TRANSIT SYSTEM DESIGN: A MODEL FOR

OPTIMIZING BUS ROUTE ALIGNMENT

by

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ABSTRACT

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Transit Route Alignment

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The design of public transportation networks is made difficult by the multitude of conflicting objectives; at the same time transit agencies are under increasing pressure to provide better transit services while facing increasing costs and reduced budgets.

Bus routing and scheduling variables are very important to transit planning because they are directly related to attributes that affect ridership. Despite the importance of routing to both transit customers and providers, routing has received little attention in the literature and there is a lack of analytical tools to aid transit planners in the design of effective route alignments.

This research addresses some of these issues and presents a decision-making framework to determine bus route alignments using weighted linear programming. The model employs a demand forecasting model and the characteristics of the transportation network to select an optimal combination of route distance and ridership given a set of physical and resource constraints. This technique, in turn, increases operator's revenue through increased ridership and the enhanced use of capital resources.

(95 pages)

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Ana Isabel Ramirez

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CHAPTER I

INTRODUCTION

The design of public transportation networks is a difficult task because it often involves conflicting objectives. Transportation agencies are faced with the problem of providing the best possible service given a fixed budget. In small and medium size transit agencies, the problem is often attenuated by the lack of resources to aid in the design of transit networks.

Bus routing and scheduling are some of the most important areas in transit systems design because consumers are very sensitive to routing and scheduling variables on the downside but much less sensitive to routing and scheduling variables on the upside (Washington and Stokes, 1988). This means that while poor routing will decrease ridership very rapidly, the reverse scenario, very good routing, will only increase ridership slowly.

Among the reasons why bus routing and scheduling are important is that many service attributes that influence transit ridership such as in-vehicle time, waiting time, and number of transfers are directly related to routing and scheduling variables. For example, average waiting time is reduced by a decrease in headway, and number of transfers can be minimized by careful analysis of origin-destination patterns and proper routing.

If transit providers were faced with unlimited resources, improvement of services would be a relatively easy task that could be achieved by reducing headways, decreasing route spacing, or adding new routes. In reality this is never the case and the transit operator's ability to manipulate routing and scheduling variables is constricted by many factors including fleet size and operating budgets. Many times, an improvement or a new service in one area must be achieved through cuts or discontinuation of services in another area.

Because routing and scheduling play such an important role on transit demand, it is imperative to design transit systems that provide the most efficient and effective service given a limited amount of resources.

In recent years, new tools have surfaced that can help transit agencies plan more effective routes. Geographic information systems (GIS) are one of them. GIS have become readily available and relatively inexpensive, and are already being used to solve or as an aid in the process of solving a variety of transportation problems, including hazardous materials shipments and transportation data analysis. In the field of public transportation their use to date has been fairly limited and mostly restricted to inventorying of existing routes and bus stops, analyzing socioeconomic and demographic variables around bus routes, and a few applications in transit scheduling and marketing.

Once a database is in place, GIS can easily produce information that until recently was difficult to compute, such as percentage of population living within a quarter mile of a bus stop or location of major employment centers with respect to bus stops.

Even though answers to these questions have value in themselves, as resources available to transit agencies diminish, there is an increasing need to develop specific methods that utilize this information to improve the existing transit network or plan a new network and that can reasonably predict what the effect of these changes would be.

Some commercially available GIS packages offer shortest path routines that can be used to design certain types of routes given a single objective function and no constraints. These routines generally work well if the problem is simple, for example, alternative paths to transport a package from point A to point B at the minimum cost. But in public transportation route design is never that simple. In addition to minimizing cost there are many other concerns such as maximizing number of trips that can be made by transit, providing access to a variety of areas, and satisfying the demands of different interest groups. What seems optimum to one interest group may not be acceptable to others.

Study objective

This research was undertaken after careful examination of the available literature on bus route aligning. The literature review revealed a lack of analytical tools in this area of bus network design.

The primary objective of this research project is to develop a decision-making framework to determine the "best" alignment for transit routes under a given a set of physical and resources constraints. The best in the present case is defined as the alignment that maximizes coverage (maximizes ridership within a predetermined distance of the route) and minimizes route distance (implying savings in operator costs).

With changes in land-use and economic development that have occurred in recent years, travel in many cities does not conform to the traditional many-to-one pattern where most trips start at a residential area and end in the central business district. Many of these cities are also characterized by low population densities, which makes the provision of services difficult and at the same time expensive.

The first part of the study will be devoted to the identification of key variables and/or factors that are linked to transit use. It includes a search for suitable methods for forecasting ridership.

The second part of the study will use these variables in a model to determine route alignments, given a set of constraints. The constraints will represent both operator-related concerns such as not exceeding the number of vehicles available and user-related concerns, for example, ensuring access to key destinations.

The role of GIS in the study will be to help visualize transit, land-use, and socioeconomic relationships and to act as an aid in manipulating spatial data as needed to run the model.

Figure 1 (at the end of this chapter) outlines how different components in the modeling process relate to each other. It also shows the required inputs and outputs produced by each of these components.

Methodology

The following tasks were undertaken to meet the objectives of the present study.

Task 1: Review current industry practices related to bus routing and scheduling (literature search). The objective of this task was to gather all relevant literature concerning transit route design as well as other types of route design that the author found pertinent to this study. Special attention was given to applications using GIS and network analysis methodology. A review was performed of both domestic and foreign literature.

Task 2: Identification of model to be used in transit ridership prediction and role of geographic information systems. In this task, first the model to be used for ridership prediction was identified as well as the variables needed to run the model; secondly sources of data were identified; and finally the role of GIS in data analysis and preparation of input data to the model were explored. Socioeconomic data required for modeling were obtained from the 1990 U.S. Census of Population and Housing and spatial data were read from the U.S. Census Bureau TIGER files on CD-ROM format.

Task 3: Model formulation. Throughout this task, weighted linear and integer programming techniques were used to developed a routing scheme that optimized a bus route with respect to the variables and constraints identified in the "Study Objectives" section of the present chapter. The mathematical modeling package LINGO was used to solve the routing optimization problem.

Task 4: Model validation. This task was concerned with the validation of the model developed in Task 3. Different combinations of weights were used in the model's objective function to see the changes with respect to the variables being optimized. Changes with respect to the model's physical and resource constraints were also explored during this task.

Task 5: Conclusions and recommendations. This task is concerned with the discussion of the model results and recommendations for further research.

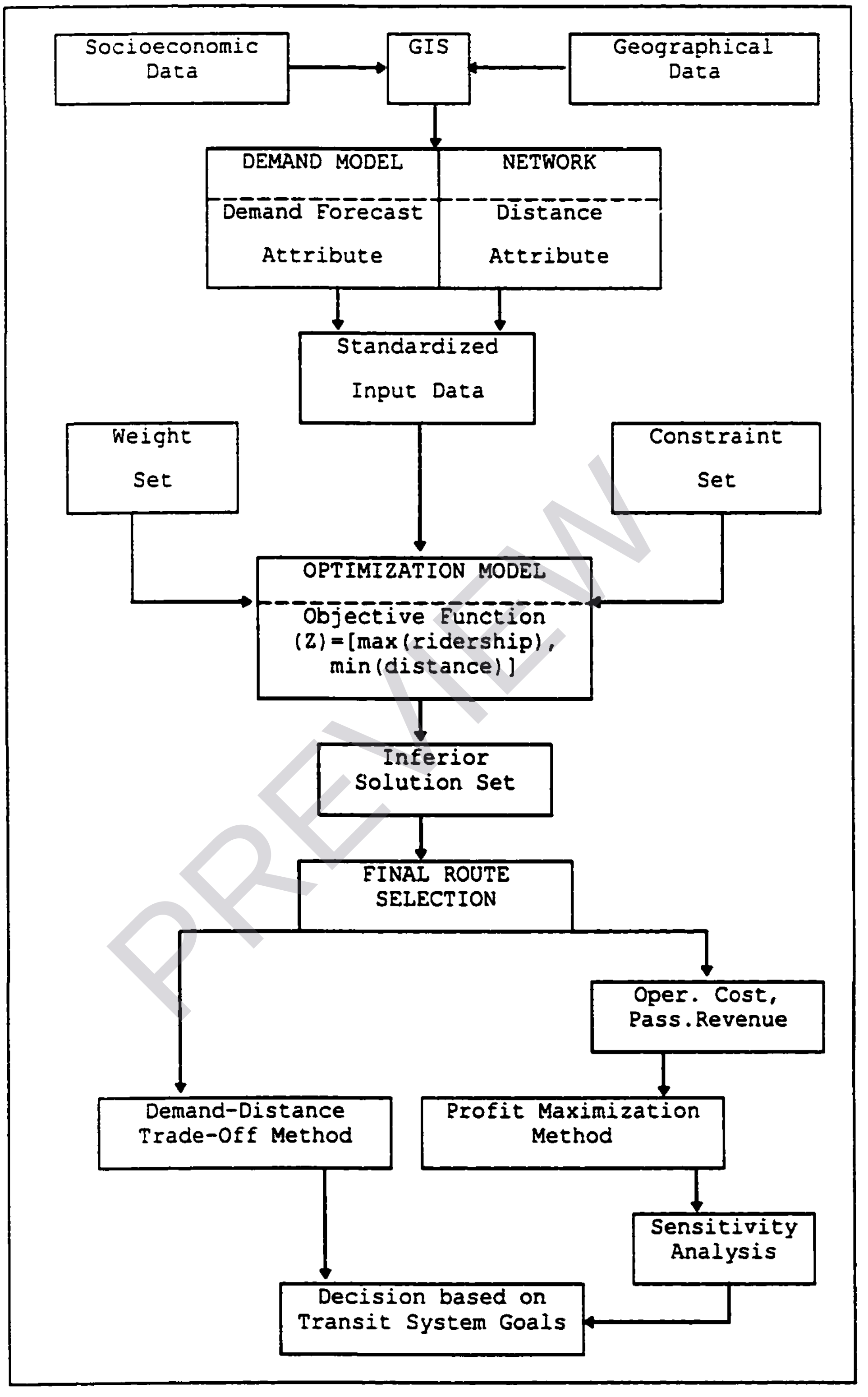

Figure 1. Route design framework.