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PARKING CHOICE BASED ON MODELLING OF BEHAVIOR OF PARKING

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Abstract

This examination concentrates on the inference of a task model that can be utilized for the assessment of Smart Parking ITS applications. Behavioural research is led to increase comprehension of the people's conduct concerning parking, on three behavioural levels (Strategic, Operational and Tactical), and for two client classes (Familiar and Unfamiliar clients). A Parking Decision Process model, which speaks to the decisions that people need to take when parking is proposed. A Stated Preference test is directed –designed utilizing effective designs– for the examination of decisions for commonplace and new clients and discrete decision models are inferred for recognizable clients. The result of the behavioral research (Parking Decision Process model and MNL Parking Discrete Choice model) is connected in the improvement of a Parking Assignment Model for re-enactment on the behavioral levels for both client classes. The segments of the Parking Assignment Model are checked and the appropriateness of the model is inspected. The after effects of the assessment represent the positive effect of the Smart Parking application to the diminishment of people's and aggregate travel times.

Key Words: Smart Parking, MNL Parking, Behavioral research, Parking Decision Process.

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1. INTRODUCTION

1.1 INTRODUCTION

Parking in urban zones is an issue of expanding significance, particularly the most recent couple of years. There is voluminous writing concerning the issues considerable to the high parking request, with specialists showing that the normal volume of the aggregate movement identified with parking amid pinnacle hours in downtown areas can achieve 30 to 50 percent of the aggregate activity (Shoup,2006; Arnett and Inci,2006). As each outing closures to a parking spot, seeking (cruising) for parking is a wonder generally met in the urban condition, and it is identified with issues as far as to give some examples: lost time, fuel utilization, activity stream, security and emanations (Kaplan and Bekhor, 2011). The primary instrument for lessening the effect of parking is the advancement of parking related approaches. Those adjust the request and supply for parking with the most conspicuous to stop valuing (Lam et al., 2006). Be that as it may, as parking estimating strategies achieve their limits because of social and political reasons, the need to grow new frameworks to lighten the parking sway has turned out to be basic. Of late, Intelligent Transport Systems (ITS), and all the more particularly Smart Parking applications are being composed and require assessment before being actualized on a wide scale.

In the writing models depicting the parking process are still in their infantry (Young, 2008; Lam et al., 2006). A large portion of them are specially appointed models produced for a specific application (Young et al., 1991) or just manage parking under particular generally stationary (Lam et al., 2006)- conditions that can't matter for its applications (Mahmassani, 2001a). There are exceptionally restricted parking reproduction models (Gallo et al., 2011; Guo et al., 2013; Benenson et al., 2008), on generally a hypothetical level, which research parking, without considering the behavioural attributes in the task process. This prompts the conclusion that there can be a sufficient model that would consider the behavioural qualities, for modelling Smart Parking applications.

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 needs 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 investigated part of the real world and what will happen in case of changing something (Bovyetal.,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.

The main reason for modelling parking is to test applications or policies which would be disturbing and costly in real life. As transportation is closely interrelated to human behaviour a rather big part of transport modelling is the representation of the discrete decisions taken by decision makers. Data is required in order to derive models with data collection methods to be of increased importance.

3. THEORETICAL PARKING BEHAVIOUR

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 fulfil those requirements there is a need to explicitly define and analyse 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 modelling framework.

The decisions are explored on a decision process level starting with pre-trip decisions and moving towards the decisions taken while individuals interact with traffic (on-trip). In order to have a clear structure of the decision process it is chosen to categorize decisions on a three-layer behavioural model. Different users of the network imply the definition of user's classes.

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 systematic process. 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 modelling. The models used to represent parking behaviour, the user classes for which behaviour was modelled, and the data collection methods were investigated. Furthermore, the modelled 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 *travellers* or *individuals*) of the system and try to aggregate them into groups (*users' classes*) characterized by the same decisions process. The results of interview, 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.

3.3 Parking Behavioural Levels

Parking behaviour is analysed on three behavioural levels, with respect to the undergoing behavioural process of individuals: Strategic, Tactical and Operational. Those three level

supply for both the familiar and the unfamiliar users however, different decisions are involved in each user class.

In this project, 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. **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 parking: 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 destination.

3.6 Familiar Users

If a traveller is familiar with the system, there are various important factors that affect their decisions. Based on personal characteristics, trip characteristics and of course parking characteristics the decisions of route choice and parking destination can described by a habitual pattern on the strategic level – before the initialization of the trip. The general idea is that by assigning utilities to each alternative familiar travellers choose both route and destination I na process which maximizes utilities (or minimizes disutility's) for both choices. The strategy realised is structured as a *strategic parking search route*.

3.7 Unfamiliar Users

Although unfamiliar travellers generally search for information's (Maps/navigation devices) before making a trip, there might by a different approach when deciding for parking on the strategic level. Speed of searching, rationality of decisions and choices are rather influenced by the unfamiliarity effect. However, it is believed that people who search for information can be treated as familiar users as they have altered their parking destination based on the information gathered.

4. EXPERIMENT DESIGN AND MODEL ESTIMATION

The design of a survey and the analysis of the acquired information are both very importantcomponents of behavioural research. As the system describing the behavioural responses ofindividuals is complex, its identification and the investigation of the experimental designswere rather limited to some basic concepts of efficient designs.

4.1 Experiment Design Process

The experimental design process for the familiar section was initially implemented from data from the literature and compared to the orthogonal design. The comparison was made on the D-error estimator (the determinant of Variance Covariance Matrix). As expected, the orthogonal design was found to be ineffective with many scenarios to be governed by dominating alternatives. As such, the first round of the pilot study was introduced to have a clearer indication of the estimators. Afterwards, the design process continued with the derivation of the second round's designed was completed with the final design. All the experiment designs were produced using Ngene. The model structure chosen to use for the designs was the MNL model.

4.2 Pilot Study: First Round

In this design there were some dominant alternatives in some scenarios and the information that could be acquired was not the maximum (the design was sub-optimal) mainly due to the combination of the two studies. However this design could again accommodate more information than an orthogonal design (which yielded a higher number of dominant scenarios)and it was chosen to be implemented in the first round of the pilot study with a small sample.

After acquiring the answers from 11 respondents an MNL model was estimated using **BIOGEME** based on their responses for the second round of the pilot study. Feedback was also provided with most respondents indicating that the survey was rather demanding and large. The MNL model estimators form the **1*LPr*** estimators' set to be used in the design of the experiment, for the second round of the pilot study. It has to be stated, that the results of this model (based on the *0LPr*) can be considered as biased. The reason this stands is due to the fact that the model represent a very small and behaviourally specific sample of outside students who live in the town, having a drivers license and occasionally using a car. However, it is believed that it provides a better representation of the estimators of the model and that the values of the estimators are closer to the vector of true values (_0). This is believed due to the fact that the **0*LPr*** were normalized estimators' values of attributes which were similar to the attributes investigated.

4.3 Pilot Study: Second Round

The second round of the pilot study is based on the *0LDes* design, from the **0*LPr*** priors. Some changes were implemented in the design, based on the information and the feedback acquired from the first round. The walking distance from destination was increased to 700meters, as it was found that 500 meters was not considered to be much different in individuals' perception from the 100 meters (during discussions after filling out the questionnaire most respondents indicated that it does not make a difference to have to walk 500 or 100 meters).

Furthermore, the travel time from home was changed towards more realistic car travel times, as in the city it is more common to cycle for such travel times. The values used in the design of the *1LDes* are presented in the Table 4.1.

Table 4.1: Parking related attributes *1LDes* Design

Attributes	Levels	Level values
Price	2	Rs 30/ Rs 50
Distance from Destination	2	100 meters/700 meters
Travel time	2	16 min/ 24 min
Parking type	2	On-street/off street
Probability upon arrival	2	10%, 40%
Probability after 4 minutes	2	30%, 70%
Probability after 8 minutes	2	60%, 100%

4.4 Final Design

For matters of consistency the final design is presented including all the questions and the way it was implemented.

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Personal Information In this part, changes were made concerning the formulation of the phrases used. The personal characteristics investigated are:

• Age

• Gender

• Income

• Education Level

• Postcode

• Possession of drivers license

• Frequency of shopping at the city centre

Unfamiliar Users This part was restructured and reformulated, to appeal more on the behaviour of travellers based on feedback received. The issues investigated are:

• Parking Search Strategy (Plan route before trip, Arrive and search, search before reaching destination)

• Parking Type Preferences (On-Street, Off-Street)

• Reaction after 4 minutes of search or wait

• Maximum searching time before going to an alternative of other parking type

Familiar Users The design for the final version of the Familiar Users part was based on the priors derived by the 2nd round of the pilot study (***2LPr***) with some important modifications.

The feedback resulted in the elimination of the attribute describing the probability of findinga vacant parking spot after 4 minutes, in an effort to make the questionnaire less complex.

The 1st level of the price attribute was also changed from 1.5 to 1.25 to introduce a wider price range. Due to the large number of questions required, it was decided to divide the scenarios' in two **blocks**, in order to reduce the number of the scenarios per respondent and increase the size of the design. 24 questions were blocked in two blocks (12 scenarios per respondent). The final design's attributes and levels are presented in Table 4.2.

Table 4.2: Parking related attributes, Final Design

Attributes	Levels	Level values
Parking type	2	On street/ off street
Price	2	Rs30/ Rs50

Distance from destination	2	100 meters/ 700 meters
Travel time	2	16 min/ 24 min
Probability upon arrival	3	10%, 40%, 70%
Probability after 8 minutes	3	40%, 70%, 100%

5. PARKING ASSIGNMENT MODEL APPLICATION

For the simulation of parking , there are several basic requirements that should be met. The primary requirements for the implementation of simulation of parking have been described indetail by Young andWeng (2005) and have been briefly presented. However, in order to fully implement the Parking Assignment Model some further requirements are important to be met.

As it has been clear parking is modelled in 3 behavioural levels. The strategic (pre-trip), the operation and the tactical. On the strategic level the parking search route for each individualis defined. On the operational level the "re-evaluation" takes place, while the tactical level includes the route choice and the search directions. The 3 levels shape the requirements for simulation:

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

Information transfer: The simulation is required to be able to include some type of infrastructure 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 modeled, in such a way that would make it possible to replicate the on street parking procedure and the parking maneuvering.

5.1 ITS Modeler

Its modeller is a simulation tool, developed by TNO that would be able to cater the needs of simulating its applications. The major advantage of its modeller is that first of all it is designed in such a way that the programming of its applications can be done in a very robust way, with pre-defined modules to be offered. The fact that it is written in java, an object-oriented programming language allows for modular programming with its modeller to offer many modules that can be used to model most its cases. a complete presentation of its

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modeller is not intended for this thesis however it is important to mention in this section the components that were used to make the parking modelling possible.

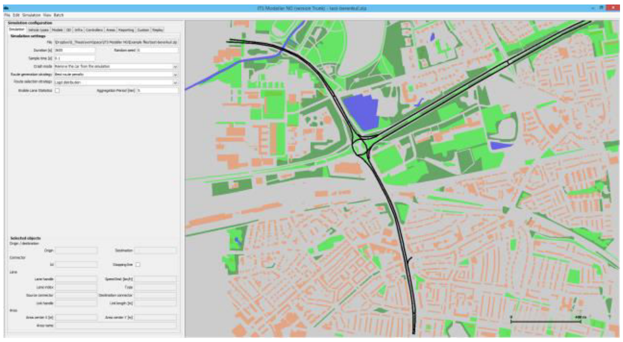

Fig 5.1: ITS modeller graphical user interface (GUI)

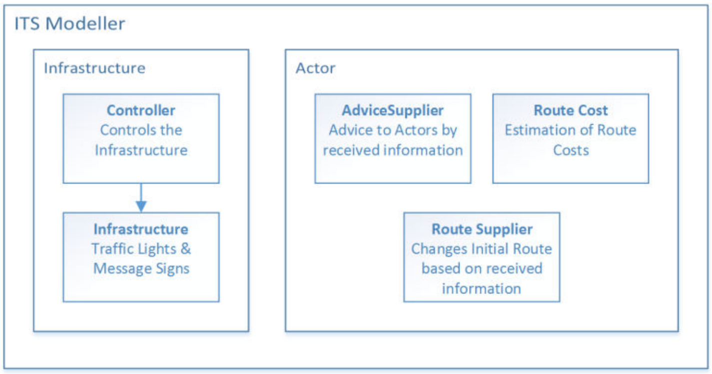

Fig 5.2: modules used in ITS modeller

5.2 ITS Modeller Limitations

ITS Modeller is a device right now being worked on by TNO and as an outcome there are a few restrictions on the functionalities of the instrument that are exhibited and in no time dissected in the following couple of passages. Those restrictions are the principle explanation for the examination of the Smart Parking application, on a somewhat illustrative frame.

Free Flow Cost Function: The principal confinement of ITS Modeller is that it doesn't consider while figuring course costs (free stream travel time as course cost) in a log it course decision model. A few remedial moves were made with a specific end goal to represent clog, for example, diminishing the scaling parameter of the Log it Model (μ), expanding the speed

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of the roadways for the course cost estimation. Despite the fact that those outcomes enhanced the task the outcomes were not sensible in contrast with genuine activity information.

5.3 Parking Facilities

The parking facilities in ITS Modeller are represented in a very simple way using a traffic light, a traffic counter and a Message Sign. When a vehicle passes the traffic counter the load of the Parking facility is increased. The parking facility is programmed as a controller (Parking Controller) that controls the traffic light and the message sign while it collects information at every time- step from the traffic counter. The message sign transfers an information object from the controller to the actors. The traffic light turns red if the parking facility is full.

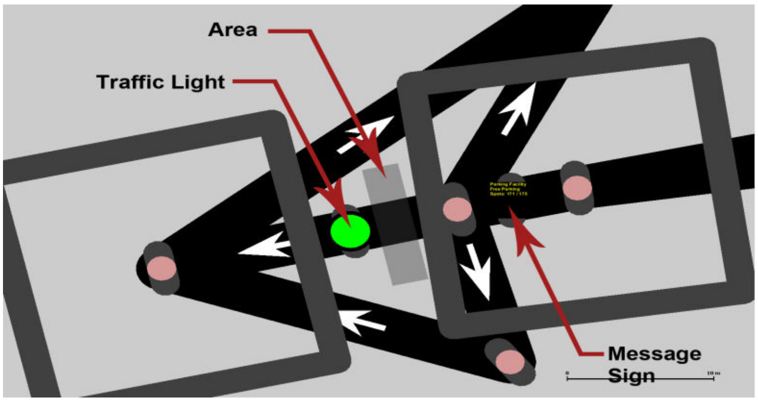

Fig 5.3: Off-street parking facility representation

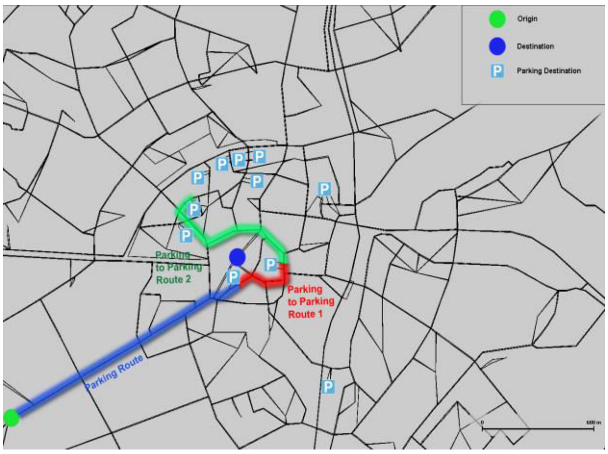

Fig 5.4: Routes followed by a random familiar user in ITS modeller

Fig 5.5: Routes followed by a random unfamiliar user in ITS modeller

5.4 Smart Parking Users

The implementation of the smart parking users was based on the Smart Parking application developed for the Sensor City. Individuals receive information about the parking destinations via an application for a Smart phone replicated by a Message Sign that is controlled from the Back-Office controller containing information for all parking destinations at the area to be visited. Individuals decide to reserve a parking spot at a parking destination. At this point it is **assumed** that all drivers using the reservation system comply with the reserved parking spot. The choice of one of proposed parking destinations is modelled using the Log it Rumbaed behavioural model derived, only for parking destinations which have available parking spots at the moment of the reservation. Given a chosen parking destination, the reservation procedure takes place by informing the Back-Office controller and the Parking controller involved to reserve the parking spot (which essentially means to increase the load of the parking destination by the parking controller). Individuals who get a reserved parking spot follow the shortest route to the destination. In case there is no available parking spot a tiny destination the same procedure is followed until a parking reservation is made.

6. CONCLUSION

The task structure was presented in ITS modeller by coding the segments for the assessment of the smart parking reservation framework created in the sensor city venture and situations were explored. the utilization of the structure demonstrates the capability of utilizing the parking assignment model. it is found that it can be executed in a reproduction domain and is fit for speaking to the circumstance practically. Then again, is found that the outcomes for the situations created demonstrate that the reservation framework can enhance the activity conditions and offer lower travel times for its clients. Both the reference cases and the situation cases are found to yield practical outcomes concerning travel times and parking decisions. Indeed, even the instance of new clients (who were found to have expanded travel time) is by all accounts practical, considering the absence of parking related signs in the usage. The upgrades of normal travel times (both aggregate and individual-based) were observed to be of rather little size, which is normal, as it is in accordance with the greatness of numerous ITS applications.

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