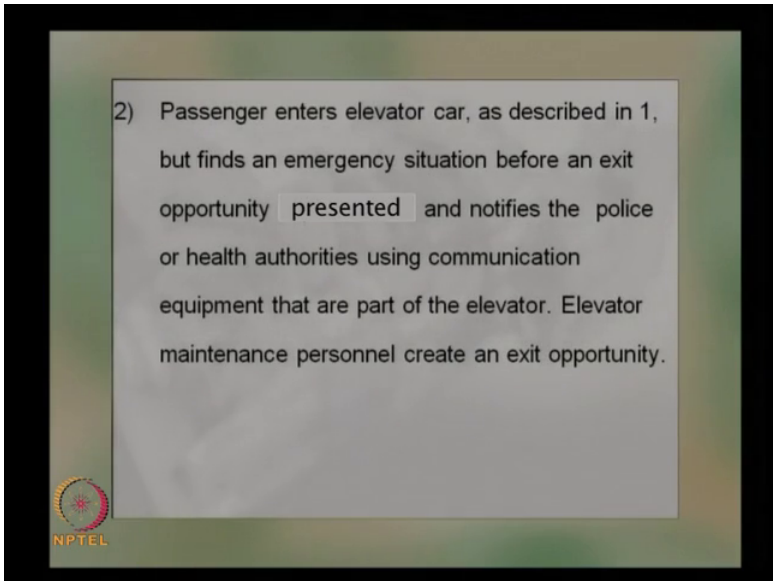

For example there is another scenario the passenger enters elevator car as described in one that in the previous same scenario, but finds an emergency situation before an exit opportunity is presented.

So, there is an emergency situation it can be a anything it can be a malfunction of a system or within the elevator or there are some smoke inside or there are some other

elevators some danger to the life of the person or some theft inside or whatever it is. So, there is an emergency situation what the passenger should do.

So, that actually that there is a finds an emergency situation before an exit opportunity is presented and notifies the police or health authorities using communication equipment that are part of the elevator. Elevator maintenance personnel create an exit opportunity. So, this is a scenario now we need to find out for this particular scenario how a input output trace can be developed and the requirements can be identified that is input output requirements how do we identify these requirements you can see here this is the input output trace for this particular scenario.

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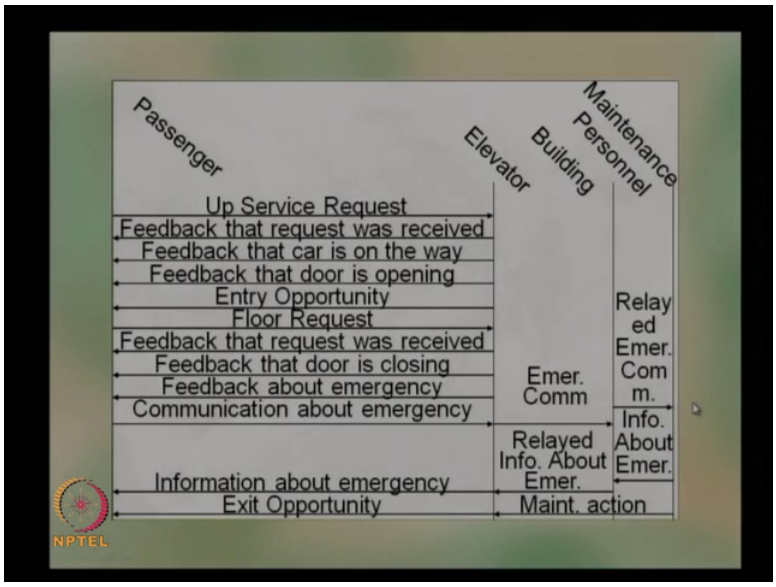

Here you can see elevator is the main system of interest, but you can see there are external systems like passenger is an external system in this case the building is an external system and maintenance personnel is an a external system . So, there will be communication between these external systems as well as the a main system we need to identify what kind of input output requirements are needed to ensure that the passenger request is accepted and then passenger is provided with a safe exit from the elevator.

So, the first few steps are the same as what we did in the previous case up to that feedback that the door is closing is given to the passenger. So, the passenger is inside the elevator now there is a an emergency. So, there is a communication about emergency or a feedback about emergency if either from the elevator or the elevator system is not

functioning or there is some emergency system identified by the elevator system and that will be given to the passenger or the passenger identifies an emergency situation that will be given to the elevator.

So, you can see that there is a input and output. So, the elevator should be capable of providing an output about the emergency at the same time the passenger should be a able to give an input to the elevator that there is an emergency situation. And once that once the elevator receive such an input then it should be able to communicate this to the building or the person who is actually managing the elevator system or the there is a if there is any particular security system employed in this building.

So, this information about the emergency should be communicated to that particular system of the building, and then once they receive this information then the building or the system which actually manages the elevator system should communicate this to the maintenance personnel. So, if it is a maintenance personnel or depending on the situation it maybe the maintenance personnel or it may be to the police or it may be to the fire depending on the emergency situation that will be communicated.

So, there is a the building should be capable of communicating this information to the maintenance personnel. So, we can identify a requirement here then there should be a there to communicate the situation or the information to the maintenance personnel, and then there will be a response from the maintenance personnel that they are acting on the request or they already they received the request and they are taking action and that information should be communicated to the elevator system, and similarly to the a passenger also. So, there is a communication from one line to the other the maintenance personnel of the communication should go all the way to the customer the passenger and the passenger should be provided with an exit opportunity at the earliest possible.

So, this is the way how the this particular scenario works. So, we need to ensure that by looking at this input output trace, you should be able to identify what are the input requirements for the elevator, what are the output requirement from the elevator, and what are the other requirements to be provided on the external systems also as you can see there is a close interaction between the external system and the main system and we should be able to identify this a input output requirements under for this particular

scenario. So, we write down these requirements as part of the input output requirement for the system.

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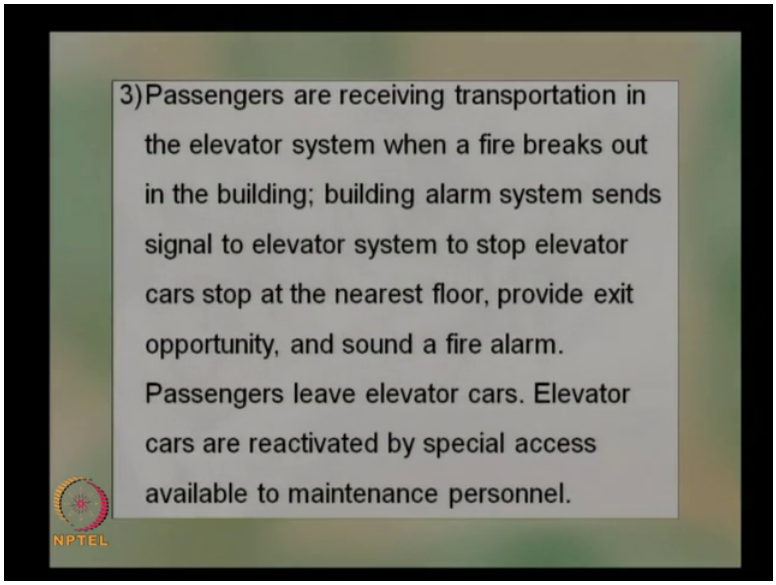

This is another scenario the passengers are receiving transportation the elevator system and a fire breaks out in the building. So, it is not in the elevator. So, the passenger may not be knowing that there is an emergency, but there is fire breaks out in the building a building along system sends signal to elevator system to stop elevator cars then the stop at the nearest the cars stop at the nearest floor provide exit opportunity and sound a fire alarm passengers leave elevator cars elevator cars are reactivated by special access available to maintenance personnel.

So, this is a scenario when there is a fire in the building. So, what all the requirements for this situation so what kind of input and output requirements to be provided by the designer they have made this particular scenario then again you can see you can down the input output trace.

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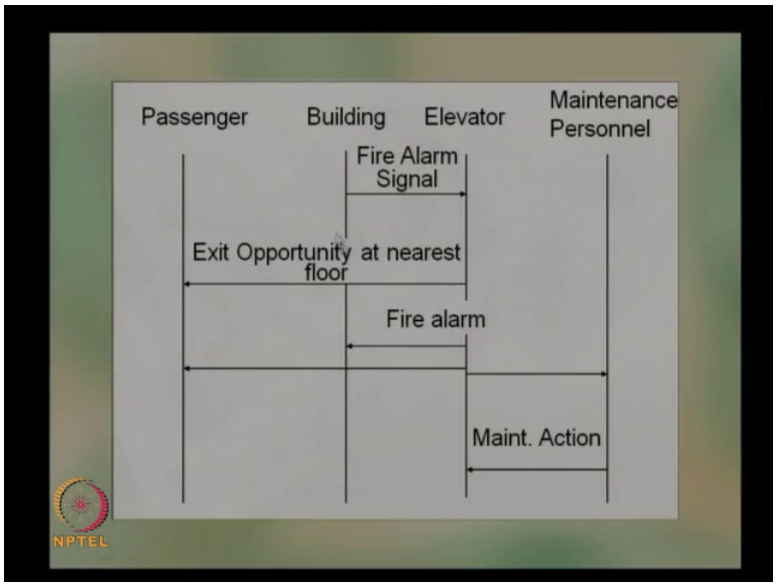

So, the fire alarm signals goes from the building to the elevator and then the elevator gives an exit opportunity to the passenger to the next floor. So, wherever the elevator is there it will just go to the next floor and open the doors and give a provide an exit opportunity the passenger will come out over the elevator and then the elevator fire alarm will be given. So, that elevator will give a Fire alarm.

So, that nobody will use the elevator and then maintenance personnel will come and then then the same information will be sent to the maintenance personnel. So, they will take the action to reactivate the elevator once the fire hazard is over or once the emergency situation is over. So, this is how the particular scenario works and looking at this you should be able to identify what kind of requirements to be provided in the system.

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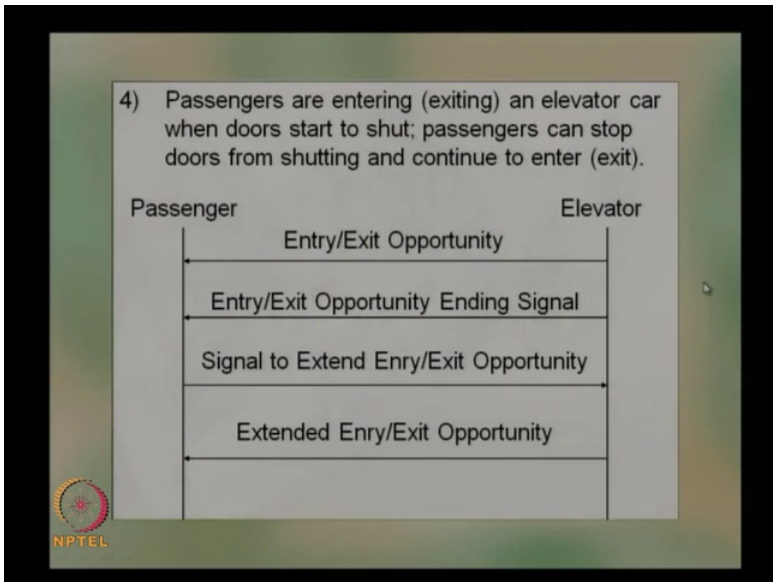

So, like that you can actually have many scenarios. So, this another scenario where the passengers are entering an elevator car when doors are start to shut passengers can stop doors from shutting and continue to enter. So, in a very common scenario, for this scenario also we can find out what kind of safety features to be provided for the elevator.

So, that the scenario will not cause any harm to the passenger again you can see that the elevator is the system here and passenger is the external system and we have this signal to extend entry exit opportunity because the passengers are still entering and then system should provide an extended entry or exit opportunity.

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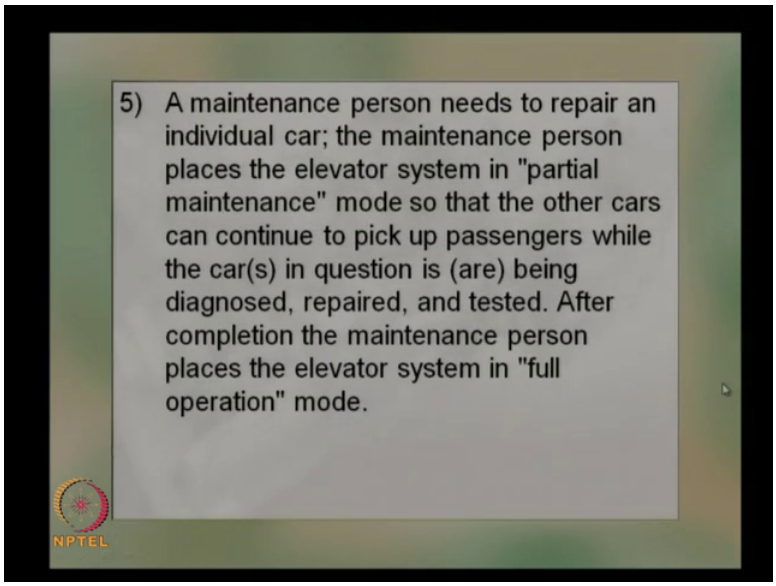

In another scenario here I am a maintenance scenario a maintenance person needs to repair an individual car the maintenance person places the elevator system in partial maintenance mode. So, that the other cars can continue to pick up passengers while the car in question is being diagnosed repaired and tested, after completion the maintenance person places the elevator system in full operation mode.

So, there are multiple cars in the elevator system it is a multi-story building with the multiple elevator cars. Then one of the cars is under maintenance then there are there should be possibility for the maintenance person to stop this car alone and carry out the maintenance were without affecting the functioning of other elevator cars.

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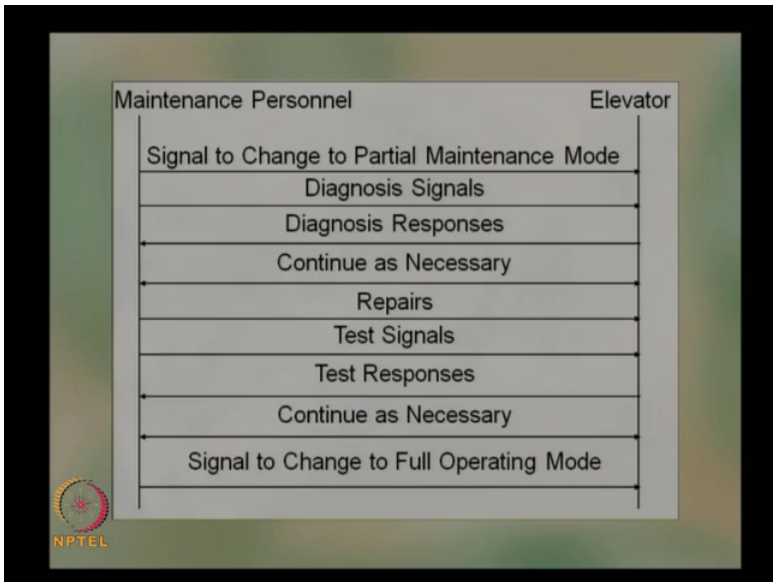

Then we can actually find out a input output trace for this and find out what are the requirements under this situation and what kind of input output requirements to be provided by the system designer to made this scenario. As you can see here the maintenance personnel is the channel system and elevator is at the main system. So, the signal to change to partial maintenance mode is given to the elevator and then diagnosis signals are given and diagnosis responses are obtained from the elevator. And then depending on the situation this will continue because the maintenance person has to do the diagnosis for various subsystems, and what the repairs are completed then the test signals are given and responses are satisfactory, and then change to full operating mode by the elevator.

So, again we can identify many requirements for this elevator to make this particular scenario of maintenance of the elevator one of the elevator cars.

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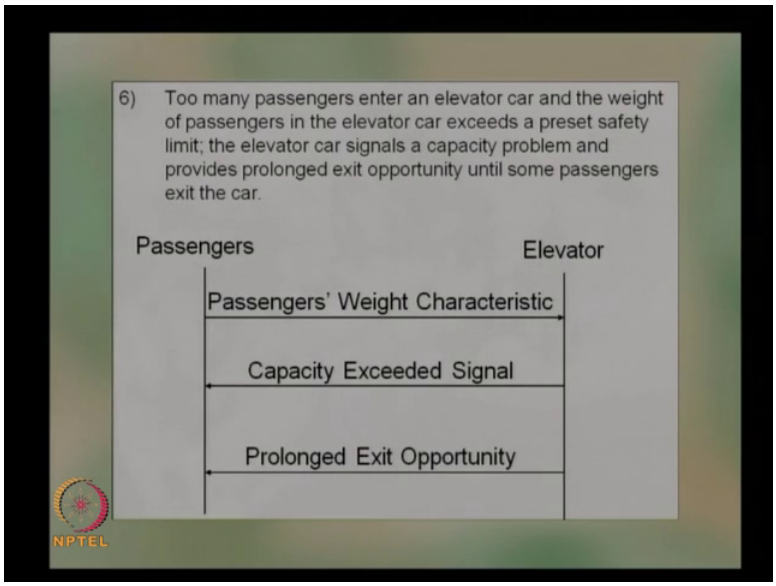

Then the scenario is too many passengers enter an elevator car and the weight of passengers in the elevator car exceeds a preset safety limit: the elevator car signals a capacity problem and provides prolonged exit opportunity until some passengers exit in the car.

So, this again another scenario what will be hard, will happen when there is and it is overloaded. So, what kind of signals to be given what kind of actions to be taken by the elevator and then who actually it will cop up this particular scenario, what kind of requirements are to be identified or what kind of requirement input output requirement are requirements has to be to provide by the designer in order to made this scenario. So, as you can see here when you have many passengers than the passengers weight characters you will be given to the elevator and the elevator will be able to identify whether there is a exceed load whether load is exceeded or not. So, for that we know that though this simply says that passengers weight characteristics and clearly is identify the requirement where the elevator should be having a facility to find out the total load on the system or total weight of the passengers.

And then when it is more than a particular value more than the set value will give a capacity exceeded signal and when there is a capacity exceeded signal should provide a exit opportunity to the passengers. So, it should be a prolonged exit opportunity till the weight goes below the set value the exit opportunity should be provided by the elevator.

So, again here you can see that the requirement is that the door should be kept open and then it should be continuously monitored the weight of the total load should be continuously monitored and whenever the weight is within the limit and then the procedure for closing the door which is already identified the requirement.

Basically we need to have different requirements for closing we were to give an indication that the door is closing or some there should be some kind of a visual audio signal should be provided. So, that everyone knows the everyone will know that the door is going to closed. So, that the safety will not be compromised and the passengers are inside or and they are trying to enter. So, that kind of requirements can be identified by this input output trace.

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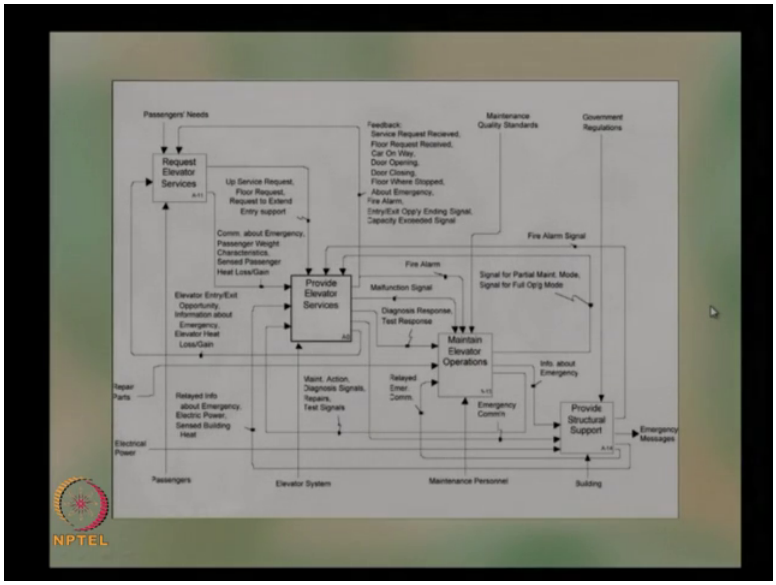

This actually a shows the system diagram or the different functions and the channel system interaction diagram here. So, you can see these are the passengers elevator system is the main system and these are the external system their maintenance personnel, building is an external system, Government regulations are there maintenance quality standards are there, then the passengers needs are there.

So, the system the main system should actually satisfy all these requirements of all these external system. So, in each case through the scenario trace you know scenario identification we and input output trace we try to identify the requirements of each external system or passenger or maintenance personnel or building and then we try to

identify what kind of interactions are taking place between this system. As you can see here the provide elevator services is the main function of the elevator and for that it is getting input from various sources is it getting input from the passengers it is get getting input from.

The building from the maintenance personnel and it is getting the regulator government regulations are playing a role in the providing elevator services. So, all these are coming as input and then it is going as output to the different system like maintain elevator operation that is the operation function and then provides structural support. So, the building is providing a structural support here the maintenance people are providing the maintenance of the system. So, you can identify the main function for each external system here as you can see the building the function of the building is basically you to provide structural support and that actually regulated by the government regulations.

And then the emergency messages are need to be given by the building for emergency situation and then again there is interaction between building and the maintenance personnel the minions personnel's basic function is basically to maintain the elevator operations, and this again coming as a there is an interaction between this and the providing the main elevator functions. The passengers as we can see the request the elevator service and they will be interacting with the elevator through various means of data input and output. So, this is the general external system and there are interaction with the main system for the elevator case study.

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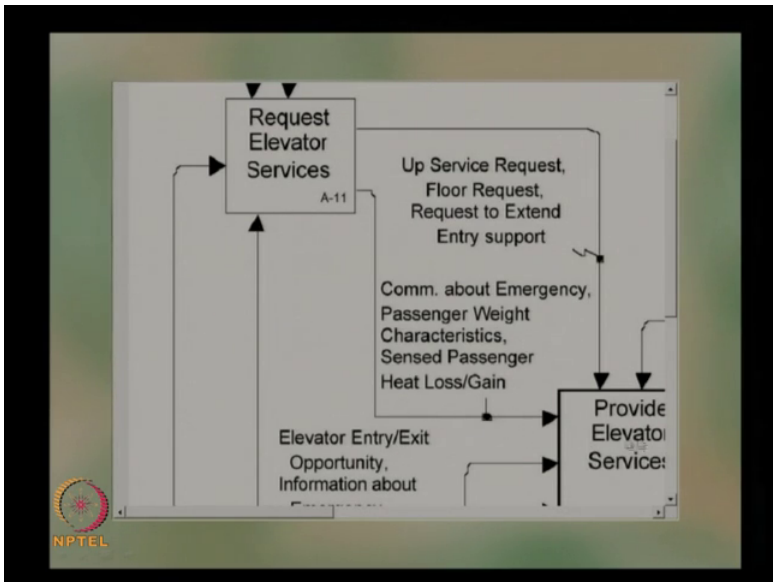

To this actually gives a more clear view of what we saw in the previous one. So, this is the passengers needs the request elevator services. So, the up service floors request to extend entry support all are given from here to the elevator system.

So, this elevator service request it is actually given to the elevator services similarly communication about emergency passenger weight characteristics sensed passenger heat loss gain etcetera are given here because of the temperature control if this is than this passenger heat loss gain also it becomes important. So, that information is also given to the elevator then again you have the entry exit opportunity information about emergency elevator heat loss gain again that given has a feedback from the here from this output from the elevator is actually given a giving a feedback back to the this system.

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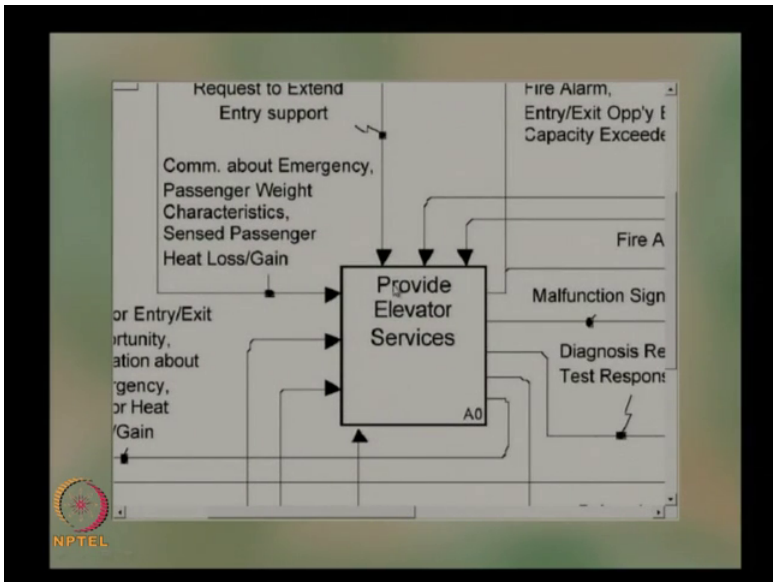

So, that there is a 2 way communications there is a input as well as output from the system. Similarly, you can see that there are different kinds of input and output for each subsystem.

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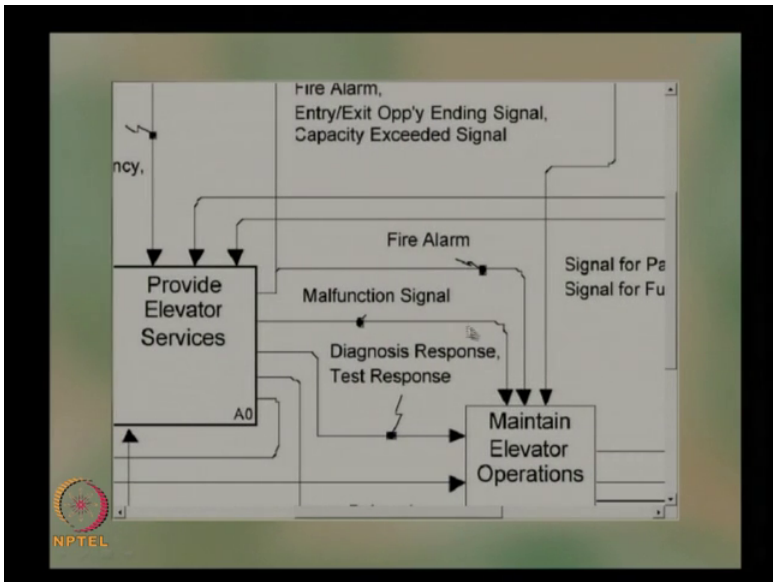

So, the malfunction signal is there then there is a diagnose or test response signal is coming over here is a fire alarm signal coming to the maintain elevator operations. So, the maintenance function we will be able to identify this maintenance input output requirement for the maintenance of the elevator similarly all other function requirements

also can be identified using this kind of interaction diagram. So, we will identify all the interactions between some systems.

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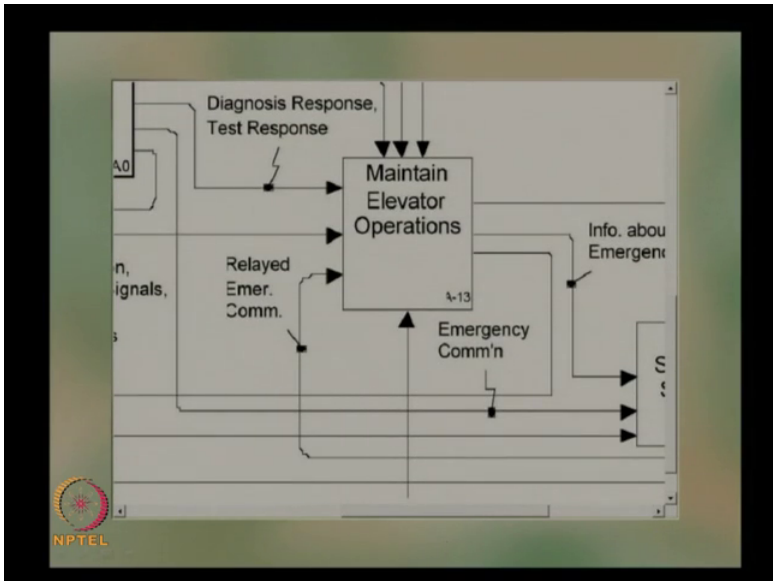

And then use these interactions to identify the requirements.

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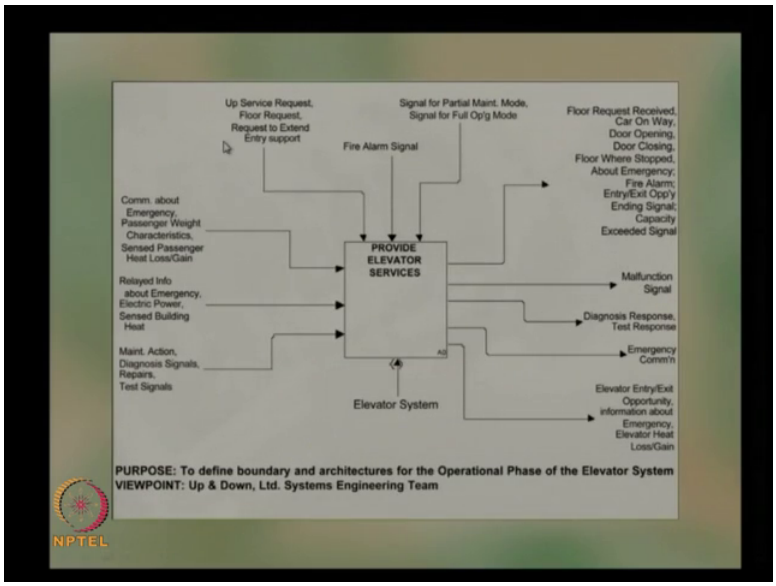

This is again a top level channel system diagram basically to define the boundary of the system what we are interested.

So, you can see that elevator system is the main system of interest and all others are the external systems. So, we actually put a boundary over here and this is what we are interested in designing and for that these are all the input and output or these are the other things which actually we need to take care we are designing the system.

So, an external system diagram basically helps us to identify the boundary of the system where actually our design efforts need to be focused, this is the same diagram with a better way view of the data over here you can see this is the main system the elevator provide elevator services and you can see these are the inputs about the emergency and then maintenance and here you can see this is the or these are the outputs.

The malfunction signal diagnose response test response emergency communication and these are the other outputs the floor request received car on way, door opening, door closing, floor where did you stopped sorry about the emergency situation fire alarm. So, these are all the outputs coming from the system.

So, by writing down this or preparing this external diagram we will be getting a very clear view of what actually we are going to design or what actually the requirement we need to provide in the system and then based on this we will be able to write down the requirements.

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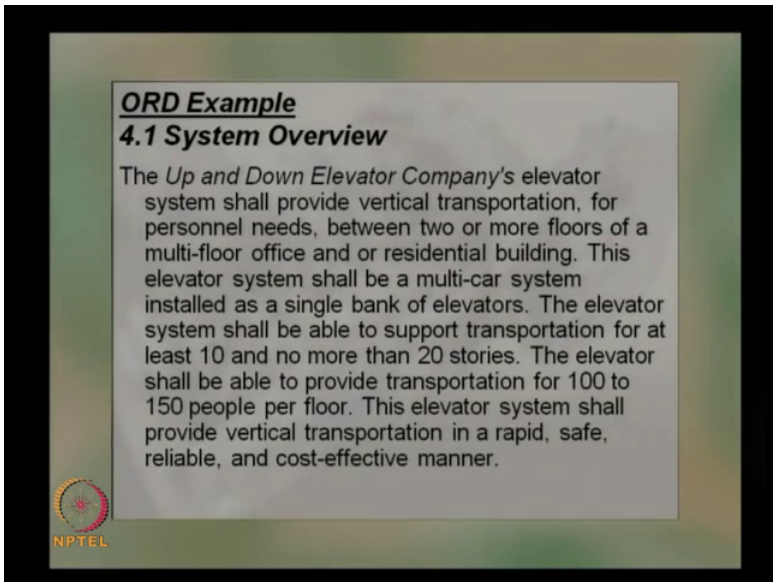

I will show you the example for ORD for this particular case. So, as I mentioned earlier the originating requirement document is the final output of this particular phase of the design.

So, we will provide a system overview in the as a introduction the up and down elevator company you can give any name to the company the up and down elevator company elevator system shall provide vertical transportation for personal needs between 2 or more floors of a multi floor office and or residential building, this elevator system shall be a multi-car system installed as a single bank of elevators. The elevator system shall be able to support transportation for at least 10 and no more than 20 stories. The elevators shall be able to provide transportation for hundred to 150 people per floor. This elevator system shall provide vertical transportation in a rapid, safe, reliable, and cost-effective manner.

So, that is the a very brief overview of the system what we are going to decide. So, this is as I mentioned this is only that the beginning of the design process. So, we do not know how we are actually going to operate it or what kind of services we are providing at the later stage, but a brief overview what is the present understanding of the system design will be mentioned in the system overview.

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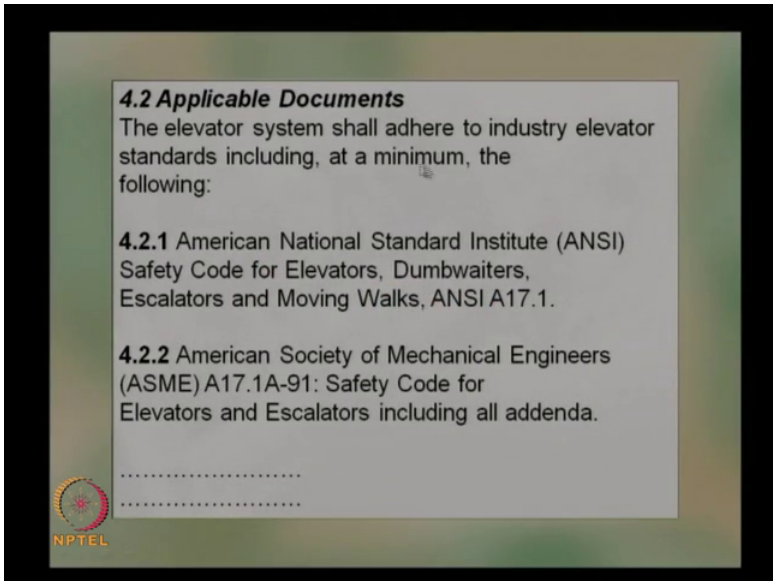

Then we will write down the applicable documents. So, if there are any standards or other documents need to be considered in the design. So, that will be added as applicable

documents. So, the elevator systems or other to industry elevator standards including the minimum the following American national standards institute Safety Code for Elevators and Dumbwaiters Escalators and Moving Walks, ANSI A 17.11 what are the document you feel that it is you needed will be introduced here.

When American society for mechanical engineers A17 1A and 91 Safety Code for Elevators and Escalators including all addenda. So, there are many are documents which actually we will come into picture when we are designing this. So, write down all those document which you identified as part of the design process. So, that is the applicable document.

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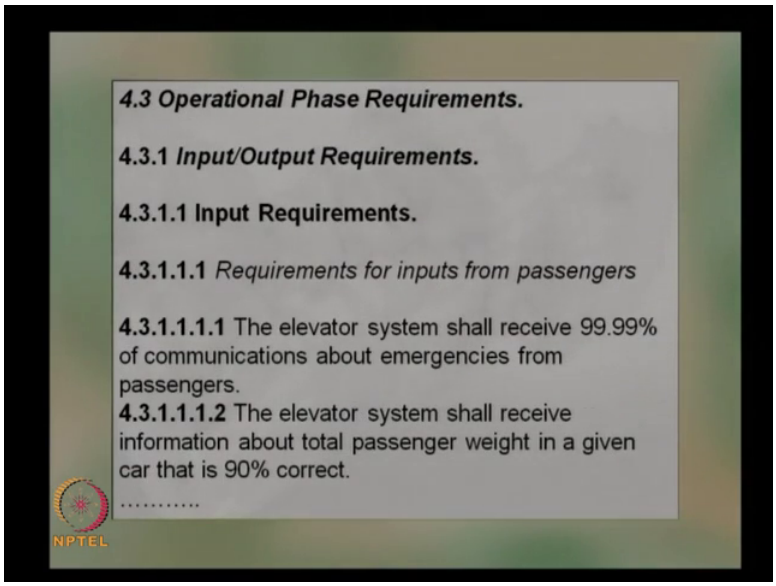

And once we have this which go to the operational phase requirements. So, there are different requirements as I told you there are different phases in the life cycle. So, we identify these requirements and for different phases for in this case you are looking only at the operational phase requirements. So, for operational requirement a phase requirement we have the input output requirement that is the first one.

So, whether the requirements for input from passengers. So, we identify the input from passengers the elevator system shall receive 99.99 percent of communications about emergencies from passengers. So, we are clearly specifying the requirement here that 99.99 percent of communications about the emergencies from the passengers should be

received sorry and the elevator systems all receive information about total passenger weight in a given car that is 90 percent correct

So, there are systems capable of identifying the total weight then of 90 percent.

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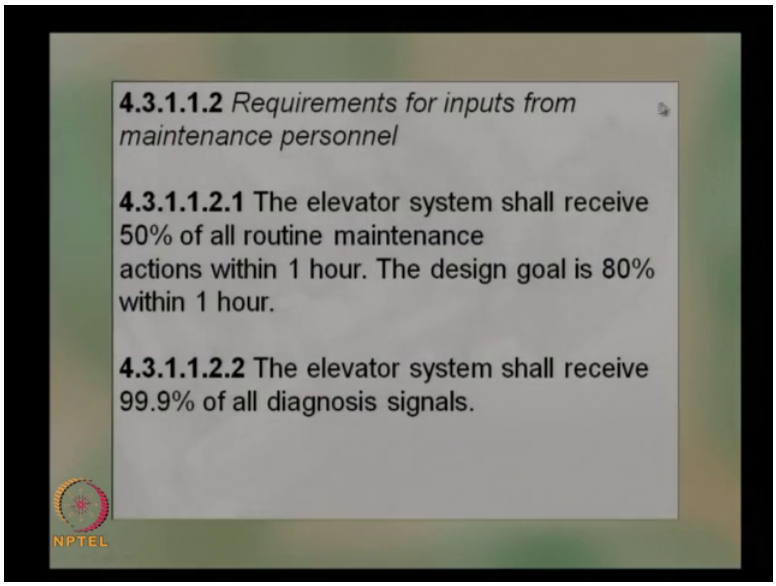

Similarly, the requirements for input some maintenance personnel the elevator system shall receive 50 percent of all routine maintenance actions within 1 hour, the design goal is 80 percent within 1 hour. So, within 80 percent this involves 80 percent in 1 hour, but at least 50 percent of all routine maintenance should be received, the elevator system shall receive 99 and 0.99 percent of all diagnosis signals.

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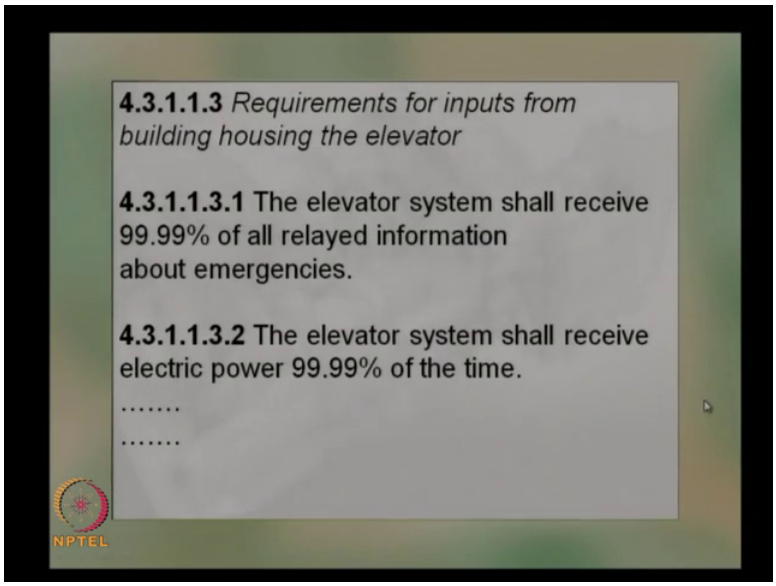

So, this is a standard way of writing the requirements as I mentioned earlier. So, you can see the requirements for input from building housing the elevator the elevator systems shall receive 99.99 percent of all relayed information about emergencies; the elevator system shall receive electric power 99.99 percent of the time.

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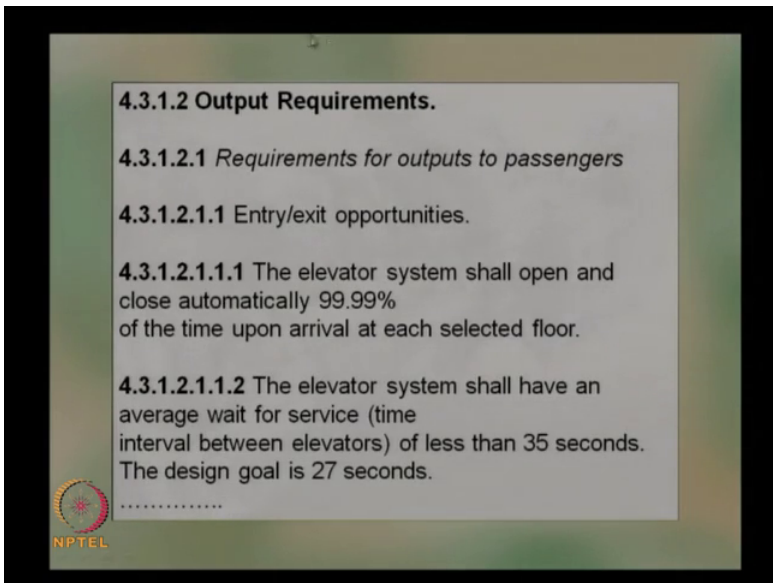

Similarly, output requirements; requirements for outputs to passengers and this exit opportunity output should be these are the requirement for entry exit opportunities, it is the elevator system shall open and close automatically 99.99 percent of the time upon

arrival at each selected floor. Similarly the elevator system shall have an a average wait of for service it is time interval between elevators of less than 35 seconds the design goal is 27 seconds that is service means that the waiting time for the passengers .

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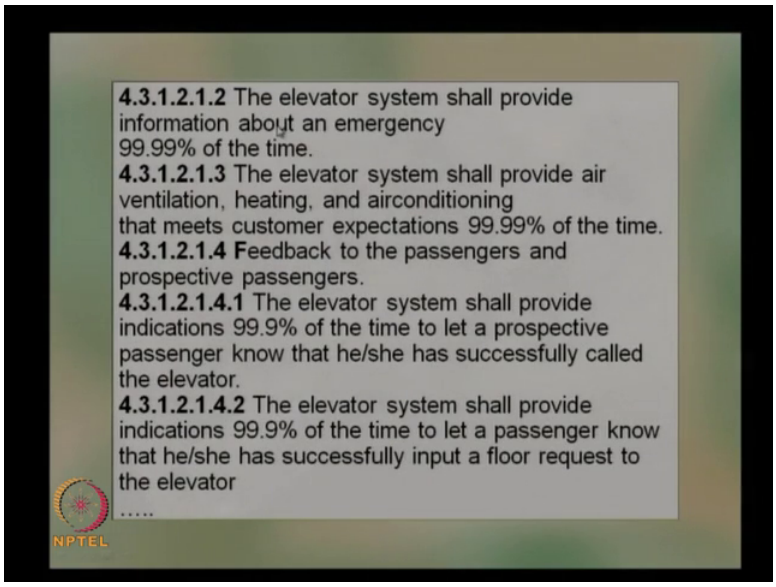

Similarly, you can write down many requirements are all the requirements identified can be written out with the proper run numbers the elevator systems all provide information about an emergency, the elevator systems all provide air ventilation heating and air conditioning that meets customer expectations 99.99 percent of the time.

Feedback to the passengers and prospective passengers the elevator system shall provide indications 99.9 percent of the time to let a prospective passenger know that he she has successfully called the elevator. That is the feedback requirement here the elevator systems shall provide indications 99.9 percent of the time to let a passenger know that he she has successfully input a floor request to the elevator .

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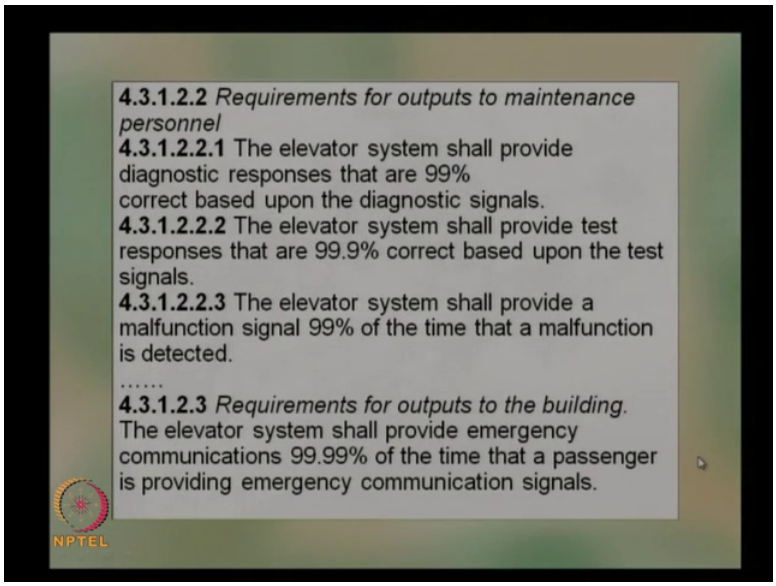

These are the requirements we write down for various situations.

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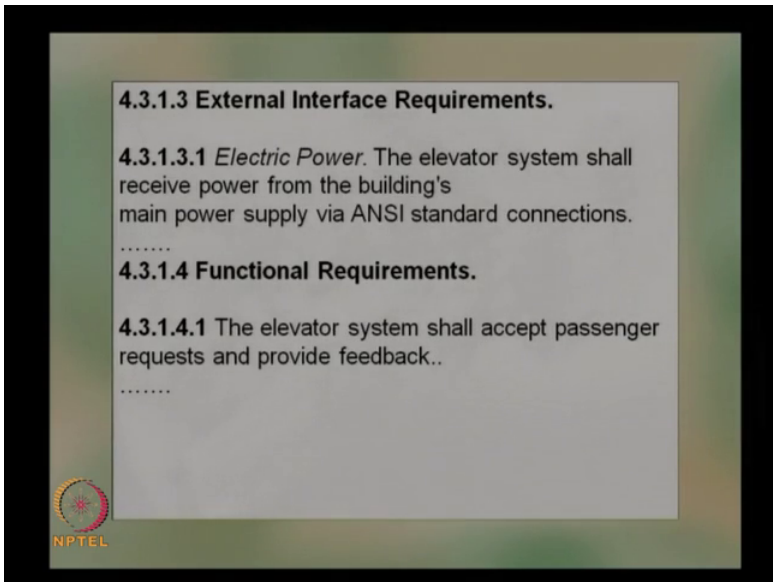

Similarly the maintenance personnel and external interface requirements the electric power the elevator system shall receive power from the buildings main power supply via ANSI standard connections and the functional requirements elevator systems are like say passenger request and provide feedback.

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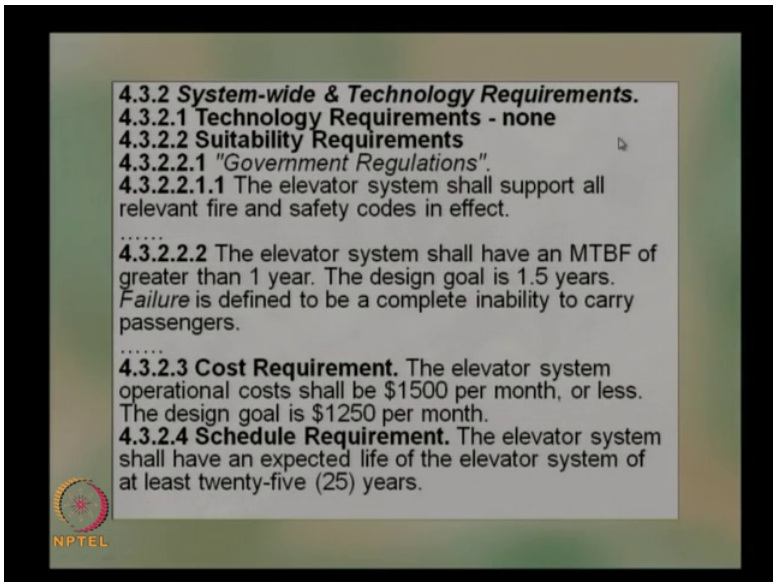

System wide and technology requirements are there. So, the technology requirements no technology requirement is identified and there are suitability requirement about the "Government Regulations". The elevator systems all support all the relevant fire and safety codes in effect the elevator systems all have an MTBF that is main between failures of greater than one year the design goal is 1.5 years failure is defined to be a complete inability to carry passengers.

And the cost requirement the elevator system operational cost shall be 1500 dollar per month or less the design goal is one thousand and 50 per month in the schedule requirement the elevator system shall have an expected life of the elevator at least 25 years then trade off requirements.

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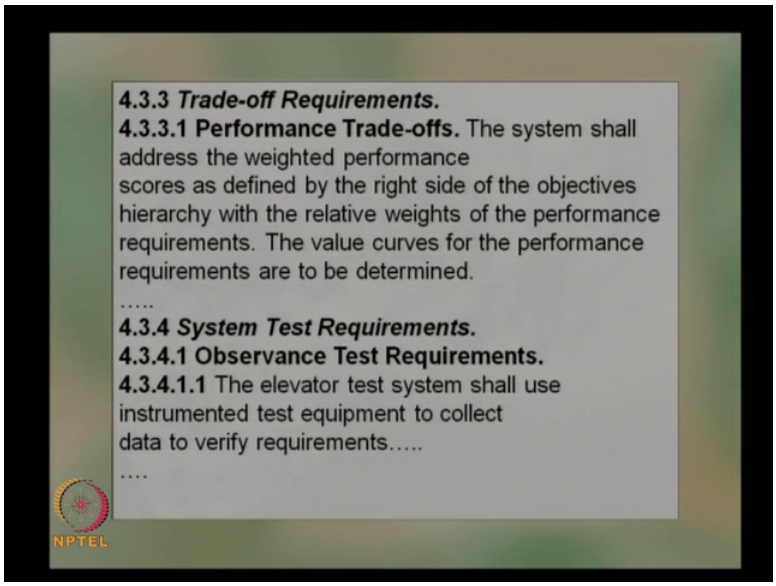

Basically the performance trade off the systems shall address the weighted performance course as defined by the right side of the objectives hierarchy with the relative weights of the performance requirements we discussed about the objectives hierarchy. So, based on that hierarchy this requirement is defined based on that the value curves for the performance requirement are to be determined in the test requirements observance test requirements the elevator system test this system shall use instrumented test equipment to collect data to verify a requirements.

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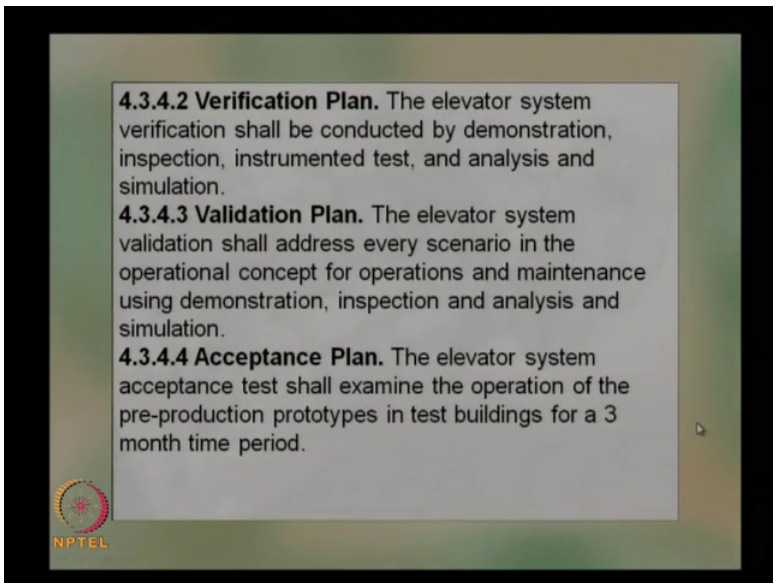

Then the verification plan and validation plan, acceptance plan. So, again the requirements for all these verification validation and acceptance also need to be identified and writ10 in the document ok.

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So, that is about the requirements documentation this actually this picture shows that airbag system what we discussed in the first lecture.

So now, we can go through this case study and see what actually went wrong in the requirement identification. As I mentioned the failure of the airbag was because of the wrong identification of requirements or non-identification of requirements. You can go through this case study and then see what actually went wrong what was the requirement what was the failure in the requirement analysis and prepare a document showing that what actually went wrong in the design of this airbag. I will provide you the assessment or the analysis result in another class.

Thank you very much. We will meet again in the next class bye.