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Parking Choice Model Based on Parking Behavior Characteristics

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ABSTRACT :

This research focuses on the derivation of an assignment model that can be used for the evaluation of Smart Parking ITS applications. Behavioural research is conducted in order to gain understanding of the individuals' behaviour concerning parking, on three behavioural levels (Strategic, Operational and Tactical), and for two user classes (Familiar and Unfamiliar users). A Parking Decision Process model, which represent the decisions that individuals have to take when parking is suggested. A Stated Preference experiment is conducted –designed using efficient designs– for the investigation of decisions for familiar and unfamiliar users and discrete choice models are derived for familiar users. The outcome of the behavioural research (Parking Decision Process model & MNL Parking Discrete Choice model) is applied in the development of a Parking Assignment Model for simulation on the behavioural levels for both user classes. The components of the Parking Assignment Model are verified and the applicability of the model is examined. Finally, the Parking Assignment Model is applied for the evaluation of the Smart Parking application, developed for the Sensor City project in Assen. The results of the evaluation illustrate the positive impact of the Smart Parking application to the reduction of individuals' and total travel times.

1.INTRODUCTION :

1.1 Research Motivation

Parking in urban areas is an issue of increasing importance, especially the last few years. There is voluminous literature concerning the problems consequential to the high parking demand, with researchers indicating that the average volume of the total traffic related to parking during peak hours in city centers can reach 30 to 50 percent of the total traffic (Shoup,2006; Arnott and Inci, 2006). As each trip ends to a parking spot, searching (*cruising*) for parking is a phenomenon widely met in the urban environment, and it is related to problems in terms of to name but a few: lost time, fuel consumption, traffic flow, safety and emissions (Kaplan and Bekhor, 2011). The main instrument for reducing the impact of parking is the development of parking-related policies. Those balance the demand and supply for parking with the most prominent to be parking pricing (Lam et al., 2006). However, as parking pricing policies reach their limits due to social and political reasons, the need to develop new systems to alleviate the parking impact has become imperative. Lately, Intelligent Transport Systems (*ITS*), and more

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specifically Smart Parking applications are being designed and require evaluation before being implemented on a wide scale.

1.2 Evaluation Approach

The evaluation of a Smart Parking application can be achieved by the evaluation of the situation without the application (reference case) and then, the evaluation of the situation –as predicted– with the application (proposed case). The evaluation on a real network and in a wide scale is most times impossible and for that reason *models* are being developed to represent the decisions and actions taken, in both the reference and the proposed case.

The parking process includes decisions and actions on how individuals cruise for parking, the parking destinations chosen and the routes taken to reach those destinations. The difference between the reference and the proposed case is found on the affect the Smart Parking appli- cation has on those decisions and actions. This directly suggests that the model definition of the parking process at the reference case and the effect Smart Parking application has on it are the two modelling modules required for the evaluation of a Smart Parking application (Figure 1.1).

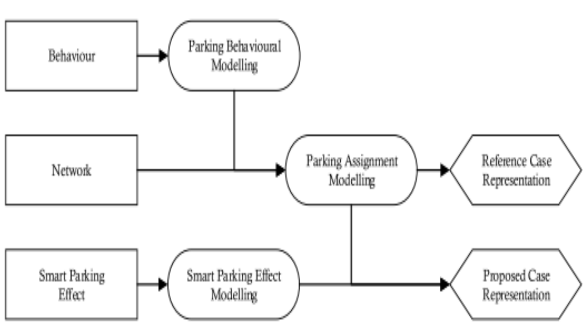

Figure 1.1: Components of the evaluation and evaluation approach

For the reference case, the need for the development of a *Parking Assignment Model*, on the basis of models that represent the behavior concerning parking was found to be imperative for two user classes (Familiar and Unfamiliar parking users). This should be accomplished in a way that enables the introduction of the Smart Parking applications effect. The investigation of the decision involved and the modeling of those decisions for assignment purposes implies the conduction of behavioral research.

1.3 Smart Parking

Smart Parking is a **parking reservation system** that can be described as it consists of mainly three entities: the user, the parking facility agent and the parking management agent (Figure 1.2). The user entity is connected to the system via a device able to communicate (GPRS-3G) and to track position (GPS/GNSS/Galileo). The parking facility entity that provide services (parking spaces) and information to users. The third entity is a control agent that gathers information from the user and the parking entities as well as from various other sources (traffic counts, road sensors) in real time and combines all pieces of information into a suggestion for reserving a specific parking space (Jonkers et al., 2011). The conceptual design of the system informs the driver about the closest - to the destination - available parking spots

15 minutes before arrival to the destination and encourages the driver to reserve a parking spot.

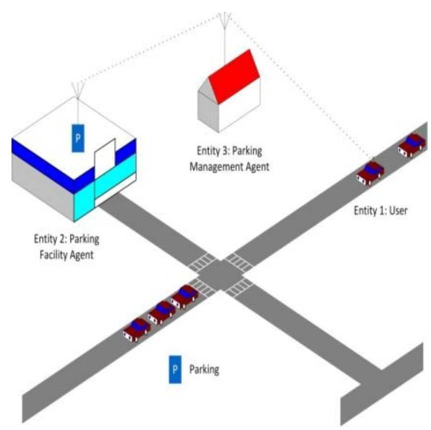

Figure 1.2: Smart Parking entities

2.Related work

One of the first papers for parking indicated that parking-related problems are the result of people wanting to park exactly outside the door of their destination (Behrendt, 1940). The increase of transportation demand changed the problem towards the difficulty of finding a vacant parking spot at all. Searching for a parking spot became a reality and solutions were proposed oriented towards increasing supply by building (usually) off-street parking. As this approach was found to create problems, the solutions were then oriented towards managing demand with policies or information applications.

The need to find solutions to the parking related problems arose the need for representing parking choices and derive models that would represent the parking dynamics. Starting from the very basics, a model is a "simplified representation of a part of reality " used to investigate a part of the real world and what will happen in case of changing something (Bovy et al.,2006). In the beginning models were very simple. However, managing demand requires more detailed characteristics of demand, yet representing the way individuals behave in relation to parking, more sophisticated models arose.

3.Theoretical Parking Behavior

The understanding of the decisions taken in the parking process, and how individuals decide upon them are crucial for the representation of the parking process. The definition of the parking decision process model and the discrete choice models help towards this direction, with the investigation of the attributes which shape those decisions and the way individuals evaluate the available alternatives to be required. In order to fulfill those requirements there is a need to explicitly define and analyze the parking system (users, network), and the decisions behavioural levels. The behavioural research is going to be used as the basis for the parking assignment modeling framework.

3.1. Process model & Choice model Derivation Process

The derivation of a Parking Decision Process model including the conceptual design of the choice models incorporated and the conceptual experiment design are conducted based on a

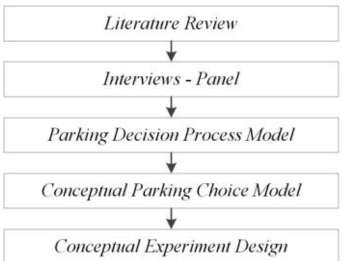

Figure 3.2: Derivation Process

systematic process presented in (Figure 3.2). The need for a choice model that would accommodate the representation of some parking- related decisions, taking into account the interaction with the transport system was used as a guideline. The starting point of this process is the available literature on parking modeling. The models used to represent parking behavior, the user classes for which behavior was modeled, and the data collection methods were investigated (presented in Chapter 2). Furthermore, the modeled attributes were identified and categorized based on their frequency of appearance.

3.2 User Classes

Before continuing with any decision process specification, there is a need to investigate the users (also referred to as travel lers or individuals) of the system and try to aggregate them into groups (users' classes) characterized by the same decisions process. The results of inter- view, the nature of the motivation system and the conclusions of the literature study lead to distinction of two user's classes. The travellers which are **familiar** with the parking situation at the destination and those who are **unfamiliar** with that situation.

In is clearly evidenced in the literature, that transport research usually focuses on travellers who are assumed to have knowledge of the system (see Bovy et al., 2006). This cannot always be the case – especially for parking. Travellers might be unfamiliar with the parking situation at areas of the cities they even dwell. It is logical that in case someone is unfamiliar with the parking situation cannot be treated as part of a group which assumes full knowledge. Unfamiliar users take different decisions, or even considers different levels of alternatives characteristics. However, there is nothing preventing unfamiliar users from becoming familiar, by acquiring knowledge of the transport system.

3.3 Parking Behavioural Levels

Parking behavior is analyzed on three behavioural levels, with respect to the undergoing behavioural process of individuals: Strategic, Tactical and Operational. Those three levels apply for both the familiar and the unfamiliar users however, different decisions are involved in each user class.

In this research, the **strategic** level incorporates the strategy individuals' devise before trip, in order to park. The **tactical** level deals with the interaction between the individuals and the traffic and parking dynamics. This level includes decisions to proceed from one parking destination to another one, given the strategy mentioned above. Furthermore, this layer contains decisions which are related to the change of the initial strategy after interacting with the transport system. Finally, the **operational** level is related to link choice when cruising, or route choice decisions while it is intended to travel from one parking destinations to another.

3.4. Behavioural Concept

The interviews and the panel conducted showed that there is a distinct pattern of behaviour among familiar and unfamiliar users. For that reason the description of every model is based on that pattern.

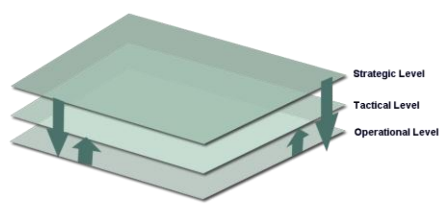

Figure 3.3: Parking Behavioural Levels

Familiar The discussion during the panel study and interviews illustrated an existence of a habitual pattern of people when choosing parking. The traffic situation at the destination as well as the state of the parking destinations available was found to be crucial in the decision process. However, it was also observed that people expect a certain amount of delay (cruising) when they want to park. In other words, people would visit a parking destination if they would expect to find a vacant parking spot in a “short” period of time but would not wait or search if this period becomes “long”. This train of thought led to the following behavioural concept:

3.5. Parking Decision Process Model

There is a twofold reasoning behind the illustration of the decision process concerning park- ing: to set the guidelines based on which the survey experiment is designed, and to guide the parking assignment framework models derivation. More specifically, the decision process framework was employed to describe the decisions taken while choosing a parking destina- tion (Figure 3.4). As already mentioned it is a corollary of the literature review, individual interviews and panel interviews. The random traveller (decision maker) who wants to travel to a city centre, **by car** can be described by a set of attributes describing the traveller (e.g. age, income, gender, age, area of living, network familiarity) and a set of preferences for the attributes which can characterize the parking alternatives. As described above, the main differentiation in the behavioural process is found based on familiarity with the parking situation at the destination.

4.Parking Assignment Model Application

The Parking Assignment Model modules capable of simulating parking in an urban environment, for the representation of the existing situation (reference case) and for representing Smart Parking Applications as scenario cases. The suitability for evaluating Smart Parking applications lies on the behavioural representa- tion of the perception on the probability of finding a vacant parking spot, which is the basis of parking-related ITS applications. The strategic level of the parking assignment model have been verified in Chapter 6 ensuring only partially the applicability of the Parking Assignment Model. In this chapter the rest of the components are verified and the applicability of the model is evaluated based on an implementation in the context of the Sensor City project for the Smart Parking application.

The implementation in a simulation environment have some requirements that should be met. In this study, the Parking Assignment Model is implemented in ITS modeller, a (Java- programmed) modelling environment, developed by TNO to simulate Intelligent Transport Systems (ITS). The reasoning for using ITS modeller and the limitations that lead to a partial implementation of the Parking Assignment Model are presented.

The evaluation of the Smart Parking application took place the city network of Assen for 5 scenarios developed. It is important to state that due to network limitations and limitations of the ITS modeller (see Section 7.3.1), the implementation takes into account only off-street parking and for an illustrative traffic demand that does not correspond to the realistic travel demand of the city. The scenarios developed are based on illustrative values of unfamiliar users and smart parkers.

Parking Search Route: The simulation is required to be able to include routes with mul- tiple *visit points*.

Information transfer: The simulation is required to be able to include some type of infras- tructure that can transfer information to individual actors such as Message Signs.

Decision Points: The simulation should have points where the parking search route strategy should be re-evaluated based on the input from the network.

Route Derivation en-route: During the simulation routes must be able to be derived.

Intersection direction choice: A decision should be able to be taken every time a vehicle is reaching an intersection while searching for on-street parking.

Ability to represent Parking Facilities On-street and off-street parking facilities should be modelled, in such a way that would make it possible to replicate the on street parking procedure and the parking manoeuvring.

Conclusions

This thesis presented the development of a simulation-based parking assignment model for the evaluation of Smart Parking applications.

Behavioural research was conducted, proposing a decision process model, that describes the choice for two user classes (familiar and unfamiliar parking users), on three behavioural levels (strategic, tactical and operations). A survey was conducted with 397 complete/stratified responses for the investigation of those decisions and several model structures were examined to derive the model that can best represent parking choices. The attribute set used in the experiment was based on those found in the literature, yet different, by combining the probability of finding a vacant parking spot and the search time, into the newly introduced attribute of the probability after some minutes of searching/waiting. All attributes investigated were found to be significant in the model structures examined, supporting this inclusion.

The two probabilities investigated (upon arrival and after some minutes of searching) allow for the connection of the parking system with the choice of individuals as they were defined using parking related stochastic characteristics such as the arrival rate and duration. For that reason, a novel probability model based on simulation is introduced to approximate the true probability experienced by individuals.

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