MULTIMODAL NETWORKS FOR URBAN PUBLIC TRANSPORTATION ROUTE PLANNING IN BARCELONA: A DECISION-MAKING PROBLEM FROM THE INDIVIDUAL'S PERSPECTIVE

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RESUMO
O âmbito desta pesquisa é um estudo sobre a modelagem de transporte público urbano. Ainda que os problemas de modelagem neste âmbito são um tema bem estudado, existe uma lacuna entre as metodologias e construções teóricas e as práticas atuais em transporte público urbano sob a perspeciva do pedestre. O objetivo principal desta pesquisa é desenhar um modelo de redes multimodais para o planejamento de rotas em transporte público urbano desde uma perspectiva comportamental do pedestre. O modelo proposto debe ser capaz de resolver problemas de tomada de decisão usando informação dinâmica. A perspeciva filosófica da pesquisa é basicamente a positivista, ainda que na fase atual da pesquisa, a abordagem interpretativa está sendo usada para analisar os dados comportamentais do pedestre. A pesquisa operacional é usado para realizar a análise, desenvolvimento e implementação do modelo proposto, Ademais, são usados dois outros métodos de pesquisa. Por um lado, o método *grounded theory* é usado para desenhar a árvore taxonômica do domínio da impedância comportamental. Por outro lado, o método *case study* é usado para validar o modelo proposto. Finalmente, as contribuições principais deste pesquisa incluem um estudo bibliográfico extensivo sobre planejamento de rotas desde a perspectiva do pedestre, uma proposta de taxonomia da impedância comportamental, um modelo de rede multimodal para transporte público urbano desde uma perspectiva comportamental do pedestre e um protótipo de sistema de planejamento de rota implementando o modelo proposto.

ABSTRACT
This research scope is a study on urban public transport modeling. Although the problems of modeling in this field are a well-studied subject, a gap between theoretical constructs and methodologies, and current practices in urban public transportation from an individual's perspective has been identified. The main goal of this research is to design a model of multimodal networks for urban public transportation route planning in Barcelona from a pedestrian's behavioral perspective, which must be able to solve decision-making problems using dynamic information. The research is mainly based on positivist philosophical perspective, although interpretative approach is being used to analyze the pedestrian behavioral data in the current phase. Operations research is used to carry out the analysis, development and implementation of proposed model. Moreover, two research methods are used. On the one hand, the grounded theory method is used to design the taxonomic tree of the behavioral impedance domain. On the other hand, the case study method is used to validate the proposed model. Finally, the main contributions of this research include an extensive bibliographic study on route planning from the pedestrian's perspective, a taxonomy proposal of behavioral impedance, a multimodal network model for urban public transportation from a pedestrian's behavioral perspective, and a route planning prototype implementing this model.

1. INTRODUCTION

Nowadays, although modeling of transportation networks is a well-known topic and there are several projects developed in this field, the application of these models to specific cases is a complex and hard task. This task becomes more difficult, when the network system is integrated by two or more modes of public transportation (e.g. bus, walk, underground, etc.), and the route planning analysis is carried out from an individual's perspective. Moreover, political interests delimit research and projects.

The main focus of this research is to propose a multimodal network model for urban public transportation from a pedestrian's behavioral perspective (MNM-B). In the present research context, a "pedestrian" is defined as someone who needs to go from an origin-point to a destination-point using a public transportation network. In this model, decision-making

problems can be solved using dynamic information of the system and considering pedestrian behavior.

Several authors deal with problems, strategies and contexts not only addressed in the analysis of public transportation networks but also in the decision-making approach. For instance, Florian (1986) surveys a study on nonlinear cost models of transportation systems; DeCorla-Souza and Jensen-Fisher (1994) survey a study based on assessing the economic efficiency of best alternatives; and Schafer and Victor (2000) present a study in which future mobility is predicted.

In this context, this research is placed in the field of geographic information system (GIS). Laurini and Thompson (1992, p. 22) use the name spatial information system to refer to GIS and define it as "a computerized environment whereby utility programs performing specific functions are used in an integrated environment, in which the user is shielded from the details of computer processing, to achieve some goal of research, education or decision making". Thill (2000) comments on the increase of the use of GIS for transportation, and Oliveira and Ribeiro (2001) also present a system for the analysis of urban traffic control problems.

The structure of the paper is as follows. Section 2 surveys the definition of the research problem. Section 3 deals with the philosophical position and the research methods used in this research. Section 4 briefly comments on the work plan of this research. Section 5 presents the concluding remarks.

2. DEFINITION OF THE RESEARCH PROBLEM

As commented before, this study is about urban public transport modeling. Although the problem of modeling is a well-studied subject, a gap between theoretical constructs and methodologies, and current practices in public transportation from the pedestrian's behavioral perspective has been identified. This gap implies very expensive implementation costs. The method chosen to analyze and solve the individual's behavioral problem requires the use and analysis of graph theory, route planning techniques and network models for urban public transportation. Also, the combined use of advanced traveler information systems can help understanding how a pedestrian performs his/her route choices.

Thus, one of the main problems found in the present research is the decision-making problem (DMP) for the selection of best routes in a public transportation network system from the individual's perspective. Shriver (1997, p. 64) argues that "pedestrian activity occurs as a function of physical and behavioral characteristics that influence individual travel decision". This approach entails strategies of travel reduction by private transport (e.g. travel by car) through switching or substitution by public transport (e.g. travel by walk, bike or rail). They are studied and commented by authors such as Gärling *et al.* (2000) and Marshall and Banister (2000).

Consequently, it is necessary to implement an efficient travel demand model (TDM). The TDM can be static or dynamic. The problem of travel demand is defined in two instants of route planning: (1) before the pedestrian starts his/her trip and (2) during the trip. In both moments the results of the search are static ones, although route planning systems (RPS) take into account all available information. In the second moment, the pedestrian can ask for a recalculation of his/her route, starting from the current localization point. A RPS should be

able to get new information, to recalculate new values, and to propose new route options.

In this context, dynamic network flow problems (DNFP) are an open research topic that helps us to solve these stochastic problems. Glockner and Nemhauser (2000) present a method to solve stochastic programs that are modeled as DNFP. Guzolek and Koch (1989) and Nelson *et al*. (1993) also present methodologies used in a real-time route planning system that can provide this research with important support. The results of the study presented by Adler (2001, p. 12) "suggest that drivers with limited familiarity with a roadway network can improve wayfinding performance in the short run by acquiring information".

3. RESEARCH METHODOLOGY

This research is mainly based on a positivist philosophical perspective, although the interpretative approach is being used to analyze the pedestrian behavioral data in the current phase. The importance of finding the cause-effect relationships and regularities in our study subject is clearly evidenced in the positivist approach. Furthermore, some methodological characteristics (e.g. formal propositions, the use of Logic and Mathematics to provide a foundation of science, and hypothesis testing, according to several authors such as Myers (1997) and Orlikowski and Baroudi (1991) used in this research have been identified.

Furthermore, the case study method (Yin, 1994; Lee, 1989; MacNealy, 1997) will be used to validate the model proposed. The case study method "is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomena and the context are not clearly evident" (Yin, 1994, p. 13).

As commented before, one of the problems found in the present research is the DMP, which is an operations research problem and can be solved by deterministic and probabilistic approaches. Now, operations research will be used to solve this type of problem, which is basically composed of three main components: a set of alternatives, a set of constraints and a set of objectives, according to several authors such as Taha (1997) and Wallace (2000).

4. WORK PLAN AND CURRENT PHASE OF THE RESEARCH

The research project where this work is included is composed of six major phases. The first phase represents a continuous bibliographic review. The second phase was a study on sidewalks in the university zone of Barcelona (Pereira and Pérez, 2000). In this phase, an experimental application has been proposed and the management, map and route modules have been implemented.

The current phase of this research is the study of a behavioral impedance domain, which is used to manage the constraints of an urban public transportation network from a pedestrian's perspective. Behavioral impedance (BI) is the term used to refer to the constraints universe related to route planning techniques basically from a pedestrian's perspective.

The fourth phase is characterized by the complete design and implementation of the MNM-B prototype. In the fifth phase, the calibration and validation of the MNM-B model will be performed. Finally, the analysis and generalization of the results acquired through application of the prototype to the selected case study (Barcelona) will be carried out in the sixth phase.

6. CONCLUDING REMARKS

The proposal of a multimodal network model for public transportation from a pedestrian's behavioral perspective (MNM-B) is the final goal of this research. For this, The MNM-B model based on the dynamic decision-making process will be designed after (1) the analysis of mono- and multimodal models found in specialized literature, and (2) the study of behavioral impedance domain in which several issues, such as environment and transportation policy take place. Furthermore, MNM-B could be very important for the mobility of a pedestrian in urban areas.

The main contributions of this research include an extensive bibliographic analysis, a taxonomy proposal of behavioral impedance, a multimodal network model for public transportation from the pedestrian's behavioral perspective, and a route planning prototype implementing the MNM-B model.

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