IS 301 DECISION SUPPORT SYSTEMS

DECISION SUPPORT SYSTEMS AND INTELLIGENT SYSTEMS,
Seventh Edition
Efraim Turban, Jay E. Aronson, and Ting-Peng Liang

Chapter 4
MODELING AND ANALYSIS

College of Computer Science and Information Technology
Department of Computer Information Systems
Prof Dr. Taleb A. S. Obaid

MODELING AND ANALYSIS

Learning Objectives

- Understand the different model classes
- Describe how spreadsheets can be used for MSS modeling and solution
- Explain what optimization, simulation, and heuristics are, and when and how to use them
- Describe how to structure a linear programming model
- Describe how to handle multiple goals
- Describe the key issues of model management

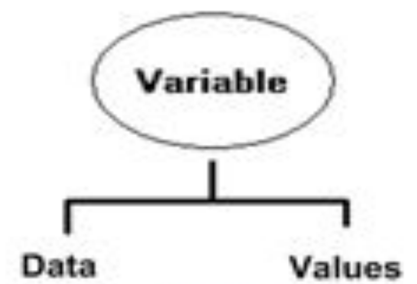
IDENTIFICATION OF THE PROBLEM AND ENVIRONMENTAL ANALYSIS

- One very important aspect is environmental scanning and analysis, which is: monitoring, scanning, and interpretation of collected information.
- No decision is made in a vacuum.
- It is important to analyze the scope of the domain and the forces of the environment.
- Business intelligence (business analytics) tools can help identify problems by scanning for them. The problem must be understood, and everyone involved should share the same frame of understanding.

IDENTIFICATION OF THE PROBLEM AND ENVIRONMENTAL ANALYSIS

VARIABLE IDENTIFICATION

- Identification of the model's variables (decision, result, uncontrollable, etc.) is critical, as are their relationships.
- You can think of a variable as a container that holds a value that can be changed. In the context of a model, a variable can be created and its value used as a tool's parameter value.
- There are two basic kinds of variables: data variables and value variables.



IDENTIFICATION OF THE PROBLEM AND ENVIRONMENTAL ANALYSIS

FORECASTING

Forecasting is essential for construction and manipulation of models because when a decision is implemented, the results usually occur in the future. There is no point in running a what-if analysis (sensitivity) on the past.

IDENTIFICATION OF THE PROBLEM AND ENVIRONMENTAL ANALYSIS

MULTIPLE MODELS

- A decision support system can include several models each of which represents a different part of the decision-making problem.

MODEL CATEGORIES

- Table 4.1 classifies DSS models into seven groups and lists several representative techniques for each category.
- Each technique can be applied to either a static or a dynamic model ,which can be constructed under assumed environments of certainty, uncertainty, or risk.

TABLE 4.1 Categories of Models

Category	*Process and Objective*	*Representative Techniques*
Optimization of problems with few alternatives (Section 5.7)	Find the best solution from a small number of alternatives	Decision tables, decision trees
Optimization via algorithm (Section 5.8 and 5.9)	Find the best solution from a large or an infinite number of alternatives using a step-by-step improvement process	Linear and other mathematical programming models, network models
Optimization via an analytic formula (Section 5.9)	Find the best solution in one step using a formula	Some inventory models
Simulation (Sections 5.12 and 5.14)	Finding a good enough solution or the best among the alternatives checked using experimentation	Several types of simulation
Heuristics (Section 5.12)	Find a good enough solution using rules	Heuristic programming, expert systems
Predictive models (Web Chapter)	Predict the future for a given scenario	Forecasting models, Markov analysis
Other models	Solve a what-if case using a formula	Financial modeling, waiting lines

IDENTIFICATION OF THE PROBLEM AND ENVIRONMENTAL ANALYSIS

MODEL MANAGEMENT

- Models, like data, must be managed to maintain their integrity and thus their applicability.

KNOWLEDGE-BASED MODELING

- DSS uses mostly quantitative models, whereas expert systems use qualitative, knowledge-based models in their applications.

CURRENT TRENDS

- There is a trend toward making MSS models completely transparent to the decision maker. Data are generally shown in a spreadsheet format , with which most decision-makers are familiar

4.3 STATIC AND DYNAMIC MODELS

DSS models can be classified as static or dynamic.

STATIC ANALYSIS

- Take a single snapshot of a situation. During this snapshot everything occurs in a single interval. E.g., a decision on whether to make or buy a product is static in nature
- A static representation assumes that the flow of materials into the plant will be continuous and unvarying

4.3 STATIC AND DYNAMIC MODELS

Dynamic models

- Represent scenarios that change over time.
- Dynamic models are time-dependent. For example, in determining how many checkout points should be open in a supermarket, one must take the time of day into consideration, because different numbers of customers arrive during each hour.

4.4 CERTAINTY, UNCERTAINTY, AND RISK

Customary, we classify this knowledge into three categories (Figure 4.1), ranging from complete knowledge to total ignorance. These categories are

- Certainty
- Risk
- Uncertainty

When we develop models, any of these conditions can occur, and different kinds of models are appropriate for each case.

DECISION-MAKING UNDER CERTAINTY

- It is assumed that complete knowledge is available so that the decision-maker knows exactly what the outcome of each course of action will be.
- The decision-maker is viewed as a perfect of the future because it is assumed that there is only one outcome for each alternative.
- Certainty models are relatively easy to develop and solve, and can yield optimal solutions.

DECISION-MAKING UNDER UNCERTAINTY

- The decision-maker considers situations in which several outcomes are possible for each course of action.
- In this case the decision-maker does not know, or cannot estimate, the probability of occurrence of the possible outcomes.
- Decision-making under uncertainty is more difficult because of insufficient information.
- Modeling of such situations involves assessment of the decision-maker's (or the organization's) attitude toward risk.

DECISION-MAKING UNDER RISK (RISK ANALYSIS)

- A decision made under risk (also known as a probabilistic or stochastic decision making situation) is one in which the decision-maker must consider several possible outcomes for each alternative, each with a given probability of occurrence.
- Risk analysis can be performed by calculating the expected value of each alternative and selecting the one with the best expected value.
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DECISION MAKING UNDER CERTAINTY (DMUC)

Decision making under certainty assumes that all relevant information required to make decision is certain in nature and is well known. It uses a deterministic model, with complete knowledge, stability and no ambiguity. To make decision, the manager will have to be quite aware of the strategies available and their payoffs and each strategy will have unique payoff resulting in certainty. The decision-making may be of single objective or of multiple objectives.

Example1 :

Consider a M/s *XYZ* company, which is developing its annual plans in terms of three objectives: (1) Increased profits, (2) Increased market share and (3) increased sales. M/S *XYZ* has formulated three different strategies for achieving the stated objectives. The table below gives relative weightage of objectives and scores project the strategy. Find the optimal strategy that yields maximum weighted or composite utility.

Measure of → Performance of Three objectives	*ROI (Profit)*	*% Increase (Market share)*	*% Increase (Sales growth)*
Weights →	0.2	0.5	0.3
Strategy			
S_1	7	4	9
S_2	3	6	7
S_3	5	5	10

Solution

(The profit objective could be stated in and measured by absolute Rupee volume, or percentage increase, or return on investment (ROI). The market share is to be measured in terms of percentage of total market, while sales growth could be measured either in Rupees or in percentage terms. Now, in order to formulate the payoff matrix of this problem, we need two things. (*i*) We must assign relative weights to each of the three objectives. (*ii*) For each strategy we will have to project **a score** in each of the three dimensions, one for each objective and express these scores in terms of utilities. The Optimal strategy is the one that yields the maximum weighted or composite utility.)

Multiplying the utilities under each objective by their respective weights and then summing the products calculate the weighted composite utility for a given strategy. For example:

For strategy $S_1 = 7 \times 0.2 + 5 \times 0.5 + 9 \times 0.3 = 6.1$

Measure of → Performance of Three objectives	*ROI (Profit)*	*% Increase (Market share)*	*% Increase (Sales growth)*	*Weighted or Composite Utility (CU)*
Weights →	0.2	0.5	0.3	
Strategy				
S_1	7	4	9	$0.2 \times 7 + 0.5 \times 4 + 0.3 \times 9 = 6.1$
S_2	3	6	7	$0.2 \times 3 + 0.5 \times 6 + 0.3 \times 7 = 5.7$
S_3	5	5	10	$0.2 \times 5 + 0.5 \times 5 + 0.3 \times 10 = 6.6$ Maximum utility

DECISION MAKING UNDER RISK (DMUR)

Decision-making under risk (DMUR) describes a situation in which each strategy results in more than one outcomes or payoffs and the manager attaches a probability measure to these payoffs. **This model covers the case when the manager projects two or more outcomes for each strategy and he or she knows, or is willing to assume, the relevant probability distribution of the outcomes.** The following assumptions are to be made: (1) Availability of more than one strategies, (2) The existence of more than one states of nature, (3) The relevant outcomes and (4) The probability distribution of outcomes associated with each strategy. The optimal strategy in decision making under risk is identified by the strategy with **highest expected utility (or highest expected value).**

Example1 :

In a game of head and tail of coins the player A will get Rs. 4/- when a coin is tossed and head appears; and will lose Rs. 5/- each time when tail appears. Find the optimal strategy of the player.

Solution

Let us apply the expected value criterion before a decision is made. Here the two monetary outcomes are + Rs. 4/- and – Rs. 5/- and their probabilities are ½ and ½. Hence the expected monetary value = $EMV = u_1 p_1 + u_2 p_2 = +4 \times 0.5 + (-5) \times 0.5 = -0.50$. This means to say on the average the player will loose Rs. 0.50 per game.

Example 2 :

A company is planning for its sales targets and the strategies to achieve these targets. The data in terms of three sales targets, their respective utilities, various strategies and appropriate probability distribution are given in the table given below. What is the optimal strategy?

Sales targets (× *lakhs*)	50	75	100			
Utility	4	7	9			
	Prob.	Prob.	Prob.			
Strategies						
S_1	0.6	0.3	0.1			
S_2	0.2	0.5	0.3			
S_3	0.5	0.3	0.2			

Solution

Expected monetary value of a strategy $= \sum$ Sales target $\times$ Probability

Expected utility of a strategy $= \sum$ Utility $\times$ Probability.

Sales targets (× lakhs)	*50*	*75*	*100*	*Expected Monetary Value*	*Expected Utility*
Utility	4	7	9		
	Prob.	*Prob.*	*Prob.*		
Strategies.					
S_1	0.6	0.3	0.1	$50 \times 0.6 + 75 \times 0.3 + 100 \times 0.1$ $= 62.5$	$4 \times 0.6 + 7 \times 0.3 + 9 \times 0.1$ $= 5.4$
S_2	0.2	0.5	0.3	$\mathbf{50 \times 0.2 + 75 \times 0.5 + 100 \times 0.3 = 77.5}$	$\mathbf{4 \times 0.2 + 7 \times 0.5 + 9 \times 0.3 = 7.0}$
S_3	0.5	0.3	0.2	$50 \times 0.5 + 75 \times 0.3 + 100 \times 0.2$ $= 67.5$	$4 \times 0.5 + 7 \times 0.3 + 9 \times 0.2$ $= 5.9$

As both expected money value and expected utility of second strategy are higher than the other two, strategy two is optimal.

DECISION MAKING UNDER UNCERTAINTY

Decision making under uncertainty is formulated exactly in the same way as decision making under risk, only difference is that no probability to each strategy is attached. Let us make a comparative table to compare the three, *i.e.* decision making under certainty, risk, and uncertainty.

Decision making under certainty	*Decision making under risk*	*Decision making under Uncertainty.*
State of Nature	*State of Nature*	*State of Nature*
N	N_1 N_2 N_3	N_1 N_2 N_3
	Probability p_1 p_2 p_3	
Strategy Utility or Payoff	Strategy Utility or Payoff	Strategy Utility or Payoff.
S_1 u_1	S_1 u_{11} u_{12} u_{13}	S_1 u_{11} u_{12} u_{13}
S_2 u_2	S_2 u_{21} u_{22} u_{23}	S_2 u_{21} u_{22} u_{23}
S_3 u_3	S_3 u_{31} u_{32} u_{33}	S_3 u_{31} u_{32} u_{33}
* One state of nature * Single column matrix * Deterministic outcomes * Optimal strategy is the one with the highest utility.	* More than one states of nature * Multiple column matrix * Probabilistic outcomes (*i.e.* Probabilities are attached to Various states of nature) * Optimal strategy is identified by the use of expected value criterian.	*More than one states of nature. *Multiple column matrix. * Uncertain outcomes (*i.e.* probabilities are not attached to various states of nature). * Optimal strategy is identified using a number of different criterian.

- In decision making under uncertainty, remember that no probabilities are attached to set of the states of nature.

- Sometimes we may have only positive elements in the given matrix, indicating that the company under any circumstances will have profit only. Sometimes, we may have negative elements, indicating potential loss.

- While solving the problem of decision making under uncertainty, we have two approaches, the first one is **pessimistic approach** and the second one is **optimistic approach**. Let us examine this by solving a problem.

Example 1 :

The management of *XYZ* company is considering the use of a newly discovered chemical which, when added to detergents, will make the washing stet, thus eliminating the necessity of adding softeners. The management is considering at present time, these three alternative strategies.

S_1 = Add the new chemical to the currently marketed detergent DETER and sell it under label 'NEW IMPROVED DETER'.

S_2 = Introduce a brand new detergent under the name of 'SUPER SOFT'

S_3 = Develop a new product and enter the softener market under the name 'EXTRA WASH'.

The management has decided for the time being that only one of the three strategies is economically feasible (under given market condition). The marketing research department is requested to develop a conditional payoff matrix for this problem. After conducting sufficient research, based on personal interviews and anticipating the possible reaction of the competitors, the marketing research department submits the payoff matrix given below. Select the optimal strategy.

	State of nature.		
Strategies.	N_1	N_2	N_3
	Utility of Payoffs.		
S_1	15	12	18
S_2	9	14	10
S_3	13	4	26

Solution

When no probability is given, depending upon risk, subjective values, experience etc., each individual may choose different strategies. These are selected depending on the *choice criterion*. That is why sometimes the decision making under uncertainty problems are labeled as **choice creation models**. Two criterians may be considered here. One is **Criterion of Optimism** and the other is **Criterion of Pessimism.**

CRITERION OF OPTIMISM

Here we determine the **best possible outcome** in each strategy, and then identify **the best of the best** outcome in order to select the optimal strategy. In the table given below the best of the best is written in the left hand side margin.

	State of nature.			*Best or Maximum outcome (Row maximum)*
Strategies.	N_1	N_2	N_3	
	Utility of Payoffs.			
S_1	15	12	18	18
S_2	9	14	10	14
S_3	13	4	26	**26 Maximax.**

While applying the criterion of optimism, the idea is to choose the *maximum of the maximum values*; the choice process is also known as **Maximax**.

CRITERION OF PESSIMISM

When criterion of pessimism is applied to solve the problem under uncertainty, first determine *worst possible outcome in each strategy* (row minimums), and select **the best of the worst outcome in** order to select the optimal strategy. The worst outcomes are shown in the left hand side margin.

	State of nature.			*Worst or minimum out come (Row minimums)*
Strategies.	N_1	N_2	N_3	
	Utility of Payoffs.			
S_1	15	12	18	**12 Maximin**
S_2	9	14	10	9
S_3	13	4	26	4

Best among the worst outcome is 12, hence the manager selects the first strategy. Maximin assumes complete pessimism. Maximax assumes complete optimism. To establish a degree of optimism or pessimism, the manager may attach some weights to the best and the worst outcomes in order to reflect in degree of optimism or pessimism. Let us assume that manager attaches a coefficient of optimism of 0.6 and then obviously the coefficient of pessimism is 0.4. The matrix shown below shows how to select the best strategy when weights are given.

Strategy.	*Best or maximum Payoffs*	*Worst or minimum Payoffs*	*Weighted Payoffs.*
Weights.	0.6	0.4	
S_1	18	12	$0.6 \times 18 + 0.4 \times 12 = 15.6$
S_2	14	9	$0.6 \times 14 + 0.4 \times 9 = 12.0$
S_3	26	4	$\mathbf{0.6 \times 26 + 0.4 \times 4 = 17.2}$ **Maximum.**

CRITERION OF REGRET

In this case, we have to determine the **regret matrix or opportunity loss matrix**. To find the opportunity loss matrix (column opportunity loss matrix), subtract all the elements of a column from the highest element of that column. The obtained matrix is known as *regret matrix*. While selecting the best strategy, we have to select such a strategy, whose opportunity loss is zero, *i.e.* zero regret. If we select any other strategy, then the regret is the element at that strategy. For the matrix given in problem 12.6 the regret matrix is

Strategies.	*State of nature.*		
	N_1	N_2	N_3
	Utility of Payoffs.		
S_1	0	2	8
S_2	6	0	16
S_3	2	10	0

Rule for getting the regret matrix: In each column, identify the highest element and then subtract all the individual elements of that column, cell by cell, from the highest element to obtain the corresponding column of the regret matrix.

To select the optimal strategy we first determine the *maximum regret* that the decision maker can experience for each strategy and then identify the *maximum of the maximum* regret values. This is shown in the table below:

Strategies.	*State of nature.*			
	N_1	N_2	N_3	
	Regret or Opportunity loss.			Maximum regret.
S_1	0	2	8	**8 minimax.**
S_2	6	0	16	16
S_3	2	10	0	10

Select the **minimum of the maximum regret (Minimax regret).** The choice process can be known as **minimax regret**. Suppose two strategies have same minimax element, then the manager needs additional factors that influence his selection.

EQUAL PROBABILITY CRITERION

As we do not have any *objective evidence* of a probability distribution for the states of nature, one can use *subjective criterion*. Not only this, as there is no objective evidence, we can assign *equal probabilities* to each of the state of nature. This subjective assumption of equal probabilities is known as **Laplace criterion,** or **criterion of insufficient reason** in management literature.

Once equal probabilities are attached to each state of nature, we revert to decision making under risk and hence can use the expected value criterion as shown in the table below:

	State of nature			
	N_1	N_2	N_3	*Expected monetary value (EMV)*
Probabilities→	1/3	1/3	1/3	
Strategy	*Utility or Payoffs.*			
S_1	15	12	18	**15 × 1/3 + 12 × 1/3 + 18 × 1/3 =15 Maximum**
S_2	9	14	10	9 × 1/3 + 14 × 1/3 + 10 × 1/3 = 11
S_3	13	4	26	13 × /3 + 4 × 1/3 + 26 × 1/3 = 14 1/3

As S_1 is having highest EMV it is the optimal strategy.

DECISION MAKING UNDER CONFLICT AND COMPETITION

In the problems discussed above, we have assumed that the manager has a finite set of strategies and he has to identify the optimal strategy depending on the condition of complete certainty to complete uncertainty. In all the models, the assumptions made are (1) Various possible future environments that the decision maker will face can be enumerated in a finite set of states of nature and (2) The complete payoff matrix is known. Now, let us consider that two rationale competitors or opponents are required to select optimal strategies, given a series of assumptions, including: (1) The strategies of each party are *known* to both opponents, (2) Both opponents choose their strategies simultaneously, (3) the loss of one party equals exactly to *gain* of the other party, (4) Decision conditions remain the same, and (5) It is a *repetitive* decision making problem (refer to Game theory).

Two opponents are considered as two **players**, and we adopt the convention that a **positive payoff** will mean a **gain** to the **row player** ***A*** or **maximizing player**, and a **loss** to the **column player** ***B*** or **minimizing player**. (Refer to 2 person zero sum game).

Consider the matrix given: maximin identifies outcome for player *A* and Minimax identifies the optimal strategy outcome for player *B*. This is because each player can adopt the policy, which is best to him. *A* wants to maximize his minimum outcomes and *B* wants to minimize his maximum loses.

		Player B				
		B_1	B_2	B_3	B_4	Row minimum
	A_1	8	12	7	3	3
Player A	A_2	$\boxed{\mathbf{9}}$	14	10	16	**9**
	A_3	7	4	26	5	4
Column maximum		**9**	14	26	16	

A selects the second strategy as it guaranties him a minimum of 9 units of money and B chooses strategy 2 as it assures him a minimum loss of 9 units of money. This type of games is known as **pure strategy game**.The alement where minimax point and maximin point are same known as **saddle point**.

HURWICZ CRITERION (CRITERION OF REALISM)

This is also known as weighted average criterion, it is a compromise between the maximax and maximin decisions criteria. It takes both of them into account by assigning them weights in accordance with the degree of optimism or pessimism. The alternative that maximizes the sum of these weighted payoffs is then selected.

Example 1 :

The following matrix gives the payoff of different strategies (alternatives) *A*, *B*, and *C* against conditions (events) *W*, *X*, *Y* and *Z*. Identify the decision taken under the following approaches: (*i*) Pessimistic, (*ii*) Optimistic, (*iii*) Equal probability, (*iv*) Regret, (*v*) Hurwicz criterion. The decision maker's degree of optimism (α) being 0.7.

Events

	W	*X*	*Y*	*Z*
	Rs.	*Rs.*	*Rs.*	*Rs.*
A	4000	–100	6000	18000
B	20000	5000	400	0
C	20000	15000	– 2000	1000

Solution (for i, ii, and iii)

	W	*X*	*Y*	*Z*	*Maximum regret. Rs.*
	Regret Rs.	*Regret Rs.*	*Regret Rs*	*Regret Rs*	—
A	16000	15100	0	0	16000
B	0	10000	5600	18000	18000
C	0	0	8000	17000	17000

	Pessimistic Maximin value	*Optimistic Maximax value*	*Equal Probability value*
A	– Rs. 100/-	Rs. 18000	Rs. ¼ (4000 – 100 + 6000 + 18000) = Rs. 6975/-
B	Rs. 0/-	Rs. 20000	Rs. ¼ (20000 + 5000 + 400 + 0) = Rs. 6350/-
C	– Rs. 2000	Rs. 20000	Rs. ¼ (20000 + 15000 – 2000 + 1000) = Rs. 8,500/-

Under pessimistic approach, B is the optimal strategy, under optimistic approach B or C are optimal strategies, and under equal probability approach C is the optimal strategy.

(*iv*) Given table represents the regrets for every event and for each alternative calculated by:

$= i^{th}$ regret = (maximum payoff – i^{th} payoff) for the j^{th} event.

As strategy A shows minimal of the maximum possible regrets, it is selected as the optimal strat egy.

(*v*) For a given payoff matrix the minimum and the maximum payoffs for each alternative is given in the table below:

Alternative	*Maximum payoff Rs*	*Minimum payoff. Rs*	*Payoff* = α × *maximum payoff* + *(1–α) minimum payoff , where* α = *0.7 (Rs)*
A	18000	– 100	$0.7 \times 18000 - 0.3 \times 100 = 12570$
B	20000	0	$0.7 \times 20000 + 0.3 \times 0 = 14000$
C	20000	–2000	$0.7 \times 20000 - 0.3 \times 2000 = 13400$

Under Hurwicz rule, alternative B is the optimal strategy as it gives highest payoff.

HURWICZ CRITERION (CRITERION OF REALISM)

This is also known as weighted average criterion, it is a compromise between the maximax and maximin decisions criteria. It takes both of them into account by assigning them weights in accordance with the degree of optimism or pessimism. The alternative that maximizes the sum of these weighted payoffs is then selected.

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Events

	W	*X*	*Y*	*Z*
	Rs.	*Rs.*	*Rs.*	*Rs.*
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B	20000	5000	400	0
C	20000	15000	– 2000	1000