IS 301 DECISION SUPPORT SYSTEMS

DECISION SUPPORT SYSTEMS AND INTELLIGENT SYSTEMS,
Seventh Edition
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Chapter 4

Decision Theory-part2

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DECISION Tables

- A technical support company writes a decision table to diagnose printer problems based upon symptoms described to them over the phone from their clients. The following is a balanced decision table.

Printer troubleshooter

		Rules							
Conditions	Printer does not print	Y	Y	Y	Y	N	N	N	N
	A red light is flashing	Y	Y	N	N	Y	Y	N	N
	Printer is recognized by computer	N	Y	N	Y	N	Y	N	Y
Actions	Check the power cable			X					
	Check the printer-computer cable	X		X					
	Ensure printer software is installed	X		X		X		X	
	Check/replace ink	X	X			X	X		
	Check for paper jam		X		X				

DECISION Tables

Let's Get Physical

If you are a new customer opening a credit card account, you will get a 15% discount on all your purchases today. If you are an existing customer and you hold a loyalty card, you get a 10% discount. If you have a coupon, you can get 20% off today (but it can't be used with the 'new customer' discount). Discount amounts are added, if applicable.

Take a look at the table below:

Conditions	**Rule 1**	**Rule 2**	**Rule 3**	**Rule 4**	**Rule 5**	**Rule 6**	**Rule 7**	**Rule 8**
New customer (15%)	T	T	T	T	F	F	F	F
Loyalty card (10%)	T	T	F	F	T	T	F	F
Coupon (20%)	T	F	T	F	T	F	T	F
Actions								
Discount (%)	X	X	20	15	30	10	20	0

Decision Table

Policies and Decision Tables

- A policy is a set of rules that governs some process of the business.
- A decision table is a tabular form of presentation that specifies a set of conditions and their corresponding actions.

Modeling Logic with Decision Tables

- A matrix representation of the logic of a decision
- Specifies the possible conditions and the resulting actions
- Best used for complicated decision logic

Modeling Logic with Decision Tables

Consists of three parts :

- Condition stubs (seed)
  - Lists condition relevant to decision
- Action stubs
  - Actions that result from a given set of conditions
- Rules
  - Specify which actions are to be followed for a given set of conditions
- Standard procedure for creating decision tables
  - Name the condition and values each condition can assume
  - Name all possible actions that can occur
  - List all rules
  - Define the actions for each rule
  - Simplify the table → table compression

DECISION TREES

- All the decision-making problems discussed above **are single stage decision-making problem.**
- It is because in all the problems, an assumption is made that the available data regarding payoffs, strategies, states of nature, competitor's actions and probability distribution is not subject to revision and that the entire decision horizon is considered as a **single stage**.
- Only one decision is made and these single stage models are static decision models, because available data is not revised under the assumption that time does not change any basic facts, and that no new information is sought.

- There are, however, business situations where the manager needs to make **not one, but a sequence of decisions .**

- These problems then become **multistage problems**; because the outcome of one decision affects subsequent decisions.

- In situations, that require a sequence of decisions, the manager can utilize a simple but useful schematic device known as decision tree.

- **A decision tree is a schematic representation of a decision problem.**

A decision tree consists of :
- **nodes**
- **branches**
- **probability estimates**
- **payoffs**.

There are two types of nodes:
- one is **decision node**
- and other is **chance node**.

A decision node is generally represented by a square, ◻ **r**equires that a conscious decision be made to choose one of the branches that emanate from the node (*i.e*. one of the availed strategies must be chosen).

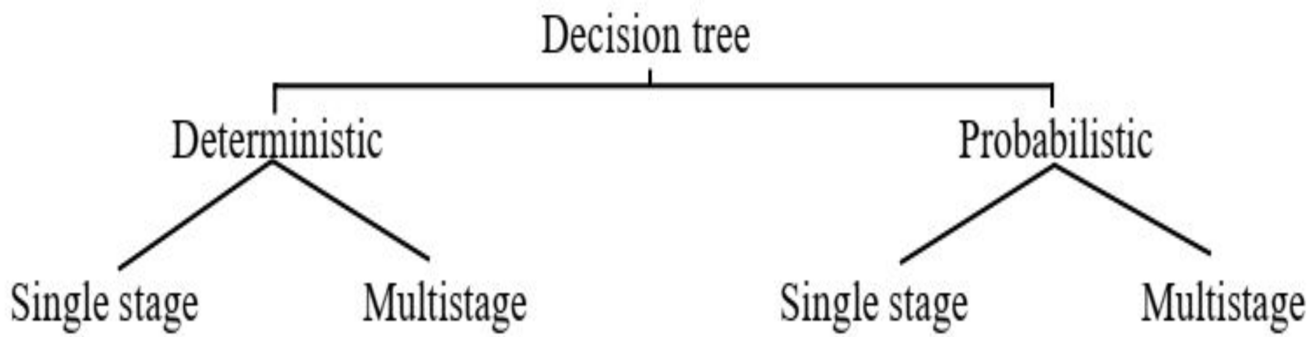
The branches emanate from and connect various nodes. We shall identify two types of branches: **decision branch** and **chance branch.**

- A decision branch denoted by parallel lines (═) represents a strategy or course of action.
- Another type of branch is chance branch, represented by single line (—) represents a chance determined event.
- Indicated alongside the chance branches are their respective probabilities.
- When a branch marks the end of a decision tree *i.e*. it is not followed by a decision or chance node will be called as **terminal branch.**
- A terminal branch can represent a decision alternative or chance outcome

- The payoffs can be positive (profit or sales) or negative (expenditure or cost) and they can be associated with a decision branch or a chance branch.

- The payoffs are placed alongside appropriate branch except that the payoffs associated with the **terminal branches** of the decision tree will be shown at the end of these branches.

- The decision tree can be **deterministic** or **probabilistic** (stochastic), and it can he represent a single-stage (one decision) or a multistage (a sequence of decisions) problem.



The classification of decision tree is shown above.

- The decision rules we examined in the previous section help to deal with situations where there is uncertainty about the states of nature and no probabilities are available to represent the chances of their happening.

- If we do have probabilities for the different states of nature we can use these probabilities to determine **expected monetary values (EMVs) for each strategy.**

- This approach is at the heart of decision trees.

- As their name implies, decision trees depict the different sequences of outcomes and decisions in the style of a tree, extending from left to right.

- Each branch of the tree represents an outcome or a decision.

- The junctions, or points at which branches separate, are called ***nodes*.**

- If the branches that stem from a node represent outcomes, the node is called a ***chance node*** and depicted using a small circle.

- If the branches represent different decisions that could be made at that point, the node is a ***decision node*** and depicted using a small square.

- All the paths in a decision tree should lead to a specific monetary result that may be positive (an income or a profit) or negative (a cost or a loss).

- The probability that each outcome occurs is written alongside the branch that represents the outcome.

- We use the probabilities and the monetary results to work out the expected monetary value (EMV) of each possible decision.

- The final task is to select the decision, or series of decisions if there is more than one stage of decision-making, that yields the **highest EMV**.

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A deterministic decision tree

A deterministic decision tree represents a problem in which each possible alternative and its outcome are known with certainty. That is, a deterministic tree does not contain any chance node. **A single stage deterministic decision tree is one that contains no chance nodes and involves the making of only one decision.**

Problem 12.9.

A business manager wants to decide whether to replace certain equipment in the first year or in the second year or not replace at all. The payoffs are shown below. Draw a decision tree to decide the strategy.

Profits or Payoffs in Rupees

Strategy	*First year*	*Second year*	*Total*
A Replace now	4000	6000	10000
B Replace after one year	5000	4000	9000
C Do not replace	5000	3000	8000

Solution: (Figure 12.1)

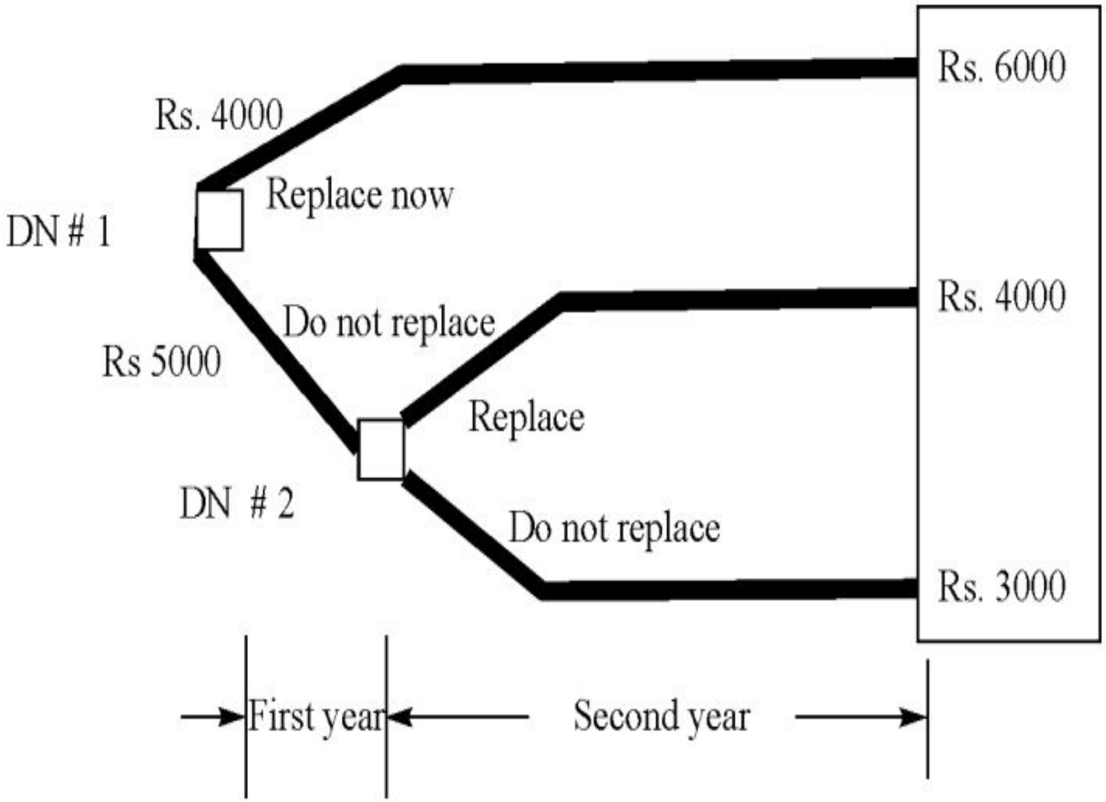


Figure 12.1

The optimal strategy is to replace the equipment now.

Stochastic Decision Trees

These are characterized by the presence of chance nodes. **A single-stage stochastic decision tree is one that contains at least one chance node and involves the making of only one decision.** Conceptually, any conditional payoff matrix can be represented as a single- stage stochastic decision tree, and vice versa. However, such problems (involving one decision) are best formulated and solved by the payoff matrix approach.

A multistage stochastic decision tree is one that contains at least one chance node and involves the making of a sequence of decisions. The decision tree approach is most useful in analyzing and solving the multistage stochastic decision problems.

Example1 :

Following the success of their CeeZee Seafood fast food restaurant in London, the proprietors, Soll and Perretts, are thinking of expanding the business. They could do this by investing in new sites or by franchising the operation to aspiring fast food entrepreneurs who would pay a fee to Soll and Perretts. The estimated profits for each strategy depend on the future demand for healthy fast food, which could increase, remain stable, or decline. Another possibility for Soll and Perretts is to accept the offer of £20m that a major international fast food company has made for their business. The expected profits are shown in Table 11.1.

Table 11.1
Expected profits (in £m) for Soll and Perretts

	State of future demand		
Strategy	**Increasing**	**Steady**	**Decreasing**
Invest	100	40	−30
Franchise	60	50	0
Sell	20	20	20

Example 11.8

The proprietors of the business in Example 11.3 estimate that the probability that demand increases in the future is 0.4, the probability that it remains stable is 0.5 and the probability that it decreases is 0.1. Using this information construct a decision tree to represent the situation and use it to advise Soll and Perrets.

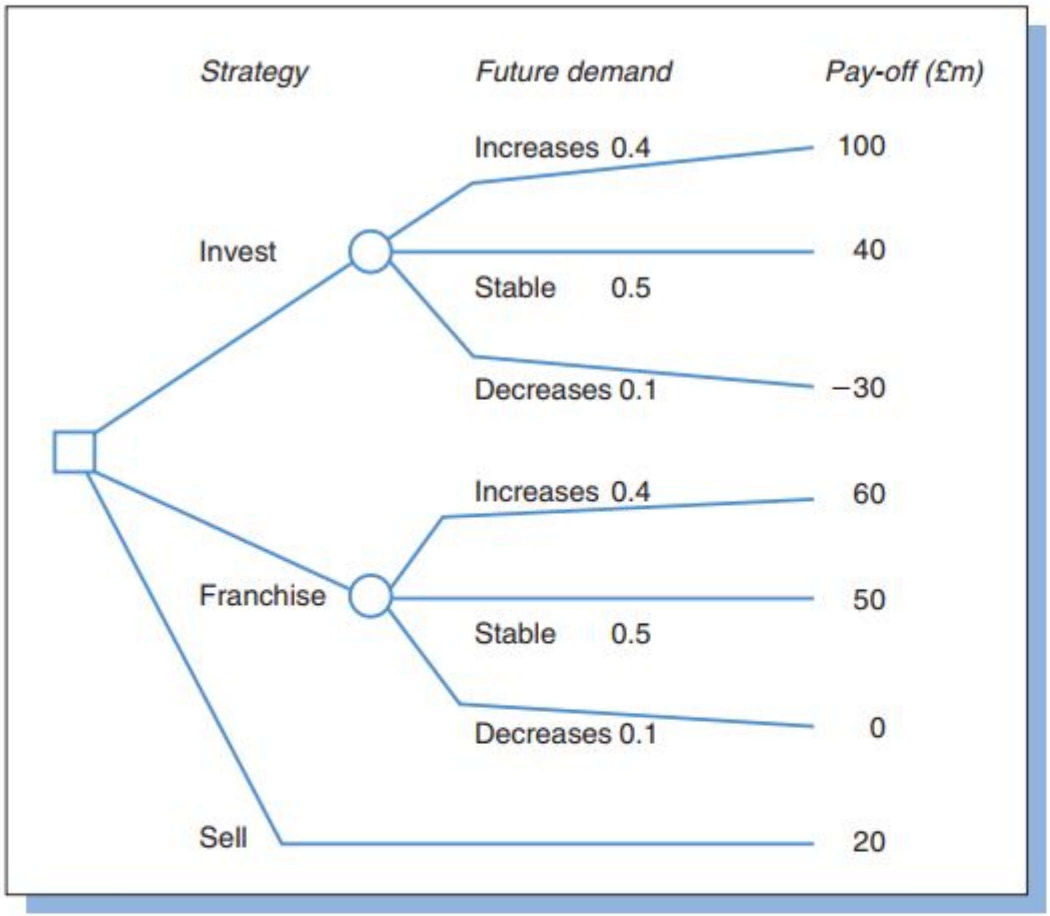


Figure 11.1
Decision tree for Example 11.8

$$\text{EMV for the Invest strategy} = 0.4 * 100 + 0.5 * 40 + 0.1 * (-30) = £57\text{m}$$

$$\text{EMV for the Franchise strategy} = 0.4 * 60 + 0.5 * 50 + 0.1 * 0 = £49\text{m}$$

$$\text{EMV for the Sell strategy} = £20\text{m}$$

The proprietors should choose to invest.

The probabilities of the states of nature in Example 11.8 were provided by the decision-makers themselves, but what if they could commission an infallible forecast of future demand? How much would this be worth to them? This is the value of perfect information, and we can put a figure on it by working out the difference between the EMV of the best strategy and the expected value with perfect information.

This latter amount is the sum of the best pay-off under each state of nature multiplied by the probability of that state of nature.

Example 2

Problem 12.10.

Basing on the recommendations of the strategic advisory committee of M/S Zing manufacturing company it has decided to enter the market with a new consumer product. The company has just established a corporate management science group with members drawn from research and development, manufacturing, finance and marketing departments. The group was asked to prepare and present an investment analysis that will consider expenditures for building a plant, sales forecasts for the new product, and net cash flows covering the expected life of the plant. After having considered several alternatives, the following strategies were presented to top management.

Strategy A: Build a large plant with an estimated cost of Rs. 200 crores.

This alternative can face two states of nature or market conditions: High demand with a probability of 0.70, or a low demand with a probability of 0.30. If the demand is high, the company can expect to receive an annual cash flow of Rs. 50,00,000 for 7 years. If the demand were low the annual cash flow would be only Rs. 10,00,000, because of large fixed costs and inefficiencies caused by small volume. As shown in figure, strategy *A* ultimately branches into two possibilities depending on whether the demand is high or low. These are identified as decision tree terminal points A_1 and A_2 (Figure 12.2).

Strategy B: Build a small plant with an estimated cost of Rs. 1 crore.

This alternative also faces two states of nature: High demand with a probability of 0.70, or a low demand with a probability of 0.30. If the demand is low and remains low for 2 years, the plant is not expanded. However, if initial demand is high and remains high for two years, we face another decision of whether or not to expand the plant. If it is assumed that the cost of expanding the plant at that time is Rs. 1.5 crore. Further, it is assumed that after this second decision the probabilities of high and low demand remains the same.

As shown in the figure 12.2 strategy *B* eventually branches into five possibilities. Identified by terminal points B_1 to B_5.

Estimate of the annual cash flow and probabilities of high demand and low demand are shown in figure 12.2.

What strategy should be selected?

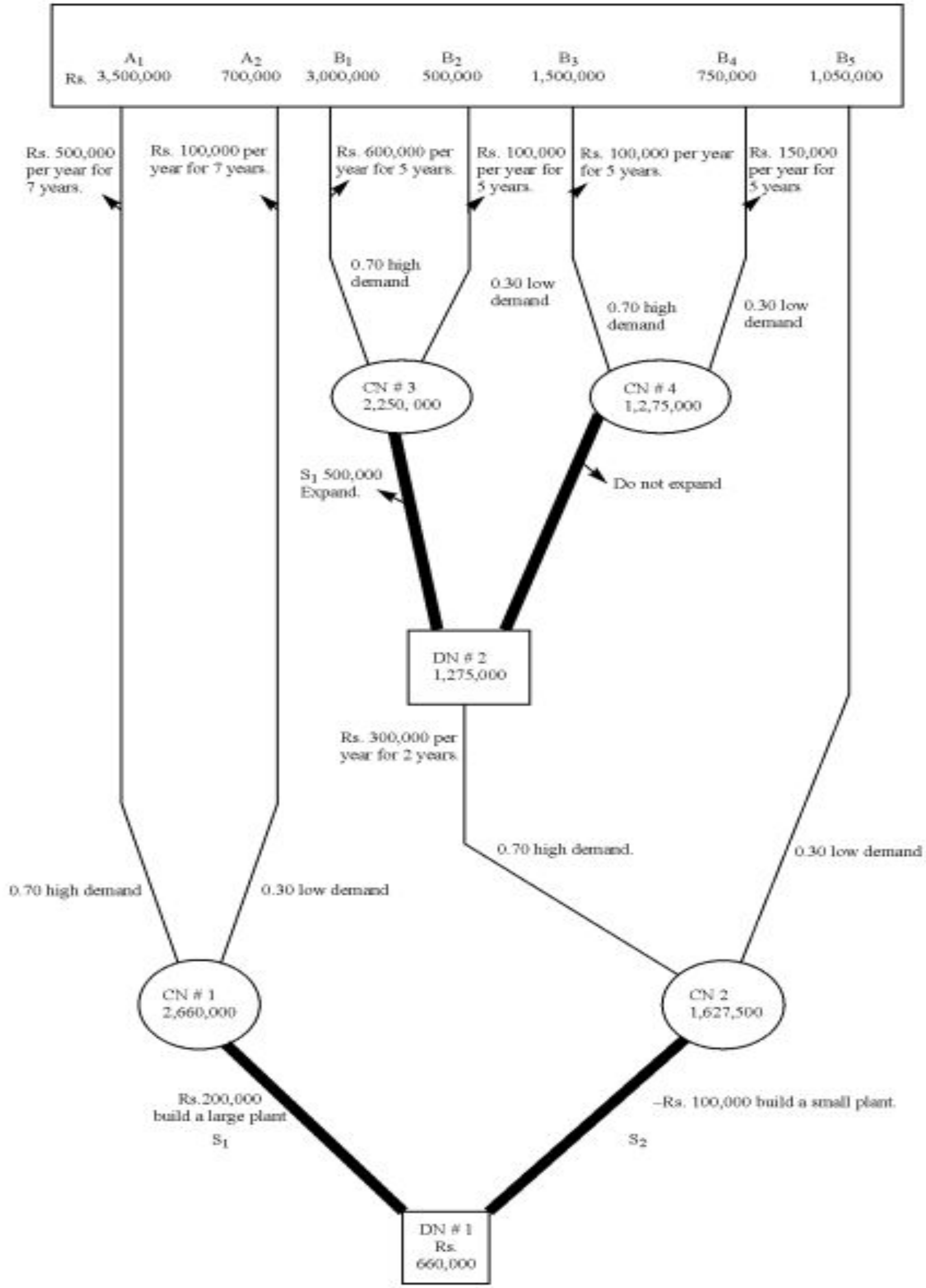


Figure 12.2. Multistage decision tree

Solution

The decision tree shown in figure 12.2 is drawn in such a manner that the starting point is a decision node and the progression is from left to right. The number of branches, and the manner, in which various decision and chance nodes are connected by means of branches, indicates various paths through the tree. Along the braches stemming from decision nodes, we write down the decision alternatives and/ or their monetary payoffs or costs, along the branches probabilities, and monetary payoff finally, at the extreme right hand side of the decision tree (terminal branches, after which no decision is made or a chance node is appeared) the relevant payoffs are shown. At the end of each terminal the related payoff is shown.

Once the relevant information regarding decision nodes, chance nodes, decision and chance branches, rewards or costs of decision branches probabilities and payoffs associated with chance braches are known, we can analyze the tree.

Analysis

The analysis of decision tree consists of calculating the **position value** of each node through the process or **roll back**. The concept of roll back implies that we start from the end of the tree, where the payoff is associated with the terminal branches as indicated and go back towards the first decision node (DN # 1) *i.e.* we proceed from right to left.

As we roll back, we can face either a chance node or a decision node. T**he position value of the chance node is simply the expected value of the payoffs represented by various branches that stem from the node.**

For example, the position value of Chance node 1 (CN # 1) is

= 0.7 (7 × 500,000) + 03 × (7 × 100,000) = Rs. 2,660,000

Position value of chance nodes 3 and 4 (CN # 3, CN # 4) are:

Position value of CN # 3 = 0.7 (5 × 600,000) + 0.3 (5 × 100,000) = Rs. 2, 250, 000.

Position value of CN # 4 = 0.7 (5 × 300,000) + 0.3 (5 × 150,000) = Rs. 1, 275, 000.

The position value of a *decision node* is the highest (assuming positive payoffs) of the position value of nodes, or the node, to which it is connected, *less* the cost involved in the specific branch leading to that node. For example, as we roll back to decision node 2 (DN # 2), we note that Rs. 150, 000 (cost of expansion) must be subtracted from the position value of chance node 3 (CN # 3) *i.e.* Rs. 225,000. That is the branch yields Rs. 2,250,000 – Rs. 1,750,000 =, Rs. 750,000. And this must be compared with the CN # 4 position value of Rs. 1,275,000. The higher of the two values i.e. Rs. 1, 275,000 is the position value of DN # 2. The position value of a node will be placed inside the symbol for the node.

Next, let us rollback to CN # 2, as in CN # 3 and CN # 4, the position value of CN # 2 is also calculated by the **expected value concept**. However, in the case of CN # 2, one of the branches emanating from it leads with a probability 0.7 to a decision node (the payoff for this branch is a total cash flow of Rs. 5,600,000 plus the position value of DN # 2) while the other is the terminal branch, having a probability of 0.3, with its own pay of Rs. 1,050, 000. Hence the position value of CN # 2 is:

0.7 (Rs. 600,000+ Rs. 1,275,000) + 0.3 ($7 \times 150{,}000$) = Rs. 1,627,500.

We are now ready to roll back to DN # 1. As shown in figure 12.2, the position values of CN # 1 and CN # 2 that are connected to decision node 1 are already calculated. From the position value of

CN # 1, we subtract Rs. 2,000,000 (cost of building a large plant) and obtain 2,660, 000 – 2,000,000 = Rs. 660,000. From the position value of CN # 2, we subtract 1, 000,000, the cost of building a small plant and get 1, 627, 500 – 1, 000, 000 = Rs. 627, 500. Thus, when we compare the two decisions branches emanating from DN #1, we find that the strategy A, to build a large plant, yields the higher payoff. Hence the position value of DN # 1 is Rs. 660, 000. That the strategy A is the optimal strategy and its expected value is Rs. 660, 000.

When we summarize, the elements and concepts needed to consider a decision are:

- All decisions and chance nodes.
- Branches that connect various decision and chance nodes.
- Payoff (reward or cost) associated with branches emanating from decision nodes.
- Probability values associated with braches emanating from chance nodes.
- Payoffs associated with each of chance branches.
- Payoffs associated with each terminal branch at the no conclusion of each path that can be traced through various combinations that form the tree.
- Position values of Chance and Decision nodes.
- The process of roll back.

Our decision tree problem described above involves a sequence of only two decisions, and a chance node had only two branches. This is obviously a simplified example, designed only to show the concept, structure, and mechanics of the decision-tree approach. The following are only some of the refinements that can be introduced in order to get more reality.

- The sequence of decision can involve a larger number of decisions.
- At each decision node, we can consider a larger number of strategies.
- At each chance node, we can consider a larger number of chance branches. Actually, we can even assume continuous probability distribution at each chance node.
- We can introduce more sophisticated and more detailed projections of cash flows.
- We can use the concept discount that would take into account the fact that present rupee value worth more future value.
- We can also obtain an idea of the **quality of the risk** associated with relevant decision-tree paths. That is, in addition to calculating the *expected value*, we can calculate such parameters as **range** and **standard deviation** of the payoff distribution associated with each relevant path.
- We can conduct Bayesian analysis that permits introduction of new information and revision of probabilities.

Admittedly, neither the problems nor the decisions are that simple in real world. However, the attempts to analyze decision problems in a quantitative fashion yield not only some "ball park" figure, but also valuable qualitative insights into the entire decision environment.

Example 3

Problem 12.11.

A client has an estate agent to sell three properties *A, B* and *C* for him and agrees to pay him 5% commission on each sale. He specifies certain conditions. The estate agent must sell property *A* first, and this he must do within 60 days. If and when *A* is sold the agent receives his 5% commission on that sale. He

can then either back out at this stage or nominate and try to sell one of the remaining two properties within 60 days. If he does not succeed in selling the nominated property in that period, he is not given opportunity to sell the third property on the same conditions. The prices, selling costs (incurred by the estate agent whenever a sale is made) and the estate agent's estimated probability of making a sale are given below:

Property	*Price of Property in Rs.*	*Selling Costs in Rs.*	*Probability of Sales*
A	12,000	400	0.70
B	25,000	225	0.60
C	50,000	450	0.50

(1) Draw up an appropriate decision tree for the estate agent.

(2) What is the estate agent's best strategy under Expected monitory value approach (EMV)?

Solution

The estate agent gets 5% commission if he sells the properties and satisfies the specified condition. The amount he receives as commission on the sale of properties *A, B* and *C* will be Rs. 600/-, RS. 1250/- and Rs. 2500 respectively. Since selling costs incurred by him are Rs. 400/-, Rs. 225/- and Rs. 450/-, his conditional profits from sale of properties *A, B* and *C* are Rs. 200/-, Rs. 1025/- and Rs. 2050/- respectively. The decision tree is shown in figure 12.3.

EMV of node D = Rs. $(0.5 \times 2050 + 0.5 \times 0)$ = Rs. 1025.

EMV of node E = Rs. $(0.6 \times 1025 + 0.4 \times 0)$ = Rs. 615.

EMV of node 3 = Maximum of Rs. (1025, 0) = Rs. 1025.

EMV of node 4 = Maximum of Rs. (615, 0) = Rs. 615.

EMV of node B = Rs. $[0.6\,(1025 + 1025) + 0.4 \times 0]$ = Rs. 1230.

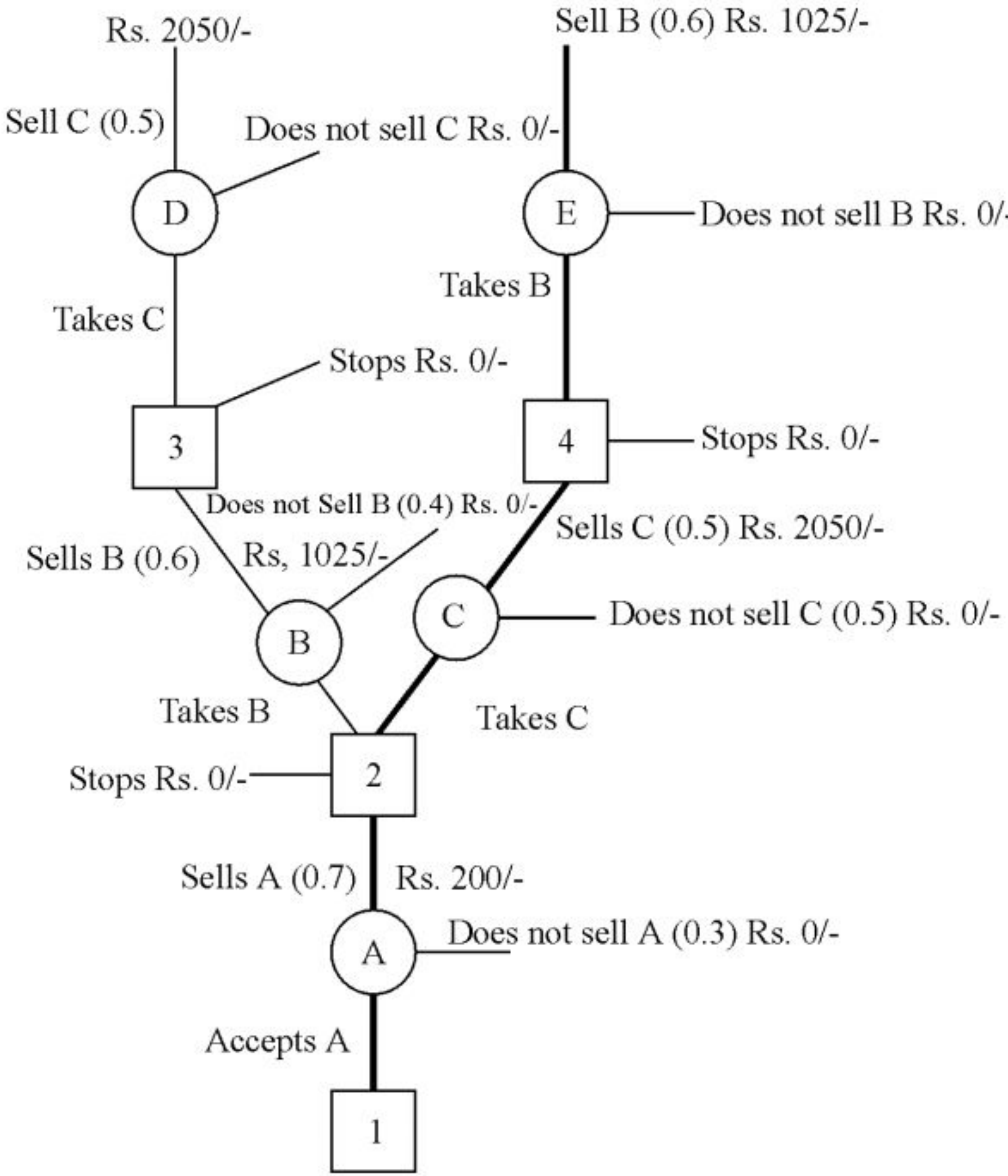
EMV of node C = Rs. $[0.5\,(2050 + 615) + 0.5 \times 0]$ = RS. 1332.50.

Therefore, EMV of node 2 = Rs. 1332.50, higher among EMV at B and C.

Therefore, EMV of node A = Rs. $[0.7(200 + 1332.50) + 0.3 \times 0]$ = Rs. 1072.75

Therefore, EMV of node 1 = Rs. 1072.75.

The optimal strategy path is drawn in bold lines. Thus, the optimum strategy for the estate agent is to sell *A*; if he sells *A* then try to sell *C* and if he sells *C* then try to sell *B* to get an optimum, expected amount of Rs. 1072.50.



Rs. 2050/-
Sell B (0.6) Rs. 1025/-
Sell C (0.5)
Does not sell C Rs. 0/-
D
E
Does not sell B Rs. 0/-
Takes B
Takes C
Stops Rs. 0/-
3
4
Stops Rs. 0/-
Does not Sell B (0.4) Rs. 0/-
Sells C (0.5) Rs. 2050/-
Sells B (0.6)
Rs, 1025/-
C
Does not sell C (0.5) Rs. 0/-
B
Takes B
Takes C
Stops Rs. 0/-
2
Sells A (0.7)
Rs. 200/-
Does not sell A (0.3) Rs. 0/-
A
Accepts A
1