

## 1. INTRODUCTION

Population growth exerts considerable pressure on infrastructure and natural resources in urban regions. One of the most obvious in daily life is the transportation system, both in terms of how it impacts the environment and the congestion typically experienced in most cities. How additional transportation demand will be served in growing urban regions is considered to be an important issue for achieving sustainability. Indeed, the relationship between the transportation system, urban form, trip demand, and energy use is paramount in addressing the challenges presented by urban growth. This may be attributed to the considerable economic inefficiency and environmental degradation associated with excessive private vehicle travel based on current technology. For these reasons, public transportation is recognized as a key component in the management and planning of urban regions.

Public transport represents a means by which people can efficiently move throughout a region with the least amount of impact on the environment. However, automobile travel offers individuals more freedom and flexibility in movement. Most urban regions in Australia and the United States, for instance, must contend with inherent automobile dependence and a reluctance of individuals to make a switch to public transportation.

The challenge for urban planners and decision makers is to identify effective strategies for dealing with resistance to travel by public transport. One important factor is ensuring that the urban public transport system is a viable travel alternative. In particular, the system must get people from where they are to where they need to go in a reasonable amount of time. Most urban regions with existing public transportation typically do a relatively good job at ensuring that stops and routes are established to sensibly serve origins and destinations. Those systems with low utilization rates, however, tend to have more difficulty competing with automobile travel times.

From the previous discussion, access provision and system efficiency are both important elements of public transport service. Thus, strategic modeling and analysis approaches are needed for evaluating public transport access and efficiency within the context of regional policies. This will better facilitate debate and discussion regarding the effectiveness of current services as well as establish a framework for developing system changes that ultimately provide better service.

Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt

appropriate new technologies from other industries, and to introduce innovations into the transit industry.

The adjustment of old networks to new needs must occur across unitary and organic vision of the problem in order to obtain maximum economy for the resources employed and maximum functionality for transport users.

The *Network Design* is certainly the most recurrent matter, at all the decisional levels, when facing the problems of planning: at the strategic level, when it is necessary to decide about the financing of large facilities such as the construction of large infrastructure; at the tactical level, when it is necessary to reorganize the lines of a urban bus network; and in more general terms, when a urban traffic control with several transportation modes has to be performed.

This study focuses on only a single transportation mode, urban bus transit system. Its purpose is to analyze and evaluate the need for upgrades and improvements in order to provide a more attractive network configuration according to the parameters of service quality and efficiency. The methodology will be to identify the most efficient improvement among a set of recommendations by conducting a Benefit Cost analysis.

Stop spacing, line spacing and vehicle frequency are key variables on bus network design and operability. They determine the costs for the operator and the travel time for the passengers. Therefore, it is important to ascertain their relationships and their influence on the final network design. This study will compare and analyze the current values of these parameters for the bus networks in Chicago and Barcelona, detect their deficiencies, and propose new values to improve the efficiency in both networks.

Network design planning process based on decision support tools has been increasing steadily for the past years. Decision support tools provide the designer with additional information on quantifying the consequences of a certain design, therefore complementing the designer's knowledge and own experience.

Decision support tools are generally analytical models that represent the reality that needs to be designed. For instance, in the case of bus network design, a decision support tool would be an analytical model that described the bus network through the parameters that are subject to study.

For the purposes of this study, an analytic model that takes into account the key design variables for a bus network service (stop spacing, line spacing, and vehicle frequency) will be chosen. The model will be described, justified for its selection and applied to the bus networks of Chicago and Barcelona. The results obtained with this model will be analyzed and will derive in a set of recommendations for the networks' improvement.

The model chosen to analyze the current bus networks efficiency and quality of service, as well as propose new values for the networks' parameters in order to provide a better service, is the analytical model proposed by van Nes (1999).

The model uses a mathematical formulation of the interests of the parties involved in the bus transit system (users, operator and authority) as the means for optimizing the key design parameters of the bus network.

This study will focus first on the description of the urban and socioeconomic characteristics that condition the operations management of a bus network, followed by the identification of the most efficient bus network configurations for the cities of Chicago and Barcelona, using the above mentioned analytical model.

The structure of this paper is as follows. Section 2 states the objectives of this study, followed by Section 3, which familiarizes the reader with the main concepts for urban bus operations (such as the description of the parameters involved in a bus network and their relationships).

The following section, Section 4, presents the analytical model used to represent the bus networks. It contains a detailed description of the model, including an explanation of the mathematical formulation of the parties' interests on the performance of the network. It also includes a review of other analytical models that, though being acceptable in their reasoning, were discarded for their use in this particular study.

Section 5 gives general information about both cities and their street layout. This information includes geomorphologic characteristics of the cities, as well as some data on the cities' land use and mobility patterns.

Section 6 analyzes both bus networks operability's, focusing on describing the key design variables for the network. Other network characteristics are also defined, such as the commercial vehicle speed.

Section 7 analyzes the mobility in both cities, regarding the public transportation supply and demand. This section emphasizes on the distribution of public transportation users among the different available transit modes. Sections 5 thru 7 are the sections intended to describe the urban and socioeconomic characteristics in both Chicago and Barcelona, in order to provide the reader with a clear picture of the trends, possibilities, and deficiencies associated with public transit system in the cities of Chicago and Barcelona.

Section 8 contains the application of this model to the two cities. It starts with the data gathering justification, followed by the results of the model application. And finally, Section 8 validates the use of the analytical model for the particular case of the cities of Chicago and Barcelona.

Section 9 presents the results of this model and proposes some improvements for the networks by means of a set of applicable measures, taking into consideration the specific characteristics of both cities.

Next, Section 10 presents some concluding remarks about the implementation of the applicable measures stated in Section 9. This paper is concluded by Section 11, presenting some recommendations for further research.