METROPOLITAN TRANSPORTATION PLANNING : A GOAL PROGRAMMING APPROACH

THESIS SUBMITTED TO
THE INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
SCIENCE

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1983

PREFACE

The present dissertation consists of eight chapters. Chapter I outlines a general introduction and explains the purpose and scope of the present work.

Chapter II contains a brief review of the concepts of goal programming including different goal programming models and solution algorithm for these models with an illustrative numerical example.

Chapter III concentrates on a general goal programming model formulation for preparing bus time-tables. The trip duration, bus arrival time, bus stop crossing by trips, trip start time, simultaneous arrival of buses, ratio of passengers travelling in the buses of the corporation to the total travelling passengers, and bus operation time saving , are considered as objectives in the model formulation. The model is demonstrated with the help of a numerical example.

Chapter IV presents an integer goal programming model formulation for the bus transportation crew planning to find an optimal schedule in which each crew is assigned two days off (consecutive or non-consecutive) per week considering several goals, such as, limit on the total number of crew having days off on each day, lower bound on the number of crew having consecutive days off for the pairs of days, and upper bounds on the number of crew having non-consecutive days off. For model demonstration purpose, a numerical example is presented.

Chapter V deals with integer goal programming model formulation for the problem of bus trips planning. The objectives which are included in the model formulation are number of trips on each route, frequency of call, total duration of all trips, duration of each trip, profit and total number of trips. A numerical example is presented to demonstrate the model.

Chapter VI is concerned with the preparation of bus schedule by combining several short trips. For this purpose, a zero-one goal programming model is formulated by considering several goals, such as, number of buses headout from the depot, required number of linked trips in a schedule, and the operation cost. This model is illustrated with a numerical example.

Chapter VII presents a mixed zero-one goal programming model formulation for the planning of setting up express bus stops on the regular routes. The goals considered in the model formulation are necessary express bus stops, maximum accommodation capacities of the bus stops, and upper limit on the total walking distance walked by all passengers. The model operation is discussed by a numerical example.

Chapter VIII summarizes the dissertation alongwith suggestions for further research in the field.

A list of bibliography is included at the end of the dissertation.

CHAPTER I

GENERAL INTRODUCTION

1.1. INTRODUCTION

Public transport either in the form of railway or bus plays an important role in the every day life of majority of the people due to high expenditure of personalized transport. The economy necessitates railways for long distance transportation where as, for daily commutation and short distance transportation such as transportation in metropolitan cities, bus transport plays a vital role either in conjunction with the railways or independently. The future of the bus transport appears to remain bright even though absolete facilities, growing demands, sharp increase in oil price and cost of spare parts, different restrictions/requirements of several agencies like, the police, politicians, community and the transportation department itself are creating seemingly insoluble difficulties. Therefore, transportation planning is the most urgent need of our metropolitan cities.

Whether government, private business, or non-profit institutions, the planning was being done manually by experienced planners. Two developments in the management science, coincidental in their occurence, contributed to its rapid growth during and after World War II. The first was the electronic computer and the second, perhaps more important the application of scientific approaches to organisational problems. The infusion of these ideas led to several changes in the planning processes. The most apparent among these changes has been the use of specialized quantitative techniques.

The most appreciated quantitative technique which is used for the planning of variety of problems is linear programming technique. The nature of linear programming model is such that all the objectives/goals of the decision maker must be integrated into one objective function in terms of single measurable criterion [15]. This unidimensional property creates an obvious limitation for linear programming technique in handling multi-objective problems which usually occur in real world.

There are two procedures by which multiple objective problems may be solved with the help of linear programming technique. In the first procedure, one required goal is selected as an objective function and the remaining goals as the constraints of the model [42]. From the set of solutions which satisfy all the constraints including goals which are treated as constraints, the computational algorithm will select a solution that optimizes the objective function. Because of the requirement that the optimal solution must satisfy all constraints and goals which are written as constraints will have a higher priority than the goal serving as the objective function. Moreover, all goals which are treated as constraints will have an equal importance to the decision maker.

The second procedure by which the multiple objective problems may be solved by linear programming technique is the transformation of multiple objectives into a single objective. Usually, the transformation is performed by using the utility theory concept, provided that intangible entities can be transformed into a single measurable quantity. But in most cases, an accurate utility function for transforming goals which are incommensurable into a single goal is rarely available. For these reasons, the decision makers are switching from single dimensional objective function to multi-dimensional objective function techniques to solve the problems involving multiple objectives [43].

One of the techniques which consider multi-dimensional objective function is goal the programming technique. In this technique, all of the decision makers' goals may be incorporated into the objective function. The objective function of goal programming is not reducible to a single dimension. The environmental conditions of the problem are satisfied before considering any goal. A set of feasible solutions which satisfies the environmental constraints is established. The optimal solution is then selected from the feasible solutions which best fulfils the decision makers' stated goals.

As mentioned before, the first and second method of solution have some problems concerning an accurate transformation of multiple objectives into a single preference or utility function. Hence, goal programming technique which does not require the transformation of multiple objectives to a single preference or utility function is being used in the recent works by operations researchers and management scientists in solving the multi-objective problems.

Apart from overcoming the above stated difficulties, the goal programming technique deals very efficiently with the problems having conflicting objectives which generally exist in all real world problems. Therefore, goal programming technique is used in the present research work.

1.2. PURPOSE AND SCOPE OF THE RESEARCH

The main purpose of this research is to develop effective goal programming models for transportation planning of metropolitan cities and to demonstrate their application potential in managerial decision-making.

The transportation planning of metropolitan cities being very complex is divided into several planning phases, such as, planning of bus time-table, bus transportation crew, bus trips, bus schedule, and express bus stop location. The model formulations for these phases are explored separately in detail. The choice of goals in these models are based on the requirement of transport management, city councils, police and society etc. For illustration purposes of the models, numerical examples are considered. The computer results of these numerical examples are discussed in detail by changing the priorities of the goals.

The factors which have been carefully considered in the formulation of goal programming models for resemblence with real world problems to the maximum extent, are: (a) The hierarchical structure of the goals because the success or failure of the model is dependent on the careful selection of goals and their relative positions in the priority hierarchy; (b) The interrelation and the interaction among the decision variables in order to obtain a workable model; (c) The number of decision variables and the length of the planning horizon because the model containing too small decision variables will not reflect a sharp image of the real situation. On the other hand, too many variables and long planning periods make the problem too complex and diffused.

In the present work, no attempt is made for detailed studies of bus transportation planning of metropolitan cities. The model structures are limited to deterministic models. The constraints and objective functions of these models are linear. The main attempt here is to investigate the way in which the new concept of mathematical programming such as goal programming can be used as a tool to solve the transportation planning problems of metropolitan cities. The results obtained, thus, can be used as a guideline for the bus transport management of metropolitan cities in checking, modifying and controlling the bus operation for approaching the target as closely as possible.