1.1 Introduction

The thesis consists of eight chapters. We discuss in this chapter the various concepts and methodologies of multi-criteria decision making (MCDM) problem as is required for proper presentation of the investigations in later chapters of the thesis. In chapter -II we have discussed the objective and motivation for our investigations carried in chapters -III through -VII. In chapter -VIII concluding remarks are made bringing forth the future scope of research.

Many real world complex decision systems involve the optimization of several conflicting objectives. Such systems with multiple conflicting and noncommensurable criteria are termed as multi-criteria decision systems. Multicriteria decision problem is a generalization of the traditional classical single objective optimization. Classical optimization approaches evaluate the decisions with their performances on a single criterion, e.g., maximization of profits or minimization of cost. In the present day society multicriteria decision problem is the most rapidly growing area of operations research and management science. There are many reasons for the increasing interest in the multi-criteria decision problems. Firstly, most of the decision problems are inherently multiobjective in nature and hence decision making using classical methods does not reflect the underlying reality.

Secondly, in many decision problems in which ranking of potential alternatives is required, the ranking is based on multiple objectives. Thirdly, many problems that occur in classical single objective models can better be viewed as multiple objective in nature. The reason for the multiple objective nature of these problems is that the out comes associated with the decisions are multidimensional.

Multiobjective programming is a powerful mathematical procedure and is applicable to a wide range of problems in private sector, public sector, nonprofitable organizations, Government Administrations, etc. It is also applicable in the process of resource allocation, public investment, facility location, financial planning and policy formulation. We now briefly indicate the nature of these problems.

Multiobjective problems arise in the design modelling and planning of many complex resource allocation systems in the areas of industrial production, urban transportation, public health, energy production and distribution, wild life management, agricultural and live stock production and local government administration.

Public investment is another area which has attracted the attention of most of the multiobjective analysts. Managerial decision problems regarding water resource systems, urban transportation planning, educational establishments, hospitals, city corporation etc.are examples of the problems in this area.

In the evaluation of urban transportation plans we may consider the objectives as the reduction of air pollution, noise, accidents, the increase of accessibility, fiscal efficiency and the attainment of more equitable income distribution. So the objectives are conflicting by the nature of the problems. Another example of multiobjectives where objectives are conflicting in nature is, ~~mast~~ straight route for an urban highway. This will usually maximize accessibility (measure as time of travel) and fiscal efficiency but gives a high level of air pollution and noise impacts. On the other hand, a circular route will have less air pollution and noise but requires longer travel times and more cost of travel. The location of public facilities represents another area to which multiple objective programming is applicable.

Managers in both the private and public sectors are often faced with the task of identifying sites that are suitable for additional facilities as the demand for services or products increases. In the private sector, for instance, the need many-may exist to locate manufacturing plants, ware-houses, distribution facilities, etc. Similarly in the public sector there may be demand for more public facilities which in turn represents the location problems such as fire stations, health clinics, hydropower plants, post offices, educational institutions, etc. Such problems present spatial conflicts among the areas served by the facility. For example, the problem in locating a fire station is whether the station should be sited near the

commercial area which is characterized by high property value and low population or it should be located near a populated area but of less property value.

Financial planning is also one of the key areas of multiobjective analysis. This involves problems on capital budgeting, working capital management and portfolio selection. Capital budgeting involves mid to long range decision regarding the allocation of capital investment among multiple projects. Working capital management involves the short term investment and financing decisions of a firm. This represents the firms multiple objectives related to its profitability, liquidity and use of financial leverage. The purpose of the multi-objective programming is to resolve such conflicting situations.

The existing methods to solve multicriteria decision making problems have been classified into three broad categories depending on three different operational attitudes of a decision maker, which are (i) the choice of a global action, (ii) the choice of a compromise action by exploring the 'efficient frontier' of efficient solutions and (iii) the choice of ranking the option actions. According to Hwang and Yoon (1981), the multiple objective decision making consists in : (i) a set of quantifiable objectives, (ii) a set of well defined constraints and (iii) a process of obtaining some trade-off information between the objectives. In the literature

many extensive survey articles [Roy (1971), Boychuk and Ovchinnikov (1973), Keeney and Raiffa (1976), Starr and Zeleny (1977), Masud (1978), Hwang and Masud (1979) and Hwang and Yoon (1981) are available which deal with this aspect of the problems of an organization.

Goal programming is one of the methods to solve the problems involving multiple objective decision making problems. In goal programming it is required to specify aspiration levels for the objectives (decision maker's intuitive judgement about the organizational goals). The key aim of goal programming is to minimize deviations from the goal values. Fixing the relevant goal values is one of the important steps of developing any goal programming model without which the formulation of the problem will lead to a wrong solution.

The origin of the goal programming model is due to Charnes and Cooper (1961). A number of publications, [Charnes and Cooper (1961, 1977), Ijiri (1965), Contini (1968), Dyer (1972), Lee (1972, 1976), Kornbluth (1973), Ignizio (1976, 1978, 1980, 1983), Steuer (1979), Nijkamp and Spronk (1979), Lin (1980), Masud and Hwang (1981), Masud (1983), Zanakis and Gupta (1985), Soyibo (1985) _7 have appeared on this topic either in journals or in the form of books and monograph.

Most of the informations received from the real world are imprecise in nature involving vagueness or, so to say,

fuzziness. In the context of MCDM and goal programming, the various parameters involved to define the goals or objectives such as aspiration values, expression of the objectives and constraints and the priorities or weighting structure to reflect the relative importance of the goals are fuzzy in nature. To tackle the situations of fuzziness of these types, fuzzy set theory which is an extension of the classical set theory as developed by Zadeh (1965) is very useful. The fuzzy set theoretic approach resolves the problems in various fields which are not solvable by classical techniques.

Fuzzy set theoretic approach due to Zadeh (1965) was later developed by Bellmann and Zadeh (1970) to deal with the problems involving decision making under fuzzy environment. This is achieved by forming a fuzzy decision function through the combination of fuzzy goals and/or constraints. A general overview of application of fuzzy set theory related to fuzzy multiple objective programming is given in the works of Tanaka et al. (1974, 1976), Zimmermann (1976, 1978), Yager (1977), Blin (1977), Leberling (1977), Wiedey and Zimmermann (1978, 1979), Kickert (1978), Thole et al. (1979), Hannan (1979), Takeda and Nishida (1980), Carlson (1980), Dyson (1980), Ignizio (1982), Feng (1983); Rao, J.R. and D. Singh (1982a,b). The attempt to study some aspects of goal programming in fuzzy environment was first made by Narashimhan (1980), Later Hannan (1981a,b,c, 1982), Narasimhan (1981), Ignizio (1982), Rao, J.R.

and M.K. Mondal (1982), Rubin and Narasimhan (1984), Llena, J. (1985); Tiwari, R.N., S. Dharmar and J.R. Rao (1985a, 85b, 86a, 86b) have investigated various aspects of fuzzy goal programming models.

Before presenting the actual review of literature, some of the basic concepts and notation are defined in section 1.2. In section 1.3 selected literature in multi-objective decision making problems is reviewed. In section 1.4 the goal programming techniques are described. In section 1.5 the elements of fuzzy set theory as much as required are summarized. Applications of fuzzy set theory in multiobjective programming is described in section 1.6. In section 1.7 a critical survey of fuzzy goal programming is given.

1.2 Basic Concepts

In the Multicriteria Decision Making Literature the most used terms are objectives, attributes, goals criteria, Multicriteria Decision Making Problem, Goal Programming. These terms together with some other relevant concepts related to fuzzy applications in goal programming are defined below.

1.2.1 Terminology

Objectives : An objective is the reflection of the desire of