Decision Making with Spreadsheet
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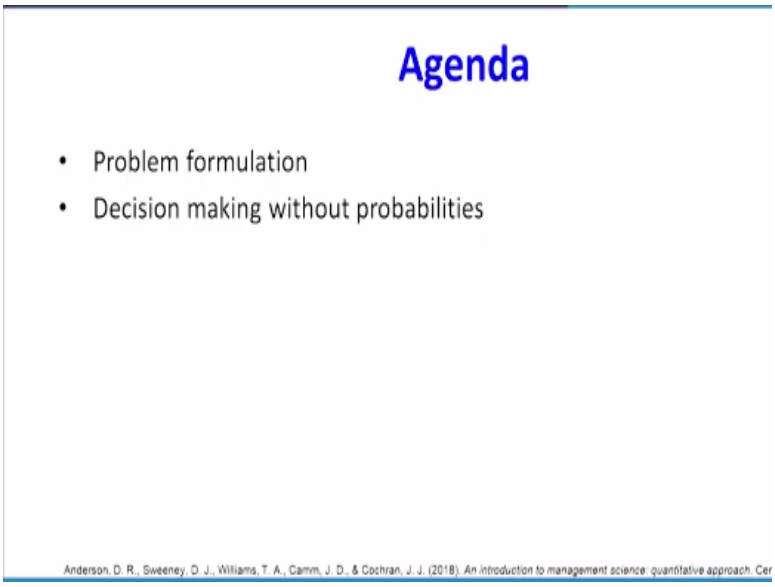
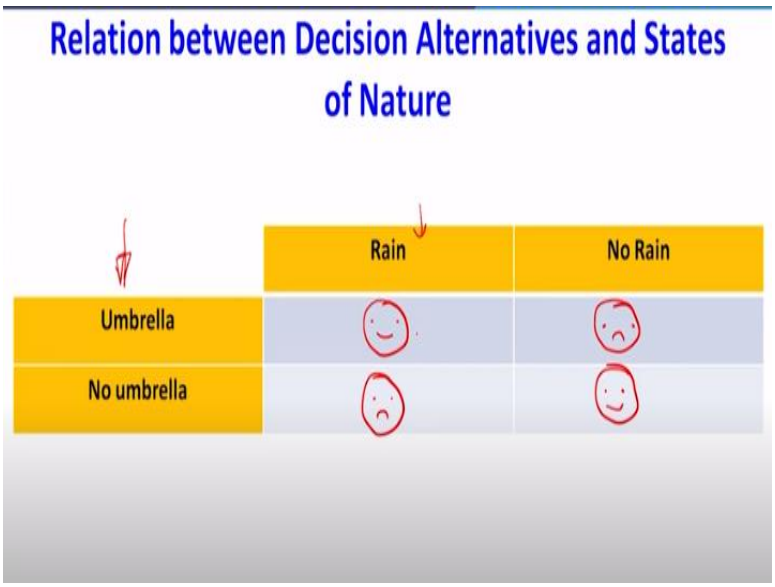
Lecture - 46
Decision Analysis - I

Dear students, in the previous lecture, I was discussing how to use spreadsheets for solving simulation problems. In this lecture, I am going to discuss decision analysis.



So, the agenda for this lecture is to formulate a decision problem and then make a decision without probabilities. What is the meaning of decision-making without probabilities? Another name we can call it is decision-making with uncertainty.

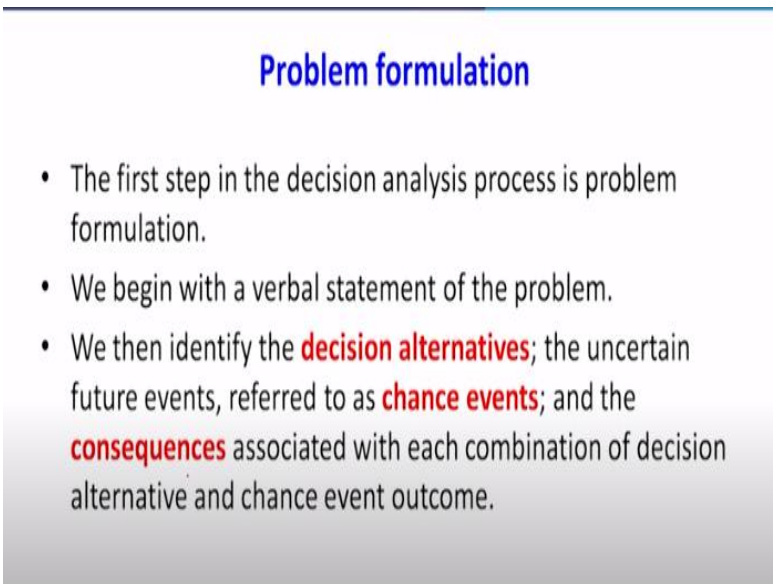


Now, I will explain the relationship between decision alternatives and states of nature in a decision analysis. Look at this table. The rows represent, in the rows, there is an umbrella, and there is no umbrella. In the column, there is rain and no rain. So, whatever there on this side is called decision alternatives. Decision alternative is something on your hand you have control over that.

For example, whether you can carry an umbrella, or you need not carry the umbrella is called a decision alternative. The other one in the column is states of nature, rain, or there is no rain. So, the act of rain is not in your hand. So, another name for this act of rain says it is a state of nature. So, whenever there is, for example, there is an intersection in this table. There is rain, and there is an umbrella.

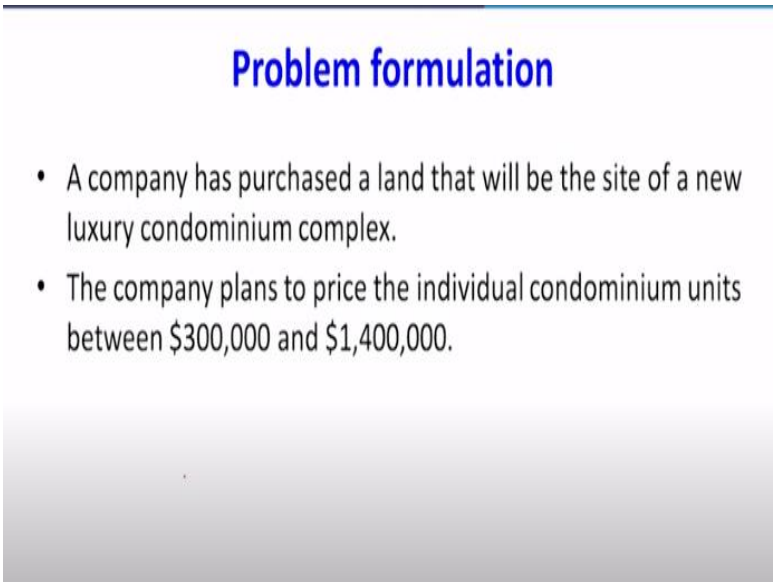
So, what will happen is that you are very happy, you are happy. And you have carried an umbrella, but there is no rain. So, what will be your feeling? You are not happy. And you did not take an umbrella, but there is rain. Again, what will happen? Here also you are not happy. Now there is no umbrella, and at the same time, there is no rain. So, what will be your state of mind?

So, you will be very happy. So, this rain or no rain is nothing but the state of nature. Carrying an umbrella or not carrying an umbrella is called your decision alternative. So, this combination of these two, so this is nothing but your payoff. The payoff is whether you are happy or not happy. That is called your payoff. So, these three terminology, we will be using in this lecture.



Problem formulation. The first step in the decision analysis process is problem formulation. We begin with a verbal statement of the problem. We then identify the decision alternatives, the uncertain future events referred to as chance events, and the consequences associated with each combination of decision alternatives and chance event outcome.

In the previous slide, I explained that the decision alternative is whether you want to carry or not carry an umbrella. That is decision alternatives. Chance event is whether there will be rain or there will not be any rain. The consequences are your feelings, your mood, and whether you are happy or not happy. So, these three important terminologies we will be using throughout this lecture.



I have a sample problem. This problem is taken from the book Anderson et al. A company has purchased land that will be the site for a new luxury condominium complex. The condominium is a type of flat building, flat. The company plans to price the individual condominium units between 300,000 to 1,400,000.

Problem formulation

- The company commissioned preliminary architectural drawings for three different projects:

90 condominiums

60 condominiums

30 condominiums

Anderson, D. R., Sweeney, D. J., Williams, T. A., Camm, J. D., & Cochran, J. J. (2018). An introduction to management science: quantitative approach. Cengage learning.

The company commissioned preliminary architectural drawings for three different projects. What are the three different projects the company is planning? They can go for the last one, for example, 30 condominiums, which are okay, smaller sizes. Then they can go for 60 condominiums, medium size. Then they can go for 90 condominiums, which are large. This is d1 small, d2 medium, d3 large. These are the three decision alternatives.

Problem formulation

- The financial success of the project depends upon the size of the condominium complex and the chance event concerning the demand for the condominiums.

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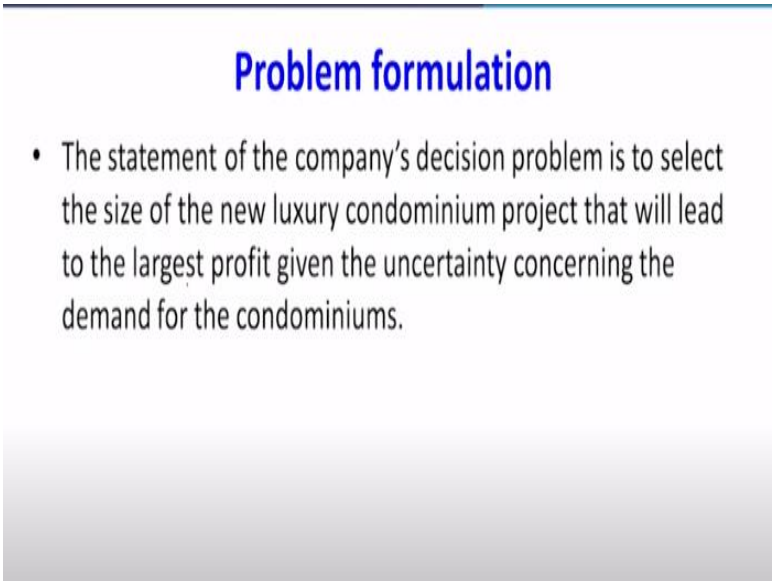
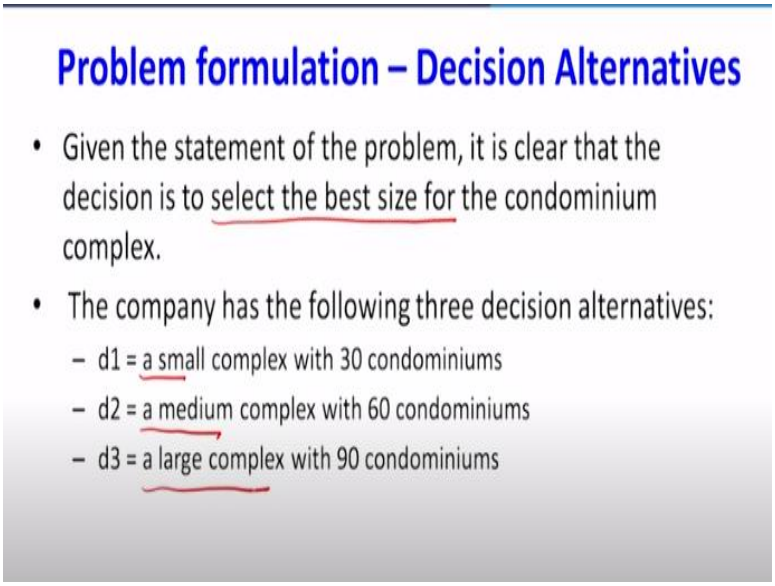
The financial success of the project depends upon the size of the condominium complex and the chance event concerning the demand for the condominium. Here, the chance event is in demand. The state of nature is in demand.



The statement of the company's decision problem is to select the size of the luxury condominium project that will lead to the largest profit given the uncertainty concerning demand for the condominiums. So what we have to suggest to this company is what the size of the condominium should be, whether small, medium, or large. What do you have to consider? The uncertain event is the demand, the payoff, and the profit.



First, we will decide what the decision alternatives are for this problem. Given the statement of the problem, it is clear that the decision is to select the best size for the condominium complex. The company has the following three decision alternatives: d1 small, d2 medium, d3 large complex. So, d1, d2, and d3 are decision alternatives.

Problem formulation

- A factor in selecting the best decision alternative is the uncertainty associated with the chance event concerning the demand for the condominiums.
- When asked about the possible demand for the condominiums, the company's president acknowledged a wide range of possibilities but decided that it would be adequate to consider two possible chance event outcomes:
  - a strong demand and
  - a weak demand.

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A factor in selecting the best decision alternative is the uncertainty associated with a chance event concerning the demand for condominiums. So here, the state of nature is in demand. When asked about the possible demand for condominiums, the company's president acknowledged a wide range of possibilities.

There are different possibilities, but I decided that it would be adequate to consider two possible chance event outcomes. What are the two possible chance event outcomes? One is that the demand may be strong demand or the demand may be weak demand. So, the demand is the state of nature that may be a strong demand or weak demand.

States of nature

- In decision analysis, the possible outcomes for a chance event are referred to as the states of nature.
- The states of nature are defined so they are mutually exclusive (no more than one can occur) and collectively exhaustive (at least one must occur); thus one and only one of the possible states of nature will occur.

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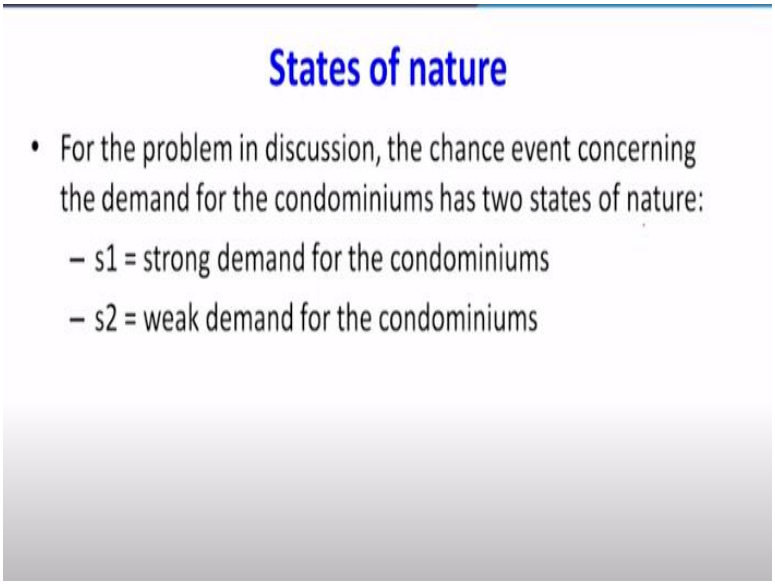
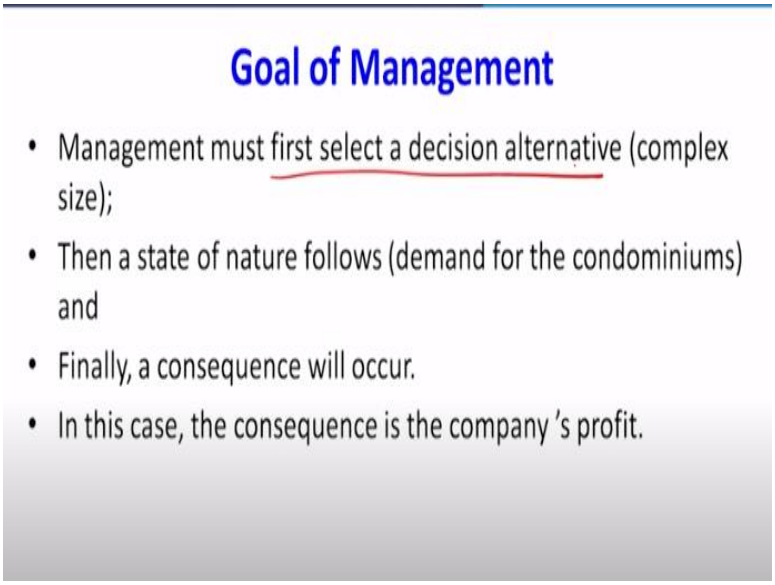
In decision analysis, the possible outcomes for a chance event are referred to as the states of nature. As I told you, whether it is raining or not, look at the picture on the

right-hand side. So, there is rain, but in the bottom one, there is no rain. In our problem, the demand may be strong demand or weak demand, okay? So, the states of nature are defined so they are mutually exclusive; no more than one can occur. And collectively exhaustive, at least one must occur.

Thus, one and only one of the possible states of nature will occur, whether it rains or not rains or whether the demand is strong or weak.



So, for the problem in the discussion, the chance event concerning the demand for the condominium has two states of nature. One is strong demand s1, weak demand s2.



So, what is the management's goal? The management must first select the decision alternatives that are complex in size. Then, the state of nature follows that there is demand for condominiums. In this case, the consequence is the company's profit.

Influence Diagrams

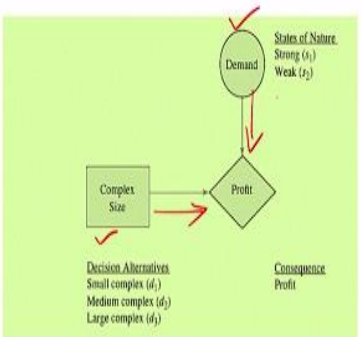
- An influence diagram is a graphical device that shows the relationships among the decisions, the chance events, and the consequences for a decision problem.
- The nodes in an influence diagram represent the decisions, chance events, and consequences.
- Rectangles or squares depict decision nodes, circles or ovals depict chance nodes, and diamonds depict consequence nodes.
- The lines connecting the nodes, referred to as arcs, show the direction of influence that the nodes have on one another.

So before getting into the problem, we will understand what influence diagrams are. An influence diagram is a graphical device that shows the relationships among the decisions, chance events, and the consequences of the decision problems. The nodes in the influence diagram represent the decisions, chance events, and consequences. Rectangles are squares that depict the decision nodes. Circles or ovals depict the chance nodes.

The diamond depicts the consequence nodes. The lines connecting the nodes, referred to as arcs, show the direction of influence that the nodes have on one another.

Influence Diagrams

- Figure shows the influence diagram for the problem.
- The complex size is the decision node, demand is the chance node, and profit is the consequence node.
- The arcs connecting the nodes show that both the complex size and the demand influence the company's profit.



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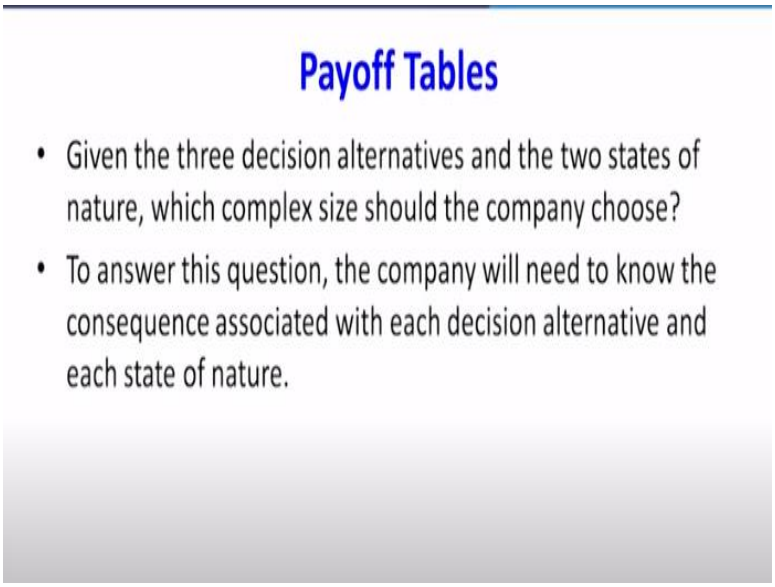
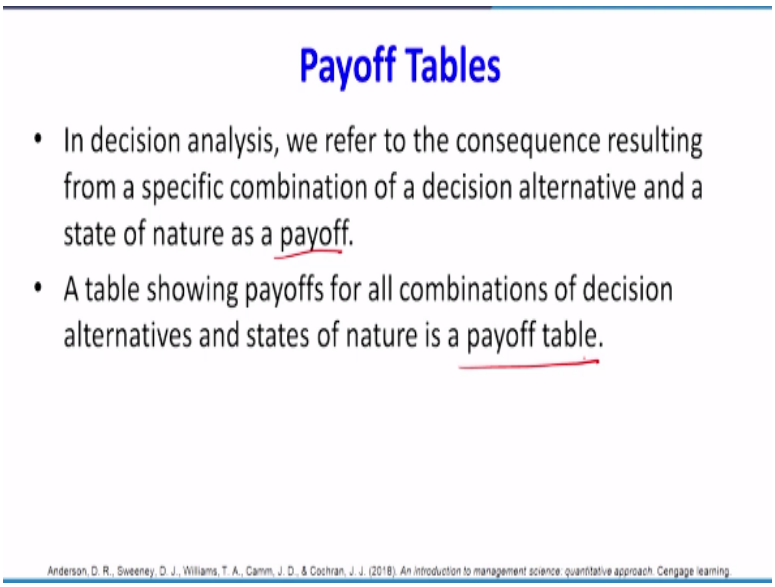
In this picture, look at the right-hand side. There is an influence diagram. The figure shows the influence diagram for the problem. The complex size is the decision node, the demand is the chance node, and the profit is the consequences node. The arc

connecting the nodes shows that both complex size and demand influence the company's profit. You see complex sizes d1, d2, and d3 that will affect your profit.

Look at the chance nodes, which are strong demand or weak demand. That also will affect your profit.



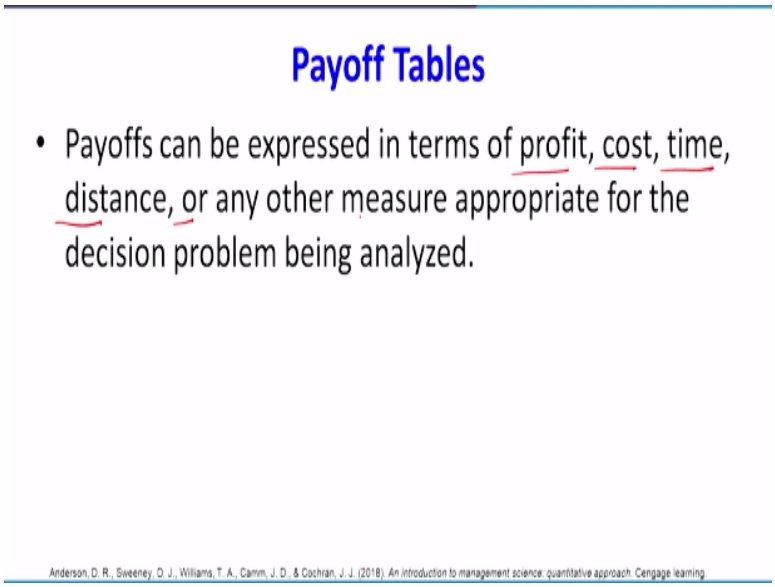
The next is a payoff table. Given the three decision alternatives and the two states of nature, which complex size should the company choose? To answer this question, the company will need to know the consequences associated with each alternative and each state of nature.



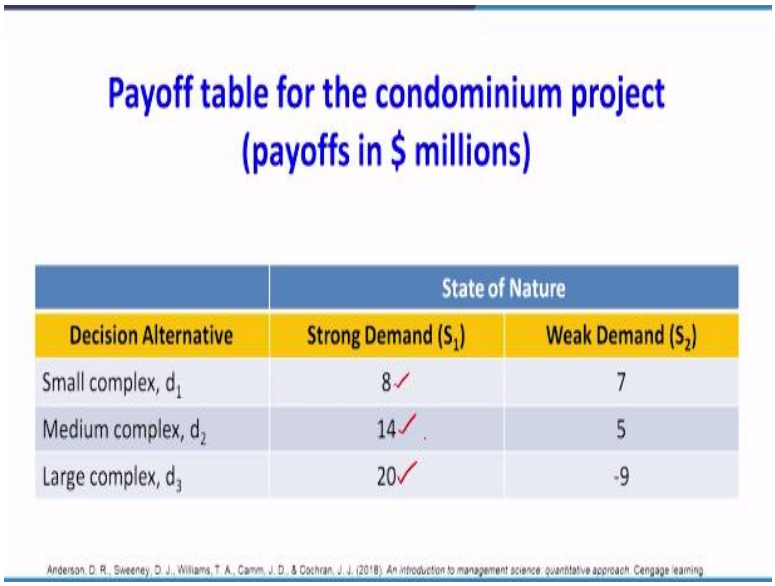
In decision analysis, we refer to the consequence resulting from a specific combination of a decision alternative and the states of nature as a payoff. So, in decision alternatives, the consequence is nothing but your payoff. A table showing the

payoff for all combinations of decision alternatives and states of nature is a payoff table. At the beginning of the lecture, I was shown that umbrella and rain.

So, the consequences are your happiness or not happiness. So that is nothing but your payoff table. The values are nothing but the payoff values.



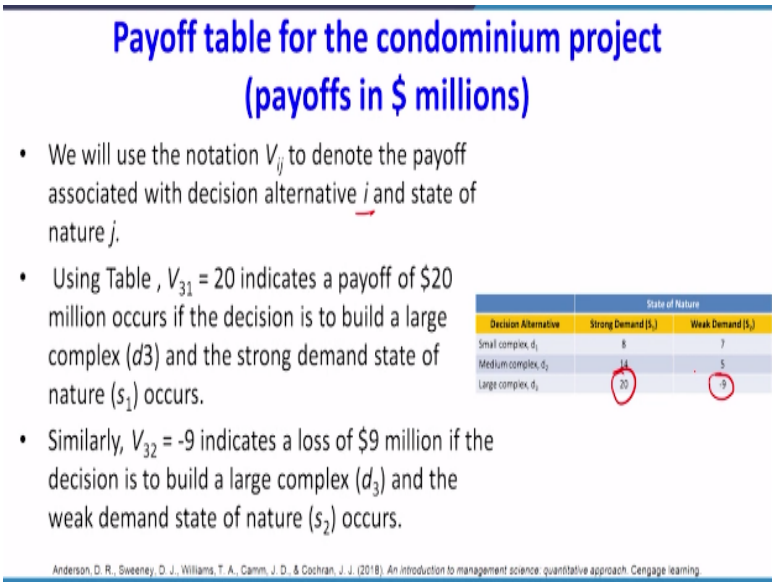
The payoff can be expressed in terms of profit. It is a very important point. The payoff can be the profit or cost, time or distance, or any other measure appropriate for the decision problem being analyzed. In this problem, the payoff is the profit. But it is not necessary. It should always be profitable. Sometimes it may be cost, sometimes time, sometimes maybe distance, and so on.



The payoff table for the condominium projects. All the payoffs are in terms of millions of dollars. You see a decision alternative d1, d2, d3, states of nature. So this

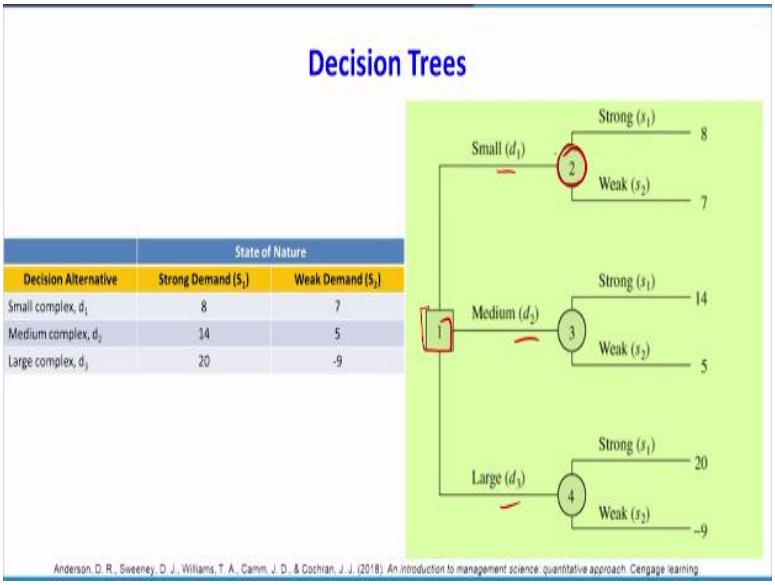
is 8 million. What is the meaning of this 8 represents? If you suggest to that company a small complex size, the demand is strong; the payoff will be $8 million. If you suggest a medium complex, the payoff will be $14 million dollars.

If you suggest a large complex, the demand is strong demand; it will be $20 million. Similarly, the values for weak demand also.



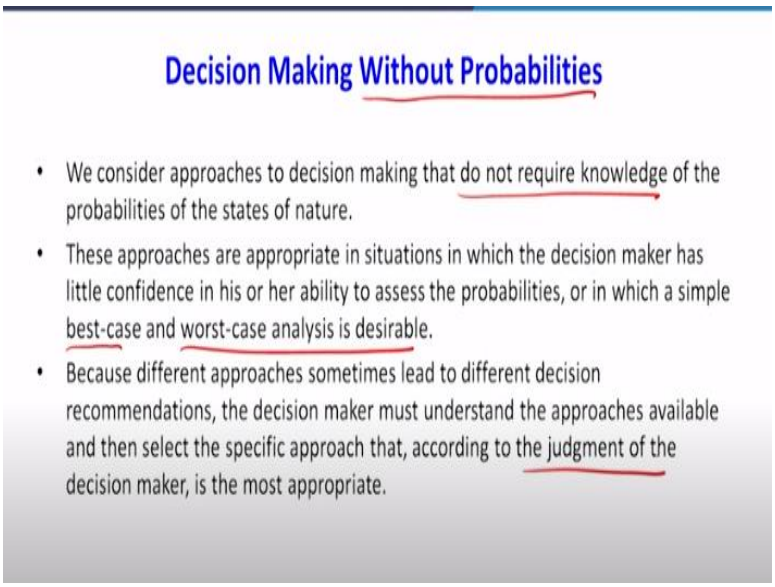
We will use the notation Vij to denote the payoff associated with the decision alternative i and the states of nature j. For example, look at Table, V31, the third decision alternative first states of nature. So that means it is 20. What is the meaning of this 20? This 20 indicates a payoff of $20 million occurs if the decision is to build a large complex and the strong demand states of nature occur.

Similarly, look at V32, which is this location. Indicate -9. V32 is -9, which indicates a loss of $9 million if the decision is to build a large complex and the weak demand states of nature s2 occur.



Another important point I wanted to make is that this payoff table can be represented in the form of a tree that is your decision tree. So, what will happen? Look at the d1, d2, d3; these are your decision alternatives. Look at the influence diagram and also, say this is the decision alternative. The circle represents the state of nature. It may be a strong demand and a weak demand.

So, the point I want to make here is that any payoff table can be represented in the form of decision trees. Because in the following lecture, I am going to explain the decision tree. So, this conversion should be very convenient for this.



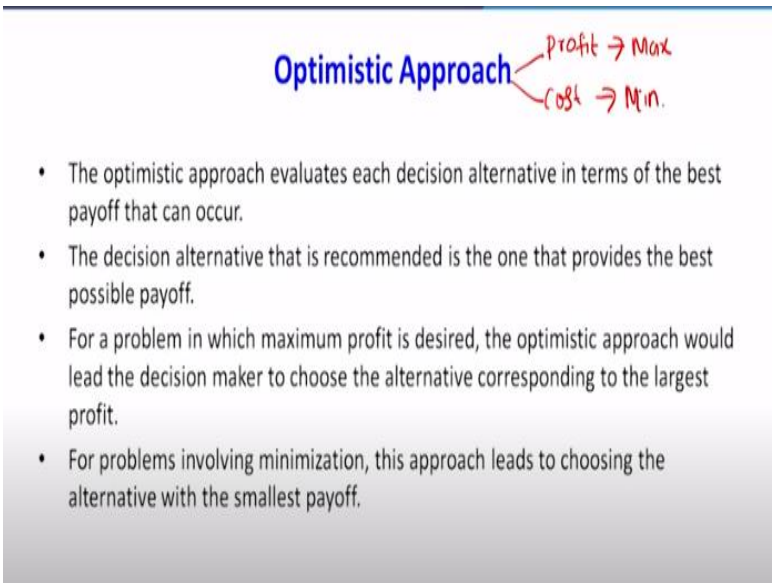
Now we will go for decision making without probabilities. Why are we saying without probabilities? The probabilities for chance, for example, whether it is a strong demand or weak demand, are not known to you. So that situation is called decision

making under uncertainty. Uncertainty means something that you cannot predict. So, the opposite of uncertainty is the risk. What is the meaning of risk?

Something you can attach certain probabilities. But for uncertainty, you cannot attach probabilities. Some examples of uncertain events are earthquakes and tsunamis. For these events, you cannot attach any probabilities. So that is an example of uncertain events. For example, demand. Next year what will be the demand? There, you can attach certain probabilities.

So that is your risk. So, we consider approaches to decision making that do not require knowledge of probabilities of the states of nature. These approaches are appropriate in situations in which the decision-maker has little confidence in his or her ability to assess probability. Sometimes, it is very difficult to assess the probability in which a simple best-case or worst-case analysis is desirable.

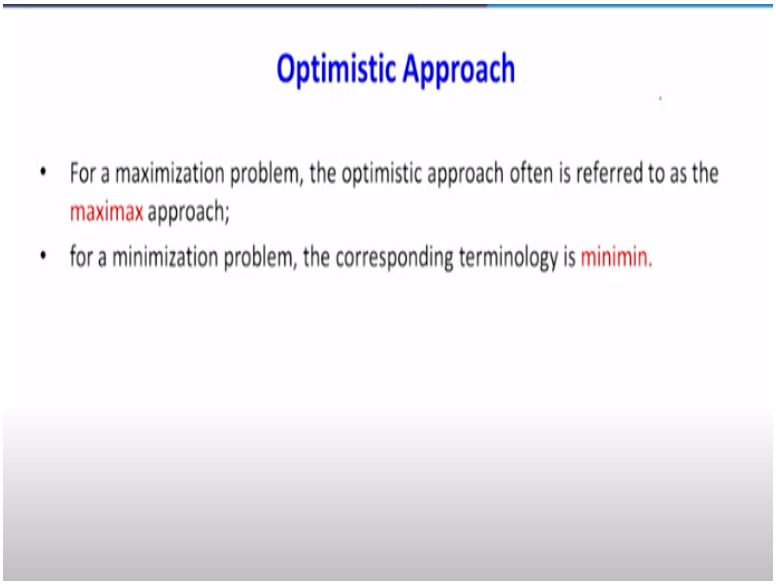
Because different approaches sometime lead to different decision recommendations. The decision maker must understand the approaches available and then select the specific approach according to the judgment of the decision maker, which is most appropriate for him. So, we are going to make the decision as per the judgment of the decision maker.



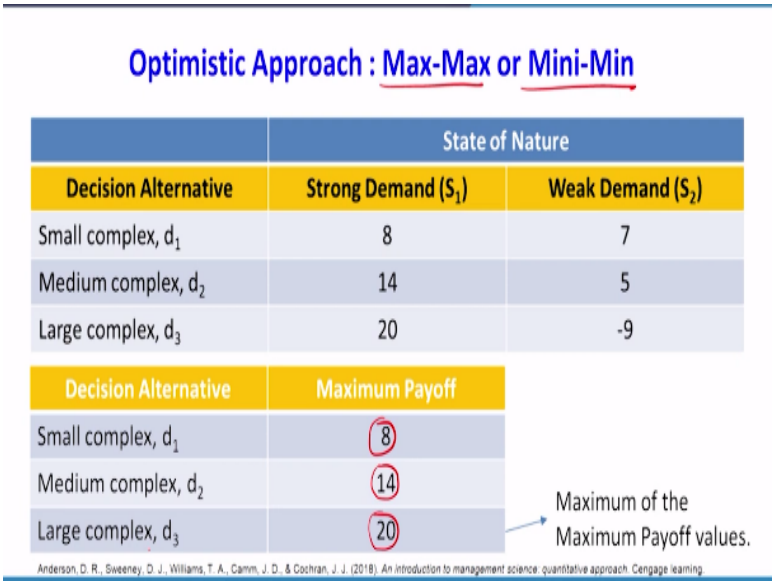
The decision maker may be an optimistic person, he is in a very optimistic approach. When I say optimistic approach, he is optimistic about the demand. The optimistic approach evaluates each decision alternative in terms of the best payoff that can

occur. The decision alternative that is recommended is one that provides the best possible payoff for a problem in which maximum profit is desired.

The optimistic approach would lead the decision maker to choose the alternative corresponding to the largest profit. For problems involving minimization, this approach leads to choosing the alternative with the smallest payoff. So, for an optimistic approach, what will you do if the payoff is the profit? We will go for maximum profit. In the optimistic approach, if the payoff is in terms of cost, we will go for minimum cost.

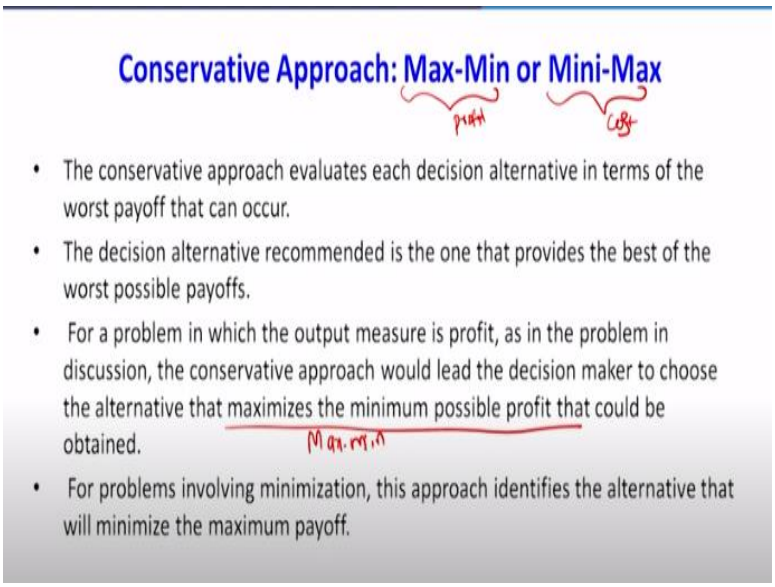


For a maximization problem, the optimistic approach is often referred to as the maximax approach. For a minimization problem, this corresponding terminology is your minimin.



First, we will make a decision based on an optimistic approach. As I told you, there are two possibilities: max-max if the problem is defined in terms of profit and min-min if the payoff is defined in terms of cost. Here the problem is in terms of profit. So what I am going to do is for each alternative, for example, small complex d1, which is the maximum payoff, so 8 is the maximum payoff.

So I have written 8. If I go for medium complex, what is the maximum payoff? 14 is the maximum payoff. If I go for a large complex, what is the maximum payoff? 20. As I told two maxi-max, so maximum of maximum. So out of these three, 8, 14, and 20, which is maximum of the maximum payoff? 20. So, the suggestion is to go for a large complex. So, if you are making a decision based on the optimistic approach, the suggestion for the management is to go for constructing a large complex.

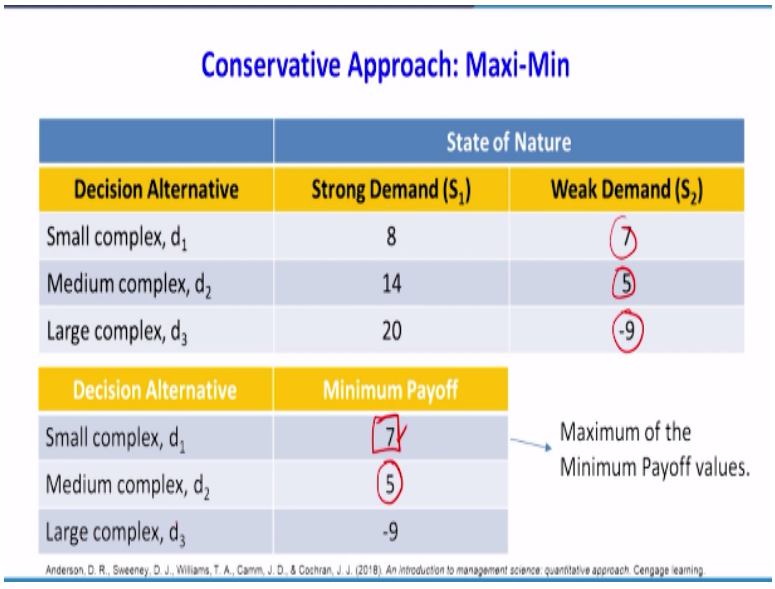


Conservative approach, max-min or mini-max. So when will you go for max-min when the payoff is defined in terms of profit? When will you only go for mini-max when the payoff is in terms of cost? The conservative approach evaluates each decision alternative in terms of the worst payoff that can occur.

The decision recommended alternative is the one that provides the best of the worst possible payoff. For a problem in which the output measure is profit, as in the problem discussion, the conservative approach would lead the decision maker to choose the alternative that maximizes the minimum possible profit. That is why it is called max-min. What is the meaning of max-min?

Maximizing the minimum possible profit that could be obtained. That is why we go for max-min, maximizing minimum possible profit as a conservative approach. For a problem involving minimization, the best approach is the alternative that will minimize the maximum payoff. So that is your mini-max.

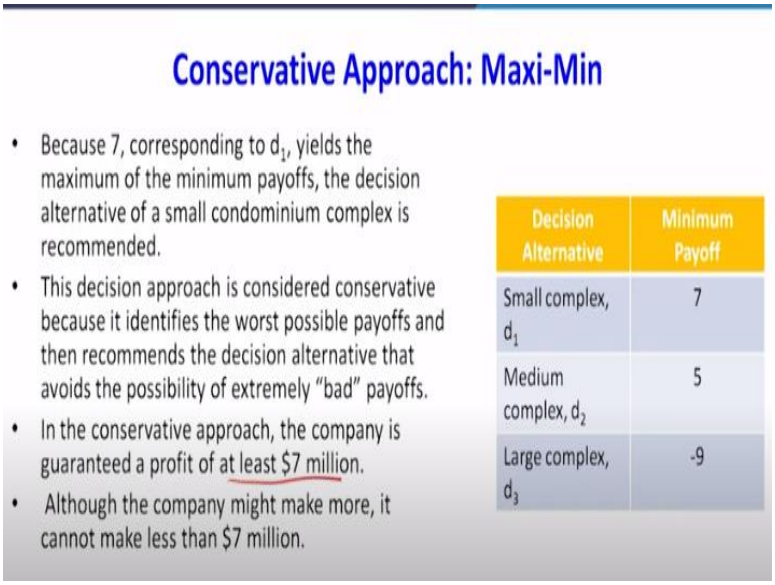
Conservative approach for a maximization problem, the conservative approach is often referred to as the maximin approach. For a minimization problem, the corresponding terminology is minimax. In this case, we are going to discuss about maximin.



Look at d1, d2, d3. First, we will go for a minimum payoff. So, between 8 and 7, which is the minimum? 7 is the minimum, so 7, I have written. Which is the minimum between 14 and 5? 5 is the minimum. Between these, 5 is the minimum that I have

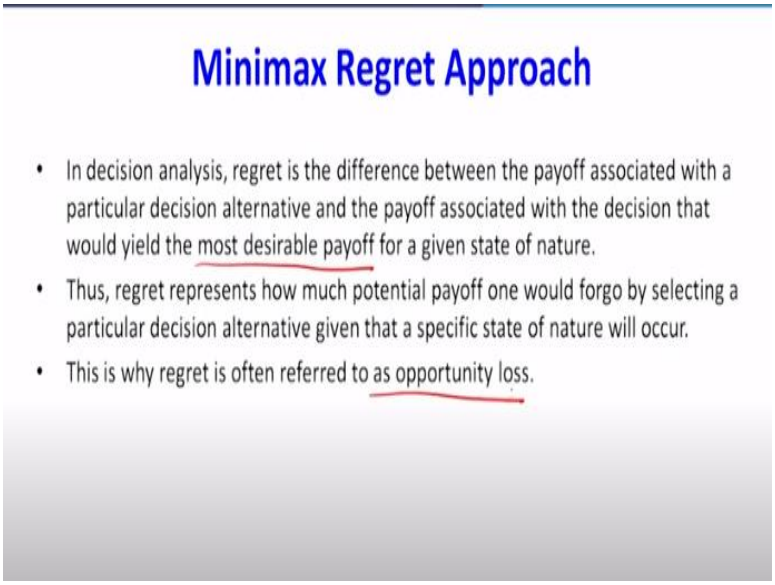
written here. Between 20 and -9, -9 is the minimum. So, 7, 5, -9. So out of the 7, 5, -9, which is the maximum? So 7 is the maximum.

So, as per the conservative approach maxi-min principle, I will be suggesting a small complex that is d1. You remember, if I am going for an optimistic approach, what was my suggestion? d3 is my suggestion, going for a large complex. If I am conservative, if you follow a conservative approach, we will go for suggesting a small complex.



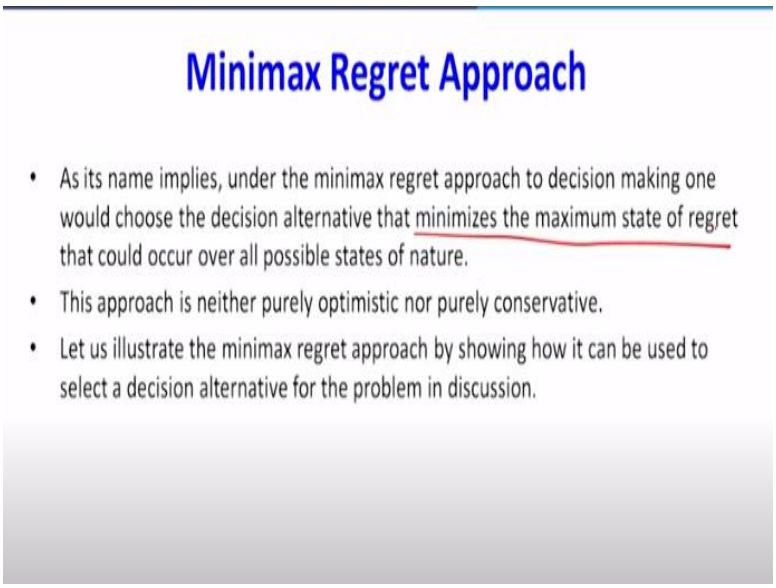
Because 7 corresponding to d1 yields the maximum or minimum payoff, the decision alternative of a small condominium complex is recommended. This decision approach is considered conservative because it identifies it identifies the worst possible payoff and then recommends the decision alternative that avoids the possibility of an extremely bad payoff. In the conservative approach, the company is guaranteed a profit of at least 7 million.

Although the company might make more, it cannot make less than 7 million. That is why this is called the conservative approach maxi-min principle.



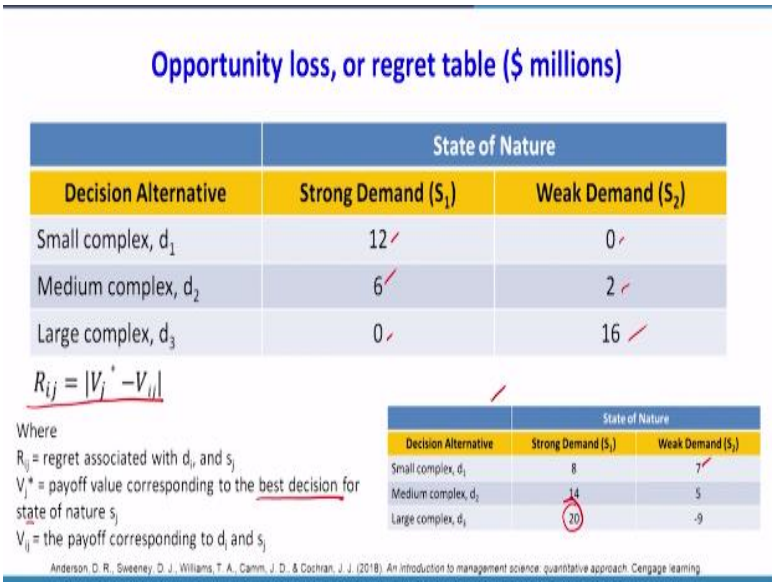
Dear students, so far, I have discussed the optimistic approach and the conservative approach. The other approach, which I am going to discuss now, is called the minimax regret approach. In decision analysis, regret is the difference between the payoff associated with a particular decision alternative and the payoff associated with the decision that would yield the most desirable payoff for a given state of nature.

So, what is the meaning of regret, the difference between the most desirable payoff and the payoff of a particular decision? Thus, regret represents how much potential payoff one would forego by selecting a particular decision alternative given that a specific state of nature will occur. This is why regret is often referred to as opportunity loss.



As its name implies, under the minimax regret approach, the decision-making one would choose a decision alternative that minimizes the maximum state of regret. So what will happen is we have to choose a decision alternative that minimizes the maximum state of regret. That could occur over all possible states of nature. This approach is neither purely optimistic nor purely conservative.

Let us illustrate the minimax regret approach by showing how it can be used to select a decision alternative for the problem in discussion.



Opportunity loss, or regret table ($ millions)

	State of Nature	
Decision Alternative	Strong Demand (S_1)	Weak Demand (S_2)
Small complex, d_1	12	0
Medium complex, d_2	6	2
Large complex, d_3	0	16

$R_{ij} = |V_j^* - V_{ij}|$

Where
R_{ij} = regret associated with d_i and s_j
V_j^* = payoff value corresponding to the best decision for state of nature s_j
V_{ij} = the payoff corresponding to d_i and s_j

	State of Nature	
Decision Alternative	Strong Demand (S_1)	Weak Demand (S_2)
Small complex, d_1	8	7
Medium complex, d_2	14	5
Large complex, d_3	20	-9

Anderson, D. R., Sweeney, D. J., Williams, T. A., Camm, J. D., & Cochran, J. J. (2018). An introduction to management science: quantitative approach. Cengage learning.

First, we have to form an opportunity loss table or regrettable. How to form this regrettable? Look at our given payoff table, which is at the bottom. Suppose the demand is strong demand; which is the best decision alternative? d3 because that has the highest payoff. So, each element has to be subtracted from this 20. So, 20 - 8, we are getting 12. 20 – 14 = 6. 20 – 20 = 0.

In case the demand is weak demand, which is the highest payoff? 7 is the highest payoff. So, 7 – 7 = 0. 7 – 5 = 2. 7 – (-9) it is 16. So here this 12, 6 represents loss. So what is the meaning? If the demand is strong demand, if you choose d 3, the loss is 0. What is the meaning of this 12? The demand is strong demand. If you choose d1, the loss is 12. So, we can write it as a formula.

What is this? A regret value through the highest value is Vj*. What is the Vj*? The payoff value corresponds to the best decision for the states of nature. What is Vij? The payoff corresponds to d i and Sj. Rij is the regret associated with di and Sj.

Opportunity loss, or regret, table ($ millions)

Decision Alternative	Minimum Regret
Small complex, d_1	12
Medium complex, d_2	6
Large complex, d_3	16

Minimum of the Maximum Regret.

So, regrettably, right now, we are going to use Minimax. So, what is the minimax? First, you have to look for maximum loss. So how did we get 12? See that d 1 maximum loss is 12. If you go for d2, the maximum loss is 6. When you go for d3, the maximum loss is 16. So I have written here 12, 6, 16. So out of this maximum regret, which is minimum? 6 is the minimum.

Note

optimistic → d_3
conservative → d_1
Min max regret → d_2

- Note that the three approaches discussed in this section provide different recommendations, which in itself isn't bad.
- It simply reflects the difference in decision-making philosophies that underlie the various approaches.
- Ultimately, the decision maker will have to choose the most appropriate approach and then make the final decision accordingly.
- The main criticism of the approaches discussed in this section is that they do not consider any information about the probabilities of the various states of nature.

Note that the three approaches discussed in this section provide different recommendations, which in itself is not bad. What are the three recommendations? When we go for an optimistic approach, my recommendation was d 3. When I go for a conservative approach, my recommendation is d1. When I go for minimax regret my recommendation was d2.

Now you see all three are different. So, it simply reflects the difference in decision-making philosophies that underline the various approaches. What are the three philosophies we have seen? Optimistic, conservative, and using the regret matrix. Ultimately, the decision maker will have to choose the most appropriate approach and then make the final decision accordingly.

The main criticism of the approach discussed in this section is that they do not consider any information about the probabilities of the various states of nature. So, regarding this probability of the various states of nature that we will discuss in the next class. Dear students, in this lecture, we have started a new topic, decision analysis. In what I have explained in this lecture, I have discussed problem formulation.

After that, I have discussed decision making without probabilities which is nothing but decision making with uncertainty. In the next class, we will be discussing decision making with probabilities. That is nothing but decision making with risk. Thank you very much.