**Fire Protection, Services and Maintenance Management of Building**
**Prof. B. Bhattacharjee**
**Department of Civil Engineering**
**Indian Institute of Technology, Delhi**

**Lecture – 18**
**Design of Lift systems: Different cases**

So, coming back to the same Lift Design, now let me just tell a few things tell a few things, right, tell a few things first of all, I talked about zoning vertical zoning related to this problem itself vertical zoning let us say, now let me tell you.

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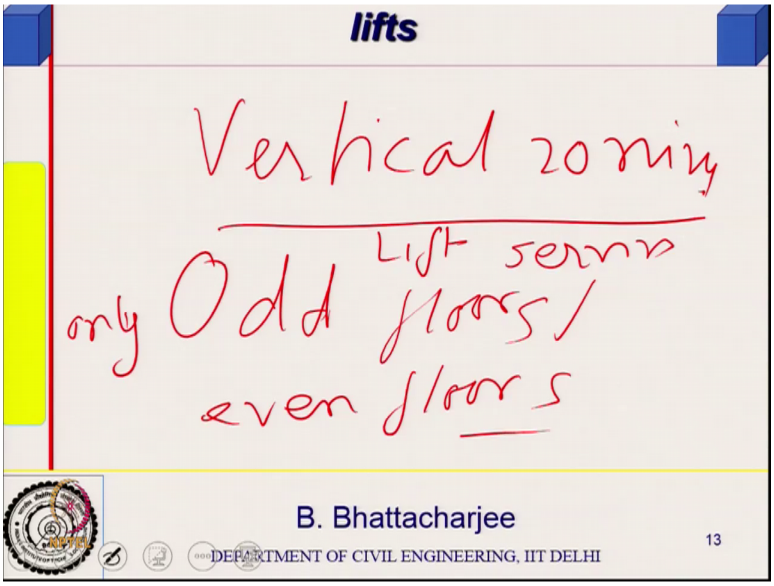


So, vertical zoning, one simple way is to do is make lift stop in odd floors or even floors. So, some lift part of the lift will be operating for odd floor zones, this is up to 16 storey's, you can work out.

Now, so, odd you know lifts are being lifts are being only odd floors or even floors now what is happening, then floor height you know floor height is the.

Student: Twice.

Twice; it is twice floor, height is twice and number of floor to be served is half number of floors; floor height you know where. So, I can actually so, you can see that your round trip time will reduce down because you know n minus the n comes in n become has become half. So, round trip time, but tv is more. Now t it not tv is a 1 floor, yeah, tv will become more and tf will become.

Student: More.

More, more, tf is the one floor jumped up now the floor height has become more right. So, this you know we are calling it df; height of the floor divided by velocity; velocity is same. So, distance of floor to floor distance that is become double; so, there is the only thing the other situation that you may come across other situation that; you may come across is you know other situation that you may come across is right.

Other situation that you may come across is I will come to vertical zoning further normally, ground floor, lobby to the first floor, height is more in many places hotels and similar because you will have certain things receptions it is even in offices, you will see modern offices.

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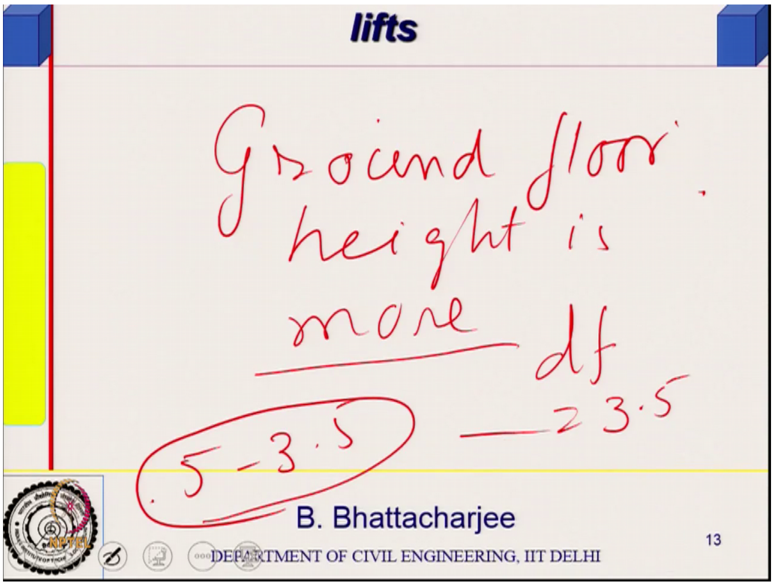


So, ground floor height is usually more ground floor height is more. So, if your ground floor height is more ground floor height is more is more rest are floors are all same, right. So, if it is more then what you do additional height of the ground floor, for example, typical df floor to floor distance, let us say is 3.5 meters, let us say the ground floor height is 5 meters, then you have got. Now, 5 minus 3.5 additional 1.5 meters, right.

Now, that additional 1.5 meters would be traveled at constant speed. So, that time you got to add twice while going up and going down. So, that time has to be added into the round trip time you know such kind of small details you have to handle depending upon the situation population different is not a problem; population different is not a problem, right and then if you are you know if your are lift access express lift for certain distance like in zoning; let us say it is expressed you know express lift for certain distance express zones vertical zones.

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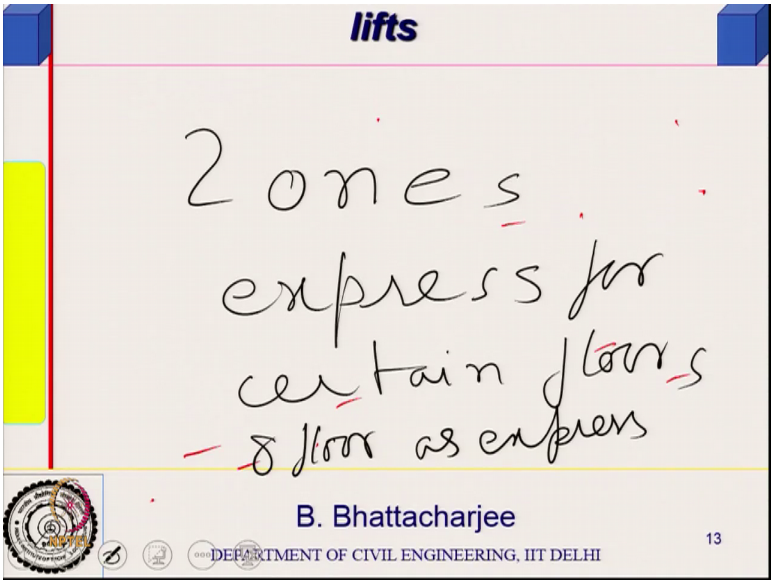


So, express for certain distance certain height certain floor height certain floor; certain floors that distance you will take at constant speed. So, it goes up to let us say 8 floors as express. So, up to 8th floor height, it will go at constant speed. So, you know like it is like having a floor height different, it is not going to stop there. So, it will straight away go to up to eighth floor, then it will you know then our formula applies. So, total number of floors will become not 16, it will be actually 8 plus plus 1 because 8 floors, let us say it is serving as passenger below ground floor. So, there is 9 floors to be served.

And ground floor height or first floor first top height will become 8 into floor heights or floor heights up to 8 floor. So, that would it would travel at constant speed constant speed and you can see that round trip term will now reduce down, if you are passenger lift, then it would have gone to all the 16 floors probability of number of stocks everything is related to n. So, n has got become half practically from 60 into let us say 9 like 60 into 9 and that is one aspect second aspect is it is traveling at constant speed for that distance.

Otherwise, it would have jump you know that many number of there. So, you can see that round trip time, I am reducing down, but making it express and if you calculate out the round trip time for the up to 8th floor this is also less.

So, you can see that you can save onto the time of travel comfort in the sense that waiting interval is less which is comfortable people like you know people dislike to wait and also space can be utilized, for example, if it is some shaft is up to 8 floor only. So, top floor; I can use the space for my functional purpose. So, this is one aspect and problems, there are problems of this problems will be there some problems are there and dealing with this several situation ok.

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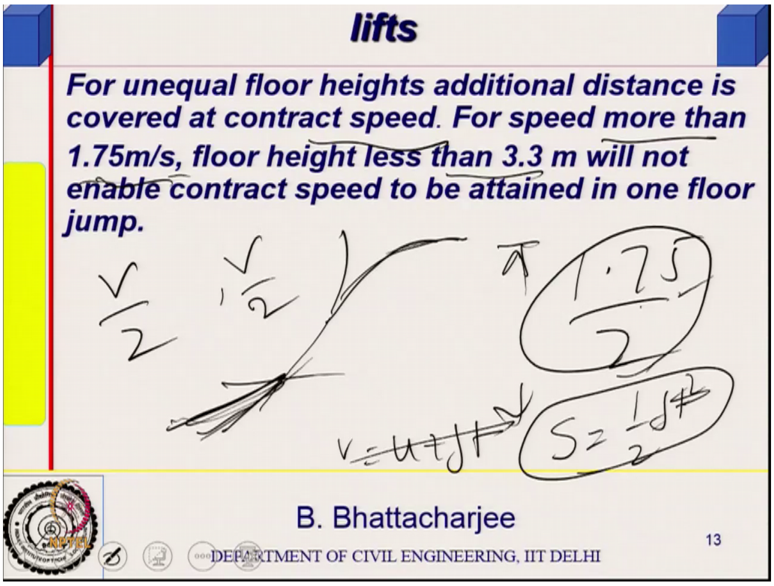


So, that is one thing. So, for unequal floor heights additional distance is covered at contract speed for speed more than 1.75 meter, right, per second floor height less than 3.3 meter will not enable contracts speed to be attained.

So, if the speed is low speed is you know for speed sorry speed is high and I need certain time to arrive at that speed right. So, you can show that if the if it is accelerating and retarding at a constant acceleration, you know usually acceleration rate is constant retarding in the constant retarding accelerating and retarding in the constant rate, I need some minimum height because otherwise within part of the it will just start accelerating somewhere, it will you have to start retarding if the height is less.

So, there is a minimum typically if the speed is velocities let us say contract speed is 1.75 meter the average velocity would be 1.75 divided by two during the acceleration period because it starts from 0 and that is what is used in our v equals to you know u plus ft formula, basically, we assume the constant acceleration and you know you can you can derive this on this basis. So, basically my average speed is v by 2 during acceleration time and during retardation time also, it is deceleration time also it is v by 2.

So, if it is 1.75 meters, I need at least 1.75 you know somewhere around 1.75 meter must be the distance, I should cover with this speed you know with this speed; what is a what is the distance I got to cover because the time would be time would be time would be the distance which I start from 0. So, it is half ft squared no time is not the issue actually average velocity is this you can show that if it is less than 3.3 meters, it will not reach actually that speed it will not reach that speed it will have to actually start decelerating even before it has reached the constant speed even before it has reached here.

So, it is in one second, it will reach in 1.75 you know in in that case, it will reach half of 1.75 velocity in 1 you know like you know sorry its constant speed is this. So, 1.75 meter, it will take actually to 7, but time is not an issue because acceleration it distance, I should be able to find out I should be able to find out distance basically I can find out v is acceleration would be.

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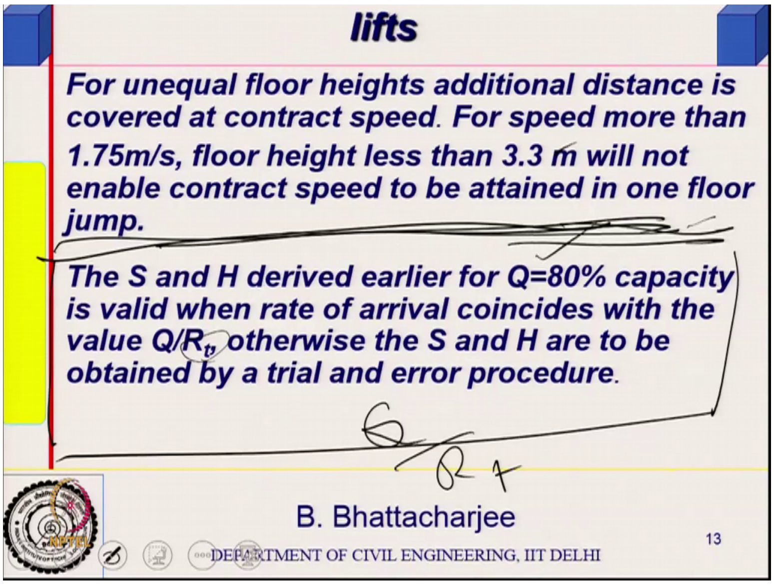


Now, no, velocity is you know average velocity is v by 2 and right, right, right, right, the distance required to arrive at that is arrived at or distance of two things are unknown acceleration and distance so.

Anyway; so, that one can show that possibly, you would need one can show that that you need at least minimum distance before it can reach to the acceleration time, I mean you cannot have very high time for accelerating you know short time I mean, it cannot accelerate to that because the velocity has to be achieved 1.75 meter per second now we cannot minimum time required to accelerate to that that you know that would possibly limit it to 3.3 meter.

So, anyway this is this is one issue this is one issue. So, floor that you can you will you can calculate this out now second issue is that is contract speed to be attained in one floor jump time so, it is ok. So, alright we can see that by calculation you can check that how we are calculating, but the acceleration rate has to be known, if it is too fast then; obviously, it can reach at lesser height, but practical heights may not make it feasible, but the second issue is the important issue, we made certain assumptions during this derivation we derived with Q is equals to.

Student: 80 percent.

80 percent capacity; now this is valid when I have sufficient rate of arrival and in a way rate of arrival matches with the rate of service, you know people come as soon as nearly 80 percent or 90 percent, you know like on an average 80 percent people have come, it goes if the rate of arrival do not match with the you know if it does not match if the rate of arrival has to coincides with Q by R t; Q is the capacity divided by round trip time during this period of time, Q is the capacity.

So, that many number of people should be coming per unit time, then in R t time because R t time, it lifts comebacks or waiting interval I can say you know it has to match actually suppose, it is a single lift by the time it comes back same number of Q 1 number of people should come, if more number of people come there waiting interval becomes more if less number of people come then it will go less, then 0.8.

So, my formula changes actually because my H and S depends upon H and S depends upon Q itself. So, if less number of people come actually S will become less H will also become less. So, my formula is not, then this is not valid actually this is not valid. So, this is assumed in a steady situation flow is steady people are coming their body and they are able to go. So, this is with respect to for a single lift if there are more number of lift my waiting interval Q divided by waiting interval must match with Q divided by waiting interval must match with the arrival rate the arrival rate of people should be matching with Q divided by you know waiting interval because Q is the capacity. So, during the waiting interval Q people must come, but this is not the case.

So, otherwise you have to get S and H by trial and error if it does not matter for example, you have I mean supposing you have decided that there will be more number of floors, then rate of arrival you have to match that if you have decided that your more number of floors more number of lifts you know then that is actually required you will find that less number of people are travelling every time because there are too many floor too many. So, waiting interval will get reduced round trip time is fine you have decided on. So, so this matching the steady states this formula is valid for steady state situation if it is not. So, then we calculate out way around and you know trial and error procedure let us see what we do.

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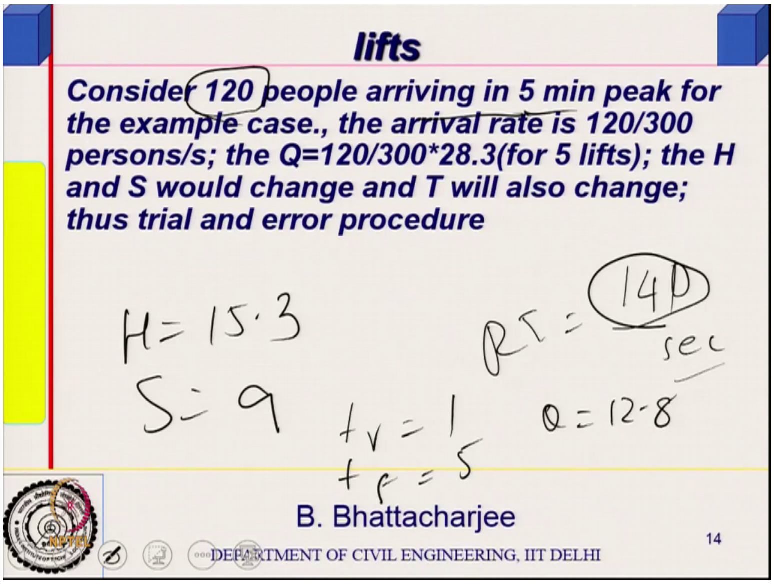


Supposing, I have a rate of arrival 120 people arrives in 5 minutes peak period, right. So, for the same case for the case; that we had we had 141 earlier that problem that we did we found out our round trip time was 140 seconds or something like that you know we found it out remember we found out floor of reversal was S equals to 9, floor of reversal was 15.3 and S was 9 and then we tv we have was given as equals to 1 and tf was 5 seconds remember that we had and Q is equals to 12.8, right that data was there.

So, based on that we calculated out based on that we calculated out, it came out to be around 140 seconds and we said if I have 5 lift; 5 divided by 140 gives me 28 is a waiting interval, right.

So, 28 was a waiting interval, it came as the 141 or something like this. So, let us say in that case in that this is what I have designed the lift with certain assumptions with certain assumption Q is same and arrival you know like population based on population and all that; I calculated, but actual arrival rate is 120 people in 5 minute peak period; in other words, the arrival rate is now 120 divided by 300.

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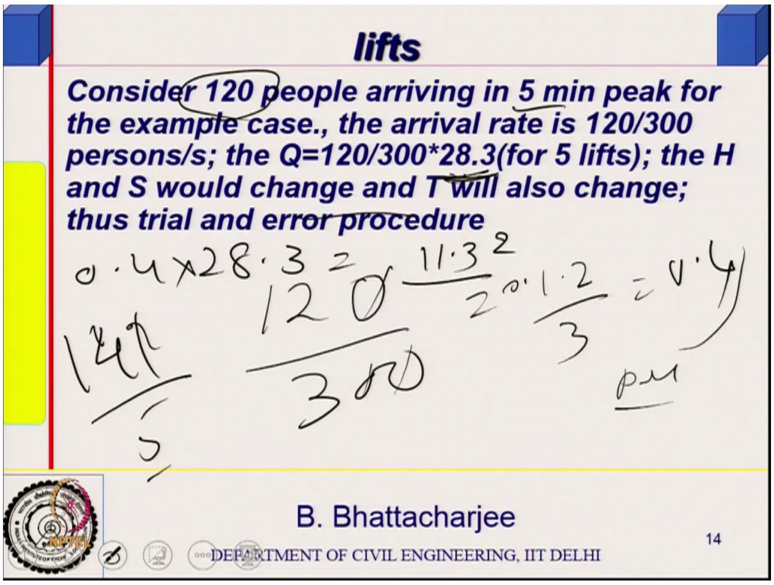


So, arrival rate is 120 divided by 300 seconds is equals to how much? 120 divided by 300 is how much 330; 12. So, it is actually 0.1 to 1.2 divided by 3, right 1 point divided by 1.2 divided by 3.4 numerically; point with 4 per second arrival rate is 0.4 per second person; 4.4 person numerical is fine because we had only doing calculation purpose it is not 1 part no.

It can be I mean theoretically it cannot be lessened, but for our calculation purpose we are saying 120 people arrive in 5 minutes which means that 120 by 300 is a number of people per second. So, that is the arrival rate persons per second actually 0.4 persons per second.

Now, I have actually assumed in you know I found out the waiting interval as 28.3 because it was 141; I think 141 divided by 5. So, exact calculate or something like the 142.

Yeah something so that is 2 and 28.3. So, my actual arrival rate is 0.4 multiplied by 28.3.

Student: 3.

While my assumption is Q was 12.8 you know calculated on the basis of 12.8. So, H and S as should change, then H and S should change because Q is equals to now 0.4 into 28.3 and which will be actually equals to.

Student: 11.3.

How much?

Student: 11.3.

Yeah. So, 11 point. So, it is less than that and all my formula is based on to the power Q; now you know power changes the value would change significantly. So, therefore, I must relook into my H and T situations, it will change and this we do by trial and error procedure.

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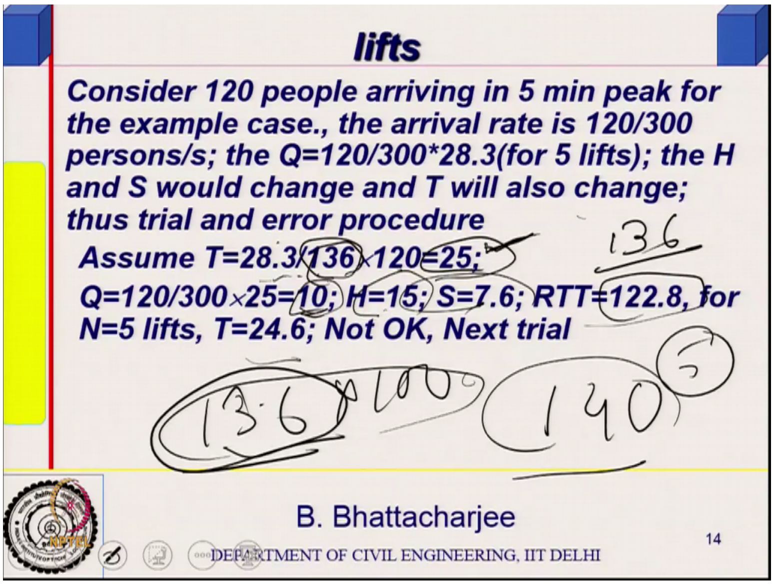


So, what is the trial and error procedure first assume a my round trip time is equals to 130 seconds, I you know what I do is that I assume that 120 people are coming. So, waiting interval what should be my waiting interval 28.3 divided by you know.

Student: 2; 136 point.

No, 136 because 130; this is a T will also of course, it will change and what I am doing is instead of assuming 140; I am reducing it down to some value reducing it down to some value, right. So, basically new I have to get assume that waiting interval is.

Student: I am going to (Refer Time: 18:25) amount to be 13.6 percent.

Yeah, that is but.

Student: (Refer Time: 18:31).

No, no, no, no, not 13.6 percent, you see waiting interval is how did we calculate out waiting interval was.

Yeah, 136 people; we take we took 136 people; 136 people 13.6 is the people 6 percent; that means, out of 1000; 13.6 person; so, in 113.6 in 1136 people 136 people that is what you know that is that is what we calculated out handling capacity, we calculate out.

So, it was handling actually 136 people, but now I want how many people to be handle? 120 people waiting interval was you know waiting interval. So, I want to find out the new waiting interval and then I will go back to because if 120 people are coming, right, I calculate I my actually I assume that 136 people will be handled in 5 minutes, but now I am handling actually 120 people in 5 minutes.

So, 120 divided by 136 into 28.3 this should be my this can be my you know new waiting I mean actual waiting interval should be even if I my waiting interval is 25 seconds and provide a Q for that. So, Q would be 120 second divided by you know. So, 10 is good enough 10 itself is good enough that is what if I take that round trip time 13.

So, I was handling actually 13.6 people in 5 minutes I should be handling 120 people in 5 minutes, right; that means, in each trip I can take less number of people and if I take less number of people in each trip assuming the waiting into you know; if I take because it will have less number of stops. So, waiting interval also will reduce.

So, proportionally I am reducing down my waiting interval because my S will reduce H will reduce Q will RTT will reduce and with 5 lifts, T will also reduce. So, I am assuming a reduced t and correspondingly finding out the new Q H is then I find new for H I find out new S I find out and my RTT comes out to be 122.8 for 5 lifts, T comes out to be 24.6 which is not same as 25, it should be sufficiently close at least to the last figure should come close to 25 or 25.1 or 24.9; this is not sufficiently close that is what is thought that it should be as close as possible, right.

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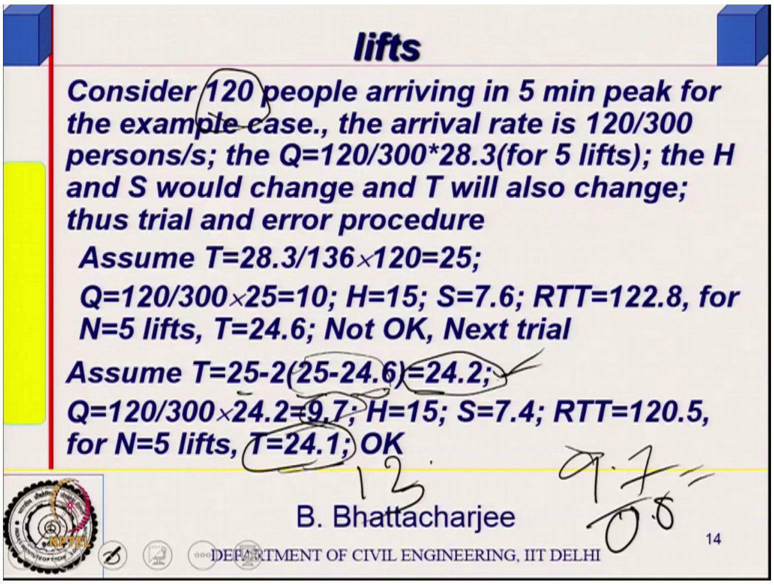


So, that your arrival rate and this matches. So, the next trial what you do 20 difference is 25.4; 25 minus 24.6 right. So, what you do is you reduce this 25; this is the difference. So, waiting interval you reduce twice of this difference actually you know this is 24.6 is lower. So, I must because if I make it 24.6, it might come still less. So, what I do is I reduce if the by difference go still below that 24.2 find out the number of Q repeat this process and I get started with 24.2 comes out to be 24.1. So, they are more or less same; it should come as close as possible only on the one decimal point.

So, the thing is that now if I choose you know 9.7 as the capacity or I might choose a capacity 9.7 divided by 0.8 divided by 0.8 that would mean basically the capacity will be you know the actual earlier, I took 16; now this will be how much 9.7 divided by 0.8 would be how much 112 or 13 capacity possibly lift would do my job.

So, if I provide 13 capacity lift my round trip time and arrival rate will by enlarge match. Now this was arrival rate earlier was based on essentially you know when I find I mean basically I assume the lift size the lift I startlingly size I have assumed Q value Q I mean 16 size and then I calculated back everything, right calculated I have of course, choice of making Q as a choice or number of lift as a choice.

Supposing I have already decided upon my you know space for the lift 12 a number of lifts that I would be providing the capacities I can play. So, this kind of you know basic idea is that the formula is valid for arrival rate matching with the service rate and we can make it as close as possible. So, instead of using 16 capacitive lift possibly, I can use 13 capacity lift and it will do you know; it will do the my serve my purpose. So, that is the idea; that is the idea. So, that is how we find out we find out the number of lifts which assumption of a given capacity now and then finally, you know do fine tuning it fine tuning to a better capacity or smaller capacity or larger capacity as it might require.

So, that is how you find out lift of course, I will talk about lift arrangement little bit later on, but let us understand this that this we can do by simulation also same procedure I can do by simulation also now to for example, this is for this for a case of single purpose office, all at same timing now you want to improve the performance of the lift or you to care less lifts capacity something like 40 50 storey building normally, of course, occupancy where we usually will not be having similar kind of occupancies might have residential occupancies.

Now, it is residential then the problem becomes less because it will not be all people will not come same time right the arrival rate would be quite different. So, one has to apply their mind, but this is the basic kind of a concepts there can be situation where I may have lot of random inter floor traffic supposing; I have same office serving from you know its floor area is in 3rd floor then maybe a 7th floor or 3rd floor to 5th floor or 7th floor in the same office another of.

So, you can have random inter floor traffic depending upon the situation in such cases when you have random inter floor traffic you can actually it is simulating is better, it is not only up going traffic, but it can be up and down coming traffic also you may have to design the number of lifts for such situation or find out lift for such situation.

But that is not usually common, but you can have those situations as well alright it is possible to simulate this also Monte Carlo simulation by assuming this has a Poisson's process what is Poisson's process; what is Poisson's process? Well Poisson's process is usually used in waiting line situations, right.

So, what you do is you assume a rate of arrival of the people, you know when you are serving people you know you there arriving and you want to provide service. So, that is the waiting situation, is it not. So, if I know the rate of arrival of the people then we what we do is in Poisson's process; what we assuming that there arriving at a very we consider a very small time.

Student: Delta t.

Delta t; yeah lambda is a waiting into I mean number of people arriving and we consider small time delta t such that not more than one person will arrive during that period of time never can happen you know. So, such small delta t that not more than 1 person will arrive at that time. Now arrival of person, then we considered to be success while not arrival is failure.

Student: Failure.

So, this becomes a binary situation, you know or binomial situation; now if you recollect binomial distribution you know statistical binomial distribution that deals with such situation probability of success or probability of.

Student: Failure.

Failure; probability of failure right probability of success so, 1 minus probability of success is probability of failure or 1 minus either or vice versa. So, only 2 situations are possible success. So, what you do is you see a possible distribution is a special case of.

Student: Binomial distribution.

Binomial distribution; when actually the you know like it depends upon I mean when you know number of trial tends to infinity.

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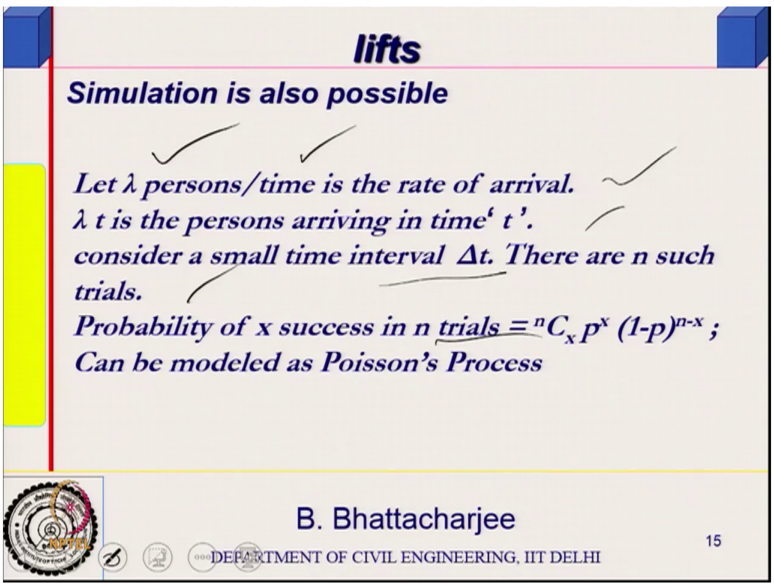

So, will see that actually just see that probability of x success in n trial is given by I will just give you the collect this actually. So, in Poisson's process what I do we assume lambda person is a rate of arrival lambda per person per unit time is a rate of arrival lambda t is the person arriving in time t consider a small interval delta t there are n such trials, there are n such trials then how many number of success in n trials; that is what the binomial probability ok; let me just go back to give simple example to you.

Supposing I am dealing with a situation of die of a die right. So, there are 6 outcomes; 6 outcome and I want to find out probability of finding 1 in 10 trials right.

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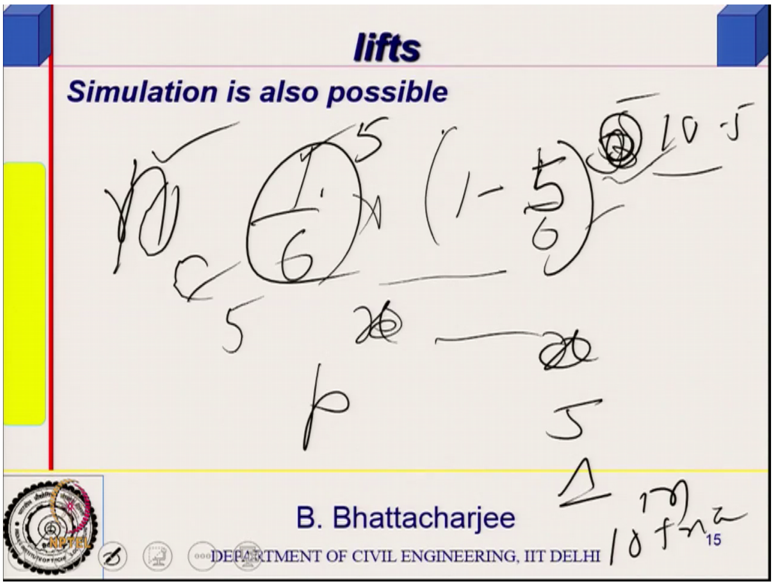


So, probability of finding 1 in one trial is 1 by 6; right and probability of finding in one trial only 1 and not finding any others. So, I should not find you know 2, 3, 4, 5, 6; you know all others. So, joint probability of finding only one and not finding all others. So, that would be 1 minus 1 by 6 to the power 5 joint probability because other 5 should not occur right and 1 should occur.

So, that is that is that is what it is. So, now in 10 trials in 10 trails now this; that means, I can what is a you know this becomes a situation of combination you know n C x; I can find out in the first trial first trial, I can find one or second trial, I can find out one. Now this is this should be actually related to. So, if I say; this is the probability p to the power x p to the power x; that means, finding in x trial. Now this is this sorry; this is wrong, this is 5 by 6 is the probability of not finding all others not now in 10 trials; I should find;

that means, in 10 trials, I should you know the probability of finding x number of or 5 number of 1 in 10 trials that is what I am trying to find out let us say 5, once in 10 trial that is what I want to find out that will be a binary.

So, if I have to find 5 in 1, 5 1 5 times then one by 6 should be joint probability of finding 1 by 6 5 times n time minus 5 other 5 cases I should not find.

Student: Any way.

Any yeah any way so, so this is the joint probability not finding them and this I can arrange first 5, I can find or any 5, I can find. So, that is what is given as 10 C 5 would be the case. So, this is the, this is a situation of binomial distribution. So, when n tends to infinity p becomes p tends to be small then this can be actually approximated to Poisson's distribution this can be approximated to Poisson's distribution; I think I might be having ok, I will just maybe I might be having something more related to this.

So, I think will discuss this simulation aspects in the next class, we will have a break and take some questions from you and then the binomial distribution related will discuss in the next class ok. So, that is what it is.