**Fire Protection, Services and Maintenance Management of Building**
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**Lecture - 19**
**Design of Lift systems: Simulation and arrangement & Escalators**

So, we continue with lift right. As we are doing and this we have looked into and then, you know we said that we can also simulation is also possible.

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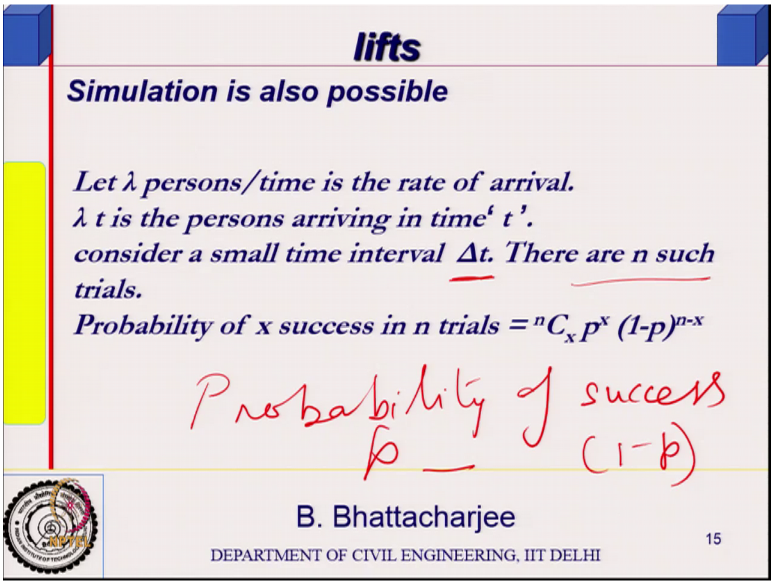


This becomes important. We are looking at when one is looking at random interflow traffic, random interflow traffic rather than you know we have gone for we have designed it on the basis of up going traffic, right. One way, but there can be situations where random interflow traffic is also there so, one can simulate it also. Now, basically this is done as a person's process; this is done is a persons process right. So, it is done is a persons process. So, what do we assuming is, first of all, let us say lambda persons per unit time is a rate of arrival. Let us say, lambda persons per unit time is a rate of arrival and lambda t is a person arriving in time t right.

Now, we assume that time interval is very small delta t such that not more than one person will arrive during that period of time it is so small that, not more than one person do. So, we call it as a success. So, one person arriving during that period of time; so, very small time delta t and during that period of time, only one person can arrive right and I have there are such n number of such trials are there. So, n number of such trials or n into delta t time I am considering right. Now, if you look at it, this is this is a you know if I look at this, this is actually a case of a what you call a binomial distribution; that means, I have either success or failure.

Student: Failure.

So, if the probability of success is probability of success probability of success probability of success. Let me call it p; then, probability of failure is 1 minus p.

Student: 1 minus p.

Supposing, I am interested in finding out of my n trials x success right, now I was just talking about last class, I start talking about scenario of a die. So, supposing I want to find out what is the probability of I have n trials; n trials of the die. I throw it n times.

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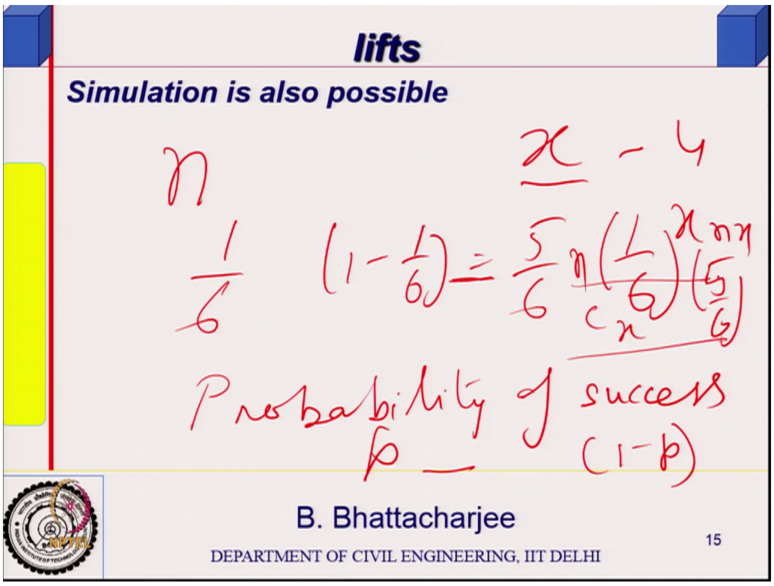


And what is the probability that I get x number of times? Only 4.

Student: (Refer Time: 02:59).

Any so, getting probability of getting 4 is successes 1 by 6 because, there are 6 outcomes possible and probability of failure is 1 minus 1 by 6 which is equals to 5 by 6. So, to get exactly x number of success out of n trials, let us say. So, you know, if I have to get x trials x, x success it is it is basically the joint probability of x success.

Student: X success.

And n minus x failure because, exactly x I want to get. So, probability of x success is 1 by 6 to the power x and joint probabilities so, multiply 1 by you know 5 by 6 to the power n minus x. So, that is the joint probability of, but this x, I can select in n C x way. For example, first x can be success, next n minus x can be?

Student: Failure.

Failure or maybe the first one itself is a failure so, I can select so, therefore, it is, so, this is this is what the concept of binomial distribution is, right. So, here also, we are applying the same thing. I have got as I said, I have got n number of trials so, probability of x successes in n trials given by this formula right. Probability of x axis and when this p is very small and n tends to infinity p is very small n tends to infinity, then this is what is a person's approximation person's approximation you know.

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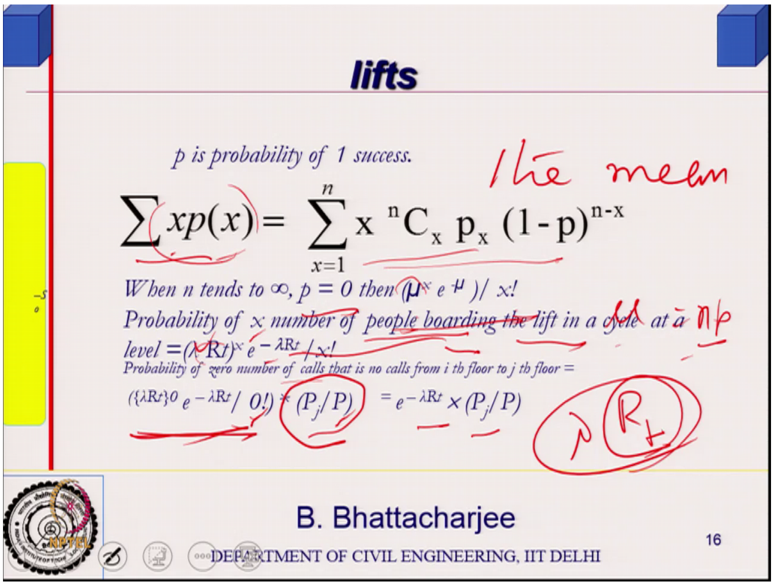


So, when p is probability of 1 success so, this is what we said binomial is when n tends to infinity p tends to 0 p is small you can show by expansion of this one. The mean of course, is x p x, the mean would be the mean would be the mean; how will you write mean? Mean will be x multiplied by the probability of x. Sum it up for all the possible outcomes then you get this value and this you can show will be equals to n p.

So, whatever it is so, when n tends to infinity, p tends to 0; one can show that this is this probability is mu to the power x e to the power minus mu divided by factorial x right. Now, mu itself is equals to n p. So, therefore, one can use this Poisson distribution concept for simulation of the, you know simulation of the lift thing also. So, let us look at this probability of finding a person in j th floor is P j by P. Probability of finding a person in j th floor. So, the lift is somewhere probability of call from j th floor like probability of call from j th floor would be P j by P and.

Student: (Refer Time: 05:58) What is P? (Refer Time: 06:00).

P is the population. P is a population.

Student: (Refer Time: 06:04).

Capital.

Student: Instead of we have to take.

J th floor.

Student: (Refer Time: 06:09).

Summation yeah. So, P should be basically total population. Or summation of all the all.

Student: (Refer Time: 06:16).

The floor yeah sigma P is etcetera. So, let us say, it is the total population. I am calling it as P total population. I am calling as P. So, probability of 0 calls right, probability of 0 calls from that flow probability of 0 number of calls or no calls from i th floor to you know to j th floor is supposing it is at i th floor, somebody wants to go to the j th floor. So, the probability is the joint probability of basically not you know joint probability of finding 0 person belonging to j th floor who is making a call from i th floor, you know. Probability of finding 0 person making a call.

Now, the mean in this case would be as I said is equals to n into p mean is n into p and in our case, you know in our case, p was equals to p rate of arrival was if R t is the round trip time, lambda R t is a people number of people coming in during that period of time. So, rate of arrival. So, you know if you if you go back to the previous slide, for binomial distribution, it is yeah probability of number of people boarding a lift. You know this is this is lambda R t, lambda is the rate of arrival R t is the round trip time. So, total number of people who are going to come during that period of time is?

Student: (Refer Time: 07:31).

Lambda R t.

Student: (Refer Time: 07:34).

Now, if x people are to arrive, x success has to have occur. Then to the power x you know and this is what we said the mu is basically is equals to mu is mu itself is lambda into R t. In this particular case, I hope I have something more than this here or I have just left it is not really. So, so, you know this is lambda R t is a lambda R t is the mean actually mu to the power x and e to the power lambda R t minus mu divided by x bar.

So, that is considering it is a Poisson's process the probability of x number of people boarding the lift in a cycle at any level is given by, lambda R t to the power x into e to the power minus lambda R t divided by factorial x. So, probability of 0 number of calls that is nobody boarding from that i th floor who will go to the j th floor is actually the joint probability of finding a person in j th floor, but nobody boarding from i th floor.

So, that is why, this multiplication 0. 0 person actually pressing for j th floor in i th floor or any floor for that matter, in this case, we are saying i th floor. So, this would be simply this is 1 and this is e to the power lambda R t P j by P. So, that is the probability of finding no person at any floor pressing for j th floor pressing for you know pressing for j th floor right. This is a kind of concept.

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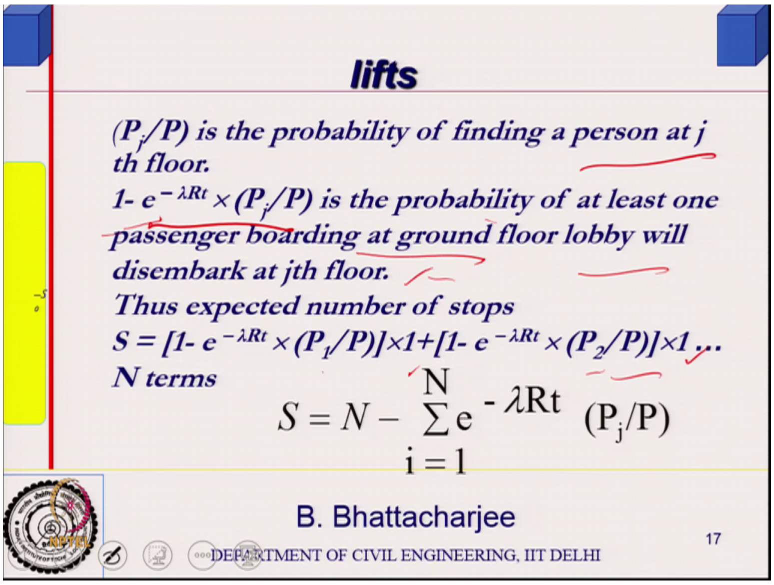


We are using P by P j by P is a probability of finding a person at j th floor. 1 minus R t is the probability of at least one passenger boarding. So, this is the probability of finding 0 person. 0 person calling to calling you know calling for going to j th floor 1 minus that would be at least one person pressing the button to go to the j th floor, yeah.

So, it is a probability of at least one passenger boarding at any floor. So, it could be ground floor, it could be ground floor lobby and which who will gives disembark at j th floor. This I can extend to any floor. I am saying ground floor because, we if we look at one way traffic, only up going traffic only, then this will be at the ground floor. So, at least one person boarding the lift to go to j th floor would be given by?

Student: 1 minus (Refer Time: 10:12).

1 minus e to the power lambda minus R t into P j by you know this 1 minus this term right thus, expected number of stops. One can then find out so, expected number of stops will be like we did earlier, this is for the first floor, this is for the second floor, this is for the third, all the n terms if I multiply, then I get expected number of floors. Because, P 1 this is probability of finding at the first floor. This is probability of finding at the third floor. This if I find one person at least one person, then multiplied by 1. That is, now one number of stop this multiplied by again 1 finding one number of stop; I mean stopping at first floor; that means, one probable stop you know probability of stopping at expected value is a one stop at every floor.

So, one multiplied by the probability of stopping at that floor so, probability of stopping at first floor, second floor, third floor and every one. I should be multiplying by 1. So, this is this n terms. I should sum up and if I sum up n terms, I get this sum there will be n such terms of 1, I get n and this I can sum up as I equals to 1 to n. Because, n is the total number of floors are e to the power lambda R t this term and this would be P j going from P where you know or P i going from you know this will go from P j going from 1 to n for all of them. I should sum it up for all of them. I should sum it up.

So, that is the problem number of stops. If you are calculating on the basis of Poisson's process, you know probable number of stops, formula remains same.

Student: R t is (Refer time: 12:26).

R t is the same by definition. It is same except that only thing we are changing here.

Student: (Refer Time: 12:31).

We are assuming it to a Poisson's process rather than a heuristic way by which we calculated the you know expected number of stops or floor of reversal that we calculated in a or rather formulated in a heuristic way. Here, we are using it as it is a Poisson process right. Well, they do not necessarily give you exactly the same answer, but this is a this is this becomes useful if you are simulating it.

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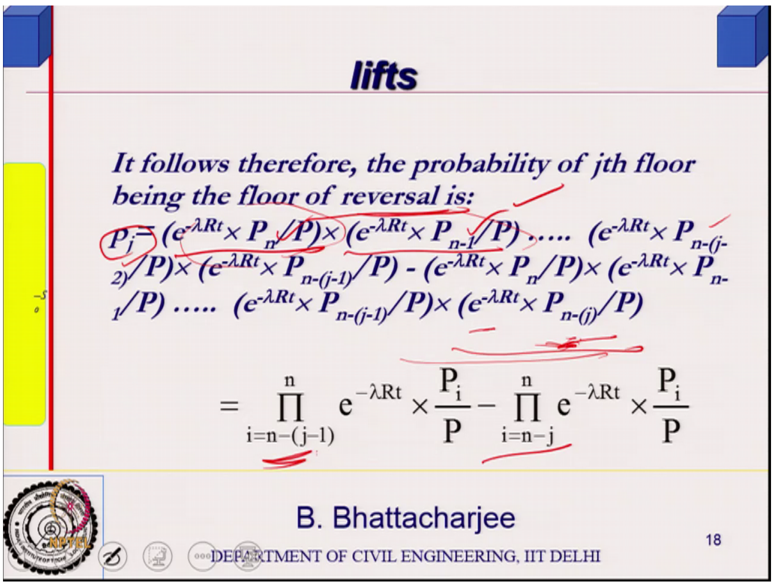

Now, if you want to find out, now floor of reversal I want to find out floor of reversal j th floor being the floor of reversal right. Like we did last time, it is the joint probability of finding you know I mean joint probability of not finding any person in nth floor n minus 1th floor n minus j th floor etcetera up to you know 1 floor above up to 1 floor. So, it is a joint probability of. So, this was probability of not finding a person going to nth floor. This is the probability of not finding a person in n minus 1th floor and so on up to the n minus. You know there is a topmost floor next topmost floor and 1 floor above j th floor. This is not finding one floor above j th floor.

So, this is P j stands for probability of not finding anybody above j th floor probability of not finding anybody above j th floor because, this is probability of not finding anybody in nth floor. This is probability of not finding in n minus 1th floor; that is, the one floor just below the top floor and so on up to one floor above j th floor. So, this is the probability of not finding any person above j th floor. This multiplied by j it is a probability of j th floor being the floor of reversal right. And sum it up for all the floors, then you will get expected floor of reversal. So, that is what we do. So, you see this is product.

This is product this is product basically this is product this is product. So, product from you know product going from m j minus 1 to n e to the power etcetera minus this gives me the probability of finding at least one person in the j th floor. Like we did earlier, you see this is not finding up to n minus probability of not finding anybody from one floor above j th floor. And this is the probability of finding you know up probability of not finding anybody one floor below j th floor. But, that is the probability of finding at least one person in j th floor. When it will become floor of reversal, you do not find anybody above, you do not need not find anybody below.

So, this is what it this is what you know this is what the probability is this multiplied by j and sum it up for all n of the n of them. Then you will get the so, then sum it up for all n of them, then you will get the expected floor of reversal like we did earlier. Now, this is if it becomes important, if you are simulating you can be assumed Poisson's process and simulates or generate random number and then you know even random interflow traffic, you can use this concept. If we calculate by this formula, if we calculate by this formula or the heuristic they do not exactly give you the same.

In fact, heuristic one gives you a better answer. If I look at for only one directional traffic you know so, we would be mostly using the earlier one for our design purposes, but I thought I will give you this concept as well for simulation if there is for random interflow traffic.

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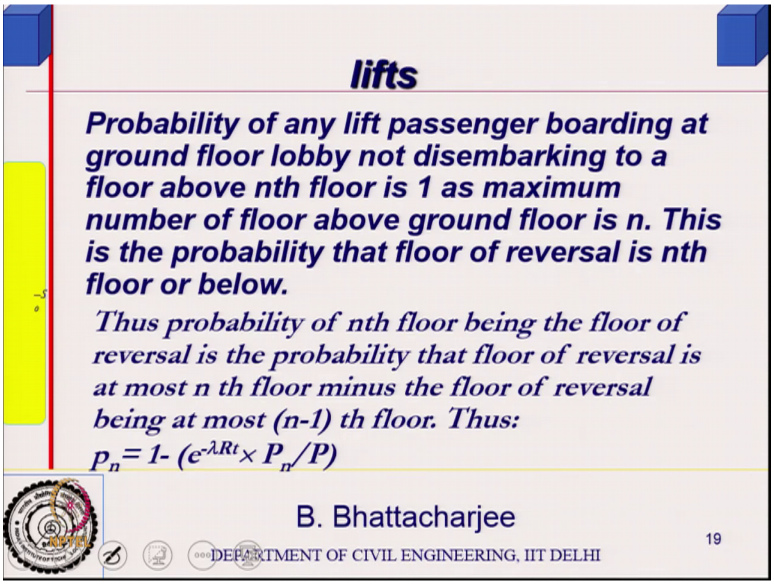


So, therefore, you know ok. So, probability of you know probability of any lift passenger boarding at ground floor lobby not disembarking to floor above nth floor is one as maximum number of floor above ground floor is n. So, this is floor of you know, if the floor of reversal this is this is probability of lift passenger boarding at ground floor lobby not disembarking to a floor above nth floor is 1. Because, there is nothing above n and you know there is no floor above the ground floor. This is a probability of that floor of reversal is nth floor or below.

The probability of nth floor being the floor of reversal is a probability that floor of reversal is at most nth floor minus the floor of reversal. Being at most n minus 1th floor, you know I am just whatever I said; I am just putting in the algebraic terms now. So, probability of nth floor being floor of reversal is this. If you have any other floor it will be something like this.

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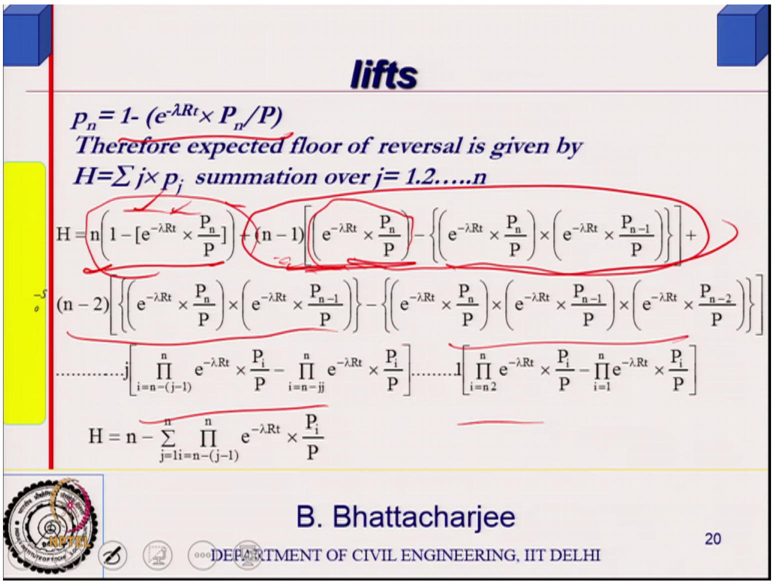


So, H would be simply j multiplied by P j, where P j is the probability of finding j th floor being the floor of reversal. So, this is the sum total for all floors P n is this n minus 1 is that same formula that I just mentioned joint probability and all that whatever we have mentioned earlier. We are calculating from this product this product, we are calculating from this product. So, expanding this putting it here in the formula overall so, H becomes n into probability of finding nth floor or below as you know finding at least one person in the nth floor. So, floor of reversal being n this floor of reversal being n minus 1 n minus 2 n minus 3 etcetera.

So, this to sum total gives you because, what was this is the probability of you know probability of probability of finding one person finding you know finding. What was this? Just let me repeat, probability of finding one person in n minus nth floor this is finding at least one person in n minus 1th floor. So, sum this different you know n minus, I mean the floor of reversal being n minus 1 is given by the this difference.

Like we did earlier, in case of heuristic as well, same thing at least one person would be there up to nth floor, one person would be there up to you know nth floor and this I repeat. So, this P i that multiplication sign I am using it expanded form, here in this one. So, this is this is in you know this expanded form. I am just using this in expanded form. And that is how it is. So, one can obtain H value something like this H can be formulated in this manner H can be formulated in this manner where n because, this n into 1 will remain. This product again will cancel out leaving one time. Because, there is n minus 1 term of this there is n term of this.

So, one term will remain one term remains similarly one term of this one remains one term of everyone remains and then this is a summation this summations plus sign here and this is a product sign product going from like earlier also, we did the same thing. 1 to n j going from 1 to n and this goes from n equals 2 j minus 1 to n. You know, if this product if I take this is this is the product part, the summation part every time a one only one term of this one remains; only one term of this one remains. And only one term of this remains. So, this can be I can sum it up. So, height of reversal expected height of reversal, I can calculate out in this manner.

So, as I said that this does not give you exactly same answer as a heuristic and heuristic gives you a better answer you know. Heuristic design is better. It is generally better and if you assume that there is rate of arrival is not same as rate of going up, then we did not trial and error procedure. That we can find out. So, you can actually design the number of you know what is a like basically if you know what is the handling capacity desirable and how many number of lifts are required. Because, based on handling capacity acceptable waiting interval handling capacity. If you remember, it was peak 5 minutes period number of people that will be handled by the lift system expresses percentage of the total population.

So, what we know is, waiting interval. From there, we can calculate out the waiting interval and what is waiting interval round trip time divided by number of lifts round trip time divided by number of lifts. So, if I calculate out the waiting interval and I assume a lift capacity, I can find out the round trip time and then find out for the waiting interval, how many number of lifts are required?

So, basic idea is a number of lifts, how many number of lifts? I should provide lift arrangement lift arrangement and operation of the lift. Whether it will act as passenger or it will act as you know express etcetera. So, scheduling of the lift operation that is what we said and this will also would be this will govern the round trip time. So, it will be related to the round trip time, right. So, basically arrangement is other aspects design. So, far we have looked.

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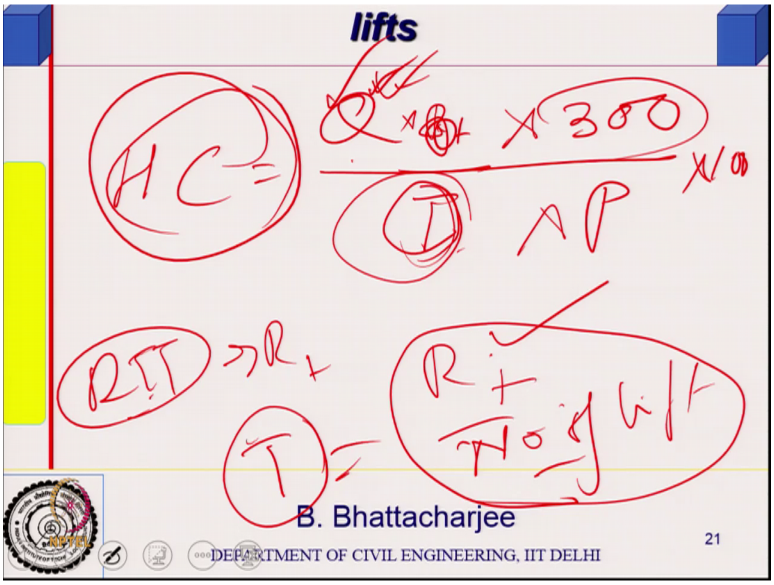


Just let me rewrite it. Handling capacity was Q right. Q is the total number, so, into 300 number of.

Student: (Refer Time: 22:31).

Trips will be round trip time divided by round trip time divided by waiting interval round trip. How many you know in each trip in each trip will be if the R t is the round trip time, sometime I might have used R T T. Whatever it is or R t is the notation I might use.

So, if R t is the round trip time, R t divided by T is the number of trips, number of trips right. Because, waiting interval is this. So, this is the number of trip during a number of trip right. In number of trips, you will have in how many seconds? In 300 seconds you will have this much number of trip actually 300 seconds.

Student: (Refer Time: 23:10) formula (Refer Time: 23:12).

Sorry, sorry, sorry this.

Student: (Refer Time: 23:15).

Yeah, 300 divided by T is the number of trips in 5 minutes.

Student: 5 minutes.

Q is the number of people going in one trip right and.

Student: Divided by formulation.

Right into x multiplied by.

Student: 100.

100. So, that is it and T, I can find out is R t divided by number of lifts. Number of lifts number of lifts is equals to t R t you know T. So, if I know this handling capacity, if I also know a desirable waiting interval right, desirable you waiting interval or you find out actually what is there for handling capacity what for choosing a particular lift size what should be value of T.

So, if you know the value of T and it should be of course, it should be of course, acceptable values, I will just give you that value as well. So, number of lifts, actually you can calculate out because T R t divided by number of lifts. So, for given non Q you can find out R t and R t divided by number of lifts that should be equals to T so on. These bases you can find out actually number of lift. Other thing that you have to do is, a arrangement of the lift other thing that you have to do is a arrangement of the lift right.

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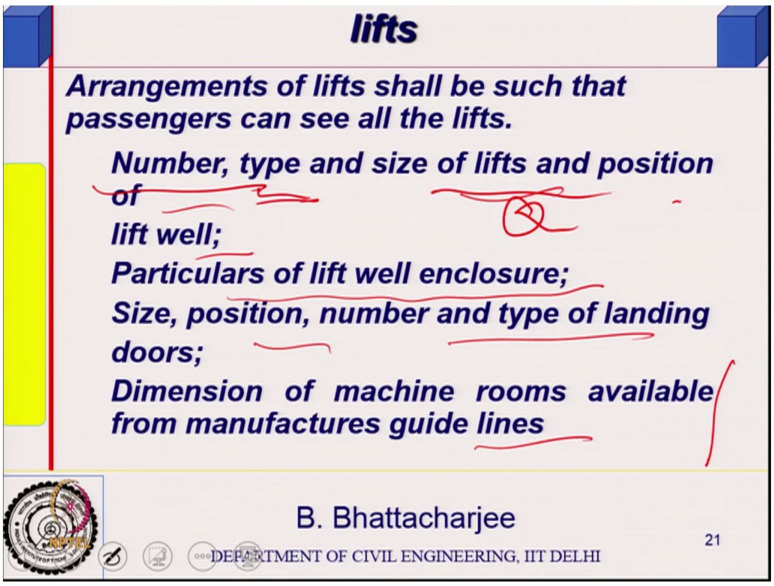


So, arrangements will be such that passengers can see all the lifts. So, number type and size of lifts and position of lift. Well, these are what this is what we got to decide particulars of lift well and closure size position number of landing doors dimension of the machine room available. This will be available from manufacturers guide line. So, basically we want to decide number of lift type of lift will depend upon occupancy type because, hospital lifts are designed for taking the passengers. So, their dimensions are different right and normal office lifts etcetera, etcetera. They are different size of the lift of course, is Q. Then position of the well depends upon the as I said, there can be I can do horizontal zoning. So, it is a part of a planning itself part of the planning itself. Usually, it is usually it would be at the central point at the central core.

In a tall building it will be in the central core. Because, that also helps in structurally also that might help or one may take advantage of that. So, size we have talked about number of type of landing doors. That also we can decide how many landings we would you know like, what kind of landing doors you might have machine room dimensions are available for manufacturer's data. This value these are given in national building code these are given your. So, only aspect remains is to find out the number of lifts and for a given capacity and desirable waiting interval for also handling capacity, you will see that you know what good is.

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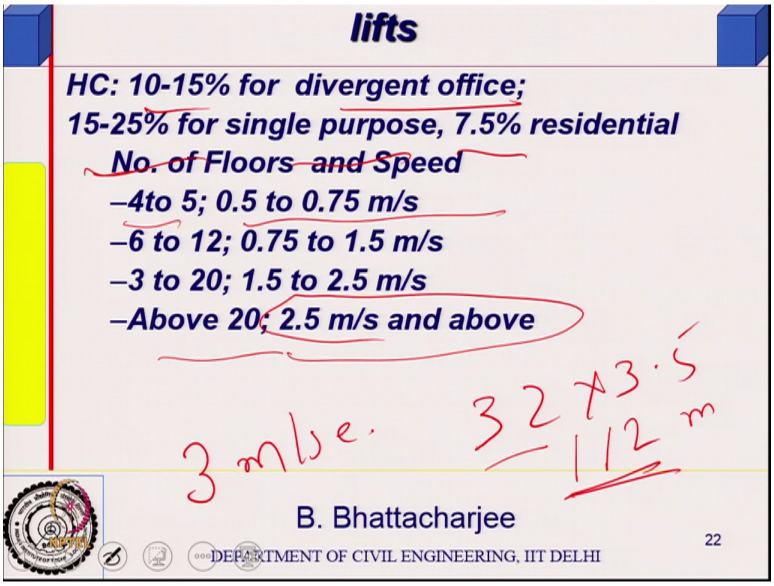


For example, 10 to 15 percent is for divergent office. Good handling capacity suggested is 10 to 15 percent for divergent office; 15 to 20 percent for single purpose office. So, what we talked about the design, that is the most complex design is single purpose office. There you should be able to handle.

Student: More.

More number of people so, 10 to 25 percent for single purpose. 7.5 percent you know is the suggested value in code for residential because, residential people do not come go. At same time it is all you know they at any different time they will go and add. And remember, number of persons per unit floor area is much less you know; if you remember, 12.5-meter square per person. While in a assembly office, it will be much less area per person. So, in residential area population density is less.

So, therefore, this is a handling capacity and number of floor and speeds up to 4 to 5 floors. These speeds are good enough right, above 22.5 meter per second and such speed. Now, just to supposing something like a 40 storey building and he want to go above let us say 32 storey and above, 32 storey means, let us say even if I take it around 32 into 3.5, let us say or 3 3 meters or 3.5 meters you know. So, how much it would be? Somewhere around 100 plus right, 112 meter right 112 meters.

Now, 32 storey 112 meters and if it is something like 3 meters per second, it will take about you know it will take about 30 seconds or so. So, that that desirable that is understandable it is fine thirty seconds people do not, but if it takes about 5 6 minutes. People will get actually disturbed. So, you have you can plan that way that it does not stop anywhere. It goes straight away up to the 30 second floor. And then of course, it goes as passenger that is fine. So, that is why, the speeds are something of this order speeds are of this order and handling capacity have been.

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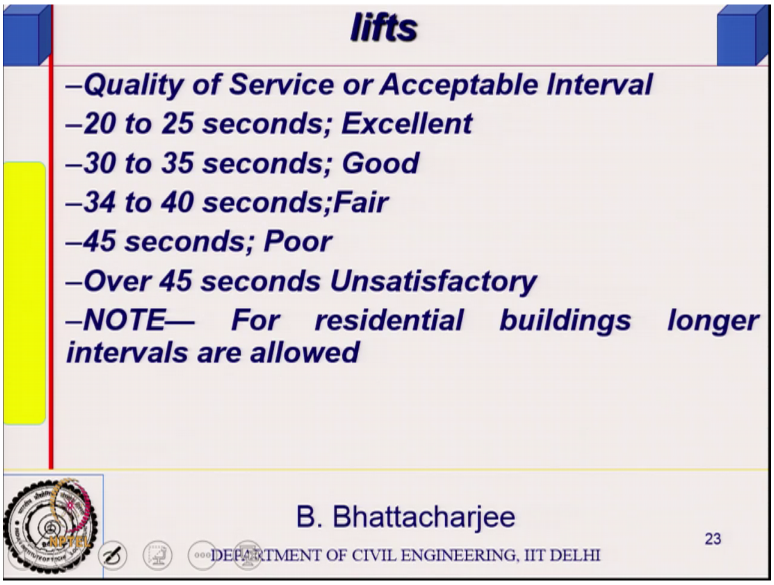


Waiting interval, quality of service, acceptable waiting interval: 20 to 25 seconds; excellent; 30 to 35 seconds; good. 30 to 40 seconds; fair. 45 seconds; unsatisfactory. For residential building of course, you know longer intervals are allowed; longer intervals are allowed. So, that is how it is. Escalators if you look at it they are used.

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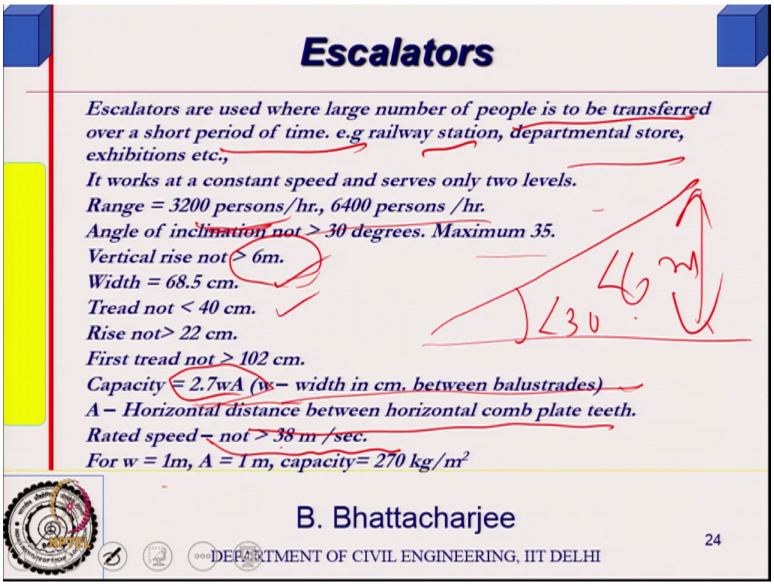


Where you have large number of people, but the height you have to serve you know service side. I mean, you go from floor to floor, 1 floor to 2 nd floor, that is it or maybe you know like then, you have to have for each floor or each one level to you know only for one level, you serve. Even if you serve 2 level, because the stop there, no intermediate stop. It simply goes starts goes down or starts at the bottom goes up.

So, basically it is serving one level only, but it can handle very large number of people in large number of people, because a continuous process. So, they are useful large number of people use to be transferred over a short period of time; railway station, airports and so on. It works at a constant speed and serves only 2 levels. 2 levels space required is also large.

So, in, but then where you want people do not you know people have to go from one level to another only and you want them to see the surrounding like in a departmental store or something like that showroom, then escalators are good right. 30 something of the order of around, it will handle something like 33000 to 6400 3200 to 6400 persons per hour. So, handle very large number of people angle of inclination is never greater than 30, never greater than 30; maximum 35. Angle of inclination is not you know it has to be limited.

So, therefore, it consumes quite a bit of space because this inclination. So, it consumes that space right and not more than 6-meter height. So, this is maximum 6 meter this is less than 30. This is less than 6 meters. So, that is what it is and width usually 62 you know widths of this kind tread comfortable. It should be less than 42 rise not more than 22 capacity. Generally, this is a simple formula. If the width is w is a width right, between the handles actually.

So, 2.7 w into A where A is a horizontal distance between horizontal comp plate and teeth. Because, it goes as a steps when it returns it returns as a flat one in the bottom side which you do not see. So, it is related to that rated speed not more than 38 meter per second. It should be 3.8 meter per second or whatever it is and w you know. So, one can calculate out the capacity using this formula 2.7 w into a right. So, one can calculate.

So, that is basically escalators. So, escalators are more or less standard design. There is nothing to be done. You have got to plan for it that ok. This is the place; I put it here and where you are only you choose them where you have large number of population to be handle I think we will break and if you have any question, we will take that.