Fire Protection, Services and Maintenance Management of Building
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Lecture – 22
Water Supply System: Variable Demand & Diversity Factor

So, far we looked into a constant demand profile.

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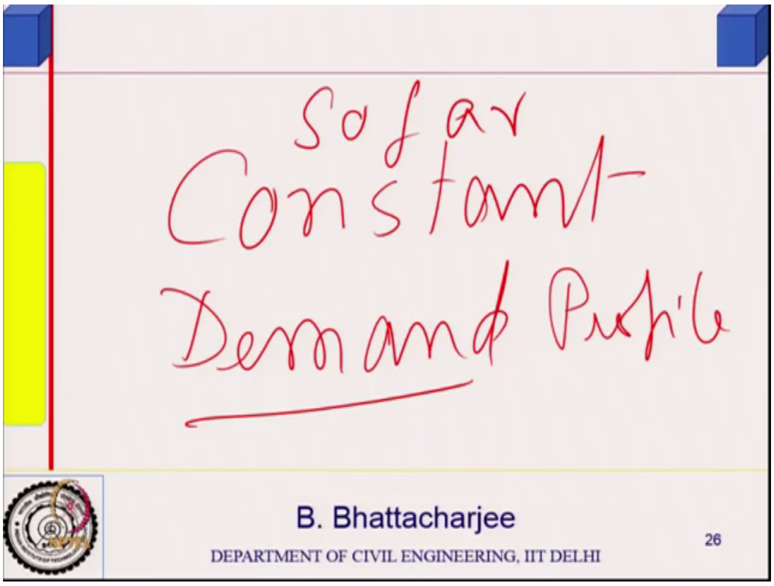

You know we looked into constant demand profile, constant demand profile that is what we looked into. But in reality this may not be constant, it might vary. There can be seasonal variation; there can be varieties of variation. For example, you consider a hotel right.

So, seasonal variation would be there, even hospitals, there can be seasonal variation of any one of the resources that you finally want to supply. For example, even you know the situations are quite different of course, but let us say oxygen storage; how many cylinders you should be keeping right all right? But we will the variable, the supply could be variable where we are we have continuously requirement over 24 hours, it can vary in certain manner right.

So, the variable demand one should actually consider variable demand one should consider and variable demand one can look into.

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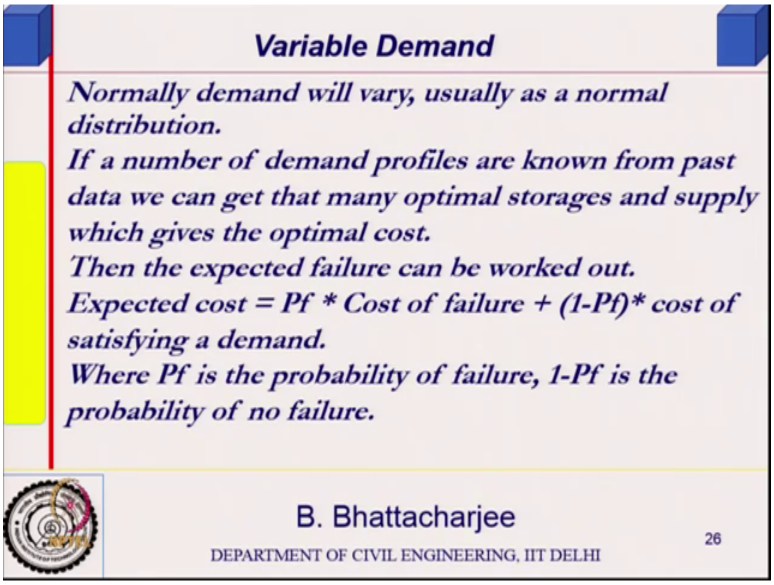

And this variable demand quite often, it might exhibit a kind of if it is more of the random type then it might show normal distribution, normally distributed population actually. So, demand will vary usually normal distribution. Now, I just to recollect your good old days, when you have got good old days statistics a little bit, where you have too many variables too many factors affecting the variable.

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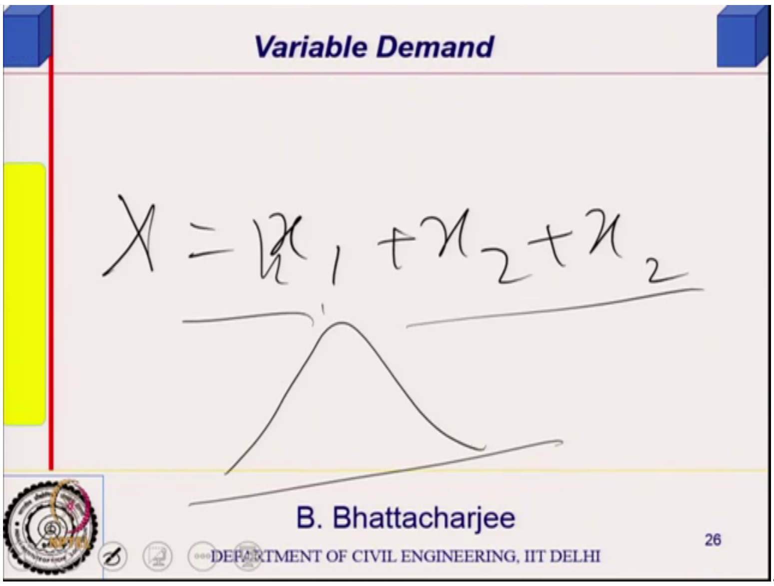

In other words, if a random variable, if a random variable if a random variable if a random variable is sum of several random variable maybe k 1 x 1 etcetera, etcetera. In that case it is likely to very normally, when there are infinite number of them likely to do very normally. In the sense that, you will have a this sort of a bell shaped distribution, right. It is very simple to understand from arguments and logic; for example, very simply supposing I have again situation of a die situation of a dice you know.

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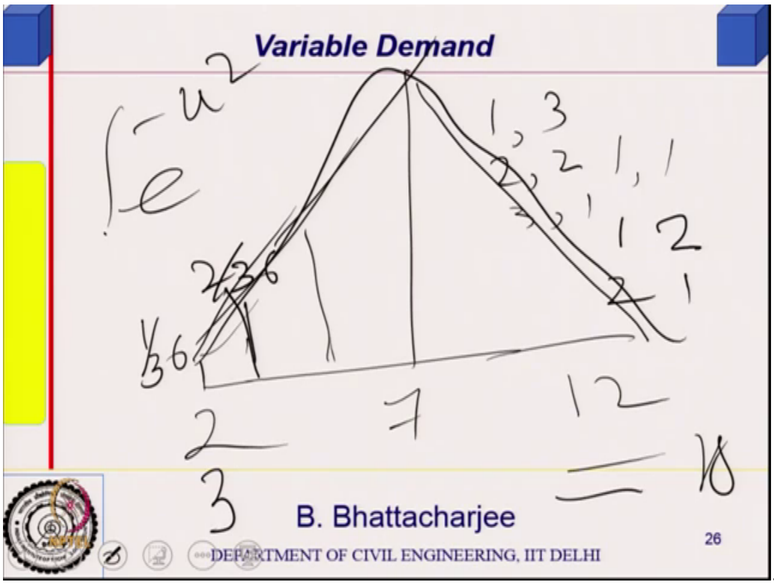

So, I have six outcomes possible, six possible outcomes; 1 2 3 4 5 6 outcome possible right and probability is uniform. So, it is uniform distribution because everybody everyone has got a probability of; say if you do 1000 times you will find one-sixth of the time it will be 1, you know a long or 6000 times 1000 times so on and so. But if I have 2 such die, I have increase the factor not 1 die now 2.

So, my variation would be now going from variation will be going from 2 to 12 spread increases 2 factors. Now how can simply 2 how can you get 2? One from each of them. So, if you calculate out the you know what are the possibilities? Possibilities are 1, 1, you know. So, if you calculate this possibilities joint probability of finding 1 in both of them. So, 1 by 36; there are 36 possibilities now.

Keep 1 6 possibilities from the second one to, so, 6; so, 36 possibilities. So, this is simply 1 by 36. What about 3? 2 by 36, how? Because 3, I can get, 1 from the first one, 2 from the second one or 2 from the first one, 1 from the second one. So, there are you know so, 2 out of 36. So, the third one would be 4 let us say, 4 I can get 1, 3, 2, 2 and 3, 1. So, it would be simply I mean one could have done from base theorem, joint conditional probability that first one is 1, what is a probability of finding?

But I think I am simply trying to explain you. So, you will find that it actually it linearly goes like this. And 12 how can you find it? 12 will be 6 6 from both. So, there for it would be something like this, you can actually do this exercise and you can find there will be triangular. With this 7 would be you know 7 would be somewhere there, 7 would be there right. Now, if you take 3 die then this spread increases from 3 to 18, spread will increase and you will find that it is no longer linear, but it tends to be curvilinear.

And when you have infinite number of dies let us say or infinite number of factors then the spread is very large. In fact, it is from minus infinity to plus infinity ideally, with a 0 mean you can actually do access shift and all that and this is a curvature of this time. So, that is the whole idea. So, e to the power minus u square etcetera etcetera, another formula that you have for normal distribution Gaussian distribution.

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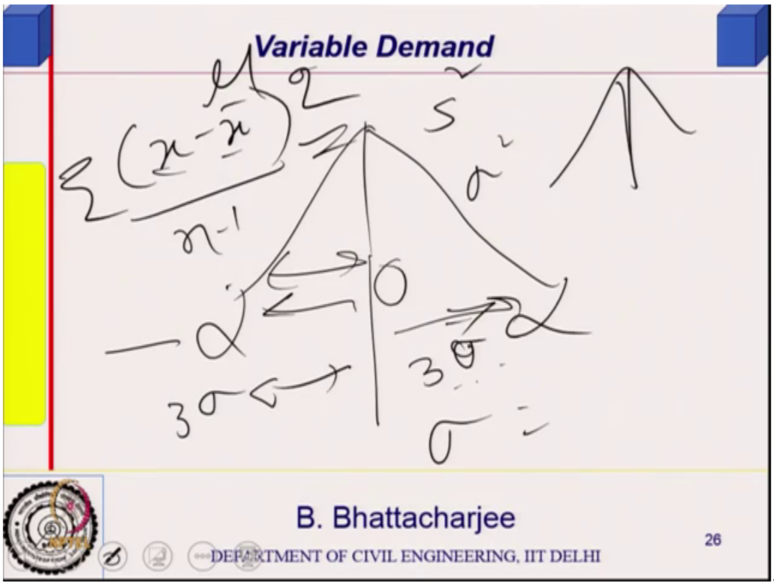

So, when you have too many factor affecting the random variable it is normal distributed and it we assume that standard normal variant of course, go from minus infinity to plus infinity and this parameters are the mean, which is 7, it was a 14 plus 12 plus 2 divided by you know 12 plus 2 was 14.

So, it is a mean, the central tendency where it will have the peak thus the that is like you have got 3 parameters, what do we call; the mean, median and modes. So, mode value is same as arithmetic average, what is call as a measure of central tendency or mean. So, mean is nothing mean can be calculated arithmetic average. So, if I have standard normal variant if I take its mean as 0, because its spread will go on both the sides, right.

So, you will have something. So, and this is varying within then we define something called standard deviation; why? Deviations I could found out, but sum total of the deviation should be 0; therefore, what we do? You find out a x minus mu over x bar or whatever you call it. If it is for sample you do it like this sum it up, sigma upon this divided by total number of them, if the sample size is large from where you have measured which otherwise n minus 1 etcetera etcetera.

So, you can find out standard deviation. This is nothing but a square would be n minus 1 or if it is large number of values you are doing for all the whole population, then you will possibility denote by mean and this would be sigma square or sigma is equals under root, root means square deviation in a way. So, this is 3 sigma this is minus, this side is also theta and sigma because now I have normalized everything. So, standard deviation is also normalized because I would have divided this standard, you know if I take this as 1.

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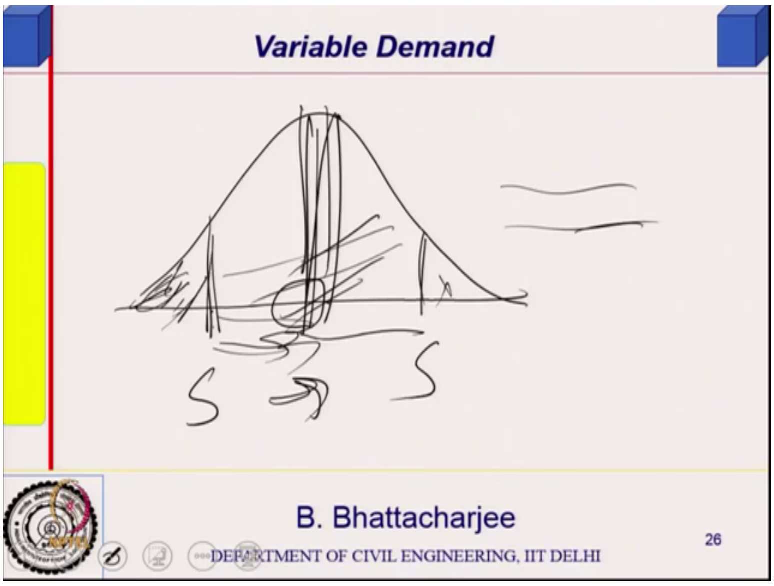

So, this will be plus 3 and minus 3. So, I can I do not think I will go further in to this but where you are too many factors affecting your demand then it will be normally distributed right, normal distribution. So, many cases you will find in engineering situations or even science where things are variation depends upon too many factors right too many factors.

So, for example, for you know like our variation of properties of material which we measure, let us say properties of asphalt in pavement or properties of concrete; these are all we assume normally distributed because too many factors would be affecting the properties. So, if we know several demand profile from the past right there optimal storage on supply, for each one of them we can find out several you know. So, optimal storage and supply we can find out the optimal combination right.

So, we can actually find out and they are likely to be normally distributed finally, and then you find out the expected cost where probability of failure for example, we found out that this is this is the you know this is if you see if your supply is more than that, if your supply is more than that the you know the basically difference between I mean basically with the demand varies in this manner. And corresponding supply supposing its more than that more than this value most of the time I mean this time it will be satisfying.

And if my supply is somewhere here, this time it will be satisfying this may not satisfy. You keep it keep it in such a manner let us say this is your demand, average demand profile or optimal demand profile something you will say. So, you can maintain your supply at such level in certain cases, I will just give you an example where if you might like to satisfy the demand, most of the time, but take a little bit of risk also.

So, this is the probability of failure this area under the curve and this is 1 minus that is the probability of not failure or success I will say. If you know the cost of failure, if you know the cost of failure if you know the cost of failure probability of failure is known, this is cost of satisfying that demand if you know then expected cost you can find out right and then choose basically corresponding supply value or you know corresponding supply and storage value whatever it is.

So, this is what. So, given set of storage and supply satisfy the there are several demands. Out of which possibly if I cumulate them you know or get that distribution, say average demand or cumulative total cumulative demand something that if you if we can I know I can use this concepts also to find out which is the best.

But this becomes simple simpler the if I can you know if I can find out the cost of failure. So, this becomes simpler for example, in a case like, let us say this simply something like this consumption of oil.

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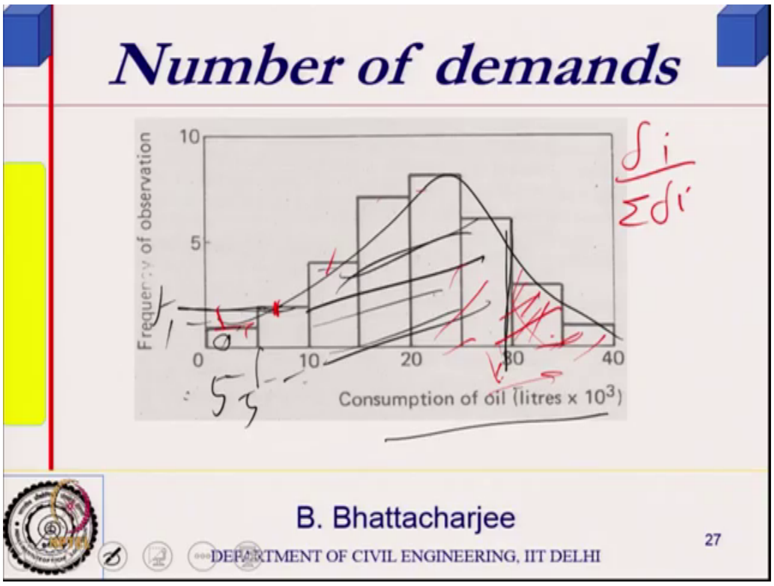

Let us say I am using oil farness oil for heating my boiler, this is an you know today of course, you might have other options consumption of oil for your hot water supply. So, you are using farness oil.

Now, you have done a lot of observations, and you found that this is the histogram plot. So, this is the you know number of times you had between 0 to 5 this is 5, 0 to 5 liters requirement is this much, 5 to 10 liter requirement this is the frequencies, this is the frequency f 1 f 2 etcetera etcetera. So, relative frequency you can talk of if you divide by the sum total of all the frequencies, you will get relative frequencies.

So, relative frequency curve you can join with by the smooth line. Now, supposing you keep your oil capacity to 30 liters you will be satisfying, all the time you keep 30 liters you will be satisfying all these demand, but you will be missing out on this demands, you will be missing out you will be missing out on this one. So, your probability of failure is given by the area under this curve if you have drawn relative you know cumulative frequency, relative frequency if you have written see f i f 1 divided by sigma f you know f i divided by sigma f i that gives me relative frequency.

So, area under the curve then will be equals to 1; because this is sum fraction this sum fraction and sum total of all this fractions will be equals to 1. So, the area under this curve if I drawn by smooth curve will be equals to 1, relative frequency distribution relative frequency. So, this is the probability of failure, and this is the probability of success if I maintain 30 liters you know capacity or 30 into you know 30 kilo liters capacity. So, this is the probability failure.

But then cost of this failure might I might lose out on my customer or I might lose out on. Supposing it is a hotel or something that kind, I might lose out on my customer or maybe I have to pay some penalty. So, cost of failure can be estimated in that manner that you are either, you know. So, cost of failure can be estimated in that manner, either you are losing your customer on the overall, because you do not supply regularly you are not satisfying your customer or might have to pay penalty and but for satisfying this I have to keep highest storage capacity; highest to inventory has to be higher storage capacity would be higher and there for there is a cost involved higher as I go on increasing this cost will be increase.

So, you find out same probability of failure multiplied by the indirect cost of failure, maybe there are some cases direct cost of failure also could be there and this is the direct cost of satisfying the requirement. So, this is a one can actually determine right.

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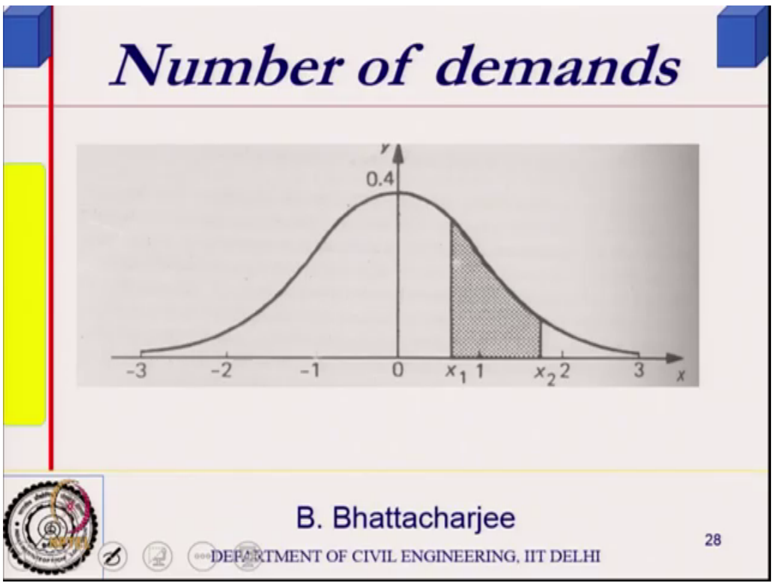

So, this is how it is shown, same the relative frequency diagram and this is I am saying 3 sigma minus 3 sigma. So, you can find out in this way.

So, you can plot actually probability of failure versus capacity. Now, probability of failure will be simply these areas you know like as I said this areas right. So, probability of failure would actually probability of failure as you increase the capacity, storage capacity of your tank, probability of failure will reduce down, right; probability of failure will reduce down and you can find out. So, that is how we do in handle in some situations, then in some other situations for example, I was talking about the hotel room right.

Now, one is seasonal variations; for example, just in many of the hotels in India, let us say theirs you know their main customers are from western world. So, large chunk of them come during the winter time December time and go back before the Christmas and things like that. So, this is seasonal variation that you can you know that seasonal variation you can plot over the seasonal know about the season and then accordingly that would go into your variation variable demand profile.

For example, you also know you know if hotels I am give you an example, there is a tourist seasons for most of the places. Say I will give example it is known, then people from let us say during certain religious time, religious festival, Navarathri time people from Gujarat go for Parikramas right. So, hotel demand will go accordingly. Similarly, you know people during almost October time lot of people travel from Bengal and people like to travel to south from north during winter period.

Now, people would not prefer to go to let us say Kerala during monsoon season, it is too much of rain you cannot travel. So, hotel scenarios they can actually find out seasonal variation and demand profile for several you know you can actually if you are looking at this, but this is one thing. The other thing is, how much I should actually how much say I want to size the hot water supply system for hotel let us say. You know I am showing the extreme case or for hospital intensive care you need oxygen supply units I need.

Now you will find that there is a diversity of uses; in the sense that if you have 100 rooms, all 100 rooms are likely to be occupied all the time, only a some fractions will be occupied based on because you might have made your capacity, of 100 rooms hotel 100 rooms assuming in over all kind of a you know overall kind of your resources and things like that.

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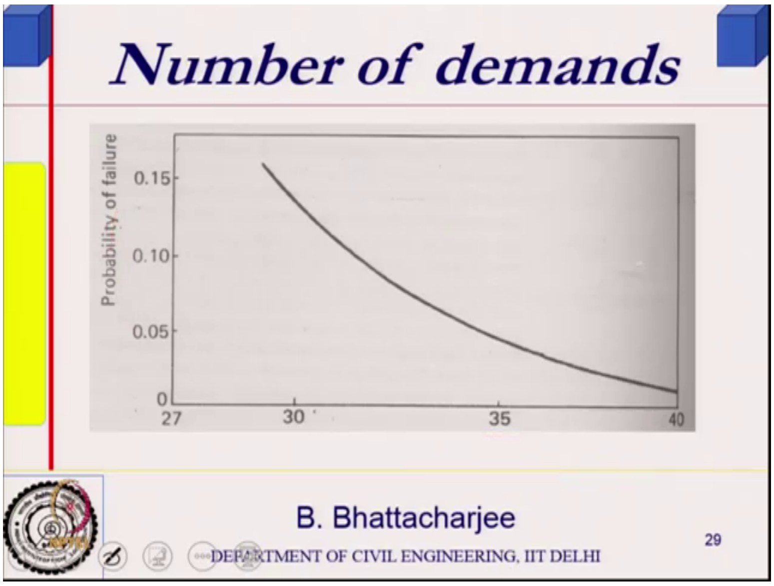

So, we looking the overall business scenario and overall kind of things like that.

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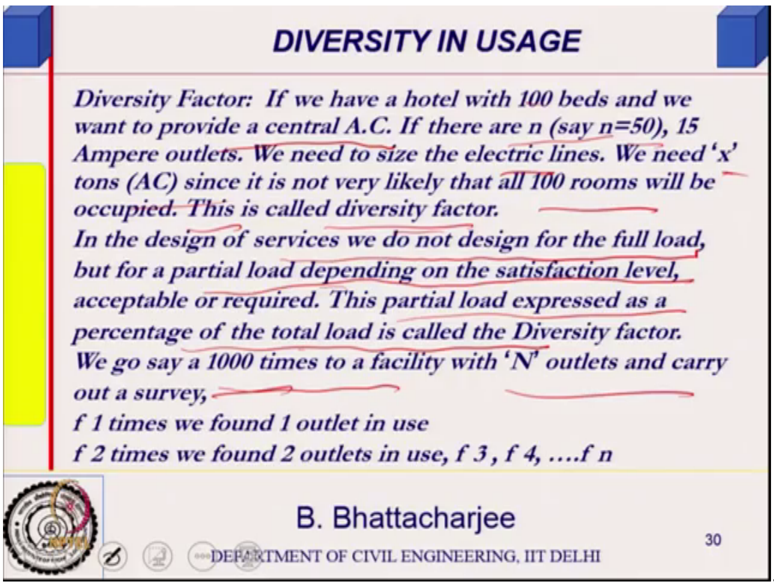

But all rooms will not be occupied all the time. So, if you are doing sizing for your hot water supply system, you need not do for all 100 rooms. Outlets will be there in all 100 rooms, but the line that is supplying to 100 rooms need not be meant for all 100 rooms.

You can multiply by a factor called diversity factor, because diversity of usage everything you are not used simultaneously. For example, all classrooms will not be used simultaneously in a lecture hall complex. So, you have to if I have to supply in the power line, and each one let us say requires you know the maximum demand is let us say 15 ampere or 32 ampere, now the pipe the line I mean not pipe the power line, which will actually be connected to all the rooms that need not be 32 multiplied by number of rooms, it will be multiplied by a factor that factor we call as diversity factor that factor we call as diverse.

So, if you have a hotel with 100 beds the example is given, we want to provide central air conditioning system let us say. If there are n 50 and or another case let us say there are 50 outlets of 15 amperes we need to size the electric lines, we need in this first case I need x turns of AC, which will be less than 100 multiplied by for a given room. Because all 100 room should not be occupied simultaneously, this is called you know. So, there is a multiplication factor that factor we call as diversity factor. But for you know in the design services you do not design for full load but for partial load depending on the satisfaction level.

If you provide for all 100 rooms you will satisfy all the time no risk you have taken, but supposing you decide to satisfy for some 50 or 60, then you will satisfy the simultaneous demand for certain proportional simultaneous demand. If it exceeds we will say oh I do not have AC room now; you know your customer might run away or maybe there, but you have to decide there, whether, but satisfying all 100 will be too costly for you because many of them you know this sizing would be too large and it would not be worth or many of the rooms nor used together.

So, this is the partial load expressed as a percentage of total load is called diversity factor and what we do is how do I find it out? I must of a must have a must of some past data available to me, something should be known to me. So, supposing I have got N outlets or N rooms AC rooms and I have gone 1000 times there that is why the example I am giving or you know it is not 1000 times just recorded.

I mean we should record it actually you should be recording it you know building services system or maintenance system that is that is makes it more scientific, which we normally it is not a very good it is not a practice in India, but is supposing this record is available to you all records. So, how many people actually occupied the building, in a similar type of building. Bin the new building if you are doing then for the new building data will not be available, but the past similar building if you have data available, and data is available means for last 5 6 years data you got. And you it let us say they are 1000 such data, how many of been use how many room was in use.

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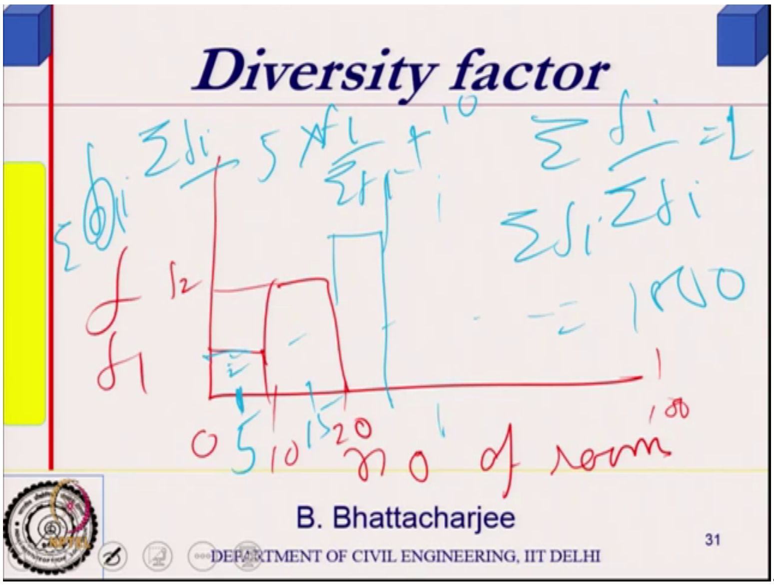

Then you will find that if I have 1000 such data, I can plot a histogram of frequency of use on this axis and number of rooms on this axis, number of rooms, right, this axis number of rooms in this axis. So, 0 to 10, 10 to 20 up to 100, let us say 100 rooms, I am talking about up to 100 and there this I call as f 1, this I call as f 2 etcetera etcetera. Let us say let me use another color; that means, another color f 3 f 4 and so, on so, forth. So, this is frequencies.

And I can now this is frequencies and sum total of this frequency will be how much? Sum of all of I. Because I have gone 1000 times 1000 data is available to me I have just said. So, this should be equals to 1000 and this f divided by 1000 this I call as relative frequency which will be a fraction; and sum total of all relative frequency that is sum total of f i divided by sigma f i is equals to 1 because each one of them will be right. So, f i f 1 by sigma f i f 2 by sigma f i if i sum them up there will be equals to one. So, area under this curve is one that is a histogram plot for relative frequency.

So, if I know this then I can find out mean number of rooms in use mean number of rooms right what that would be? That would be simply you know f 1 multiplied by sigma f i, sum total of you know sigma f i basically this how do I find out the value of the random variable multiplied by it is relative frequency. So, if I know this average will be not a f 1 this value is 5, this value is 15 I am taking the class you know the central point in the class interval or average of the class interval.

So, 5 into f 1 divided by sigma f i plus 10 into. So, this would be the mean is given as simply given as let me just write it down x i sigma f i, I mean f i sigma f i that is why. So, sigma upon this I going from one to whatever the value is.

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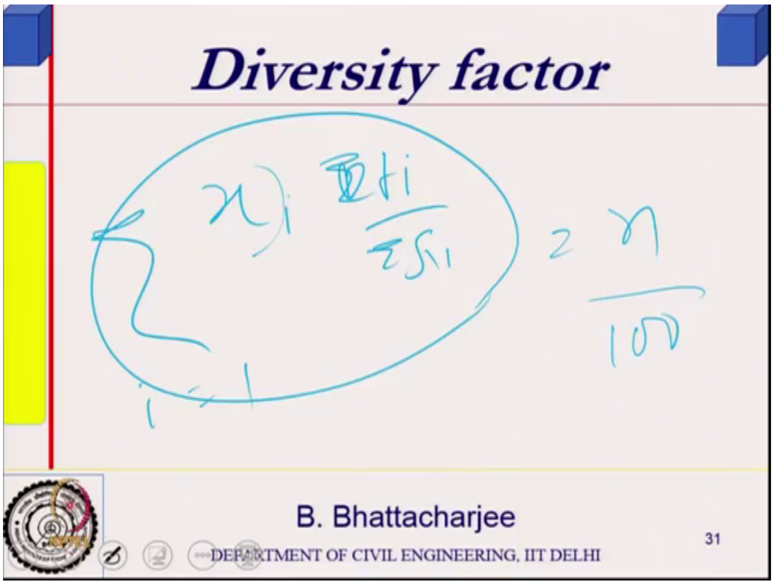

So, that is the mean that is how we find out the value of the random variable multiplied by the relative frequency or the probability, if you summed that up that gives you expected value or the mean. So, I can find out the mean number of rooms that was in use.

Now, I had 100 rooms; I had 100 rooms, out of this mean number of rooms that was used in will be given by this, let me call this as n, let me just call this is a n; n number of rooms on an average I found was in use. So, n divided by 100 will be the probability of finding one room in use on an average. Probability of finding one room in use at any point of time, right. So, this is how I can obtain probability of finding.

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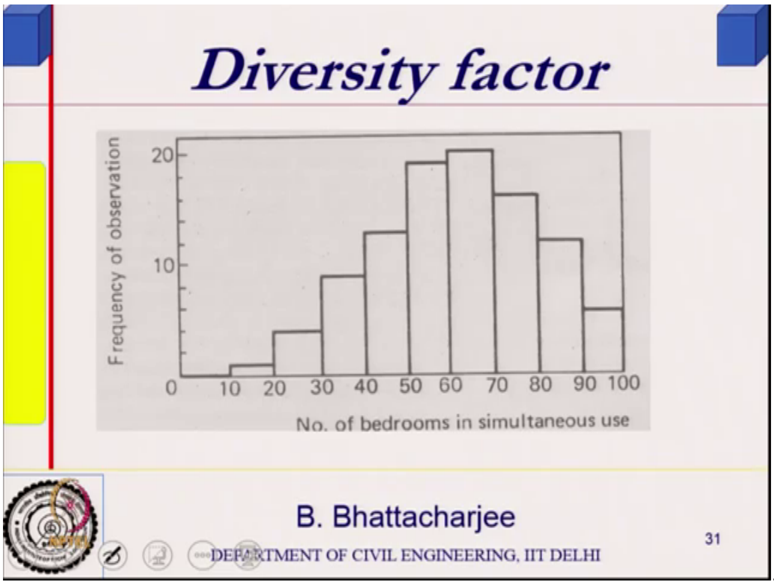

So, this is the histogram, number of bedrooms in simultaneous use, I mean one room you know I found 0 to 10 room, I did not find any time; it was a good case 10 to 20 right and so on so forth that is how I find out.

So, if I have find out then I can find out mean number of rooms in use this divided by 100 gives me probability of finding, only one room in use that I call as probability of success. You know like we did in lift we call it probability of success.

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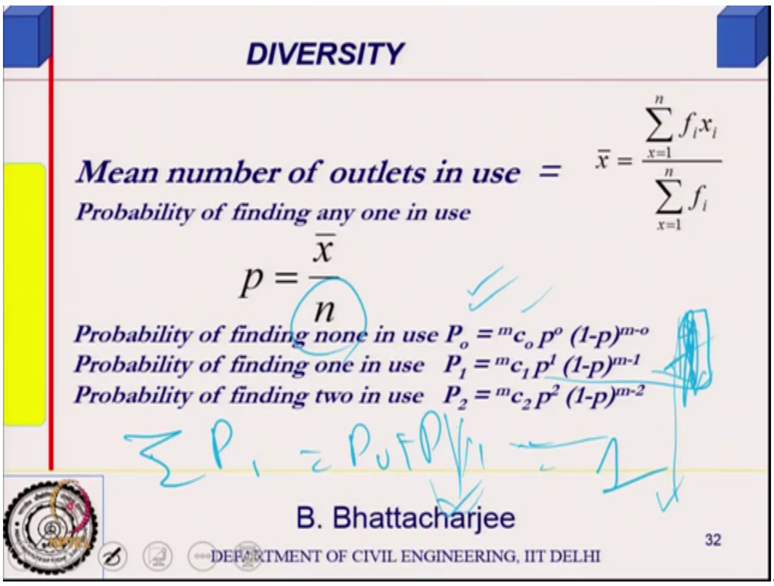

So, mean number use room is in use that is that I have just given you the formula x bar I am calling it right sigma f i xi divided by sigma f I, and probability of finding one room in use would be given by bar divided by n where n is 100 in my case x bar is the minimum.

So, probability of right; so, probability of finding only one room in in use out of say 60 room, only one room in (Refer Time: 26:40) you use is the binomial distribution because probability of success now one room in use is given by this, probability of success; 1 minus p is probability of failure or not success no room in use. So, this how probability of finding 0 room in use is given by mc 0 which we have done earlier, we have discuss this earlier sometime right in connection with we discuss this now binomial distribution, just (Refer Time: 27:13); we discussed you know talking of poisons distribution.

So, m c 1 probability of finding only one room is use and m rooms are not in use, m minus 1 rooms are not in use is this. Now, if you find out so, probability of 0 room in use, probability of one room is in use, probability of 2 room is in use then 8 is not in use. If I sum this up all sum total will make it equals to 1, because possibilities are no room in use, 1 room in use or 2 rooms are use simultaneously or 3 rooms are used simultaneously or all m rooms are used simultaneously.

So, these are the you know all out comes possible sum total of this outcome will be equals to 1 and if you sum this up you will; obviously, you can show that algebraically that comes out to be 1. Now you go on adding this up you go on adding this up, supposing I provide only for one room myself you know let us say ducts AC ducts, I am 100 room capacity I provide for only one room, I will satisfy only this much percentage of my simultaneous 100 percent simultaneous demand. 100 percent simultaneous demand corresponds to all m room being supplied.

If I supply less certain percentage of time, I will not be able to satisfy the simultaneous demand of all rooms. So, this is this sum will give me sum percentage of fraction because sum total of P z P i, this P 0 which is equals to P 0 plus P 1 plus this is equals to 1 100 percent up to m right, but you find out that probability of m room being used is relatively less, that you can see from this diagram; this diagram which is this becomes less this is not high whereas, up to this is pretty high.

So, I can possible supply up to 80 rooms and take risk of this much right, but that will be a managerial decisions how much risk I want to take alright how much risk I want to take.

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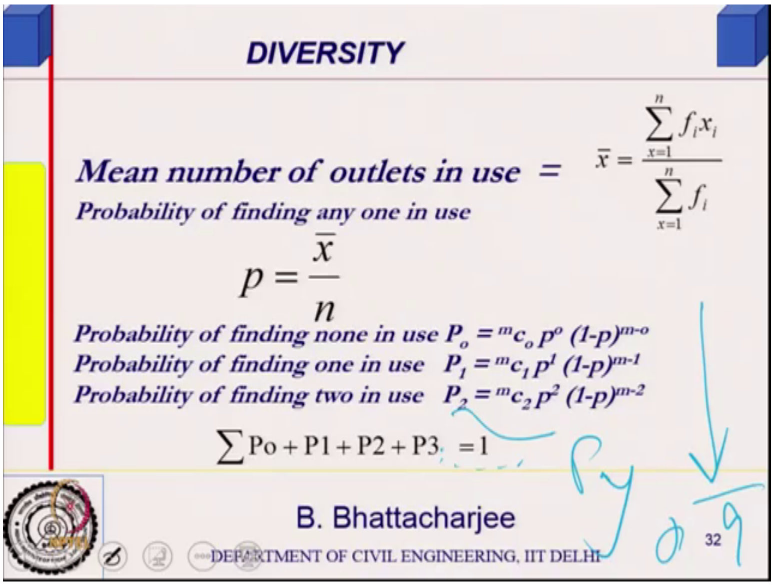

So, this I can sum this up and all sum will be equals to you know dot dot dot dot dot dot it will be equal to one and I have to take a decision, that how much risk I want to take. Let us say I decide 90 percent satisfaction, 10 percent risk I will take. So, I go on summing them up and at sum value of P let us say P y, this value will corresponds to 0.9. Then y is the number of you know rooms to which I will cater my pipelining everything such that I am taking 10 percent risk because y corresponds to 0.5.