SOUTHWESTERN UNIVERSITY NIGERIA

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LECTURE NOTE

ON

ANALYSIS FOR BUSINESS DECISION I (BUA 411)

Lecture I

Elements of Decision Analysis

Introduction

Business Decision Analysis takes its roots from Operations Research (OR). Operation Research as we will learn later is the application of scientific method by interdisciplinary teams to problems solving and the control of organized (Man-Machine) systems so as to provide solution which best serve the purpose of the organization as a whole (Ackoff and Sisieni 1991) . In other words, Operations Research makes use of scientific methodsand tools to provide optimum or best solutions to problems in the organization. Organisations are usually faced with the problem of deciding what to do; how to do it, where to do it, for whom to do it etc. But before any action can be taken, it is important to properly analyse a situation with a view to finding out the various alternative courses of action that are available to an organization. Operations Research helps the organisation with the job of critically analysing a situation and finding out the various alternatives available to choose from. OR also helps the organization to identify the best alternative available there by enabling the enterprise to make the most rational decision after having identified and analysed all available alternatives.

In the light of the above, it could be said that Operations Research provides the scientific process, tools, techniques, and procedure for optimum decision in business analysis. In this chapter, we shall concern ourselves with those critical elements and tools that organisations utilise to make sound decisions.

What is a Decision?

A decision can be defined as an action to be selected according to some pre-specified rule or strategy, out of several available alternatives, to facilitate a future course of action. This definition suggests that there are several alternative courses of action available, which cannot be pursued at the same time. Therefore, it is imperative to choose the best alternative base on some specified rule or strategy. Decision making is the process of selecting the best out of several alternatives.

WHO IS A DECISION MAKER?

A decision maker is one who takes decision. It could be an individual or a group of individuals. It is expected that a good decision maker should be skilled in art of making decisions. He is also expected to apply all necessary procedure, rules and techniques in arriving at the best alternative which will either maximize wellbeing or profit, or minimize losses, or help to achieve any other objective or goal that has been set.

DECISION ANALYSIS

Decision making is a very important and necessary aspect of every human endeavour. In life, we are faced with decision problems in everything we do. Individuals make decisions daily on what to do, what to wear, what to eat etc.

Every human being is assumed to be a rational decision maker who takes decisions to improve his/her wellbeing. In business, management has to make decision on daily bases on ways to improve business performance. But unlike individual decision making, organizational or business decision making is a very complex process considering the various factors involved. It is easy to take decision for simple situation but when it gets complex, it is better not to rely on intuition. Decision theory proves useful when it comes to issues of risk and uncertainty (Adebayo et al 2010). When making decisions involving risk and uncertainty, it is important to apply complex rules, techniques and procedures in analysing the various factors involved in the decision situation. This is where the question of decision analysis comes in.

Decision Analysis has been defined as a logical procedure of balancing the factors that influence a decision. According to Howard (2004), the procedure incorporates uncertainties, values, and preferences in a basic structure that involves the decision. Typically, it includes technical, marketing, competitive, and environmental factors. Considering risk and uncertainty factors in the process of decision making and applying relevant methods to manipulate these factors enable organizations to make sound decisions. Adebayo et al(2010) describe decision analysis as a scientific technique that consists of a collection of principles and methods whose principal objectives is the aid decision making by individuals, groups of individuals, management of organization and others who have to make one decision or the other. In decision analysis, complex decision problems are broken down into smaller elements which may be probabilistic, differential or value oriented.

Components of Decision Making

Earlier, we stated that complex decision problem involve risk and an uncertainty and as such, certain logic, rules, procedures should be applied when analysing such situation. The major components that constitute risk and uncertainty in decision making are:
Decision alternatives States of Nature
The decision itself
Decision screening criteria

Decision Alternatives

These are alternative courses of action available to the decision maker. The alternatives should be feasible, and evaluating them will depend on the availability of a well-defined objective. Alternative courses of action may also be seen as strategies or options from which the decision maker must choose from. It is due to the existence of several alternatives that the decision problem arises. If there were only one course of action, then there will be no decision problem. Alternatives present themselves as:

Choices of products to manufacture,
Transportation roots to be taken,
Choice of customer to serve,
Financing option for a new project,
How to order job into machines, etc.

States of Nature

A state of nature is a future occurrence for which the decision maker has no control over. All the time a decision is made, the decision maker is not certain which states of nature will occur in future, and he has no influence over them (Taylor III, 2007). For instance, if a company has a contract to construct a 30km road, it may complete the construction of the full stretch of road in six months in line with a laid down plan. But this plan will be hinged on the possibility that it does not rain in the next six months. However, if there is consistent heavy rain for the first three months, it may delay the progress of work significantly and as a result, prolong the completion date of the project. But if actually there is no occurrence of heavy rainfall, the company is likely to complete the road as scheduled.

In this situation, the state of nature is the occurrence of heavy rainfall and no rainfall. Therefore, the state of nature that occurred after a decision has been made will determine the outcome of the decision. States of nature could be market conditions, economic conditions, customer taste, state of goods, competition, political situation, weather condition, and other future occurrences that are not known to the decision maker and which he neither has control over nor could manipulate.

The Decision

The decision itself is a choice which is arrived at after considering all alternatives available given an assumed future state of nature. In the view of Dixon-Ogbechi (2001), “A good decision is one that is based on logic, considers all available data, and possible alternative and employs quantitative technique” she further noted that, occasionally, a good decision may yield a bad result, but if made properly, may result in successful outcome in the long run.

Decision Screening Criteria

In the section above, we mentioned that the decision itself is a choice which is arrived at after considering all other alternatives. Consideration of alternative courses of action is not done arbitrarily, it is done using some standardize logic or methodology, or criterion. These criteria form the basis upon which alternatives are compared. The strategy or alternative which is finally selected is the one associated with the most attractive outcome. The degree of attractiveness will depend on the objective of the decision maker and the criterion used for analysis (Ihemeje 2002). They could be a variety of objectives of the decision maker. The most prominent among business objectives include maximization of profit, and minimization of cost. We shall see how all these will be put into action later.

Phases of Decision Analysis

The process of analysing decision can be grouped into four phases. These four phases from what is known as the decision analysis cycle. They are presented as follows:

Deterministic Analysis Phase: This phase accounts for certainties rather than uncertainties. Here, graphical and diagrammatic models like influence diagrams and flow charts can be translated into mathematical models. Necessary tools are used for predicting consequences of alternatives and for evaluating decision alternatives.

Probabilistic Analysis: Probabilistic analyses cater for uncertainties in the decision making process. We can use the decision tree as a tool for probabilistic analysis.

Evaluation Phase: At the phase, the alternative strategies are evaluated to enable one identify the decision outcomes that correspond to sequence of decisions and events.

Choice Activity Phase: This is the final phase of the decision analysis cycle. It is the judgemental stage where the decision maker decides on the best strategy to adopt having carefully analyses all other options.

Errors that can Occur in Decision Making

The following are possible errors to guide against when making decisions.

Inability to identify and specify key objectives: Identifying specific objectives gives the decision maker a clear sense of direction.

Focusing on the wrong problem: This could create distraction and will lead the decision maker to an inappropriate solution.

Not giving adequate thoughts to trade-offs which may be highly essential to the decision making process.

Not taking uncertainty and risk into consideration.

Lack of foresight about plan especially when decision has some risk over time.

Lecture II

Approaches to Decision Analysis

Introduction

The two main approaches to decision analysis are the *qualitative and quantitative* approaches.

Qualitative Approach to Decision Making

Qualitative approaches to decision analysis are techniques that use human judgement and experience to turn qualitative information into quantitative estimates (Lucey 1988) as quoted by Dixon – Ogbechi 2001). He identified the following qualitative decision techniques:

(i) Delphi Method
(ii) Market Research
(iii) Historical Analogy

According to Akingbade (1995), qualitative models are often all that are feasible to use in circumstances, and such models can provide a great deal of insight and enhance the quality of decisions that can be made. Quantitative models inform the decision maker about relationships among kinds of things. Knowledge of such relationships can inform the decision maker about areas to concentrate upon so as to yield desired results.

Akingbade (1995) presented the following examples of qualitative models:

(i) Influence diagrams.
(ii) Cognitive maps.
(iii) Black box models.
(iv) Venn Diagrams.
(v) Decision trees
(vi) Flow charts, etc. (Dixon – Ogbechi 2001)

Let us now consider the different qualitative approaches to decision making.

Delphi Method: The Delphi method is technique that is designed to obtain expert consensus for a particular forecast without the problem of submitting to pressure to conform to a majority view. It is used for long term forecasting. Under this method, a panel is made to independently answer a sequence of questionnaire which is used to produce the next questionnaire. As a result, any information available to a group of experts is passed on to all, so that subsequent judgements are refined as more information and experience become available (Lucey 1988).

Market Research: These are widely used procedures involving opinion surveys; analysis of market data, questionnaires designed to gage the reaction of the market to a particular product, design, price, etc. It is often very accurate for a relatively short term.

Historical Analogy: Historical Analogy is used where past data on a particular item are not available. In such cases, data on similar subjects are analysed to establish the life cycle and expected sales of the new product. This technique is useful in forming a board impression in the medium to long term (Lucey, 1988 as quoted by Dixon-Ogbechi, 2001).

Quantitative Approach

This technique or approach lends itself to the careful measurement of operational requirements and returns. This makes the task of comparing one alternative with another very much more objective. Quantitative technique as argued by Dixon-Ogbechi (2001), embraces all the operational techniques that lend themselves to quantitative measurement. Harper (1975) presents the following quantitative techniques:

Mathematics: Skemp (1971) defined Mathematics as “a system of abstraction, classification and logical reasoning”. Generally, Mathematics can be subdivided into two:

(a) Pure Mathematics
(b) Applied Mathematics

Pure Mathematics is absolutely abstract in not concerning itself with anything concrete but purely with structures and logical applications, implications and consequences of such structures.

Applied Mathematics is the application of proved abstract generalization (from pure Mathematics) to the physical world (Akingbade, 1996). Both pure and applied Mathematics can be broken into the following subdivisions:

Arithmetic
Geometry
Calculus
Algebra
Trigonometry
Statistics

Probability: Probability is widely used in analysing business decisions. Akingbade (1996) defined probability as a theory concerned with the study of processes involving uncertainty. Lucey (1988) defined probability as “the quantification of uncertainty”. Uncertainty may be expressed as likelihood, chance or risk.

Mathematical Models: According to Dixon-Ogbechi (2001), A Mathematical model is a simplified representation of a real life situation in Mathematical terms. A Mathematical model is Mathematical idealization in the form of a system proposition, formula or equation of a physical, biological or social phenomenon (EncartaPremium, 2009).

Statistics: Statistics has been described as a branch of Mathematics that deals with the collection, organization, and analysis of numerical data and with such problems as experiment design and decision making (Microsoft Encarta Premium, 2009).

Objective of Decision Making

Before a decision maker embarks on the process of decision making he/she must set clear objectives as to what is expected to be achieved at the end of the process. In Business decision analysis; there are two broad objectives that decision makers can possible set to achieve. These are:

Maximization of profit, and Minimization of Loss

Most decisions in business fall under these two broad categories of objectives. The decision criterion to adopt will depend on the objective one is trying to achieve.

In order to achieve profit maximization, the Expected Monetary Value (EMV) approach is most appropriate. As will be seen later, the Expected Value of the decision alternative is the sum of highlighted pay offs for the decision alternative, with the weight representing the probability of occurrence of the states of nature. This approach is possible when there are probabilities attached to each state of nature or event. The EMV approach to decision making is assumed to be used by the *optimistic* decision maker who expects to maximize profit from his investment.

The technique most suitable for minimization of loss is the Expected opportunity loss (EOL) approach. It is used in the situation where the decision maker expects to make a loss from an investment and tries to keep the loss as minimum as possible. This type of problem is known as minimization problem and the decision maker here is known to be *pessimistic*. The problem under the EMV approach is known as a maximization problem as the decision maker seeks to make the most profit from the investment. These two approaches will be illustrated in details in the next section.

Steps in Decision Theory Approach

Decision theory approach generally involves four steps. Gupta and Hira (2012) present the following four steps:

Step 1: List all the viable alternatives

The first action the decision maker must take is to list all viable alternatives that can be considered in the decision. Let us assume that the decision maker has three alternative courses of action available to him a, b, c.

Step 2: Identify the expected future event
The second step is for the decision maker to identify and list all future occurrences. Often, it is possible for the decision maker to identify the future states of nature; the difficulty is to identify which one will occur. Recall, that these future states of nature or occurrences are not under the control of the decision maker. Let us assume that the decision maker has identified four of these states of nature: i, ii, iii, iv.

Step 3: Construct a payoff table
After the alternatives and the states of nature have been identified, the next task is for the decision maker to construct a payoff table for each possible combination of alternative courses of action and states of nature. The payoff table can also be called contingency table.

Step 4: Select optimum decision criterion
Finally, the decision maker will choose a criterion which will result in the largest payoff or which will maximize his wellbeing or meet his objective. An example of pay off table is presented below.

Contingency Table 1

Alternative	**State of Nature**			
	i	**ii**	**iii**	**iv**
a	a_i	a_{ii}	a_{iii}	a_{iv}
b	b_i	b_{ii}	b_{iii}	b_{iv}
c	c_i	c_{ii}	c_{iii}	c_{iv}

Fig2.1: An example of the payoff table.

As we can see from the payoff table above, a,b,c are the alternative strategies, i, ii, iii, iv are the states of nature. Therefore the decision maker has identified four states of nature and three alternative strategies. Apart from the alternative strategy column and the raw representing the states of nature, other cells in the table are known as condition outcomes. They are the outcomes resulting from combining a particular strategy with a state of nature. Therefore we can say that the contingency table shows the different outcomes when the states of nature are combined with the alternatives.

Decision Making Criteria

There are five criteria with which a decision maker can choose among alternatives given different states of nature. Gupta and Hira (2012) are of the view that choice of a criterion is determined by the company's policy and attitude of the decision maker. They are:

(a) Maximax Criterion or Criterion of Optimism
(b) Maximin Criterion or Criterion of Pessimism (Wald Criterion)
(c) Minimax Regret Criterion (Savage Criterion)
(d) Laplace Criterion or Equally likely criterion or criterion of Rationality (Bayes' Criterion)
(e) Hurwicz Criterion or Criterion of Realism

Now let us see how we can solve problems using the above criteria.

Example 2.1: Consider the contingency matrix given below

Contingency Table 2

Alternative Products	Market Demand		
	High (₦)	Moderate (₦)	Low (₦)
Body Cream	500	250	-75
Hair Cream	700	300	-60
Hand Lotion	400	200	-50

Fig2.2: Pay-off table

The matrix above shows the payoffs of an investor who has the choice either investing in the production of Body Cream, or Hair cream, or hand lotion. Whichever of the three products he decides to produce; he will encounter three types of market demand. It may turn out that the market demand for any of the product is high, or moderate of low. In other words, the production of body cream, or hair cream, or hand lotion represent the alternative courses of action or strategies available to the investor, while the occurrence of either high demand, or moderate demand, or low demand represent the states of nature for which the investor has no control over. Now, how would the investor arrive at the choice of product to manufacture? We are going to analyse the decision problem using the five criteria earlier listed below.

Maximax Criterion (Criterion of Optimism)

The maximax criterion is an optimistic criterion. Here, the decision maker aims to maximize profit or his outcome. It involves an optimistic view of future outcomes. This is done by selecting the largest among maximum payoffs. However, the disadvantage of this criterion is that it does not make use of all available information in getting the quantitative values. This is not often the case on real life situations. The criterion has also been criticises for being too optimistic and assumes that the future will always be rosy.(Adebayo et al, 2006)

Contingency table 3

Alternative Products	Market Demand			Max Column (₦)	Maxi max (₦)
	High (₦)	Moderate (₦)	Low (₦)		
Body Cream	500	250	-75	500	
Hair Cream	700	300	-60	700	700
Hand Lotion	400	200	-50	400	

Fig2.3: Pay-off table.

Let us now try to solve the decision problem in the matrix above using the maximax criterion.

Step 1: Create and additional column to the right hand side of the matrix and call it max column as shown below.

Step 2: Identify the **maximum** pay-off in each alternative course of action (i.e. either the role for Body Cream, or Hair Cream, or Hand Lotion) and place it in the corresponding cell on the maximum column.

Step 3: Identify and select the pay-off with the highest value on the maximum column. This value becomes your optimal value using the maximax criterion.

Step 4: Make recommendations.

As we can see from Contingency table 3 above, the maximax value is **N**700.

Recommendation: Using the maximax decision criterion, the decision maker should manufacture hair cream to maximize worth **N**700.

Maximin Criterion (Criterion of Pessimism)

Under the maximin Criterion, the decision maker is assumed to be pessimistic. The objective here is to maximize the minimum possible outcome. It is a decision situation where the decision maker tries to make the most of bad situations and avoids taking risks and incurring huge losses. According to Adebayor et al (2006), the weakness of this criterion is that the result may not always be unique.It has also been criticized for being an unduly careful. However, it has the advantage of helping one to be in the best possible condition in case the worst happens.
In analysing a decision situation using this criterion, we use the following steps:

Step 1: Create an additional column to the rights hand side of your pay-off matrix-minimum column.

Step 2: Select the **minimum** pay-off from each alternative and place on the corresponding call in the minimum column.

Step 3: Identify and select the maximum pay-off in the minimum column

Step 4: Make recommendation

Using data in contingency matrix 2

Minimum Col **(₦)**	Maximin **(₦)**
75	
60	
50-50	

Fig2.4: Payoff table- Minimum and Maximum Columns.

Recommendation: Using the maximin decision criterion, the decision maker should manufacture hand lotion with a pay-off of - **N**50.

Minimax Regret Criterion (Savage Criterion)

This decision criterion was developed by L.J. Savage. He pointed out that the decision maker might experience regret after the decision has been made and the states of nature i.e. events have occurred. Thus the decision maker should attempt to minimize regret before actually selecting a particular alternative (strategy) (Gupta and Hira, 2011). The criterion is aimed at minimizing opportunity loss.
The following steps are used to solve problems using this criterion.

Step 1: For each column, identify the highest payoff
Step 2: Subtract the value from itself every other pay-off in the column to obtain the regret matrix.
Step 3: Create an additional column to the right of your regret matrix and call it maximum column.
Step 4: Identify and select the maximum value from each alternative strategy
Step 5: Find the minimum value in the maximum column created.
Step 6: Make recommendations.

Example 2.2

Contingency table 4

Alternative Products	**Market Demand**		
	High (₦)	**Moderate (₦)**	**Low (₦)**
Body Cream	500	250	-75
Hair Cream	700	300	-60
Hand Lotion	400	200	-50

Fig.2.5: Payoff table.

Regret matrix 1

Alternative Products	**Market Demand**			**Max Column (₦)**	**Minimax (₦)**
	High (₦)	**Moderate (₦)**	**Low (₦)**		
Body Cream	200	50	25	200	
Hair Cream	0	0	10	10	10
Hand Lotion	300	100	0	300	

Fig.2.6: Regret matrix

Recommendation: Using the minimax regrets criterion, the decision maker should manufacture hair cream to minimize loss worth N10.

Equally Likely of Laplace Criterion (Bayes' Or Criterion Of Rationality)

This criterion is based upon what is known as the principle of insufficient reasons. Since the probabilities associated with the occurrence of various events are unknown, there is not enough information to conclude that these probabilities will be different. This criterion assigns equal probabilities to all the events of each alternative decision and selects the alternative associated with the maximum expected payoff. Symbolically, if "n" denotes the number of events and "s" denotes the pay-offs, then expected value for strategy, say s_i is

1/N[P1 + P2 + …. + Pn]

or simply put

$$\frac{P_1 + P_2 + \ldots\ldots + P_n}{n}$$

The steps to follow are:

Step 1: Compute the average for each alternative using the above formula.
Step 2: Select the maximum outcome from the calculation in step 1 above
Step 3: Make recommendations

Example 2.3

Contingency table 5

Alternative Products	**Market Demand**			**Average Column (₦)**	**Max Col.**
	High (₦)	**Moderate (₦)**	**Low (₦)**		
Body Cream	500	250	-75	$\frac{500+250+75}{3} = \frac{675}{3} = 225$	
Hair Cream	700	300	-60	$\frac{700+300-60}{3} = \frac{940}{3} = 313.3$	313.3
Hand Lotion	400	200	-50	$\frac{400+200-50}{3} = \frac{550}{3} = 183.3$	

Fig. 2.7: Payoff table.

Recommendation: Using the equally likely criterion, the decision should manufacture Hair Cream worth N313.3

Hurwicz Criterion (Criterion of Realism)

This criterion is also called weighted average criterion. It is a compromise between the maximax (optimistic) and maximin (Pessimistic) decision criteria. This concept allows the decision maker to take into account both maximum and minimum for each alternative and assign them weights according to his degree of optimism or pessimism. The alternative which maximises the sum of these weighted pay-offs is then selected. (Gupta and Hira, 2012).

The Hurwicz Criterion Comsprises the following steps:

Step 1: Choose an appropriate degree of optimism (lies between zero and one (0 <1), so that (1-) represents the degree of pessimism. is called coefficient or index of optimism.
Step 2: Determine the maximum as well as minimum value of each alternative course of action.
Step 3: Determine the criterion of realism using the following formula CRi = (Max in Row*i*) + (1 -) (Min in Row*i*)
Step 4: Select the maximum outcome in step 3 above
Step 5: Make Recommendation

Example 2.4
EXAMPLE: Using the contingency table 3 above,

Maximum	Min in Row
500	-75
700	-60
400	-50

Fig. 2.8: Max. and Min. Rows

For alternative Body Cream (b)

$(R_b$ = (Maxim Row_b) + (1 - α) (min in Row_b)

Let us assume = 0.5

CR_{bc} = 0.5 (500) + (1 – 0.5) (-75)
0.5 (500) + 0.5 (-75)
250 – 37.5 = **212.5**

For alternative Hair Cream

CR_{hc} = 0.5 (700) + (0.5) (-60)
350 + (- 30)
350 – 30 = **320**

For alternative Hand Lotion

CR_{hl} = 0.5 (400) + (0.5) (-50)
200 – 25 = 177

Therefore

CR_{bc}= N212.5; CR_{hc} = N**320**; CR_{hl} = N175

Recommendation: Using the Hurwicz Criterion, the decision maker should manufacture Hair Cream worthN320.

We have seen how interesting and simple it is to use the five criteria in analysing decision problems. However, the above analysis can only be used under a situation of uncertainty where the decision maker neither knows the future states of nature nor have the probability of occurrence of the states of nature.

Lecture III

Types of Decision Situations

Elements of Decision Situation

Dixon – Ogbechi (2001) presents the following elements of Decision Situation:

The Decision Maker: The person or group of persons making the decision.

Value System: This is the particular preference structure of the decision maker.

Environmental Factors: These are also called states of nature. They can be

i.	Political;	ii.	Legal;	iii.	Economic factors
iv.	Technological factors	v.	Cultural factors	viii.	Natural Disasters
vii.	Social factors				

Alternative: There are various decision options available to the decision maker.

Choice: The decision made.

Evaluation Criteria: These are the techniques used to evaluate the situation at hand.

Types of Decision Situations

According to Gupta and Hira (2012), there are four types of environments under which decisions can be made. These differ according to degree of certainty. The degree of certainty may vary from complete certainty to complete uncertainty. The region that lies between corresponds to decision making under risk.

1. DECISION MAKING UNDER CONDITION OF CERTAINTY

In this environment, only one state of nature exits for each alternative. Under this decision situation, the decision maker has complete and accurate information about future outcomes. In other words, the decision maker knows with certainty the consequence of every alternative course of action. It is easy to analyse the situation and make good decisions. Since the decision maker has perfect knowledge about the future outcomes, he simply chooses the alternative with the optimum payoff. The approach to analysing such decision problem is deterministic. Decision techniques used here include simple arithmetic for simple problem, and for complex decision problems, methods used include cost-volume analysis when information about them is precisely known, linear programming, transportation and assignment models, deterministic inventory models, deterministic quelling models and network model. We shall discuss these models later.

Decision-Making under Conditions of Uncertainty

Here, more than one state of nature exists, but the decision maker lacks sufficient knowledge to allow him assign probabilities to the various state of nature. However, the decision maker knows the states of nature that may possibly occur but does not have information which will enable him to determine which of these states will actually occur. Techniques that can be used to analyse problem under this condition include the Maximax criterion, Equally likely or Laplace's criterion and Hurwicz criterion or Criterion of Realism. These techniques have earlier been discussed. We shall consider a more difficult problem for further illustration.

***EXAMPLE3.1*- Word Problem**

A farmer is considering his activity in the next farming season. He has a choice of three crops to select from for the next planting season – Groundnuts, Maize, and Wheat. Whatever is his choice of crop; there are four weather conditions that could prevail: heaving rain, moderate rain, light rain, and no rain. In the event that the farmer plants Ground nuts and there is heavy rain, he expects to earn a proceed of N650,000 at the end of the farming season, if there is moderate rain N1,000,000, high rain – N450,000 and if there is no rain – (- N1,000)If the farmer plants Maize, the following will be his proceeds after the harvest considering the weather condition: heavy rain – N1,200,000, moderate rain – N1,500,000, Light rain – N600,000 and no rain N2000. And if the farmer decides to plant wheat, he expects to make the following: heavy rain – N1,150,000, moderate rain – N1,300,000, Light rain- N800,000 and No rain – N200 -000. The farmer has contact you, an expert in OR to help him decide on what to do.

Question: Construct a payoff matrix for the above situation, analyse completely and advise the farmer on the course of action to adopt. Assume = 0.6.

Solution
First, construct a contingency matrix from the above problem.

Contingency Matrix 1a

Alternative Crops	Weather Conditions			
	Heavy Rain (S_1) (₦)	Moderate Rain (S_2) (₦)	Light Rain (S_3) (₦)	No Rain (S_4) (₦)
Groundnut (d_1)	750,000	1,000,000	450,000	-1,000
Maize (d_2)	1,200,000	1,500,000	600,000	2,000
Wheat (d_3)	1,150,000	1,300,000	800,000	-200,000

Fig. 3.1a: Pay- off Table

Contingency Matrix 1b

Alternative Crops	Weather Conditions					
	S_1 (N'000)	S_2 (N'000)	S_3 (N'000)	S_4 (N'000)	Max Col	Min Col
d_1	750	1,000	450	-1	1,000	-1
d_2	1,200	1,500	600	2	1,500	2
d_3	1,150	1,300	800	-200	1,300	-200

Fig. 3.1b: Pay - off Table

Regret Matrix 1

Alternative Crops	Weather Conditions					
	S_1 (N'000)	S_2 (N'000)	S_3 (N'000)	S_4 (N'000)	Max Col	Min Col
d_1	1200-750 450	1,500-1,000 500	800-450 350	2-(-1) 3		
d_2	1,200-1,200 0	1,500-1,500 0	800-600 200	2-2 0	202	200
d_3	1,200-1,150 50	1,500-1,300 200	800-800 0	2-(-200) 202		
Col Max.	1,200	1,500	800	2		

Fig. 3.2: Regret Matrix1

1. **Maximax Criterion**

Alt.	Max Col.
d_1	1,000
d_2	**1,500**
d_3	1,300

Recommendation: Using the maximax criterion, the farmer should select alternative d2 and plant maize worth N1500,000.

2. **Maximin criterion**

Alt.	Min Col.
d_1	-1
d_2	**2**
d_3	-200

Recommendation: Using the maximin criterion, the farmer should select alternative d2 and plant maize worth ₦2,000.

3. Minimax Regret Criterion

Choice of Crops	Weather Conditions					
	S_1	S_2	S_3	S_4	Max Col	Min Col
d_1	450	500	350	3	500	
d_2	0	0	200	0	200	200
d_3	50	200	0	202	202	

Fig. 3.3: Pay- off Table

Recommendation: Using the Mini Max Regret Criterion, the decision maker should select alternative d_2 and plant maize to minimize loss worth N200,000

Laplace Criterion

$$d1 = \frac{750+1000+450-1}{4} = 549.75$$

$$d2 = \frac{750+1000+450-1}{4} = 825.50$$

$$d3 = \frac{1150+1300+800-200}{4} = 762.50$$

Recommendation: Using the Equally Likely or Savage Criterion, the farmer should select alternative d2 to plant maize worth N825,500.

Hurwicz Criterion

α = 1 - 0.6 = 0.4
CRi = (max in row) + (1- α) (min in row)

CR1 = 0.6 (1000) + (0.4) (-1) = 600 + (-0.4) = 599.6

CR2 = 0.6 (1500) + (0.4) (2) = 900 + 0.8 = **900.8**

CR3 = 0.6 (1300) + (0.4) (-200) = 780 + (-80) = 700

Recommendation: Using the Hurwicz criterion the farmer should select alternative d2 and cultivate maize worth N900,800.00.

3. Decision-Making under Conditions of Risk

Under the risk situation, the decision maker has sufficient information to allow him assign probabilities to the various states of nature. In other words, although the decision maker does not know with certainty the exact state of nature that will occur, he knows the probability of occurrence of each state of nature. Here also, more than one state of nature exists. Most Business decisions are made under conditions of risk. The probabilities assigned to each state of nature are obtained from past records or simply from the subjective judgement of the decision maker. A number of decision criteria are available to the decision maker. These include:

(a) Expected monetary value criterion (EMV)
(b) Expected Opportunity Loss Criterion (EOL)
(c) Expected Value of Perfect Information (EVPI) (Gupta and Hira, 2012)

We shall consider only the first two (EMV and EOL) criteria in details in this course.

Expected Monetary Value (EMV) Criterion

To apply the concept of expected value as a decision making criterion, the decision maker must first estimate the probability of occurrence of each state of nature. Once the estimations have been made, the expected value of each decision alternative can be computed. The expected monetary value is computed by multiplying each outcome (of a decision) by the corresponding probability of its occurrence and then summing the products. The expected value of a random variable is written symbolically as E(x), is computed as follows:
(Taylor III, 2007)

Example 3.2

A businessman has constructed the payoff matrix below. Using the EMV criterion, analyse the situation and advise the businessman on the kind of property to invest on.

Contingency Matrix 2

Decision to Invest	**State of Nature**		
	Good Economic Conditions (N)	Poor Economic Conditions (N)	Turbulent Economic Conditions (N)
Apartment building (d_1)	50,000	30,000	15,000
Office building (d_2)	100,000	40,000	10,000
Warehouse (d_3)	30,000	10,000	-20,000
Probabilities	0.5	0.3	0.2

Fig. 3.4: Pay- off Table. Adapted from Taylor, B.W. III (2007)
Introduction to Management Science, New Jersey: Pearson Education Inc.

SOLUTION

EVd1 = 50,000 (0.5) + 30,000 (0.3) + 15,000 (0.2)
25,000 + 9,000 + 3,000
N37,000

EVd2 = 100,000 (0.5) + 40,000 (0.3) + 10,000 (0.2)
= N50,000 +12,000 + 2000
= **N64,000**

EVd3 = 30,000 (0.5) + 10,000 (0.3) + (-20,000(0.2)
= 15,000 + 3000 - 4000
= N14,000

Recommendation: Using the EMV criterion, the businessman should select alternative d2 and invest in office building worth N64,000.

Under this method, the best decision is the one with the greatest expected value. From the above EXAMPLE, the alternative with the greatest expected value is EVd1 which has a monetary value of N37,000. This does not mean that N37,000 will result if the investor purchases apartment buildings, rather, it is assumed that one of the payoffs values will result in N25,000 or N9,000 or N 3,000. The expected value therefore implies that if this decision situation occurs a large number of times, an average payoff of N37,000 would result, Alternatively, if the payoffs were in terms of costs, the best decision would be the one with the lowest expected value.

Expected Opportunity Less (EOL)

The expected opportunity Loss criterion is a regret criterion. It is used mostly in minimization problems. The minimization problem involves the decision maker either trying to minimize loss or minimize costs. It is similar the Minimax Regret Criterion earlier discussed. The difference however, is that is has probabilities attached to each state of nature or occurrence.
The difference in computation between the EMV and EOL methods is that, unlike the EMV methods, a regret matrix has to be constructed from the original matrix before the EOL can be determined.

Example3.3

We shall determine the best alternative EOL using contingency matrix 2 above First, we construct a regret matrix from contingency matrix 2 above. Remember how the Regret matrix table is constructed? Ok. Let us do that again here.

Quick Reminder

To construct a regret matrix, determine the highest value in each state of nature and subtract every payoff in the same state of nature from it. Your will observe that most of the payoff will become negative values and zero.

Regret Matrix 2

Decision to Invest	**State of Nature**		
	Good Economic Conditions (N)	Poor Economic Conditions (N)	Turbulent Economic Conditions (N)
Apartment building (d_1)	(100,000-50,000) 50,000	40,000-30,000 10,000	15,000-15,000 0
Office building (d_2)	100,000-100,000 0	40,000-40,000 0	15,000-10,000 5,000
Warehouse (d_3)	100,000-30,000 70,000	40,000-10,000 30,000	15,000-(-20,000) 35,000
Probabilities	0.5	0.3	0.2

Fig. 3.3: Regret Matrix 2

EOLd1 = 50,000 (0.5) + 10,000 (0.3) + 0(2)
25,000 + 3,000+0
N28,000

EOLd2 = 0.(0.5) + 0(0.3) + 5,000 (0.2)
= 0 + 0 + 1,000
= N1,000

EOLd3 = 70,000(0.5) + 30,000 (0.3) + 35,000 (0.2)
= 35,000 + 9,000 + 7,000
= N51,000

Recommendation: Using the EOL criterion, the decision maker should select alternative d2 and invest in office building worth N1,000.

The Optimum investment option is the one which minimizes expected opportunity losses, the action calls for investment in office building at which point the minimum expected loss will be N1,000.

You will notice that the decision rule under this criterion is the same with that of the Minimax Regret criterion. This is because both methods have the same objectives that is, the minimization of loss. They are both pessimistic in nature. However, loss minimization is not the only form minimization problem. Minimisation problems could also be in the form of minimisation of cost of production or investment. In analysinga problem involving the cost of production you do not have to construct a regret matrix because the pay-off in the table already represents cost.

NOTE: It should be pointed out that EMV and EOL decision criteria are completely consistent and yield the same optimal decision alternative.

iii) Expected Value of Perfect Information

Taylor III (2007) is of the view that it is often possible to purchase additional information regarding future events and thus make better decisions. For instance, a farmer could hire a weather forecaster to analyse the weather conditions more accurately to determine which weather condition will prevail during the next farming season. However, it would not be wise for the farmer to pay more for this information than he stands to gain in extra yield from having this information. That is, the information has some maximum yield value that represents the limit of what the decision maker would be willing to spend. This value of information can be computed as an expected value – hence its name, expected value of perfect information (EVPI).

The expected value of perfect information therefore is the maximum amount a decision maker would pay for additional information. In the view of Adebayo et al (2007), the value of perfect information is the amount by which the profit will be increased with additional information. It is the difference between expected value of optimum quantity under risk and the expected value under certainty. Using the EOL criterion, the value of expected loss will be the value of the perfect information.

Expected value of perfect information can be computed as follows

EVPI = EVwPI – EMVmax

where

EVPI = Expected value of perfect information
EVwPI = Expected value with perfect information
EMVmax = Maximum expected monetary valueor Expected value without perfect information
(Or minimum EOL for a minimization problem)

EXAMPLE3.4
Using the data on payoff matrix 3 above,

Decision to Invest	State of Nature		
	Good (N)	Poor (N)	Turbulent (N)
Apartment building (d_1)	50,000	30,000	15,000
Office building (d_2)	100,000	40,000	10,000
Warehouse (d_3)	30,000	10,000	-20,000
Probabilities	0.5	0.3	0.2

Fig. 3.3: Pay-off Tale

EVwPI = Pj x best out on each state of nature (Sj).

The expected value with perfect information can be obtained by multiplying the best outcome in each state of nature by the corresponding probabilities and summing the results.
We can obtain the EVwPI from the table above as follows:

EVwP1 = 100,000 x 0.5 + 40,000 x 0.3 + 15,000 x 0.2
= 50,000 + 12,000 + 3,000
N**65,000**

Recall that our optimum strategy as calculated earlier was N64,000.
EVP1 = EVwP1 – EMVmax
= N65000 - 64,000
N1,000

The expected value of perfect information (EVPI) isN1000. This implies that the maximum amount the investor can pay for extra information is N1000. Because it is difficult to obtain perfect information, and most times unobtainable, the decision maker would be willing to pay some amount less than N1000 depending on how accurate the decision maker believes the information is. Notice that the expected value of perfect information (N1000) equals our expected opportunity loss (EOL) of N1000 as calculated earlier.

Taylor III (2007) provides a justification for this. According to him, this will always be the case, and logically so, because regret reflects the difference between the best decision under a state of nature and the decision actually made. This is the same thing determined by the expected value of perfect information.

iv) Decision under Conflict

Decision taken under conflict is a competitive decision situation. This environment occurs when two or more people are engaged in a competition in which the action taken by one person is dependent on the action taken by others in the competition. In a typical competitive situation the player in the competition evolve strategies to outwit one another. This could by way intense advertising and other promotional efforts, location of business, new product development, market research, recruitment of experienced executives and so on. An appropriate techniques to use in solving problems involving conflicts is the Game Theory (Adebayo et al 2007).

Lecture IV

Operations Research

Historical Development of Operations Research

Gupta and Hira (2012) traced the development of Operations Research (OR) thus:

i) The Period Before World War II

The roots of OR are as old as science and society. Though the roots of OR extend to even early 1800s, it was in 1885 when Ferderick, W. Taylor emphasized the application of scientific analysis to methods of production, that the real start took place. Taylor conducted experiments in connection with a simple shovel. His aim was to find that weight load of Ore moved by shovel would result in the maximum amount of ore move with minimum fatigue. After many experiments with varying weights, he obtained the optimum weight load, which though much lighter than that commonly used, provided maximum movement of ore during a day. For a "first-class man" the proper load turned out to be 20 pounds. Since the density of Ore differs greatly, a shovel was designed for each density of Ore so as to assume the proper weight when the shovel was correctly filled. Productivity rose substantially after this change.

Henry L. Gantt, also of the scientific management era, developed job sequencing and scheduling methods by mapping out each job from machine to machine, in order to minimize delay. Now, with the Gantt procedure, it is possible to plan machine loading months in advance and still quote delivery dates accurately.

Another notable contributor is A.K. Erlang a Danish Mathematician who published his work on the problem of congestion of telephone traffic. During that period, operators were unable to handle the calls the moment they were made, resulting in delayed calls. A few years after its appearance, his work was accepted by the British Post Office as the basis calculating circuit facilities.

Other early contributors include F.W. Harris, who published his work in the area of inventory control in 1915, H.C. Levinson an American Astronomer who applied scientific analysis to the problems of merchandizing.

However, the first industrial Revolution was the main contributing factor towards the development of OR. Before this period, most of the industries were small scale, employing only a handful of men. The advent of machine tools – the replacement of man by machine as a source of power and improved means of transportation and communication resulted in fast flourishing industries. If became increasingly difficult for a single man to perform all the managerial functions (Planning, sales, purchasing production, etc). Consequently, a division of management functions took place. Managers of production marketing, finance, personal, research and development etc. began to appear. For example, production department was sub-divided into sections like maintenance, quality control, procurement, production planning etc.

ii) World War II

During War II, the military management in England called on a team of scientists to study the strategic and tactical problems of air and land defence. This team was under the leadership of Professor P. M. S. Blackett of University of Manchester and a former Naval Officer. “Blackett’s circus”, as the group was called, includedthree Physiologists, two Mathematical Physicists, one Astrophysicist, one Army officer, one Surveyor, one general physicist and two Mathematicians. The objective of this team was to find out the most effective allocation of limited military resources to the various military operations and to activities within each operation. The application included effective use of newly invented radar, allocation of British Air Force Planes to missions and the determination best patters for searching submarines. This group of scientist formed the first OR team.

The name Operations Research (or Operational Research) was coined in 1940 because the team was carrying out research on military operations. The encouraging results of the team’s efforts lead to the formation of more of such teams in the British Armed services and the use of such scientific teams soon spread to the western allies – United States, Canada, and France. Although the science of Operations Research originated in England, the United States soon took the lead. In the United States, OR terms helped in developing strategies for mining operations, inventing new flight patterns, and planning of sea mines.

Post World War II

Immediately after the war, the success of military teams attracted the attention of industrial mangers who were seeking solutions to their problems. Industrial operations research in U.K and USA developed along different lines, and in UKthe critical economic efficiency and creation of new markets. Nationalisation of new key industries further increased the potential field for OR. Consequently OR soon spread from military to government, industrial, social and economic planning.

In the USA, the situation was different impressed by is dramatic success in UK, defence operations research in USA was increased. Most of the war-experienced OR workers remained in the military services. Industrial executives did not call for much help because they were returning to peace and many of them believed that it was merely a new applicati0on of an old technique. Operations research has been known by a variety of names in that country such as Operational Analysis, Operations Evaluation, Systems Analysis, Systems Evaluation, Systems Research, Decision Analysis, Quantitative Analysis, Decision Science, and Management Science.

In 1950, OR was introduced as a subject for academic study in American Universities. They were generally schools of Engineering, Public Administration, Business Management, Applied

Mathematics, Economics, Computer Sciences, etc. Since this subject has been gaining ever increasing importance for the student in Mathematics, statistics, commerce, Economics, Management and Engineering, to increase the impact of operations research, the Operations Research Society of America (ORSA) was formed in 1950. In 1953 the Institute of Management Science (IMS) was established. Other countries followed suit and in 1959, International Federation of OR Societies was established, and in many countries, International Journals OR began to appear.

Today, the impact of Operations Research can be felt in many areas. This is shown by the ever increasing member of educational institutions offering it at degree level. The fast increase in the number of management consulting firms speak of the popularity of OR. Lately, OR activities have spread to diverse fields such as hospitals, libraries, city planning, transportations systems, crime investigation etc.

Definition of Operations Research

Many definitions of OR have been suggested by writers and experts in the field of operations Research. We shall consider a few of them.

Operations Research is the applications of scientific methods by inter disciplinary teams to problems involving the control of organized (Man-Machine) Systems so as to provide solutions which best serve the purpose of the organization as a whole (Ackoff & Sasieni, 1991). Operations Research is applied decision theory. It uses any scientific, Mathematical or Logical means to attempt to cope with the problems that confront the executive when he tries to achieve a thorough going rationality in dealing with his decision problems (Miller and Starr, 1973).

Operations research is a scientific approach to problem solving for executive management (Wagner, 1973). Also, operations Research is the art of giving bad answers to problems, to which, otherwise, worse answers are given (Saaty, 1959).

OR, in the most general sense, can be characterized as the application of scientific methods, tools, and techniques to problems involving the operations of systems so as to provide those in control of the operations with optimum solutions to the problems. (Churchman, Ackoff and Arnoff, 1957).

It could be noticed that most of the above definitions are not satisfactory. This is because of the following reasons.

i. They have been suggested at different times in the development of operations research and hence emphasis only one other aspect.
ii. The interdisciplinary approach which is an important characteristic of operations research is not included in most of the definitions.

iii It is not easy to define operations research precisely as it is not a science representing any well-defined social, biological or physical phenomenon.

Characteristics of OR

Ihemeje (2002) presents four vital characteristics of OR.

The OR approach is to develop a scientific model of the system under investigation with which to compare the probable outcomes of alternative management decision or strategies.
OR is essentially an aid to decision making. The result of an operation study should have a direct effect on managerial action, management decision based on the finding of an OR model are likely to be more scientific and better informed.

It is based on the scientific method. It involves the use of carefully constructed models based on some measurable variables. It is, in essence, a quantitative and logical approach rather than a qualitative one. The dominant techniques of OR are mathematical and statistical.

OR model will be constructed for a particular “problem area”. This means that the model has “boundaries” and only considers a small part of a large organization or system. This may result in sub-optimisation of solution to a problem. An OR project is often a team effort involving people drawn from many different backgrounds including accountants, economists, engineers as well as OR experts themselves.

Other characteristics of OR are:

It is system (Executive) Oriented
It makes use of interdisciplinary teams
Application of scientific method
Uncovering of new problems
Improvement in quality of decision
Use of computer
Quantitative solution
Human factors (Gupta & Hira, 2012)

Scientific Method in Operations Research

Of these three phases, the research phase is the longest. The other two phases are equally important as they provide the basis of the research phase. We now consider each phase briefly as presented by Gupta & Hira (2012).

The Judgement Phase

The judgement phases of the scientific method of OR consists of the following:

Determination of the Operation: An operation is the combination of different actions dealing with resources (e.g men and machines) which form a structure from which an action with regards to broader objectives is maintained. For example an act of assembling an engine is an operation.

Determination of Objectives and Values Associated with the operation: In the judgement phase, due care must be given to define correctly the frame of references of operations. Efforts should be made to find the type of situation, e.g manufacturing, engineering, tactical, strategic etc.

Determination of Effectiveness Measures: The measure of effectiveness implies the measure of success of a model in representing a problem and providing a solution. It is the connecting link between the objectives and the analysis required for corrective action.

Formulation of the Problem Relative to the Objective: Operation analysis must determine the type of problem, its origin, and causes. The following are some types of problems:

i. Remedial type with its origin in actual or threatened accidents e.g. air crashes, job performance hazards.
ii. Optimization type e.g. performing a job more efficiently.
iii. Transference type consisting of applying the new advances, improvements and inventions in one field to other fields.
iv. Prediction typee.g. forecasting and problems associated with future developments and inventions

The Research Phase

The research phase of OR includes the following:

Observation and Data Collection: This enhances better understanding of the problem.

Formulation of Relevant Hypothesis: Tentative explanations, when formulated as propositions are called hypothesis. The formulation of a good hypothesis depends upon the sound knowledge of the subject–matter. A hypothesis must provide an answer to the problem in question.

Analysis of Available Information and Verification of Hypothesis: Quantitative as well as qualitative methods may be used to analyse available data.

Prediction and Generalisation of Results and Consideration of Alternative Methods: Once a model has been verified, a theory is developed from the model to obtain a complete description of the problem. This is done by studying the effect of changes in the parameters of the model. The theory so developed may be used to extrapolate into the future.

The Action Phase
The action phase consists of making recommendations for remedial action to those who first posed the problem and who control the operations directly. These recommendations consists of a clear statement of the assumptions made, scope and limitations of the information presented about the situation, alternative courses of action, effects of each alternative as well as the preferred course of action.

A primary function of OR group is to provide an administrator with better understanding of the implications of the decisions he makes. The scientific method supplements his ideas and experiences and helps him to attain his goals fully.

Necessity of Operations Research in Industry

Having studied the scientific methods of operations research, we now focus on why OR is important or necessary in industries. OR came into existence in connection with war operations, to decide the strategy by which enemies could be harmed to the maximum possible extent with the help of the available equipment. War situations required reliable decision making. But the need for reliable decision techniques is also needed by industries for the following reasons.

Complexity: Today, industrial undertakings have become large and complex. This is because the scope of operations has increased. Many factors interact with each other in a complex way. There is therefore a great uncertainty about the outcome of interaction of factors like technological, environmental, competitive etc. For instance, a factory production schedule will take the following factors into account:

Customer demand.
Raw material requirement.
Equipment Capacity and possibility of equipment failure.
Restrictions on manufacturing processes.

It could be seen that, it is not easy to prepare a schedule which is both economical and realistic. This needs mathematical models, which in addition to optimization, help to analyse the complex situation. With such models, complex problems can be split into simpler parts, each part can be analysed separately and then the results can be synthesized to give insights into the problem.

Scattered Responsibility and Authority: In a big industry, responsibility and authority of decision-making is scattered throughout the organization and thus the organization, if it is not conscious, may be following inconsistent goals. Mathematical quantification of OR overcomes this difficulty to a great extent.

Uncertainty: There is a lot of uncertainty about economic growth. This makes each decision costlier and time consuming. OR is essential from the point of view of reliability.

Knowledge Explosion: Knowledge is increasing at a very fast pace. Majority of industries are not up-to-date with the latest knowledge and are therefore, at a disadvantage. OR teams collect the latest information for analysis purpose which is quit useful for the industries.

Scope of Operations Research

We now turn our attention towards learning about the areas that OR covers. OR as a discipline is very broad and is relevant in the following areas:

In Industry: OR is relevant in the field or industrial management where there is a chain of problems or decisions starting from the purchase of raw materials to the dispatch of finished goods. The management is interested in having an overall view of the method of optimizing profits. In order to take scientific decisions, an OR team will have to consider various alternative methods of producing the goods and the returns in each case. OR should point out the possible changes in overall structure like installation of a new machine, introduction of more automation etc.

Also, OR has been successfully applied in production, blending, product mix, inventory control, demand forecast, sales and purchases, transportation, repair and maintenance, scheduling and sequencing, planning, product control, etc.

In Defence: OR has wide application in defence operations. In modern warfare, the defence operations are carried out by a number of different agencies, namely – Air force, Army, and Navy. The activities perfumed by each of these agencies can further be divided into sub-activities viz: operations, intelligence, administration, training, etc. There is thus a need to coordinate the various activities involved in order to arrive at an optimum strategy and to achieve consistent goals.

In Management: Operations Research is a problem-solving and decision-making science. It is a tool kit for scientific and programmable rules providing the management a qualitative basis for decision making regarding the operations under its control. Some of the area of management where OR techniques have been successfully applied are as follows:

a) Allocation and Distribution

Optimal allocation of limited resources such as men, machines, materials, time, and money. Location and size of warehouses, distribution centres retail depots etc as well as distribution policy

b) Production and Facility Planning

- Selection, location and design of production plants, distribution centre and retail outlets.

- Project scheduling and allocation of resources.
- Preparation of forecast for the various inventory items and computing economic order quantities and reorder levels.
- Determination of number and size of the items to be produced.
- Maintenances policy and preventive maintenance.
- Scheduling and sequencing of production runs by proper allocation of machines.

c) Procurement

- What, how, and when to purchase at minimum purchase cost.
- Bidding and replacement policies.
- Transportation planning and vendor analysis.
-

d) Marketing

- Product selection, timing, and competitive actions.
- Selection of advertisement media.
- Demand forecast and stock levels.
- Customer preference for size, colour and packaging of various products.
- Best time to launch a product.

e) Finance

- Capital requirement, cash-flow analysis.
- Credit policy, credit risks etc.
- Profit plan for the organisation.
- Determination of optimum replacement policies.
- Financial planning, dividend policies, investment and portfolio management, auditing etc.

f) Personnel

- Selection of personnel, determination of retirement age and skills.
- Recruitment policies and assignment of jobs.
- Wages/salaries administration.
-

g) Research and Development

- Determination of areas for research and development.
- Reliability and control of development projects.
- Selection of projects and preparation of budgets.

Scope of Operations Research in Financial Management

The scope of OR in financial management covers the following areas

Cash Management: Linear programming techniques are helpful in determining the allocation of funds to each section. Linear programming techniques have also been applied to identify sections having excess funds; these funds may be diverted to the sections that need them.

Inventory Control: Inventory control techniques of OR can help management to develop better inventory policies and bring down the investment in inventories. These techniques help to achieve optimum balance between inventory carrying costs and shortage cost. They help to determine which items to hold, how much to hold, when to order, and how much to order.

Simulation Technique: Simulation considers various factors that affect and present and projected cost of borrowing money from commercial banks, and tax rates etc. and provides an optimum combination of finance (debt, equity, retained earnings) for the desired amount of capital. Simulation replaces subjective estimates, judgement and hunches of the management by providing reliable information.

Capital Budgeting

It involves evaluation of various investment proposals (viz, market introduction of new products and replacement of equipment with a new one). Often, decisions have been made by considering internal rate of return or net present values. Also the EMV method as discussed early can be used to evaluate investment proposals/project.

Lecture V

Modelling in Operations Research

Definition

Scientific modelling is an activity the aim of which is to make a particular part or feature of the world easier to understand, define, quantify, visualize, or simulate. It requires selecting and identifying relevant aspects of a situation in the real world and then using different types of models for different aims, such as conceptual models to better understand, operational models to operationalize, mathematical models to quantify, and graphical models to visualize the subject (http://en.wikipedia.org/wiki/Scientific_modelling)

Adebayo et al (2010) define Modelling as a process whereby a complex life problem situation is converted into simple representation of the problem situation. They further described a model as a simplified representation of complex reality. Thus, the basic objective of any model is to use simple inexpensive objects to represent complex and uncertain situations. Models are developed in such a way that they concentrate on exploring the key aspects or properties of the real object and ignore the other objects considered as being insignificant. Models are useful not only in science and technology but also in business decision making by focusing on the key aspects of the business decisions(Adebayo et al, 2010).

A model as used in Operations Research is defined as an idealised representation of real life situation. It represents one of the few aspects of reality. Diverse items such as maps, multiple activity charts, an autobiography, PERT network, break-even equations, balance sheets, etc, are all models because they each one of them represent a few aspects of the real life situation. A map for instance represents the physical boundaries but ignores the heights and the various places above sea levels (Gupta and Hira, 2012). According to Reeb and Leavengood (1998), Models can be defined as representations of real systems. They can be iconic (made to look like the real system), abstract, or somewhere in between.

Classification of Models

The following are the various schemes by which models can be classified:

By degree of abstraction
By function
By structure
By nature of the environment
By the extent of generality
By the time horizon

Let us now briefly discuss the above classifications of models as presented by Gupta and Hira (2012)

i) By Degree of Abstraction.
Mathematical models such as Linear Programming formulation of the blending problem, or transportation problem are among the most abstract types of models since they require not only mathematical knowledge, but also great concentration to the real idea of the real-life situation they represent.

Language models such as languages used in cricket or hockey match commentaries are also abstract models.

Concrete models such as models of the earth, dam, building, or plane are the least abstract models since they instantaneously suggest the shape or characteristics of the modelled entity.

ii) By Function

The types of models involved here include:

Descriptive models which explain the various operations in non-mathematical language and try to define the functional relationships and interactions between various operations. They simply describe some aspects of the system on the basis of observation, survey, questionnaire, etc. but do not predict its behaviour. Organisational charts, pie charts, and layout plan describe the features of their respective systems.

Predictive models explain or predict the behaviour of the system. Exponential smoothing forecast model, for instance, predict the future demand

Normative or prescriptive models develop decision rules or criteria for optimal solutions. They are applicable to repetitive problems, the solution process of which can be programmed without managerial involvement. Liner programming is also a prescriptive or normative model as it prescribes what the managers must follow.

iii) By Structure

Iconic or physical models
In iconic or physical models, properties of real systems are represented by the properties themselves. Iconic models look like the real objects but could be scaled downward or upward, or could employ change in materials of real object. Thus, iconic models resemble the system they represent but differ in size, they are images. They thus could be full replicas or scaled models like architectural building, model plane, model train, car, etc.

Analogue or Schematic Models
Analogue models can represent dynamic situations and are used more often than iconic models since they are analogous to the characteristics of the system being studied. They use a set of properties which the system under study possesses. They are physical models but unlike iconic

models, they may or may not look like the reality of interest. They explain specific few characteristics of an idea and ignore other details of the object. Examples of analogue models are flow diagrams, maps, circuit diagrams, organisational chart etc.

Symbolic or mathematical models

Symbolic models employ a set of mathematical symbols (letters, numbers etc.) to represent the decision variables of the system under study. These variables are related together by mathematical equations/in-equations which describe the properties of the system. A solution from the model is, then, obtained by applying well developed mathematical techniques. The relationship between velocity, acceleration, and distance is an example of a mathematical model. Similarly, cost-volume-profit relationship is a mathematical model used in investment analysis.

iv) By Nature of Environment

Deterministic models

In deterministic models, variables are completely defined and the outcomes are certain. Certainty is the state of nature assumed in these models. They represent completely closed systems and the parameters of the systems have a single value that does not change with time. For any given set of input variables, the same output variables always result. E.O.Q model is deterministic because the effect of changes in batch size on total cost is known. Similarly, linear programming, transportation, and assignment models are deterministic models.

Probabilistic Models

These are the products of the environment of risk and uncertainty. The input and/or output variables take the form of probability distributions. They are semi-closed models and represent the likelihood of occurrence of an event. Thus, they represent to an extent the complexity of the real world and uncertainty prevailing in it. As a example, the exponential smoothing method for forecasting demand a probabilistic model.

v) By Extent of Generality

General Models: Linear programming model is known as a general model since it can be used for a number of functions e.g. product mix, production scheduling, and marketing of an organisation.

Specific Models: Sales response curve or equation as a function of advertising is applicable to the marketing function alone.

v). By the Time Horizon

Static Models: These are one time decision models. They represent the system at specified time and do not take into account the changes over time. In this model, cause and effect occur almost simultaneously and the lag between the two is zero. They are easier to formulate, manipulate and solve. EOQ is a static model.

Dynamic Models: These are models for situations for which time often plays an important role. They are used for optimisation of multi-stage decision problems which require a series of decisions with the outcome of each depending upon the results of the previous decisions in the series. Dynamic programming is a dynamic model

Characteristics of Good Models

The following are characteristics of good models as presented by Gupta and Hira (2012)

The number of simplifying assumptions should be as few as possible.
The number of relevant variables should be as few as possible. This means the model should be simple yet close to reality.
It should assimilate the system environmental changes without change in its framework.
It should be adaptable to parametric type of treatment.
It should me easy and economical to construct.

Advantages of a Model
1 It provides a logical and systematic approach to the problem.
It indicates the scope as well as limitation of the problem.
It helps in finding avenues for new research and improvement in a system.
It makes the overall structure of the problem more comprehensible and helps in dealing with the problem in its entirety.
It permits experimentation in analysis of a complex system without directly interfering in the working and environment of the system

Limitations of a Model
Models are more idealised representations of reality and should not be regarded as absolute in any case.
The reality of a model for a particular situation can be ascertained only by conducting experiments on it.

Constructing a Model

Formulating a problem requires an analysis of the system under study. This analysis shows the various phases of the system and the way it can be controlled. Problem formulation is the first stage in constructing a model. The next step involves the definition of the measure of effectiveness that is, constructing a model in which the effectiveness of the system is expressed as a function of the variables defining the system. The general Operations Research form is

$$E = f(x_i, y_i)$$

where E = effectiveness of the system,
x_i = controllable variables,
y_i = uncontrollable variables but do affect E.

Deriving a solution from such a model consists of determining those values of control variables xi, for which the measure of effectiveness is measure of effectiveness is optimised. Optimised includes both maximisation (in case of profit, production capacity, etc.) and minimisation (in case of losses, cost of production, etc.).

The following steps are involved in the construction of a model

Selecting components of the system
Pertinence of components
Combining the components
Substituting symbols

Types of Mathematical Models
The following are the types of mathematical models available:

1. Mathematical techniques
2. Statistical techniques
3. Inventory models
4. Allocation models
5. Sequencing models
6. Project scheduling by PERT and CPM
7. Routing models
8. Competitive models
9. Queuing models
10. Simulation techniques.

Lecture VI

Simulation

Definition

According Budnick et al (1988), Simulation is primarily concerned with experimentally predicting the behaviour of a real system for the purpose of designing the system or modifying behaviour. In other words, simulation is a tool that builds a model of a real operation that is to be investigated, and then feeds the system with externally generated data. We generally distinguish between deterministic and stochastic simulation. The difference is that the data that are fed into the system are either deterministic or stochastic. This chapter will deal only with stochastic simulation, which is sometimes also referred to as Monte Carlo simulation in reference to the Monte Carlo Casinos and the (hopefully) random outcome of their games of chance.

According to Gupta and Hira (2012), simulation is an imitation of reality. “They further stated that simulation is the representation of reality through the use of models or other device which will react in the same manner as reality under given set of conditions. Simulation has also been defined the use of a system model that has the designed characteristics of reality in order to produce the essence of actual operation. According to Donald G. Malcom, a simulated model may be defined as one which depicts the working of a large scale system of men, machine, materials, and information operating over a period of time in a simulated environment of the actual real world condition.

A good example of simulation is a children amusement or a cyclical park where children enjoy themselves in a simulated environment like Amusement Parks, Disney Land, Planetarium shows where boats, train rides, etc. are done to simulate actual experience.

In simulation, operational information of the behaviour of a system which aides in decision making is obtained unlike that which exist in analytical modelling technique where optimal solution attempt is made to obtain descriptive information through experimentation. Generally, a simulation model is the totality of many simple models, and model interrelationship among system variables and components. A model can thus, be decomposed into many simple but related models. Models can be used for predicting the behaviour of a system under varying conditions. It focuses mainly on detailed physical or financial operations of a system.Model development through the use of computers for simulation has resulted in techniques for identifying possible optimal solution for a decision problem by evaluating various suggested alternatives and then suggesting results (Adebayo et al, 2010).

Advantages of Simulation Technique

When the simulation technique is compared with the mathematical programming and slandered probability analysis, offers a number of advantages over these techniques. Some of the advantages are:

Simulation offers solution by allowing experimentation with models of a system without interfering with the real system. Simulation is therefore a bypass for complex mathematical analysis.
Through simulation, management can foresee the difficulties and bottlenecks which may come up due to the introduction of new machines, equipment or process. It therefore eliminates the need for costly trial and error method of trying out the new concept on real methods and equipment.

Simulation is relatively free from mathematics, and thus, can be easily understood by the operating personnel and non-technical managers. This helps in getting the proposed plan accepted and implemented.

Simulation models are comparatively flexible and can be modified to accommodate the changing environment of the real situation.

Simulation technique is easier to use than mathematical models and its considered quite superior to mathematical analysis.

Computer simulation can compress the performance of a system over several years and involving large calculation into few minutes of computer running time.

Simulation has the advantage of being used in training the operating and managerial staff in the operation of complex plans.

Application of Simulation

Simulation is quite versatile and commonly applied technique for solving decision problems. It has been applied successfully to a wide range of problems of science and technology as given below:

- In the field of basic sciences, it has been used to evaluate the area under a curve, to estimate the value of, in matrix inversion and study of particle diffusion.
- In industrial problems including shop floor management, design of computer systems, design of queuing systems, inventory control, communication networks, chemical processes, nuclear reactors, and scheduling of production processes.
- In business and economic problems, including customer behaviour, price determination, economic forecasting, portfolio selection, and capital budgeting.

- In social problems, including population growth, effect of environment on health and group behaviour.
- In biomedical systems, including fluid balance, distribution of electrolyte in human body, and brain activities.
-
- In the design of weapon systems, war strategies and tactics.
- In the study of projects involving risky investments.

Limitations of Simulation Technique

Despite the many advantages of simulation, it might suffer from some deficiencies in in large and complex problems. Some of these limitations are given as follows:

a) Simulation does not produce optimum results when the model deals with uncertainties, the results of simulation only reliable approximations subject to statistical errors.
b) Quantification of variables is difficult in a number of situations; it is not possible to quantify all the variables that affect the behaviour of the system.
c) In very large and complex problems, the large number of variables and the interrelationship between them make the problem very unwieldy and hard to program.

Simulation is by no means, a cheap method of analysis.
Simulation has too much tendency to rely on simulation models. This results in application of the technique to some simple problems which can more appropriately be handled by other techniques of mathematical programming.

Monte Carlo Simulation

The Monte Carlo method of simulation was developed by two mathematicians Jon Von Neumann and Stainslaw Ulam, during World War II, to study how far neurone would travel through different materials. The technique provides an approximate but quite workable solution to the problem. With the remarkable success of this technique on the neutron problem, it soon became popular and found many applications in business and industry, and at present, forms a very important tool of operation researcher's tool kit.

The technique employs random number and is used to solve problems that involve probability and where physical experimentation is impracticable, and formulation of mathematical model is impossible. It is a method of simulation by sampling technique. The following are steps involved in carrying out Monte Carlo simulation:

i) Select the measure of effectiveness (objective function) of the problem. It is either to be minimised or maximised.
ii) Identify the variables that affect the measure of effectiveness significantly. For example, a number of service facilities in a queuing problem or demand, lead time and safety stock in inventory problem.

iii) Determine the cumulative probability distribution of each variable selected in step 2. Plot these distributions with the values of the variables along the x-axis and cumulative probability values along the y-axis.
iv) Get a set of random numbers.
v) Consider each random number as a decimal value of the cumulative probability distribution. Enter the cumulative distribution along the y-axis. Project this point horizontally till it meets the distribution curve. Then project the point of distribution down on the x-axis.
vi) Record the value (or values if several variables are being simulated) generated in step 5. Substitute the formula chosen for measure of effectiveness and find its simulated value.
vii) Repeat steps 5 and 6 until sample is large enough to the satisfaction of the decision maker.

Let us consider a simple example as presented by Gupta and Hira (2012).

Example
Customers arrive at a service facility to get required service. The interval and service times are constant and are 1.8minutes and minutes respectively. Simulate the system for 14minutes. Determine the average waiting time of a customer and the idle time of the service facility.
Solution
The arrival times of customers at the service station within 14 minutes will be:

Customer :	1	2	3	4	5	6	7	8
Arrival time : *(minutes)*	0	1.8	3.6	5.4	7.2	9.0	10.8	12.6

The time at which the service station begins and ends within time period of 14 minutes is shown below. Waiting time of customers and idle time of service facility are also calculated

Customer	*Service*		*Waiting Time*	*Idle Time of*
	Begins	*Ends*	*of Customer*	*Service Facility*
1	0	4	0	0
2	4	8	4 - 1.8 = 2.2	0
3	8	12	8 – 3.6 = 4.4	0
4	12	16	12 – 5.4 = 6.6	0

The waiting time of the first four customers is calculated above. For the remaining, it is calculated below:

Customer:	5	6	7	8
Waiting time (min) :	14 – 7.2 = 6.8	5.0	3.2	1.4

Therefore, average waiting time of a customer

$$= \frac{0 + 2.2 + 4.4 + 6.6 + 6.8 + 5 + 3.2 + 1.4}{8} = \frac{29.6}{8} = 3.7 \text{ minutes}$$

Idle time of facility = nil.

Lecture VII

Simulation

Definition

The word system has a long history which can be traced back to Plato (Philebus), Aristotle (Politics) and Euclid (Elements). It had meant "total", "crowd" or "union" in even more ancient times, as it derives from the verb sunìstemi, uniting, putting together.

"System" means "something to look at". You must have a very high visual gradient to have systematization. In philosophy, before Descartes, there was no "system". Plato had no "system". Aristotle had no "system"(McLuhan. 1967).

In the 19th century the first to develop the concept of a "system" in the natural sciences was the French physicist Nicolas Léonard Sadi Carnot who studied thermodynamics. In 1824 he studied the system which he called the working substance, i.e. typically a body of water vapour, in steam engines, in regards to the system's ability to do work when heat is applied to it. The working substance could be put in contact with either a boiler, a cold reservoir (a stream of cold water), or a piston (to which the working body could do work by pushing on it). In 1850, the German physicist Rudolf Clausius generalized this picture to include the concept of the surroundings and began to use the term "working body" when referring to the system.

One of the pioneers of the general systems theory was the biologist Ludwig von Bertalanffy. In 1945 he introduced models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relation or 'forces' between them.

Significant development to the concept of a system was done by Norbert Wiener and Ross Ashby who pioneered the use of mathematics to study systems. (*Cybernetics,* 1948 *) (Chapman& Hall, 1956).*

In business, System Analysis and Design refers to the process of examining abusiness situation with the intent of improving it through better procedures and methods. System analysis and design relates to shaping organizations, improving performance and achieving objectives for profitability and growth. The emphasis is on systems in action, the relationships among subsystems and their contribution to meeting a common goal.

Definition

The term system is derived from the Greek word *systema* , which means an organized relationship among functioning units or components. A system exists because it is designed to achieve one or more objectives. We come into daily contact with the transportation system, the telephone system, the accounting system, the production system, and, for over two decades, the computer system.

Similarly, we talk of the business system and of the organization as a system consisting of interrelated departments (subsystems) such as production, sales, personnel, and an information system. None of these subsystems is of much use as a single, independent unit. When they are properly coordinated, however, the firm can function effectively and profitably.

There are more than a hundred definitions of the word system, but most seem to have a common thread that suggests that a system is an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective. The word component may refer to physical parts (engines, wings of aircraft, car), managerial steps (planning, organizing and controlling), or a system in a multi-level structure. The component may be simple or complex, basic or advanced. They may be single computer with a keyboard, memory, and printer or a series of intelligent terminals linked to a mainframe. In either case, each component is part of the total system and has to do its share of work for the system to achieve the intended goal. This orientation requires an orderly grouping of the components for the design of a successful system.

The study of systems concepts, then, has three basic implications:

A system must be designed to achieve a predetermined objective. Interrelationships and interdependence must exist among the components.

The objectives of the organization as a whole have a higher priority than the objectives of its subsystems. For example, computerizing personnelapplications must conform to the organization’s policy on privacy, confidentiality and security, as well as making selected data (e.g. payroll) available to the accounting division on request.(Jawahar, 2006**)**
A system can also be defined is a collection of elements or components or units that are organized for a common purpose. The word sometimes describes the organization or plan itself (and is similar in meaning to method, as in "I have my own little system") and sometimes describes the parts in the system (as in "computer system").

According to the International Council of Systems Engineers (INCOSE), a system can be broadly defined as an integrated set of elements that accomplish a defined objective. People from different engineering disciplines have different perspectives of what a "system" is. For example, software engineers often refer to an integrated set of computer programs as a "system." Electrical engineers might refer to complex integrated circuits or an integrated set of electrical units as a "system." As can be seen, "system" depends on one’s perspective, and the “integrated set of elements that accomplish a defined objective” is an appropriate definition.

The Systems Theory

The general systems theory states that a system is composed of inputs, a process, outputs, and control. A general graphic representation of such a system is shown below:

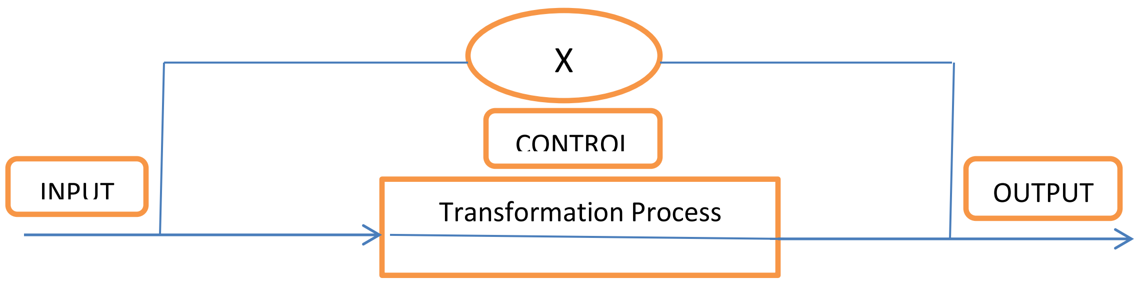

Fig. 8.1: An Operational System

Adapted from Ihemeje, (2002), Fundamentals of Business Decision Analysis, Lagos- Sibon Books Limited.

The input usually consists of people, material or objectives. The process consists of plant, equipment and personnel. While the output usually consists of finished goods, semi-finished goods, policies, new products, ideas, etc.

The purpose of a system is to transform inputs into outputs. The system theory is relevant in the areas of systems design, systems operation and system control. The systems approach helps in resolving organisational problems by looking at the organisation as a whole, integrating its numerous complex operations, environment, technologies, human and material resources. The need to look at the organisation in totality is premised on the fact that the objective if the different units of the organisation when pursued in isolation conflict with one another. For instance, the operation of a manufacturing department favours long and uninterrupted production runs with a view to minimising unit cost of production, including set-up costs. However, this will result in large inventories, and leading to high inventory costs. The finance department seeks to minimise costs as well as capital tied down in inventories. Thus, there is a desire for rapid inventory turnover resulting in lower inventory levels. The marketing department seeks favourable customer service and as a result, will not support any policy that encourages stock outs or back ordering. Back ordering is a method of producing later to satisfy a previously unfulfilled order. Consequently, marketing favours the maintenance of high inventory levels in a wide variety of easily accessible locations which in effect means some type of capital investment in warehouse or sales outlets. Finally, personnel department aims at stabilizing labour, minimizing the cost of firing and hiring as well as employee discontentment. Hence, it is desirable from the point of view of personnel to maintain high inventory level of producing even during periods of fall in demand.

Therefore, pursuing the interest of a section of the organization can result in solution which will not be optional from the point of view of the total organization, yet 'optimal' from the point of view of the section concerned. Such a situation is called sub-optimization. Adoption of the systems approach will eliminate this. The systems approach will produce an optimal solution, which attempts to resolve the conflicting objectives of the various sub-units of the organization. The adoption of the systems approach in OR methodology therefore puts its shoulder above other focus mainly on the solution of functional areas-based management problems only, i.e. those that adopt the piecemeal approach.

Elements of a System

Following are considered as the elements of a system in terms of Information systems:

- Input
- Output
- Processor
- Control
- Feedback
- Boundary and
- interface Environment
-

INPUT: Input involves capturing and assembling elements that enter the system to be processed. The inputs are said to be fed to the systems in order to get the output. For example, input of a 'computer system' is input unit consisting of various input devices like keyboard,mouse,joystick etc.

OUTPUT: The element that exists in the system due to the processing of the inputs is known as output. A major objective of a system is to produce output that has value to its user. The output of the system maybe in the form of cash, information, knowledge, reports, documents etc. The system is defined as output is required from it. It is the anticipatory recognition of output that helps in defining the input of the system. For example, output of a 'computer system' is output unit consisting of various output devices like screen and printer etc.

PROCESSOR(S): The processor is the element of a system that involves the actual transformation of input into output. It is the operational component of a system. For example, processor of a 'computer system' is central processing unit that further consists of arithmetic and logic unit (ALU), control unit and memory unit etc.

CONTROL: The control element guides the system. It is the decision-making sub-system that controls the pattern of activities governing input, processing and output. It also keeps the system within the boundary set. For example, control in a 'computer system' is maintained by the control unit that controls and coordinates various units by means of passing different signals through wires.

FEEDBACK: Control in a dynamic system is achieved by feedback. Feedback measures output against a standard in some form of cybernetic procedure that includes communication and control. The feedback may generally be of three types viz., positive, negative and informational. The positive feedback motivates the persons in the system. The negative indicates need of an action, while the information. The feedback is a reactive form of control. Outputs from the process of the system are fed back to the control mechanism. The control mechanism then adjusts the control signals to the process on the basis of the data it receives. Feedforward is a protective form of control. For example, in a 'computer system' when logical decisions are taken,the logic unit concludes by comparing the calculated results and the required results.

BOUNDARY AND INTERFACE: A system should be defined by its boundaries-the limits that identify its components, processes and interrelationships when it interfaces with another system. For example, in a 'computer system' there is boundary for number of bits, the memory size etc. that is responsible for different levels of accuracy on different machines(like 16-bit,32-bit etc.). The interface in a 'computer system' may be CUI (Character User Interface) or GUI (Graphical User Interface).

ENVIRONMENT: The environment is the 'supersystem' within which an organisation operates. It excludes input, processes and outputs. It is the source of external elements that impinge on the system. For example, if the results calculated/the output generated by the 'computer system' are to be used for decision-making purposes in the factory, in a business concern, in an organisation, in a school, in a college or in a government office then the system is same but its environment is different.

Types of Systems

Systems are classified in different ways:

- Physical or abstract systems.
- Open or closed systems.
- 'Man-made' information systems.
- Formal information systems.
- Informal information systems.
- Computer-based information systems.
- Real-time system.

Physical systems are tangible entities that may be static or dynamic in operation. An open system has many interfaces with its environment i.e. system that interacts freely with its environment, taking input and returning output. It permits interaction across its boundary; it receives inputs from and delivers outputs to the outside. A closed system does not interact with the environment; changes in the environment and adaptability are not issues for closed system.

Forms of systems

A system can be conceptual, mechanical or social. A system can also be deterministic or probabilistic. A system can be closed or open.

Conceptual system
A system is conceptual when it contains abstracts that are linked to communicate ideas. An example of a conceptual system is a language system as in English language, which contains words, and how they are linked to communicate ideas. The elements of a conceptual system are words.

Mechanical system
A system is mechanical when it consists of many parts working together to do a work. An example of a social system is a typewriter or a computer, which consists of many parts working together to type words and symbols. The elements of the mechanical system are objects.

Social system
A system is social when it comprises policies, institutions and people. An example of a social system is a football team comprising 11 players, or an educational system consisting of policies, schools and teachers. The elements of a social system are subjects or people.

Deterministic system
A system is deterministic when it operates according to a predetermined set of rules. Its future behaviour can therefore be predicted exactly if it's present state and operating characteristics are accurately known. Example s of deterministic systems are computer programmes and a planet in orbit. Business systems are not deterministic owing to the fact that they interfere with a number of in determinant factors, such as customer and supplier behaviour, national and international situations, and climatic and political conditions.

Probabilistic system
A system is probabilistic when the system is controlled by chance events and so its future behaviour is a matter of probability rather than certainty. This is true of all social systems, particularly business enterprises. Information systems are deterministic enterprises in the sense that a pre-known type and content of information emerges as a result of the input of a given set of data. This assumes that the information system operates according to pre-decided and formulated rules
– which it generally would do. In a broader sense, information systems can be regarded as probabilistic because the wide variability in the nature of their input introduces many indeterminate and of their future behaviour i.e. output is not absolutely certain.

Closed system
A system is closed when it does not interface with its environment i.e. it has no input or output. This concept is more relevant to scientific systems that to social systems. The nearest we can get to a closed social system would be a completely self-contained community that provides all its own food, materials and power, and does not trade, communicate or come into contact with other communities.

Open system
A system is open when it has many interfaces with its environment, and so needs to be capable of adopting their behaviour in order to continue to exist in changing environments. An information system falls into this category since it needs to adapt to the changing demands for information. Similarly, a business system must be capable of reorganizing itself to meet the conditions of its environment, as detected from its input; it will more rapidly tend towards a state of disorganization. When functioning properly, an open system reaches a state of dynamic equilibrium. This is a steady state in which the system readily adapts to environmental factors by re-organizing itself according to the internal forces of its sub-systems. With a manufacturing company, for instance, the steady state can be thought of as the purchasing of materials and productive means, and the manufacturing and selling of products. An environmental factor could be an increase in the selling prices of its products (Ihemeje, 2002)

The Concept of Entropy in a System

The term entropy is used as a measure of disorganisation. Thus, we can regard open systems as tending to increase their entropy unless they receive negative entropy in the form of information from their environment. In the above example, if increased cost of cost of materials were ignored, the product will become unprofitable and as a result, the organisation may become insolvent, that is, a state of disorganisation.

Systems analysis is an activity, process, or study of critically examining the ways performing frequently occurring tasks that depend on the movement processing of information by a number of people within an organisation. System analysis may be carried out to either install a new system or overhaul an already existing one. This implies that a system is analysed for three main purposes- system design, system operation, and system control (Ihemeje, 2002).