Decision Making Under Uncertainty
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Lecture - 03
Risk, Uncertainty and Variability

The next topic is - Risk, Uncertainty and Variability. Now, this topic could be somewhat controversial because different people have different notions and meanings for these three words. And, the good news is it does not matter what we call some of these things, but the more important thing is how do we use that to make decisions. However, I think for the sake of completeness it is important to address these things.

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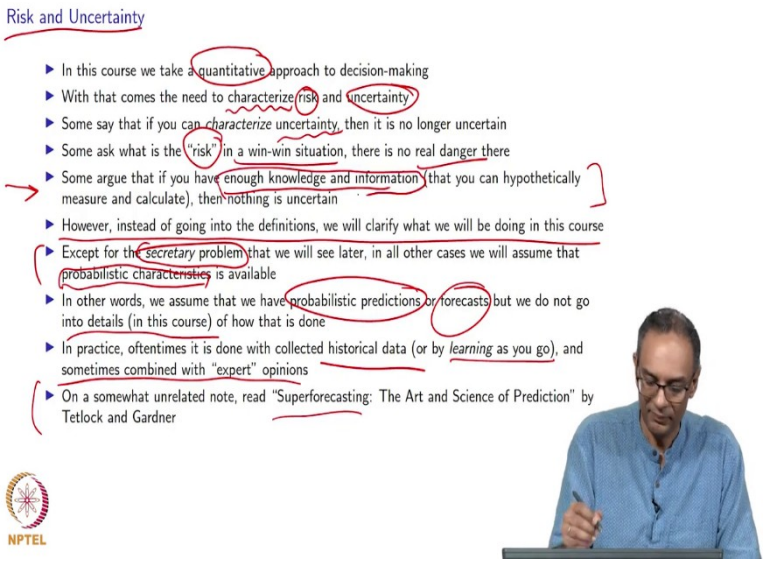

First, let us talk about risk and uncertainty. Now, we are going to take a quantitative approach for the most part. There is very little qualitative decision making that we are going to talk about in this course. So, when we look at a quantitative approach, we are talking about somehow quantifying various things.

Now, the uncertain things such as risk and so on need to be quantified or characterized; these two things are important. So, the question is – How do we go about characterizing this thing called risk and this thing called uncertainty? Now, the words “risk” and “uncertainty” mean different things to different people. If you want to characterize uncertainty, some people say – “Well! If you can characterize it, what is uncertain about it?”. For example, if you toss a coin

and there is nothing uncertain about it, you are going to get one of two things heads with probability 0.5 and tails with probability 0.5. What is uncertain in there? Yeah, there is a slight uncertainty that it might stand straight in the middle, but other than that, there is no real uncertainty, according to some people. I am not in that camp.

I am in the camp that prefers to call that as uncertain; that means, the outcome of something is not known with certainty. That's what I mean by uncertain. So, when I say, "When I toss a coin, I might get a heads or tails", what I really mean is the outcome is not certain. You don't know with probability 1 that something is going to occur; that is what I mean.

However, there are lot of people who will not call that uncertain. In fact, there are even people who believe that if you toss a coin, you know exactly where it should land. We will talk about that in just a moment. Now, the word "risk" also has some situations. For example, a lot of people call what I call probabilistic characteristics as risk. But sometimes, if you are in a win-win situation, what is the risk involved, right? I mean you are making a decision between options such as, for example, you have come into IIT and you are deciding which program to go into, which department to join or which major to go into. Well, that decision is pretty much a win-win situation. There is no risk really. It is not like you take one thing and you are not going to have a job versus another. It's really not that way. So, there is really no major danger there. So, the word "risk" actually has a very negative connotation and I personally do not like to use the word "risk" when there is something positive, something to celebrate about. Again, all this can be debated; we could go on and on debating what should we call this – risk, uncertainty, etcetera.

Now, there are other people like I said who have a different view about the coin toss example; if you know the exact force that was used, the speeds and you could characterize exactly where you hit when you tossed a coin, then you could actually exactly determine where it is going to fall. There is really nothing uncertain about it. Yes, if you had enough knowledge and information, I agree. Now, this could be hypothetical like in the coin toss example that you could actually measure and calculate the exact values of the speeds and so on. Then yes, maybe even the result of the coin toss is somewhat certain. So, a lot of people think that there is nothing in the world that is uncertain so to speak because if you had all the knowledge and information, you can make. And, I think I am subscribing to that notion and like I said, this topic is somewhat controversial. However, most of the time we do not have

the knowledge and we do not have that information and in that situation, what we do is we characterize that as something that is random or something that is uncertain and that's what we are going to be doing in this course.

So, instead of giving you the definition of what is uncertain, what is risk and so on, I am just going to say, "Well! If you perform an experiment or if you do something or analyze a process and in future you don't know what is going to happen with certainty, we are going to call that as uncertain for the rest of this course".

Characterizing is a very important piece which we actually are not going to go to great detail. But, we will see that we are going to assume the probabilistic characteristics; for example, if you toss a coin, I am going to get heads or tails with probability 0.5. These types of characteristics I am going to assume throughout the course is available to us. In practice, how this is done is using historical data. We will use historical data in order to figure out what is going to be the probabilities of various events going into the future. But, in our course, we are going to assume that we have these probabilistic predictions or we have forecasts. In this course, we will not talk about how this is done. However, that is where a lot of engineering and managerial intuition goes in actually. So, turns out that is a very important piece; however, the amount of science that goes into some of these things is so enormous in some sense. Also, so specific to a situation, it is hard to make something that is overarching over variety of domains. So, in some sense, we are going to look at a situation where somebody has done all this work and are giving us some probabilistic characterizations. That's what can happen in this course with the caveat that if you want to do this the right way, you will have to know how to take the historical data and convert it into these probabilistic predictions. That's something we will not go into in this course.

However, in the beginning of the next chapter or the next topic, we will talk about something called a secretary problem. That's the only problem throughout this course where we will not worry about the probabilistic characteristics; we will pretend like we don't know what that is. But, other than that, for every other single problem, we are going to assume that some characterization is already made.

Now, the other thing is we sometimes use expert opinions. Sometimes, it is not even possible to use historical data. Now, I do want to say that with a grain of salt that many times experts also use some type of historical data to make some predictions into the future. We are not

talking about taking of horoscopes and doing a little forecasting about how your life is going to be. We are talking about somebody who has an expert on some subject matter and can say how things are going to go into the future.

So, in practice however, we do use historical data. Sometimes, we could learn and as we go. We may not have enough historical data. But, we are going to collect them as we go and finetune our decisions. So, I do want to also recommend this one book called "Superforecasting: The Art and Science of Prediction"; this is a beautiful book by written by Tetlock and his co-author Gardner. It is a wonderful book which talks about what one uses to make great decisions, how do super forecasters go about making wonderful decisions. It's not a technical book; there is not much depth in terms of probability and so on. However, I highly recommend that book.

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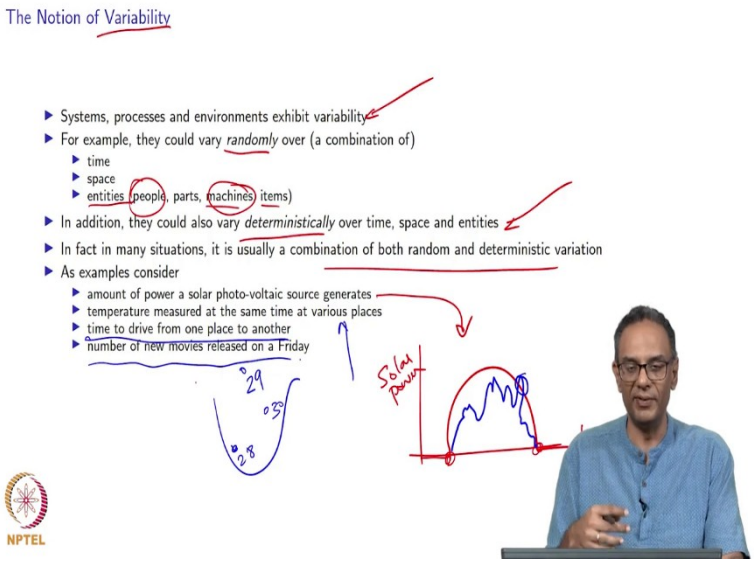

Alright. We move to the next notion which is that of "variability". Now, this is something that is commonly used. In fact, we will use the word "random variables" quite a bit in this course. So, we want to talk a little bit about variability. So, you are going to see a lot of variability. Systems, we are talking about large things or processes; smaller things like, a system could be an entire manufacturing enterprise. A process could be something that a particular machine undergoes. An environment could probably be even larger than the enterprise. All these exhibit some amount of variability over time; they have variability across space or across locations. There is also a variability across entities. We are talking

about people or parts that are made in manufacturing or the machines themselves are the items that are made and so on. So, all these things also have tremendous amount of variability.

Now, the variability is considered to be random. For example, the color of the shirt, the next person walking into the door, is random as far as we are concerned. So, if you look at the status of the machine at this point of time until we know what is going to happen, the status of the machine or the wear on the tool kind of goes randomly over time. There is also a little bit of determinism in it and we will talk about that in the next bullet. However, for the most part, if you try to collect data which a lot of companies are doing this day and age especially with all the big data, they are collecting samples across time and across space; And, if you model those things, you see some amount of randomness in it and that randomness is what we call as "variability". And, that happens across time, it happens across space, it also happens across entities. For example, who did you vote for; each person votes for a different person/candidate and that is considered randomly varying across people. Now what is random in here? Well, if you don't have the information that we saw in the previous slide, we model those things as being random across time or across space. And, by space, what we mean is from one location to another location. Now, there is also variability deterministically and this is something that we make a major deal out of. By deterministic variability, we mean something that you can determine in advance. For example, if you draw at a particular speed, let's say you drove on a road where there is no cars and you set your car to be driving at 80 kilometer per hour, you will go exactly 80 kilometers in 1 hour. So, there is nothing random in there. However, if you had traffic and you got slowed down, then clearly your travel time could change significantly. So, there is a combination of both random as well as deterministic variation.

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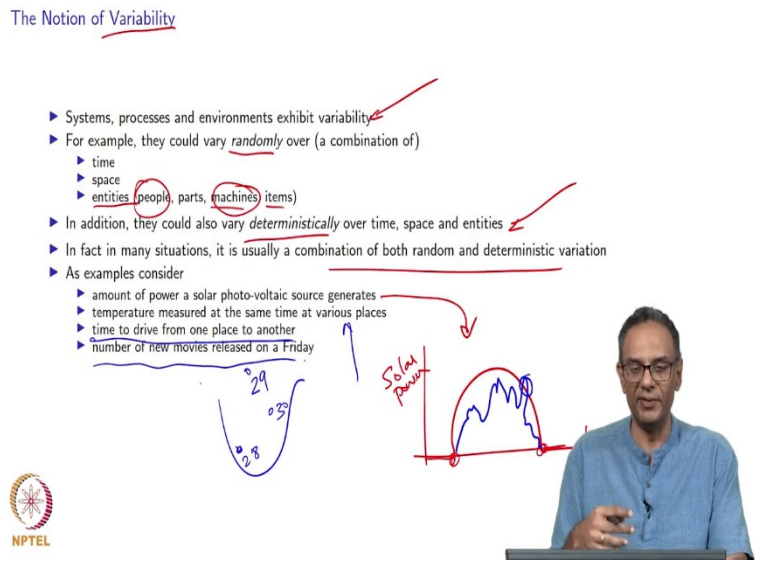

One of my favorite examples is the solar cell. If you look at solar power over time and on a cloudless day, it is a nice deterministic function which goes up and then comes down. If there is some cloud or we had tremendous amount of clouds, then you are getting some random movement. Yeah, you wonder why this happens. This could potentially happen I was told when you have these clouds actually reflecting off some light and actually increasing; but for the most part, it is going to be below. So, the amount of solar power because of clouds could be below what is actually available on a day that is sunny. So, if you look at the blue line, there is this deterministic plus a random variability. So, the variability across time has both a deterministic structure in the blue one. Obviously at night, there is no light and no solar power; that is determine and there is nothing random about it. You know for sure there is not going to be any solar power. But in the day, it could be random because of the way the clouds are randomly moving about.

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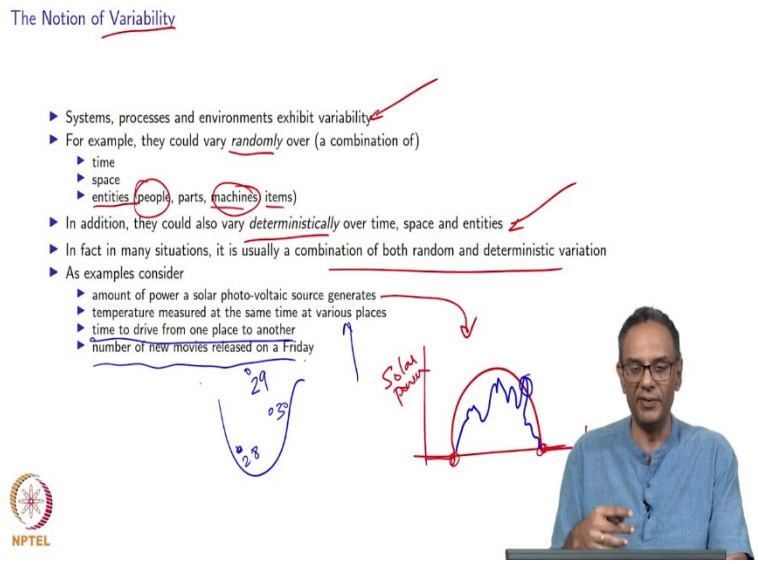

Now, another thing is you could think of temperatures at various places and look at different locations on a country's map to see the temperature here. Let's say it is 30 degrees at one place, the temperature at another place is 28, temperature is 29 degrees at another place and so on. The actual temperature itself could be a random quantity. However, if there is some amount of deterministic variability, certain parts of the country are necessarily cooler, and certain parts are warmer; that depends on the altitude and other things.

Now, you also think about like the example that I gave a little while ago the time to drive. There is some deterministic time. You cannot go from Delhi to Agra in exactly say 3 hours. However, you cannot go there in say in 1 minute either. So, there is some amount of determinism where you know roughly how long it is going to take, but it could be a bit longer. There is also some amount of combination of determinism and uncertainty in terms of how many movies for example, are released on a Friday. If it is a holiday season or a new year or a popular holiday, you could see that there are more movies released around that time. So, there is some amount of deterministic variability; however, it's not easy to predict how many movies will be released exactly say for example, next Friday.

So, there are those notions of variability that could be both deterministic where we know exactly what is going to happen and also variability where there is tremendous amount of uncertainty. That said, one more time, I do want to say that the notion of risk, uncertainty and variability are somewhat ambiguous and unclear and we will try to clarify some of those. But,

let’s not be too hung up on those words and let’s go forward thinking – “Well! I am going to derive some probabilistic notions for everything that we are going to see”. Alright. That’s going to be the next topic which would be somewhat mathematical.

Thank you.