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Optimising Price and Location of Parking in Cities under a Sustainability Constraint

"SUSTAPARK"

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FINAL REPORT

OPTIMISING PRICE AND LOCATION OF PARKING IN CITIES UNDER A SUSTAINABILITY CONSTRAINT

"SUSTAPARK"

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KAREL SPITAELS
DR. SVEN MAERIVOET
GRIET DE CEUSTER
TRANSPORT & MOBILITY LEUVEN (TML)

GREG NIJS
VÉRONIQUE CLETTE
PROF. DR. PIERRE LANNOY
UNIVERSITE LIBRE DE BRUXELLES (ULB)
CENTRE DE RECHERCHE URBAIN (CRU)

KAREL DIEUSSAERT
KOEN AERTS
PROF. DR. THÉRÈSE STEENBERGHEN
KATHOLIEKE UNIVERSITEIT LEUVEN (KUL)
SPATIAL APPLICATIONS DIVISION LEUVEN (SADL)

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Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person: Georges Jamart
+32 (0)2 238 36 90

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Sven Maerivoet, Karel Spitaels, Griet De Ceuster
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1 The SUSTAPARK project

1.1 Motivation

A lot of cities in Belgium, and therefore their policy makers, are struggling with parking problems. Having too much parking spaces for cars causes traffic problems, congestion, emissions, noise, and above all an over-consumption of expensive land. Too little parking also has disadvantages: the inner city is less accessible, and many people will keep searching for the scarce parking spots and might therefore cause even more traffic-related problems. Yet, vehicles must park at every destination. On average, an automobile is parked 23 hours each day and uses several parking spaces each week [Lit2006].

Parking is therefore an important part of a sustainable mobility management, itself a crucial component of urban sustainability. But the transportation system is also closely coupled to land use in a city. Transport infrastructure (roads and parking facilities) uses up valuable land, but also increases accessibility. This might lead to city growth through urban sprawl and more trips across greater distances.

Combined land use and transport planning aims to reduce the need to travel. A favoured policy approach is to constrain urban development so as to minimise trips and facilitate public transport. Infrastructure measures are often targeted on reducing car use, for instance through parking management and guidance, traffic calming, and bus priority measures. Pricing and traffic management usually contribute to the overall strategy. Parking management refers to various policies and programmes that result in a more sustainable use of parking resources, and forms in fact a bridge between all of the items mentioned above in mobility management. It contains land use, price, infrastructure, and traffic management aspects.

1.2 Project objectives

The SUSTAPARK project aims to provide policy makers with knowledge for parking policy and tools to assess the impact of novel parking policies. These tools can be found in the integrated SUSTAPARK model that is the main result of the project. The main goals of the SUSTAPARK project were:

- **Provide advice on sustainable parking to policy makers.** Sustainability has social, environmental, and economical aspects, and a distinct time dimension, requiring models to assess the long-term effects of policies. Sustainability is usually assessed by means of indicators that express a certain aspect of the sustainable city. To provide advice the SUSTAPARK model needs to be able to run different scenarios that provide the raw data for the calculation of various indicators.

- **Describe and evaluate parking management strategies.** Most often it is considered prudent and useful to model a new policy before it is implemented, as this might lead to the detection of possible problems, estimates of the net benefits and an optimisation of the implementation. To evaluate these strategies SUSTAPARK simulates the parking behaviour, jointly with a detailed modelling of the traffic, in a given city.

- **Provide an account of the criteria on which parking strategies of drivers are based**. Accurate determination and knowledge of the criteria on which this is based might lead to novel parking management strategies, which can then be assessed by the SUSTAPARK model. With this knowledge policy recommendations and transport management projects can be more firmly based and are more likely to have some impact on parking and travel behaviour in the future.

The main result of the SUSTAPARK project is an integrated model for city parking, intended for policy support. The overall model design and underlying principles are described in this report. It provides detailed information on the inputs and outputs of the various components of the integrated model and on the calculation methods and algorithms. It also includes information on the data necessary for the implementation of the model and a description of the model estimation method.

The integrated model includes important results from the different subtasks, including:

- A deeper understanding of parking behaviour at an aggregate and individual level.
- A descriptive set of factors that influence parking choice on an urban level.
- A model that – starting from socio-economic data and traffic flows – can generate parking demand at district level (in a GIS-environment).
- An economic model relating choices in parking behaviour to price and walking distance.
- An integrated model for parking policy assessment on an urban level.
- An impact module that translates the results of the model to sustainability indicators.
- A methodology for quantifying the parking demand at the urban level.
- Recommendations for policy makers that take our new insights (concerning parking demand management) into consideration.

1.3 Parking research overview

Parking first became a problem around 1930 when rising levels of automobile ownership made it impossible for every driver to park on the streetside. Policy makers then came up with what seemed (and was) a wonderful solution at the time: minimum parking requirements. New buildings in cities were obliged to provide a minimum of on-street parking spaces. Where land was cheap, as in the United States, this resulted in a feedback loop where plentiful parking space encouraged car use which led to more emphasis on providing parking space (contributing significantly to the phenomenon of 'urban sprawl') [Sho2005].

In the older, already densely built cities of Europe, but also in some older cities in the United States, like New York, providing plentiful off-street parking places was and is often not possible. This contributed to companies relocating to the periphery if accessibility could not be achieved by some other means, such as a well-developed public transport system [Sho2005]. It should be noted that the responsibility for parking requirements usually lies at the municipal level, leading to a wide array of parking requirements, adjusted to suit the local needs [Hea1992]. The justification for these requirements is not known or unclear. The Institute of Transportation Engineers does have a publication 'Parking Generation' [ITE2004] that forms the world's largest collection on data for parking demand at buildings of various sizes and purposes. Shoup questions the reliability of these figures and decries the misuse of them by city planners [Sho2002].

Problems associated with parking in the twenty-first century include additional congestion, emissions, noise, and a decrease in the liveability of neighbourhoods as a consequence of drivers cruising for parking. Also, providing parking places means the consumption of expensive, scarce land. Parking shortages can also result in cities gaining a reputation for poor accessibility, causing shoppers, tourists, and commuters to stay away and eventually businesses to leave the city.

As parking is strongly connected to other systems of a city, most notably the transportation system and land use, its 'performance' and use spreads throughout the entire fabric of the city. Parking revenues can be used to fund street works, increase police surveillance and many other measures that increase the attractiveness of the city. A good functioning parking system is a major attraction point for a city, leading to more businesses coming to the city and therefore to more workplaces. Decreasing parking problems also means a reduction in congestion, emissions, noise, and visual hindrance. It also means a reduction in the time lost searching for a parking place and an increase in the liveability of the city.

Because solutions to parking problems take time to implement, which might lead to a changed situation by the time the policy becomes operational, care should be taken that the new policies contribute to the economic, social, and environmental goals of the sustainable city. Parking problems and their direct effects form only a part of the mobility and sustainability problems that cities face today. Research into and solutions for parking problems should not happen independently from the rest of the transportation system in the city.

Despite the relevance of the issues raised by parking problems and the fact that the average automobile is parked 95% of a day (or about 23 hours each day), scientific interest in parking and its economic, social, and environmental aspects has been intermittent at best, and certainly low in comparison to the attention topics such as road pricing have received. One reason road pricing is more interesting from a theoretical point of view is that it can be used to influence a much larger group of externalities than parking policies can [Mar2006]. In recent years interest in parking has increased, as shown by the publication of books by Litman and Shoup [Lit2006, Sho2005] and the publication of a special issue of Transport Policy on parking. This issue contains, among other articles, a good review of the current literature on parking policies [Mar2006] and an article on cruising for parking [Sho2006].

There is little empirical knowledge of the parking behaviour of drivers. For example, it is not known how many drivers in cities are cruising for parking, let alone how this number varies during the day or what the relation, if any, is with the local circumstances. Journalists frequently mention a figure of about 30 %, a figure that likely originated from the research in the United States of Shoup. However, this figure is an average over multiple studies that often produced widely differing results and took place in a time span of more than 70 years [Sho2006]. As Shoup himself notes, these studies are probably not very good and likely underestimate the amount of cruising for parking [Sho2005]. The circumstances surrounding parking, such as traffic volume and the availability of parking places, changed substantially during this period. Also, the study locations cannot be considered to have been free of bias. The comparability of these studies with each other and the representativity of their results is therefore doubtful. Still, these studies do indicate that cruising for parking can contribute substantially to traffic in the city.

Theoretical research into parking was performed mostly in the field of economics. Most authors consider parking pricing as a means either to internalise search externalities or to set an optimal price if road use is underpriced. The most advanced of these models include on-street and off-street parking and traffic congestion [Cal2002, Arn2007]. Older models consider only one or two of these aspects [Cal2004]. The aggregate, macro-economic methods applied can be criticised, however. They mostly ignore the local nature of parking and the heterogeneity in purpose and characteristics of the driver coming to the city. They also assume that the government has perfect instruments, while ignoring the high cost of (necessary) enforcement for on-street parking. While parking policy is often intended to lessen car pressure by indirectly encouraging non-car modes of transport [Mar2006], no attention seems to have been paid to this aspect in the economic literature.

In the economic models that take congestion on the road network of a city into account, it is not clear what is meant by a 'congested' street network. The conventional definition of congestion is that the travel time on the road is higher than what is normal for that road. However, in transportation engineering it is known that traffic in a city is almost fully determined by delays at crossroads and intersections [Mae2006]. If parking is taken into account, additional delays are caused by drivers looking to park and drivers parking their car or leaving their parking place. It is therefore not at all clear what congestion means in a city, as the primary cause of delays is an inherent part of the normal travel time.

In the field of traffic engineering parking has gathered some interest too. An overview of the research in this field is provided by Young [You2000]. The most notable contribution was the PARKSIM model of Thompson and Young [You1986, You1987a, You1987b], which models in great detail the behaviour of parkers in parking lots and is intended to aid in the design of new parking lots. Young distinguishes 5 types of parking models, namely parking-design models, parking-allocation models, parking-search models (both in parking lots and in a street network), parking-choice models, and parking-interaction models [You2000]. He concluded that in all of these types of models more emphasis should be placed on the assessment of urban parking policies and the behavioural response of parkers to them.

1.4 Report overview

The main goal of this project is the creation of a model for city parking. We chose to adopt a microscopic approach with a high level of detail. The city streets are modelled through a cellular automaton. In the cellular automaton a synthetic population of model agents drives around, searching for parking. Each of the agents follows a behavioural routine that is based on research with actual drivers looking to park. Due to this behavioural model, competition for parking places can be modelled, as well as the often highly local effects of cruising for parking.

- In Chapter 2 'Spatial aspects of the model' the representation of the city in the model is discussed. The method and implementation of cellular automata for the street network is described, as is the allocation of attractions for different activities in different streets.
- In Chapter 3 'Behaviour in the streets: searching for a parking place' the results of behavioural research with parking drivers are described. Issues of routing, interaction with the environment, search strategies, and willingness to pay and walk are explored in detail.
- In Chapter 4 'Parking agents' the model agents and their behaviour are discussed. The concept of agents, their pattern of activities throughout the day, the implementation of the search behaviour of the previous Chapter, and the underlying choice models are introduced and their implementation explained.
- In Chapter5 '*Model use*' instructions for the use and application of the model are given.
- In Chapter 6 '*Case study: the inner city of Leuven*' an application of the model is described and the results of some scenarios run with the model are presented.
- In Chapter 7 '*Conclusions'* the strengths and weaknesses of the model are discussed. Possible improvements and avenues for further research are given. Some broader aspects of parking than those covered in the model are also discussed.

1.4.1 Software choice

Because SUSTAPARK requires the use of detailed geo-referenced data, some link to a Geographic Information System (GIS) is necessary. The most widely used package for this in the academic world is ESRI ArcGIS. ArcGIS also allows extensions to be programmed in ArcGIS VBA. It was, however, decided to program the SUSTAPARK model in the Java programming language under the argument that this will allow greater speed and flexibility in the code than would have been possible in ArcGIS VBA. The choice for the Java language also allows the use of many libraries that are freely available for the platform. One such library allows the translation of data from GIS maps (used by ESRI ArcGIS) into data objects that can be manipulated in Java. ArcGIS and GIS maps are used as input and also for high-quality visualisation of the project results as maps.

The Java code composing the SUSTAPARK model is made publicly available under the Open Source GNU license. The intellectual property rights of the model will rest with the Federal Science Policy of Belgium. Note that although the Java program code is in the public domain, the ArcGIS software is not. In addition, the data requirements on the model imply that a lot of the necessary data to run SUSTAPARK are also not publicly available.

2 Spatial aspects of the model

2.1 Introduction

For the start, the focus of the SUSTAPARK model was the parking problem within cities, because there it is the most severe as a high demand meets a limited and difficult to expand supply. With a focus on cities the question arises on what level of detail the city must be represented in the model. Because parking is a highly localised problem and because the effects of drivers searching for a parking place are of interest, an approach with a high level of detail was chosen. By representing the individual parking places and the streets, many effects that are invisible in more aggregate approaches can be studied. Therefore it was chosen to represent the entire street network of the city in a cellular automaton, with on-street parking places attached to these streets and with attractions for specific types of activities attached to each street.

This high level of detail implies huge data requirements for the model, which is certainly an issue. Although the use of digital maps by cities is increasing, many cities do not have a sufficiently detailed digital map of their street network available. The location and number of on-street and off-street parking places is not well known in many cities. The calculation of the attractions of the streets for certain types of activities also requires a large data input.

2.2 Cellular automata

Because of the choice to consider individual agents in the SUSTAPARK project, the most logical course of action is to select and implement a microscopic traffic flow model. This class of models gives a higher level of detail than a macroscopic model. Their downside, however, is that they have an increased level of complexity, resulting in longer computation times. One way of dealing with this issue, is by adopting the use of so-called traffic cellular automata (TCA) models. These provide a computationally efficient implementation of microscopic models. As such, a TCA model was selected to form the core of the SUSTAPARK model.

Within the paradigm of traffic cellular automata models, vehicles drive on roads that consist of a number of consecutive cells. Each cell can either be empty, or is occupied by exactly one vehicle; we use the term single-cell models to describe these systems. As time advances, vehicles move from one cell to another (possibly jumping forward for more than one cell) according to an update rule. An example of the tempo-spatial dynamics of such a system is depicted in figure 1, where two consecutive vehicles *i* and *j* are driving on a one-dimensional lattice.

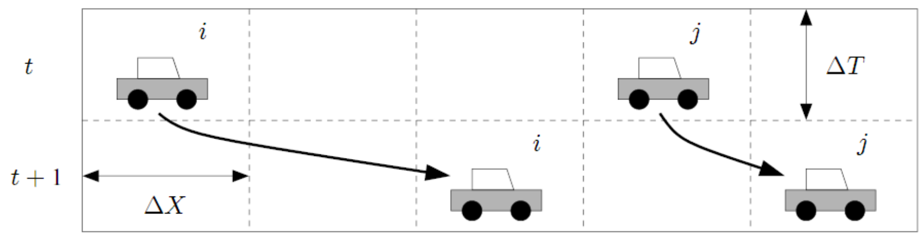


Figure 1: Schematic diagram of the operation of a single-lane traffic cellular automaton (TCA); here, the time axis is oriented downwards, the space axis extends to the right. The TCA's configuration is shown for two consecutive time steps t and $t + 1$, during which two vehicles i and j propagate through the lattice.

Several properties related to driving, such as the possible speeds and the length of the cars, are dictated by the parameters of the cellular automaton and its discrete nature [Mae2006]. In a single-cell CA the cars move from cell to cell, where only one car can be in a cell at a given time. Therefore the length of the cars is fixed. Since the updating of the model happens in discrete time steps, the speeds of the cars are also discrete. A fairly coarse cellular automaton was chosen and therefore the number of possible speeds is very limited.

A driving car in the CA is an easy concept to grasp. There are however many practical details attached to this basic idea that will be discussed below. The spatial discretisation of the CA is a cell with a length of 7.5 m, enough for an average-sized car, including the bumper-to-bumper distance when standing still. The temporal discretisation of the CA is 1 second. Together these two properties of the CA determine the (discrete) speeds that are possible within the CA, here 0 km/h, 27 km/h and 54 km/h [Mae2006]. Higher speeds are not needed within the SUSTAPARK model, as the general speed limit within a city is 50 km/h in Belgium. Sometimes this speed is only 30 km per hour.

Another important part of a CA is the update rule. The SUSTAPARK rule needs to prevent collisions and allow for realistic changes in speed of the cars. It preferably is also quite simple, as the advanced study of driving behaviour is of no real interest for the model and this can add a lot of computational burden to the model. CA models with stochastic components are also avoided for the latter reason. Therefore the rule set chosen is the deterministic Fukui-Ishibashi TCA (DFI-TCA) [FI1996, Mae2006]. The rules in this rule set are (all quantities expressed in number of cells with *i* denoting the *i*-th vehicle):

R1 : acceleration and braking

$$v_i(t) \leftarrow \min\{v_i(t-1)+1, g_{s_i}(t-1), v_{\max}\}$$

R2 : vehicle movement

$$x_i(t) \leftarrow x_i(t-1)+v_i(t)$$

The first rule calculates the speed of a vehicle for the current time step, the second rule updates the position of the vehicle with its speed for the current time step. Note that a consequence of the first rule is gradual acceleration and instantaneous braking. The gradual acceleration is ensured by the first term in the first rule, which allows the speed to increase only with 1 cell per time step, up to the maximum speed v_{max} in the model. The instantaneous braking is ensured by the second term in the first rule, which states that the speed of the vehicle cannot be larger than its space headway, i.e., the number of cells between the vehicle and the vehicle in front of it.

A parallel method to update the speeds and positions of all the vehicles in the TCA model was chosen. This means that all the updates of the vehicle speeds and the vehicle positions are calculated on the cellular automaton, unchanged from the previous time step. This does necessitate the use of a buffer where the updated positions of all vehicles are written to, before their positions in the cellular automaton are updated.

SUSTAPARK models crossroads and intersections by means of a yellow box model. This models the intersections not physically but uses a link table to transfer vehicles between the roads connected to the intersections. Multi-lane streets are not implemented at this stage of the development. Currently, the model does not allow overtaking vehicles within cities. Neither is lane changing implemented as to prevent the additional complexities this would introduce.

2.3 The street network of the model city

The spatial information for the modelled city is stored in a GIS. The GIS format chosen is ESRI's ArcGIS, currently the market leader in GIS software. GIS are only used as input and to visualise output; not for the model calculations or actions. Therefore the model can be migrated to another GIS software environment, if wanted. In this Section, we give a description of how various spatial components are treated in the SUSTAPARK city model.

2.3.1 Road network

The base GIS data is read through a Java library. This results in a model of the road network of the city, represented as nodes (all types of junctions and crossroads) and links (street segments). The whole of this functions as a directed graph. The nodes then become the intersections and the links get a single-lane one-way cellular automaton attached to them (one in each direction allowed). Roads with multiple lanes in the same direction are not implemented because this would not add much value, since almost all roads in a city are single lane. A method to implement lane-changing behaviour is therefore not required.

The network implementation implies that the coordinate system is completely relative. Since the model itself does not operate in GIS it is not straightforward to translate the relative coordinates back to spatial coordinates. This means that it is only feasible to measure distances along the roads of the network and not distances as the crow flies. This should be kept in mind when distances are mentioned in the rest of this report.

The roads with the simple cellular automata are the foundation of the cellular automaton of the city in the SUSTAPARK model. Not only are the vehicles moved in the cellular automaton, all on-street parking happens in the cellular automaton. A lot of the properties of parking places in a street, like the price, will be the same for all these parking places. Therefore the street level is a convenient choice to define a lot of these properties.

To differentiate the roads for route choice three road levels were implemented. The highest level is the ring road, the middle level are the main roads in the city centre and the lowest level are all other roads in the city centre. The route choice in the model is independent of the network load, i.e. there is no impact of congestion.

The crossroads and junctions are not modelled in detail in the cellular automaton. They are treated as a point with a table to assign traffic (individual vehicles) over the different roads of the junction. This is the classic 'yellow box' modelling of intersections.

2.3.2 Parking places

A parking place refers to all the places where a driver can park. This includes all on-street parking places, which are connected directly to the cellular automata of the streets. Illegal (on-street) parking places are not implemented, though these might be a substantial number in some cities. Parking places also include all forms of off-street parking: parking garages, parking lots, squares, homes with garages, … The term garage will be used as shorthand to refer to all these types of off-street parking. The movement of traffic within a garage is not modelled.

For the implementation each on-street parking place is connected to a specific cell in the adjacent lane in the cellular automaton. The parking place is only accessible from this adjacent cell and only one car may be parked there. Off-street parking places (garages) are similar to on-street places, except that more than one car may be parked there (depending on the capacity of the garage). This also means that there is no on-street parking place directly in front of a garage, as this space is used by the access road to the garage. In reality, such places may be used by drivers to park their car, especially when supply is much lower than demand.

Because of the way in which the parking places are implemented, their properties can (in principle) be quite detailed, even down to the individual parking place. When a driver looking for a parking place then comes near a parking place, he/she can 'see' its properties and incorporate this information in his parking behaviour.

2.3.3 City gates

The geographical scope of the SUSTAPARK model is a city. Therefore a substantial part of the traffic will come from outside the city and care must be taken to define the boundary of the city. This might be problematic at the edges of the city where in reality parking might occur just outside the actual boundary of the city. If the boundary is badly chosen, 'outside' parking will lead to edge effects that will result in unrealistic disturbances in the whole model. Due to the choice for the ring road as the boundary of the modelled area in SUSTAPARK, this is not judged to be problematic.

A city normally has a lot of roads entering and exiting its area. To prevent unnecessary complexities, the number of entry and exit points in the model is kept fairly small. These points are termed 'gates' through which vehicles enter and leave the city. The gates in the model function as parking garages with an unlimited capacity. The vehicles that wish to enter the city are placed there at the start of a model run. As they leave the city during the day, they are stored at the gates.

2.3.4 Attractions

A city is spatially heterogeneous with respect to the types of activities that are performed in the city. To provide the SUSTAPARK model with a way of reproducing this heterogeneity attractions are used. An attraction for each of the types of activity (eight in total, see Section 4.1.3 for a list) is assigned to each street segment. The attraction itself is merely a relative numerical value, indicative of how interesting this particular street is for this particular activity. For more information on how these values are used, see Section 4.1.4.2, about the generation of the activity schedules.

Competition between different locations (shops for example) is not implemented on this level and is certainly not the focus of the SUSTAPARK model. The decision where to go to is driven by the activity schedules of the agents and any specific location is chosen before the trip generation.

3 Behaviour in the streets: searching for a parking place

3.1 Introduction

The behavioural analysis of parking choice aims at descriptive accounts of actual criteria on which users' parking strategies are based. In order to reach this objective, we opted for a comprehensive understanding of actual behaviours and strategies of car drivers. The output of this description has to serve as input for the final model. The output is constructed in a decisional matrix (see Appendix A).

The experimental setup adopted was to sit with drivers in their cars as they searched for parking places. Before the experiment (the whole setup is termed interview) some questions were asked to the driver. During the search the driver was filmed, so that his verbal and non-verbal (eye movements, hand movements, …) utterances and signs could be analysed afterwards. From these films a few shots are presented (termed videostills) and some literal transcripts of the utterances of the drivers are provided (separated from the remained of this text in shaded boxes). After the search a second set of questions was asked to the driver as to how he evaluated the search and his parking place himself. Drivers were taken on parking searches to areas both familiar and unfamiliar to them. The interviews took place in the Belgian cities of Brussels and Leuven.

Our approach is grounded in the idea that for accomplishing a comprehensive understanding, the real-world search has to be grasped to a full extent. That means adopting a pragmatic stance and analysing the action in its unfolding. To this end, the understanding rests on approaches of embodied cognition and distributed agency. This positioning enables to rehabilitate the active role of the surroundings and of space in carrying out the driving activity and the search for a parking place.

First, we followed the idea of embodied spatiality, which is a specific understanding – a topology – of space and place constructing itself during practices like walking, taking public transport, or driving. Theories of embodied cognition include considering the emergence, activation, and fabrication of skills from the relations between a body and its environment (composed of objects and configurations of objects). This relation is mediated by a body of sensorial, emotional and cognitive constituents.

Second, we took into account the theories of distributed cognition to enlighten the process of action. According to Eric Laurier, it can be put forward that space is there as a resource for and as a product of a myriad of practices [Lau2005]. The built environment (engineered or intelligent infrastructures, informational technology, traffic management devices, traffic rules, …) is full of constraints and resources. This means that besides the agency of the person originating from the possibility to act upon the world, the world itself acquires agency, too. This means that the accomplishment, the outcome of an action is the result of a heterogeneous composition of humans and non-humans.

In such theoretical perspective, the notion of plan and strategy has to be understood as process-making. Plans or strategies can be seen as interior to the agent: the agent having internalised a mental map to guide his actions during their execution. Plans and strategies can also be seen as exterior to the agent: seen as a sort of suspension of knowledge, staying vague or un(der)determined until the agent finds himself in the local context of the execution of the specific action. It is the in-between position that is adopted in this research (following Conein and Jacopin, [Con1994]). Plans and strategies are seen as an element of the action that cannot be achieved but in its execution.

To grasp this oscillation between these two ideal-types of plan, the temporality dimension of the course of action needs to be added. For the parking search we have introduced three sequences types (Inception Sequence, Preparation Sequence, Stake & Trial Sequence). Indeed, plans and strategies have to be seen in function of the different sequences or phases of the action (of driving to a destination zone and of searching for a parking place). Depending on the sequence, an agent is more in 'A plan as a program': made up of instructions that have to be executed. The instructions are strict, precise and as such leave very few degrees of freedom in the execution of the course of actions. Or the agent is more in 'A plan as a resource', based on guidelines rather than instructions. Its degrees of freedom are far less limiting. It gives a sense of direction, without formulating how to follow this direction. It can indicate points of passage, or (land)marks that can serve as signs in the ongoing course of action, without being necessary passage points. In the room left for improvisation, the agent can make more use of the environment that surrounds him, and of the knowledge of (cultural) logics on which environments are based.

This part of the report is subdivided into three main lines of analysis:

- The uses of the road network and its potential strategic function as spatial device.
- The tactics, the skills, and the specific uses of the environment the driver makes and that allow him to adjust himself to the present and unexpected situations that arise continuously during the search.
- The process constructing the preferences that lead the driver to choose (or ignore) a parking place.

3.2 On routing, roads, and road choice

The road network is one element of the built environment that is of utmost importance for moving in a car through space. Roads can be seen as "*normalized space that facilitates the realization of urban activities*" [Rel1996]. It is mainly through material delegation that roads are normalised (which means that actions are rendered intelligible for other users, on which they base expectations to coordinate their own actions within the same space). The parameters of the road itself (like width, number of lanes, …), along with a whole set of objects make up the material semiotic translation of norms that persist in a given collective. At the same time and in the same movement, the material prescriptions invite for certain actions, which are seen as the 'convenient actions' within the space [Thé1990]. However, this does by no means imply that every user will use the space in the way(s) that it is intended. Uses of the same road can be and are in general differentiated. The differentiation holds true for the roads themselves, too. The functional differentiation of roads not only means that their function is different, but – more importantly – that the actions possible in it are different/differentiated. This double differentiation – that of use by users, and the different uses proposed by different material configurations – make strategic conduct possible. It literally fabricates a strategic matrix of possibilities.

The itinerary of an agent from the origin to the destination point, or the routing of the agent, thus passes on a road network that is differentiated. This differentiation allows the agent to choose the roads to get to the destination zone. Following our sequential analysis, we can divide the routing from origin to destination point in:

- the routing 'towards' the destination zone (Inception Sequence),
- the routing 'around' the destination zone (Preparation Sequence),
- and the routing 'in' the destination zone (Stake & Trial Sequence).

The choice of roads – from a pragmatic and cognitive point of view – can be justified in a number of ways. In the following examples we will address some of the justifications given by our interviewees, as well as discuss what they could mean.

3.2.1 Routing towards the destination zone (IS)

If we look at the road network with its different road types, and their commensurate functions (that are given by traffic planning), as some sort of distributed cognition, using different road types could be seen as delegating agency or cognitive control from the driver to the environment (in this case to the road network). The road as a spatial "dispositif" (device), as it is called in French, "*plays a role as a support for evaluation, that is to say, it facilitates the information treatment present in the environment and minimizes computational load*" [Con1993]. So the agent can use the environment and the information that it conveys to lower his or her own computational load. However, different types of roads have different computational loads for different agents. Moreover, their road choice will differ in the justification of their choice.

3.2.1.1 The big axes as a wayfinding support

Henriette is a frequent visitor of Brussels. Several times a week she comes to the city for professional reasons. However, she admits that in general she uses the large axes to get around in the city:

> Henriette: "Perhaps one thing to say is that, as I am not from Brussels, I don't choose an itinerary in bird's flight, you see, because I don't see the details of the streets. And so, since some years, I choose particular itineraries. Itineraries that are generally big axes." Interview of Henriette, woman, 55 years old, Brussels.

Henriette doesn't drive in "bird's flight" towards her destination zone. Driving in bird's flight would mean to drive across the city, taking whatever road type available, in other words the shortest route towards the destination zone. Yet, she takes the big axes because she doesn't "see" the details of the streets. Because she doesn't see, or rather know the streets, she takes big axes, knowing that they are thought of in this way and that they will lead her towards her destination zone without having to look for herself too much. She delegates, as it were, the knowing, the cognition to what she knows about big roads and road networks, namely that they will take her closer to her destination zone without her having to worry all the time at decision points such as crossroads.

3.2.1.2 The big axes as a driving support

David is a resident of Brussels. He frequently drives in the city, and knows it very well. Nevertheless, he doesn't take the small roads to get to his destination. Rather, he also takes the big axes, but for another reason than H does. On the small ring road of Brussels he states:

> David: "[I take roads] that I know. I am not an urban adventurer […] Not by car, at least. By car I have the impression that it is more careful. It is more careful to take the roads you know.
> Interviewer: "Careful, what for? For not losing time?
> David: "Careful in terms of accidents and the like. You know the crossroads and things like that.
> Interviewer: "Managing the roads, or what?"
> David: "Managing the road… It's true that you anticipate a bit all the stuff, and at the same time it allows you to be less attentive, which is in fact false, but… Because it allows you to be attentive but less attentive of the fact that you drive. So it is totally wrong, but… at least you can think of something else." Interview of David, man, 30 years old, Brussels.

The example of David shows another reason for taking the big roads, namely "to be less attentive", that is "less attentive of the fact that you drive". In doing so, "at least you can think of something else". This is a common remark made during our interviews. Even if you know the smaller roads, you still take bigger roads as to keep your head free for things other than driving. From a cognitive scientific point of view, David takes the environment of the big roads to lower the computational load of way finding/driving. Though, as he states, this lowering of attention/computational load is only relative, as it only allows him to give attention to something else, to think of something else. The latter is true for a lot of drivers. As driving can be seen as a multi-activity, drivers aren't only occupied with driving. They often even aren't only driving and way finding, but as another interviewee (Jaques) put it: "When you have the children in the back of the car, you have to divide your attention between them and the road." (Interview of Jaques, man, 44 years old, Brussels) Besides children, attention can go to listening to the radio, having a conversation with passengers, or making phone calls, to give some examples.

One of the reasons that big axes allow, or rather afford, to be less attentive or not having to 'see' the smaller axes or streets that could connect origin and destination, in computational terms is that it lessens the decision points. Decision points in a road network are the nodes or crossroads. The advantage of big axes is that they 'automatically' propose less decision points than smaller axes. In heading towards the destination zone, taking smaller streets (or any combination of road type) means having to take more decisions, for at every crossing the agent has to decide whether to go further or not.

3.2.1.3 The big axes as an emotional mediator

Big axes are not only advantageous in terms of cognition/computational load, they also present less perceptive and praxeologic costs (i.e. the study of human conduct). Smaller road types most of the time literally are smaller, which means that the overview is less, and that there is a lot more happening within a more confined space. There where the traffic flows of different modes/vehicular units on bigger roads are separated, on smaller roads they have to share the same space. Manoeuvring through these smaller streets asks for a lot more vigilance and ability. However, we should add that because of these conditions, the actions taking place in these environments are executed at a lower speed, which 'alleviates' some of the difficulties. Even so, the idea of… can prompt drivers to stay on the biggest axis possible for as long as possible. Otherwise, the lived-through experience intensifies and the role of emotion becomes more important.

Ludo is a commuter who comes to Leuven every day, since some years now. He knows the city fairly well, but not the street names: "I know the names of the big axes, but not of all the small streets that connect them". Although he doesn't mind driving in general, he utterly dislikes driving in the city:

> Interviewer: Do you think of Leuven as a user-friendly city for car driving?
> Ludo: No.
> Interviewer: Could you…?
> Ludo: By extension, I think not one city is user-friendly for car driving, but that's my personal opinion. A lot of people can find the contrary, but I don't like to drive in the city, not at all!
> Interviewer: Why not?
> Ludo: The bustle. That's not my thing.
> A few moments later he shows why:
> Ludo: "You have to watch out for all the cyclists. And here you have the exit of the hospital's parking."
> Ludo: "All that wriggling or how do I put it. That's nothing for me…" Interview of Ludo, man, 50 years old, Leuven.

Figure 2: Videostills of driver L. In the videostill on the left he remarks on the cyclists; in the videostill on the right he remarks on the bustle in the city.

What Ludo utters could perhaps indicate that the perceptive cost of driving in smaller streets is higher. The complexity augments when the linearity - so supportive of the predictability of driving-in-traffic - is swapped for non-linearity of vehicular units and their movements. As Ludo already gets nervous in only knowing that he will have to pass through the city, his perception of his immediate environment becomes filled with connotations. His vehicular Umwelt gets filled with dangers-of-collision because he emotionally prepares for it in this way. Whereas for other drivers driving in the city is like driving anywhere else: cyclists or exits of parking garages do not signify anything special, they almost stay invisible. But for Ludo, knowing that he is going to drive in the city augments his sensitivity to see things. In other words, through his availability for signs (of 'danger'), these signs become more visible. This visibility, in turn, augments the perceptive cost of driving-in-the-city for Ludo. For other drivers, other processes of signification can come into play. In general, whatever the significations given to the elements making up a driver's vehicular Umwelt, the perceptive cost changes with the different types of road.

3.2.2 Routing around the destination zone (PS)

At a given point the big axes have to be left to get closer to the destination zone. This means leaving the biggest road type for smaller road types. Here, too, there are varying possibilities. In any case, the driver sets a course to position himself vis-à-vis his destination zone. Whatever the logic the driver follows in approaching the destination zone, the routing around the destination zone has to do with 'actions of preparation': "*[The] state [of the temporal distribution of actions] supposes a temporal distribution between two classes of action: those tied to the execution of the principal goals, and those that aim at facilitating the realization of the first.*" [Con1994]. The principal goal is finding a parking space in the destination zone. To facilitate that goal, that is, to prepare the action of searching, the driver positions himself towards the destination zone. In doing so, the driver negotiates his access to the zone. Negotiating access or preparing the 'entry' to the destination zone can be done in a more 'knowledgeable' fashion, using one's knowledge of the local roads. Often this means that the driver follows 'his logic'. On the other hand, the negotiation of access can be done by following the 'logic of the system'. Let us start by considering the latter.

3.2.2.1 Following the logic of the system

As we already saw above, a lot of drivers facilitate their routing by following the logic of the road system. In the routing towards the destination zone (inception sequence) this entails taking the biggest roads possible (i.e. large axes, ring way, highway, …). In the routing around the destination zone (preparation sequence), this entails taking the officially qualified 'entry roads' that are proposed as such by the road system. When we say officially qualified, we have the entry roads in mind that are proposed as such by traffic planning. In general, the roads labelled entry roads by traffic planners are of a smaller road type than the big axes or ring roads, but of a bigger road type than backstreets. The logic of the system then can be followed in a certain way that seems most logic and the shortest. The agent just 'descends' from the biggest road type (i.e. the ring roads) onto a smaller entry road closest to the destination zone with the idea of in a final step descending another road type level at the height of the destination zone. We will consider an empirical example to describe how this works in practice and elaborate on the workings of a traffic flow system as a system of distributed cognition.

Sam, being an inhabitant of the suburbs of Leuven, is a frequent visitor of the city. Nevertheless, when he approaches his destination zone, he does this 'the simplest way' (in his own wordings). Consider the following extract:

> Interviewer: "Concerning the route; your choice to take the ring way, is that…?
> Sam: … That's the only, …, anyhow, with all the one-way streets… the best option is to take the ring way and then take a street off the ring road. That is the simplest, I think, in Leuven."
> Interviewer: "So euhm…"
> Sam: "… Otherwise I wouldn't know. […] I think, actually, that the ring way is the only, or at least the shortest route."
> Interviewer: "And cutting through the city centre, do you use the system?"
> Sam: "No, I actually don't know. Maybe I do so, but without knowing. But not knowingly, no. No, most of the time I take the ring way and I turn off, more or less a street straight to the destination."
> Interviewer: "So you take the gate closest to your destination?"
> Sam: "Yes, yes." Interview of Sam, man, 25 years old, Leuven.

Continuing the point that we made above, namely, that the road system could be viewed as a sort of system of distributed cognition, in which cognition is distributed over (at least) an agent and the different road types of a local road system. In the former examples, a case was made by some drivers to follow the logic of the system by taking the biggest road type possible up to the destination zone for reasons of 'mental ease'/keeping heads free or for not knowing the roads to take when driving at bird's flight. In the current example, the reason or justification is as simple as straightforward: echoing some thoughts of the former two examples, this respondent claims that following the strategy proposed by the road system as the 'simplest', the 'only', and the 'shortest' way to the destination zone. But what does this mean? Surely, taking the ring way and the gate or entry road closest to the destination zone isn't the 'only' way! However, the system makes it seem the only right way. It does this by rendering 'cognitive seeing' or 'seeing ahead' more difficult. The traffic flow system in Leuven is designed in such a way that going through the city centre is made difficult through the installment of a whole system of one-way streets that guide the driver out of the city. As a system of cognitive distribution, it 'thinks' the city flows for the drivers/agents. The road system imposes its logic by deciding for drivers how they are to reach their destination or how to cross the city. At least, it makes some decisions more possible, and thus, easier than others. That is why we could read Sam's answer of 'this' way being the 'simplest' way to lower the calculation load of routing of the agent by following the proposed logic of the system.

This however doesn't clear out why Sam also claims the ring-way-then-entry-point-closest-to-the-destination-zone logic proposed by the system is the 'shortest' way? We should ask ourselves here: what 'type' of short does he mean? It could be the Euclidean distance that is meant by Sam, that is, the geometrical distance. This is an answer that would seem logical, if it were only for the way in which distance is often seen and thus semantically seems to be most related to the word 'short'. However, there are other ways of seeing distance. If simple is related to short, more than short is related to fast, we could instead understand Sam's account of 'short' as a measure of 'cognitive distance'. Without pinning the exact meaning of cognitive distance down, we will describe it as a form of distance having to do with the computational load of an action that takes place in a timespace, which is influenced – amongst others - by the number of steps, sidesteps, decisions and decision points available in a constrained but not too constrained decisional space, along with the action components that allow a certain degree of freedom and an error range with certain costs for certain errors (e.g. repeating past actions, augmenting the number of actions, …).

'Short' in that case means in fewer steps, with less decisions to take, and with a smaller error range. Hence short and simple go hand in hand in this example. In this way, Sam is right: if we look at the map, then Sam's itinerary brings him to his destination zone in the least possible steps (3 steps in a system with 3 road types). Even if Sam doesn't follow the system 'knowingly', he is satisfied with its workings. In its use and in its performance, the road system of Leuven alleviates the task of finding the right way or negotiating access to the destination zone by making it simpler than other possibilities. We shall see in the coming paragraphs that this isn't necessarily so for everyone.

3.2.2.2 Short cuts

There is something relatively humorous and paradoxical about the idea of a short cut when talking about the routing of a driver or agent. A short cut most often involves leaving a bigger road type for a smaller one. As we saw above, this kind of decision actually augments the cognitive and praxeological costs of driving and routing. In a way, then, a short cut can be said to be a detour! There must be some reason why a driver takes (or rather 'creates') a short cut. In the following, we will discuss two types of short cut that seem to be most common: the routine short cut and the contingency short cut.

Routine short cuts are routes that have a certain logic for the driver in question, and that have stabilised over time and in space (often as a sort of learning effect from previous contingencies). Most often, they combine the preparation or access to the destination zone with other advantages (or the avoidance of disadvantages). They can be related to time, distance, complexity of traffic situations, better access to the destination zone, more opportunities to evaluate or even find a parking space along this way, … Again, the short cut draws upon the strategic use of the road network by a driver. Through the driver's knowledge of the road network (or its logic through adequate spatial skills) he uses the different road types to his advantage. Besides the driver and the road, short cuts generally also create an advantage vis-à-vis other road users. The strategic use of the road network – in the case of routing and short cuts – has to do with the play of opportunities and constraints in the network between different drivers.

With respect to the road types, the combinations of different road types that make up the route/short cut can be as complex as they can be simple. The complexity lies in the tension between the singularity or even idiosyncrasy of the driver's logic and the 'common sense' of the system's logic. In other words, we can distinguish system's logic short cuts from driver's logic short cuts. However, the real-world examples always are some mix of both. In a system's logic short cut the driver actually still adheres or follows part of the logic proposed. This means that he progressively descends the size of the road type, but not – as in the above example of Sam – 'system-optimally'. He will do it to his own preference, and often as a consequence of local situations that are known by the driver [that are less visible from a topological/planning point of view, but the more from 'within' the traffic situation]. The example of Eline can clarify this.

Eline is a resident of Leuven, she lives in the inner city. When coming home from work in the evening, she has to take almost half of the ring road from the gate where she arrives to the gate closest to her destination (her home). If she would follow the logic of the system, then, she would follow the ring road up to the gate closest to her home. However, she does not do so. She takes a gate halfway, which she states she routinely takes. The first reason she gives is that there is always less traffic in this street than on the ring road. This is due to the high number of traffic lights on that part of the ring road, still according to Eline. On the other hand it allows her to prepare for her routine search route immediately. By taking this street, she first arrives at a street she prefers most to find a parking space. In this way, she combines the relatively 'easy' shortcut (taking a transversal line of a road type that is just one size smaller than the ring road) with the positioning towards her destination zone, that is, she negotiates her access to the zone.

Contingency short cuts are specific cases, and could be said of to be more in the realm of the driver's logic. They become necessary either because the driver has no other option (road works, manifestation, cultural activities, deviation, …) or because the situation he finds himself in is judged as unpreferable (that is, when the situational preferences are not met). What happens in these cases is a re-routing. The easiest way of re-routing in case of a local contingency is the 'incision': the driver cuts out the contingency by locally descending to a smaller road type to get back on it as fast as possible.

> Interviewer: And how are you going to try to resolve this small problem?
> Henriette: I'm going to try to get back on the axis that I had put as my objective, Av. Louise. I don't have a sense of orientation […] So, when I'm obliged to deviate, I'm not going to try to get on an oblique street. I take a parallel and get back on the other street as fast as I can. Otherwise it frightens me. Interview of Henriette, woman, 55 years old, Brussels.

Another way of re-routing in case of a contingency short cut is to 'bridge' from one route, the current route, to another route that is known to the driver. It could be that it is a route that is a routine route, too. It can be that it is a route that is attached to the same activity or trajectory, but a route that is used when coming from another origin or direction. It can also be that it is a route that is connected with some other activity, and that has its place in the driver's biography and knowledge of the zone/territory. In either case, the bridging from one route to another entails that the road type does not play a big role between the two respective routes. The driver is just trying to get on the new routing. A last way of re-routing is a re-routing that is less frequent, but that is not unimportant. It entails re-routing in 'bird's flight'. When a driver is re-routing in bird's flight, the road types are of no importance whatsoever, the driver just tries out different roads to get closer to his destination. In this way, for future routes, and in terms of the forging of territories, the driver gets to know new ways of getting to his destination (while at the same time perhaps discovering new parking zones that could interest him).

Figure 3: Videostill of driver Henriette, following a shortcut strategy.

3.2.3 Routing in the destination zone (S&TS)

The routing in the destination zone is of a different nature. The most important reason for this is that the goal of the actions changes. Instead of routing towards a destination zone, the driver is now preoccupied with finding a parking space. This means that the use of the different road types changes. Often, the paradigm of the road types turns around completely. Instead of wanting to stay on the big road types as much as possible, it are the small road types that are favoured. The reason given for that is that of not wanting to be caught up in the big flows (again). The small streets now offer more time and possibilities to find a parking space, whereas the big road types have the spatiotemporal disadvantage of taking the driver away from his destination at a very fast pace. However, this does not mean that the bigger road types are necessarily completely avoided. In this sequence, too, the different road types play a strategic role in their use by different drivers. The different ways in which the road types are used to form strategic forms of parking search can be described in at least five types of routing: isle, block, cascade, erratic, and spiral:

- The **block strategy** does not distinguish road types according to their hierarchy. It partitions the road network in different equivalent pieces (i.e. blocks) that the driver drives around several times to find a parking place. The starting point generally is the destination point. There are two advantages: trying to control one's position and one's distance vis-à-vis the destination point, and organising the searches in a systematic way. Furthermore, this strategy is privileged in neighbourhoods or city parts with a high parking turnover rate. In such a situation, it becomes interesting to reiterate the same route. This strategy depends on the possibilities offered by the urban traffic circulation planning.

- The **cascade strategy** privileges the main roads (i.e. the biggest road type available) as much as possible over secondary (or smaller) road types. The driver moves towards or away from the destination point in a diagonal, cascade manner. The secondary roads have the function to connect two main roads, but can also serve as possible 'calmer' zones to find a parking place. The advantages are that the driver can multiply his chances both in the streets with high flux and in the smaller streets that serve as connection anyway. This type of strategy is often privileged when the car is left for a short time and the driver wants to 'take off' almost immediately. As with other strategies, the absence of knowledge of the place or city part will be compensated by the readability of the road network.

- The **erratic strategy** rests on a good to very good urban knowledge of where to find possible parking places. The road network is used indifferently to link together these different places, points or zones according to the values attributed to them by the driver. The starting point corresponds to the potential parking place closest to the destination point. This strategy requires a good knowlegde of the punctual events or situational variations (road works, rush hours, bottle necks, …).

- The **spiral strategy** deploys a circle around the destination point that grows bigger: the hierarchy of the streets is indifferent and the street corners are orientation points. Similar to the advantages of the block strategy, the spiral strategy allows the driver at the same time to control his position and distance vis-à-vis the destination point. This type of strategy is often used in residential neighbourhoods, where the parking turnover rate is rather low.

- The **island strategy** divides the territory in several search zones. These are each delineated by important roads that are considered as impassable. In this way, the secondary roads are considerably privileged. Generally, the driver carries out his search while staying in the same search zone. The advantage of this strategy is that the driver can stay close to the destination point without having to fear being 'taken away' by the fluxes of the main road types.

3.3 Searching for a parking space: an ecological approach

3.3.1 The environment and its resources

As we saw, the road network, through its materiality, is not just prescribing uses. It also fulfils a plurality of functions that comes to help, in various ways, the journey of the drivers. Thus, it is able to multiply the possibilities in terms of strategy depending on the uses that are made of it. To analyse the process of the parking search, in itself, we will now adopt a more ecological approach that is more related with the notion of 'attunement' than with the 'delegation' one. This we do out of consideration that urban environment is full of the resources required to accomplish the parking search, but that do not act by themselves. They are resources that become active only by the intermediate contact there is between the drivers, on the one hand, and the element (objects), the configuration of elements (objects), flows and movements that compose the traffic-space, on the other. We will later deepen the context of these contacts or relations. First of all, it is necessary to distinguish the various types of resources that exist. It is not the same to say about an object that it informs, canalises, suggests, or yet, that it reveals. Above all, the effects of the resources are not the same at all.

3.3.1.1 Environments that "afford"

With the notion of 'affordance', we introduce the first perspective that enables considering the environment as a resource. The concept comes from ecological theories of perception that emphasise the important role played by the physical environment in all types of action and courses of action. It is through functional values and salient properties, endowed in the environment, that the latter becomes a sort of medium for the action. By the intermediary of their properties, the form in particular, objects and configurations of objects are like invitations to act in certain ways and not others [Con2005]. Therefore, following Donald Norman, the physical appearance of the object provides the most important clues required for its use [Nor1999]. Concerning the components of the traffic environment, for example, the difference between the way a street corner 'afford' parking and the way a linear roadside 'afford' parking.

Moreover, it is a concept that ties the course of action, its environment and the process of perception. Indeed, an 'affordance' does not appear by itself as an autonomous attractor able to invite the agent to act according this or that way. Its production is conditioned by the perceptive activity of the agent that contributes to specify what are reliable resources for action [Hef1985,Gib1979]. This leads to considering the 'loop' relation that exists between perception and action. An object is perceived, and really affords, only if it fits with the current course of action. Let us follow Eric Laurier in his suggestion when he says that "*search's travelling implies an array of procedures produces relevant features in the city centre (e.g. spaces between parked cars are investigated as potential parking spaces)*" [Lau2005]. When one is not searching for a parking space, these spaces are seen as hollow, invisible or non-existent. Furthermore, we note also that the same object corresponds with a plurality of affordances.

Meanwhile, urban areas, and the roads in particular, are built and arranged in all their folds. In the words of Relieu, we can say that "*normalized space that facilitates the realization of urban activities*" [Rel1999]. In other words, urban areas are equipped in such a way that they encompass a wide range of intentional affordances in matter of parking. Namely, all the installations or the artefacts designed in order to direct parking in some specific ways. i.e. the 'echelon' parking that forces the oblique parking (what is more due to the shape of the empty space there is between the parked cars than the effect of the white lines marking) or the parking area and its spatial features that determine the directions of circulation for the cars that enter into it. Unlike the roadside that naturally affords the parking, the potential of manoeuvres is much less important within this kind of areas, what entails the reduction of the repertory of the agent actions, including the search strategies.

3.3.1.2 Environments dwelling with signs

In addition to the affordances, a lot of signs are also resources for the action. First, there are the traffic signs of course (the signing of regulation, the signage, all the road markings, …) which are conventional signs. Even if they provide instructions concerning the convenient way the actions have to be executed, however, the decision to follow them remains arbitrary [Nor1999]. So, they sometimes work with other spatial objects that act as a physical constraint that makes certain actions possible or impossible. An example are the small posts that prevent the car parking and thus, can be considered as an affordance with a negative value. Whatever they are, positive or negative, it is sure that affordances are important traffic regulators as much as the signage, if not more.

Beside the official signs, there are other kinds of signs present in various urban situations (the interactions, the movements, the presence of such object in such place, …) that also give information on the convenient way an action can be accomplished. We call them clues. In contrast with the official road signs designed to compose a sign, these spatial components provide information only if they are deciphered (decoded). Information is only enlightened by inference [Con2005]. Furthermore, the information that a singular spatial component contains is often uncertain. They should be gathered to each other and, by this way, being able to acquire a more obvious signification.

Unlike affordances, road signs and clues, more often play only a role of indication for the action, they do not have a role of control on the action.

3.3.2 PS and S&TS: two sequences based on spatial skills

In an ecological perspective, the notion of 'strategy' refers to the skills to use the environment in such a way that the forthcoming actions may be accomplished with success. Some authors speak about 'management of the environment' or 'organisation of the environment. It does mean that certain actions aim at organising the environment to facilitate the realisation of future actions. These actions correspond to all the operations during which objects are manipulated – are moved, positioned, arranged together, or yet classified – in order to create a favourable situation for pursuing the tasks/actions [Kir1999].

In this regard, the car driving situation is particular being given that the road does not allow to be arranged in this way. A driver does not adapt the traffic space to his drive as one arranges one's private place in such a way that working will be easier. Nevertheless, we suggest to retain the idea of an environment that can be organised in anticipation of the future actions. The next actions are prepared, not from the objects ordered all around oneself but from the movements of the body around all the different objects of the environment. In other words, the ratio objects/body is inverted since it is the body that moves around the objects and not the objects that are moved around the body. However, we follow the theoretical perspective that considers space not as a receptacle of movement, but space as generated by movement. So, "*for competent members of a particular place, moving in all its details is accountably actions*" [Lau2005].

Deploying a task can thus be carried out in two steps: first a step of preparation (or stabilisation) and second a step of execution. We will call them, respectively, the preparation sequence (PS) and the stake and trial sequence (S&TS).

The PS is important. It is the sequence during which the access to the searching zone is negotiated (as we saw in the routing Section) but it is also during this sequence that plans emerge slowly from the situation. These plans are dynamic and are constructed over the course of the action, when/ where opportunities are encountered [Con1993]. Indeed, the future operations are specifying and the driver organizes himself spatially so that he will take advantage of his position to reach his aim later on.

In short, this sequence comprises a double stake: 1) to orientate oneself and to position oneself, which reduces the range of the possibilities in terms of action. The advantage is to simplify the visual search (restrict the abundance of elements at which to pay attention) and, also, to lessen the number of decision points. 2) identify the clues and the signs that will help to evaluate the scope of choice and to anticipate the next actions and their order. For both of these stakes, we will see later which kinds of skills are required.

The plans constructed during the PS only play a role of orientation. They do not give any information on the modus operandi of the search in itself. They stop when the search really begins: "When you really reach to the detailed actions that have to be carried out in situ, you do not rely on the plans anymore but on the embodied skills that you possess." [Suc1990]. Once the search begins, plans are abandoned. At this stage, embodied skills (modes of attention, tacit knowledge of the signs endowed within the environment, …) allow the driver to respond adequately to the contingencies. In a way, this is a sequence that calls for more improvisation since contingencies can not be fully anticipated. When the same search is carried out several times, the skills start to be inscribed into sequences that have become routine and are revocable if the conditions are changed.

Each time an S&TS fails or seems to fail, a new PS tends to readjust the active search. This can be done by swapping search zone, by arbitrating differently the preferences of the search or by broadening the search zone. That means that these two sequences follow each other repeatedly and, sometimes, overlap in a very short space-time. And this overlapping precisely reflects the peculiarity of what is the search for a parking space: several passings that follow one another very quickly and continuously between information moments (during which information is gathered) and reaction moments (adaptation to this information).

3.3.3 Seeing with the car and seeing from within the car: driving as a multi-activity

Having discussed the role of the environment and the reciprocal relationship of the driver with this environment, we still have to elaborate on the action of driving itself. For, the relation between the 'driver-car' [Dan2004] and its 'vehicular Umwelt' [Lyn1993], or the immediate environment of the car, is made up of a dynamic perceptive play. That is, play of perceptive attunement in which a double-packed perceiving hybrid (the driver and his car) continuously tries to stay in touch with an environment constructed for the action of driving: "*the social category of 'driver' is topically bound to actions within this built environment, in which space is already fashioned for use.*" The perceptive attunement is an ongoing engagement that is part of the action of driving itself. It is part of the embodied actions that make up driving as a whole.

Driving a car can be seen as an embodied action in which "the vehicle in motion is not an extension of their body but their very embodied sensation" [Lau2005]. Besides the embodied actions of feeling the car and becoming one with it, however, we have to take interest in the embodied actions of seeing with the car [Lau2005]. In this way, we see driving and searching as a multi-activity [Mon2006]. In our case, the multi-activity is that of driving and searching for a parking space, or for clues/affordances that could lead to the finding of a parking space. An important note on the latter is that the driver is not (or cannot be) either engaged or disengaged in the activity. It is impossible for a driver to be either open to all thoughts the activity can envelop, or gives his full attention to only one part of the action (e.g. either driving or searching). This opposition dissolves in the ongoing course of action, because the driver cannot give his full attention only to the search (for this would cause a lot of accidents!). This is why we propose, to look at driving, searching and the division of attention in terms of preoccupation: "*Preoccupation pulls the individual out of the passive contemplative mode that can characterize the exercise of a pure or transcendental thinking, without inasmuch engaging the worker [driver] in an activity that is defined once and for all. It characterizes an individual that is engaged to different degrees in several activities, with each activity being able to take precedent over another spontaneously and dynamically. Different configurations and significations of the environment are thus pertinent for the individual. Preoccupation thus is not only a mental, cognitive, or emotional state of the person, assigned to its mind or his corporeal envelop. It is distributed. Preoccupation is indissociable from the obstinate presence of solicitations in its ecology, and of the more or less haunting character of the pragmatic modalities through which they invite to act. These solicitations refer to projects with instable and varying temporal horizons.*" What does this mean for driving and searching? From a praxeologic standpoint (or rather 'movepoint') the course of action of driving cannot be ceased to look, to perceive, and to take decisions. The perception when driving is done while moving [Rel1999]. This means that the driver has to slide between preoccupations. On the one hand (at least) he has to stay on the road and not cause an accident by driving into other vehicular units. On the other hand he has to scan the perimeters for clues in his project of finding a parking space. At every point in timespace, the ecology of the environment presents multiple solicitations for action, solicitations 'inviting for action'. Driving is a multi-activity in which his preoccupation slides from one goal to another according to what the environment affords at that point in timespace.

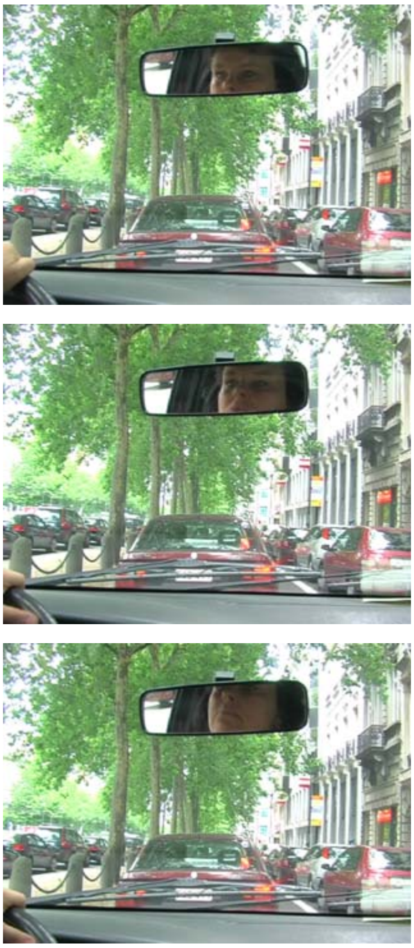


Figure 4: Preparing the action, being 'ahead of time' [Hut1995, Nor1999]. In this case orienting toward the destination point to estimate what actions to take or what actions are possible. The field of perception is enlarged, there where this is not afforded by the car, nor by the immediate environment.

3.4 The process of perceptive attunement: "How do things fit?"

Following this, we need to look at how this is actually done: how is 'seeing with the car' pragmatically achieved? First of all, we have to take a closer look at what we presented elsewhere in this report, namely that the driver and the (built) environment are in a reciprocal relationship. The information that the driver needs to know to 'go on', or know 'what's next', can be present in the environment. But this is not necessarily so. Moreover, the information 'this driver' needs that is present in the environment at a given moment isn't necessarily perceived by the driver. It is only when the two 'find each other', that the perception can lead to an action. So, the driver is looking for information, while the information (through its presence and position) seeks to be found. Bringing the two together implies a process of attunement.

3.4.1 Continuous negotiation of the field of vision

The ongoing process of attunement while driving is realised through perception (in our case mainly visual perception). A particular form of perceiving, which follows from the fact that one is driving in and with a car. Though other authors have insisted on the particularity of the perceptual space of driving as a specific "topological order" of a "linear society of traffic" in which one is "laned and trained", we would like to emphasise, without refuting the latter, that perception-in-action is far less linear than its environmental prescriptions would suggest. Especially when the driver is looking for a parking space or clues that could lead him to one, the perceptual space is multi-directional and multi-layered. From a pragmatic point of view, the field of vision of a driver isn't fixed at any point in time (space). On the contrary, the field of vision is negotiated in an ever-varying play of possibility and constraint. The driver's field of vision depends on the position within traffic-space. Traffic-space can be more or less dense, enabling more or less vision, through the configuration of the built elements and the vehicular units that add to this density. What is more, now, is that the driver's position within the car and of the car within traffic space play a mediatory role in negotiating the actual, lived-in field of vision. The negotiation of the field of vision passes through the negotiation of seeing with the car and seeing from within the car. It is this negotiation of perception that we will turn to now.

Figure 4: An 'in depth' look to investigate what lies 'behind' the empty parking space, to qualify the availability for 'this' driver and his preferences.

Figure 5: In the stills above we see that the eyes join the head, now both moving to the right. From this point on, the head movement intensifies. At the end of the head movement (0:27:24) the car is increasingly guided to the right (until she disqualifies the place at 0:28:18).

3.4.1.1 Adjusting positions: in the vehicle and of the vehicle

Seeing from within the car.

The perceptual space of car driving may be multi-sensorial, for our purpose we will focus on the role of visual perception. The organs of visual perception are more often than not said to be the eyes. However, because perceiving is an embodied practice (par excellence, even), the organs of visual perception can also be said to include the head, the neck, and the rest of the body [Ing2000]. The entire body thus can be mobilised to negotiate the field of vision. It is not the case that drivers sit still in their car and only move their eyes to look what is happening around them. Because the car, the built environment and the vehicular Umwelt (with other vehicular units) structure the possibilities of the gaze, moving the eyes alone never is enough. The so-called immutable mobile is rarely really immutable (from a praxeologic point of view). Negotiating the field of vision, trying to look at things, always involve movements of the body.

Seeing with the car.

Seeing with the car is another way of changing the field of vision to render the space more suitable for inspection. In this case it could be designated as actual embodied seeing. For another 'organ of visual perception' is the car itself. The hybrid of the driver and the car move together to change their position vis-à-vis the immediate environment. The position is the relative position of the car on the road. Both make use of the degrees of freedom afforded by the road to do so. Looking with the car is mostly combined with corporeal adjustments. Moreover, they literally work together without 'having to think about it'.

So the different organs of perception (eyes, head, neck, body, and car) work together in an embodied manner as to perceive what is happening around them. Another, last, example of this also underlines the multi-activity of car driving and searching for a parking space. We suggested that driving and searching involve more than one activity, and that the engagement of the driver slides between different actions and their goals. A common operation is that of 'keeping the situation in place'. When a driver is inspecting a potential parking space through what we call an attention zoom, the situation around him and especially in front of him doesn't stay the same. Essentially this means that the driver has to keep both situations in place.

Figure 6: The next step unfolds at the last car before the potential empty place. After bending forward her body and thus her head, the driver now turns her head right. Her positioning vis-à-vis the empty place and the resulting field of perception allows her to more closely examine the place (whether or not it is a legitimate parking place for her). This is a glance literally 'in depth', looking for indices 'behind' the empty spot. At the same time she guides the car gently to the right (see 0:27:12 until 0:27:16). But before doing this, the driver first checks what is happening in front of her. The glance thrown at the situation in front of the car starts at 0:27:02 and she will keep this glance until 0:27:16. This means that the glance forward is held while the head is turning right, preparing the head position for the eyes. The eyes will join the head movement, and the head movement intensifies from that point on (see 0:27:16 until 0:27:24). In the above stills we see the head beginning to turn right (see pink curve). The eyes stay fixed on the situation in front of the car. At the same time the car is gently beginning to be guided towards the right.

3.4.1.2 Vantage point and dilatation of time

In addition to the movements already mentioned – inside the car and with the car – other skills or tactics are there as mediation to manipulate the field of vision, particularly, by taking advantage of the surrounding environment and its characteristics. This is the case when the driver makes the most of his position at strategic places we call 'vantage points' because they maximise the field of vision. Examples are crossroads, broad avenues, or junctions. More exactly, they are catalysts of visibility on the condition of being apprehended in a suitable way. Actually, it is the combination between driver postures and physical configurations that increase the opportunities of visibility.

The videostills in figure 8 show three times the same kind of scene: the driver moves near a vantage point, i.e. a crossroad, slows down considerably almost until the stopping point, balances his body right ahead and casts a glance in as many directions as possible. By slowing down, the driver operates a kind of dilatation of time that allows him to collect the maximum of information he needs.

Figure 7: Videostills of drivers slowing down near a vantage point and looking around.

Actually, staying on the road but quasi-stationary – the dilatation of time – is a tactic that enables reducing the driving preoccupations for one moment. Thereby, the driver benefits from a short time to focalise his attention on the plans that have to be set up. It is what makes the slowing down so frequent in a parking search. Indeed, the junction is a forced opportunity to slow down but the deceleration is much more pronounced than necessary in order to really suspend the time of manoeuvring and driving.

Figure 8: Videostills showing a driver who stops to let some pedestrians cross and takes the opportunity to assess his situation.

An example of the dilatation of time is a driver who needs to stop to let some pedestrians cross, which produces the opportunity for the driver to think longer about the routing and the potential zones towards which he thinks it is better to move to find a parking space. In other words, it means that the plans and their elaboration are co-dependent on moments during which the time is suspended.

What is emphasised is that driving is based on a double condition: the information need to be sought and the environment must afford. When these two conditions are fulfilled, we talk about attunement. That attenuates the point of view to which the road misadventures are due to the distraction of the drivers only. In this case, the notion of 'distraction' refers to the modalities of the driver's attention. But it is necessary to widen the problem by linking the perception and the action not only to the predispositions of a person, but also to the objective qualities of a physical environment [Jos1999]. Traffic environments are dense and complex, and it sometimes happens that the road design is not adapted to what necessitates certain actions, a large field of vision for example. Road signing or other indications can be excluded from the field of vision, being made 'invisibles' following the perceived inadequacy between a trajectory and a specific physical environment.

3.4.1.3 Visual routine and expert glances

The meaning of the environment, according to Isaac Joseph, constitutes resources for an activity, and thus depends on the objective characteristics of the environment and on the postures of conduct, the driving in our case [Jos1999]. But we need to add that this availability is also conditioned by the knowledge of the environment that the drivers has. There is local knowledge that is inextricable from a 'field of practices'. Moreover, they are generated within a 'field of practices' [Ing2000]. For example, to know exactly where and when it is needed to turn, to know in which turn it is necessary to slow down and in the same way, to know exactly where to look at. Indeed, having repeatedly searched for a parking space during journeys that are very familiar has generated a whole range of knowing where to look (at). We can call them 'visual routines'. They are very useful because they are a way to immediately distinguish the spatial configurations that are relevant according to the goals at a given time [Lab1999].

In the following example, we can notice that the driver knows the itinerary very well. She uses it every day to go to her workplace.

> Danièle: "There are two streets adjacent to the shop [her workplace] where I usually look for a place. It is a free parking zone. So I have two possibilities, but, more often, I have more chance in the second one. Nevertheless, I am still looking at the first street. And at the first glance, I see there is no place. As I always have more chance here, I'm trying here." Interview of Danièle, woman, 65 years old, Brussels.

The glance thrown at the first street was very fast and a sufficiently expertly one to make a good observation. It is what allows the driver to quickly lessen the alternatives in terms of choice and so to facilitate her task.

Figure 9: Videostills showing the expert glances cast by a driver.

Engaged in the street of her choice, a second expert glance is thrown at the street in oblique, on the right. Again, this glance serves to minimise, as fast as possible, the alternatives. Here, it is all the more important as it enables, if necessary, to avoid to take this street. One that, as the driver explains, entails a lot of useless detours if no place is found. It is in the street she expected that the driver finally found a place.

Figure 10: Further videostills showing expert glances of drivers.

The succession of expert glances is specific to routine journeys. This succession is important for two reasons at least. It allows the driver to reduce the multitude of possible choices without interrupting the course of his driving, and this without (too) carefully and analytically examining the situation. The less degrees of freedom an agent has, the simpler will be its task [Kir1999].

In contrast with the 'sweeping visual', when one's eyes are looking at a whole situation, the 'expert glance' is accurate and aimed. It is a spatial skill – to know exactly where and what to look at/for – embedded into the detailed knowledge about the environment of the action. For instance, knowing that if this or that place is occupied, that chances are great that the search will be hard and long. A trivial place for some becomes a witness-place in the expert's eye.

A last illustration below shows another way in which the expert glance is manifested. The orange arrow indicates the location of the available place that the driver perceives, more or less, from his position. However, one can say that the place is extremely distant and not very visible for the driver at this moment. That is why he slows down until the position from where he can confirm the availability of the parking space. And we notice that the driver was right, the place was actually available. With this example, we observe that with an accustomed sight, one knows exactly from where to look at (from what angle, what place, what moment, ...) and where precisely to look at.

15.55.12 16.09.05

Figure 11: Videostills showing the way in which the expert glance is manifested.

3.4.2 When things do not fit: ambiguity and road signage

Among all the signs that the driver uses, there is, of course a plethora of official traffic signs that display obligation, forbidding, information, or yet, that warn about a potential danger. Following Daniel Normak [Nor2006], we can say that these signs serve above all as base for the social negotiations between the different users of the road (the driver but also the pedestrian, the resident, official authorities, …). In other words, it means that rules and norms – supposedly universal – conveyed by the traffic signs are continuously negotiated according to the real contexts of driving. Consequently, we can consider that the social orders, governing the uses of the road, also emerge from the local situations. This implies looking at traffic signs in their diversity of use (and not only their uniformity) and in what ways their use is improvised (and not only routinised).

More than others, some situations with official traffic signs require to be interpreted so that the action may be achieved. There are situations that are ambiguous because the meaning of the signs does not appear clearly. For various reasons, there are situations that do not let the official information pass. We can then consider that there are bad attunements. Either because of physical element within the environment that blocks the information – for example, a bad adjustment between the positioning of a notice board and the design of the road in such a manner that the signing is not visible. Or because the driver judges that the available signs are not appropriated to the present situation.

The analysis of these situations is particularly interesting. It indicates which skills are required in order to adjust oneself to the situation, a priori fuzzy. Below, three examples illustrate several ambiguous situations that, during a short time, bring confusion around the nature of the expected place to park in: does it fit or not?

3.4.2.1 Ambiguity due to low visibility and readability of signage

More than ordinarily, the situation illustrated in the first two videostills (figure 13) needs to be decoded. Indeed, the instruction given by the temporary notice boards are not really readable. And also, the timeworn appearance of the pedestrian crossing makes its validity very uncertain. It is thus difficult then to grasp and understand the rules in force concerning the parking.

> Aurélie: "Then there, there is a place but I don't know what the notice boards are telling me. Ha no, it is a dilapidated pedestrian crossing." Interview of Aurélie, woman, 30 years old, Brussels.

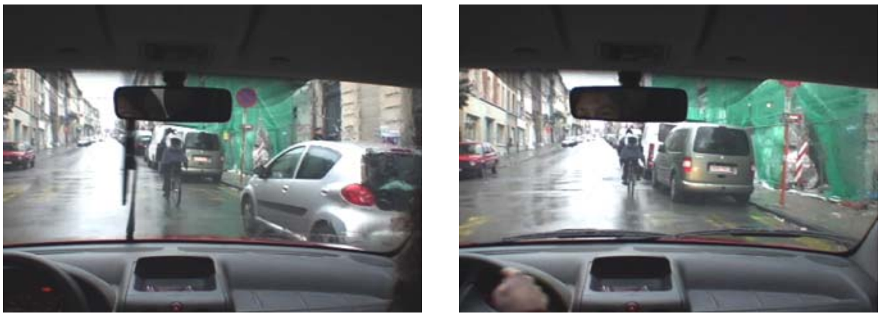


Figure 12: Videostills illustrating low visibility of signage. The driver mistakingly thought that the faded pedestrian crossing was parking place.

In a very short period of time, the driver suggests an interpretation of the situation based on a decoding of the notice boards in order to assess whether the place is convenient or not. The stake for the driver, at this moment, is not to check if the interpretation is really correct for this would interrupt the continuity of the course of action. Only the elements within easy reaching are mobilised and the driver quickly gives them certain legitimacy, sufficient for dissipating the starting ambiguity and pursuing the action. Decoded together as if there was a relationship between them, the two signs (the notice board and the pedestrian crossing) tend to show that it is better to seek a place further.

A few meters farther, the driver sees a place where she decides to park.

> Aurélie: "Ha! Here there is a place. So I don't know if it is a legal place because there are road works but it doesn't seem to have any notice boards and there are a lot of cars already parked." Interview of Aurélie, woman, 30 years old, Brussels.

Again, we can see that the continuity of the action is preserved. And it is only from the moment that the driver is parked that she starts paying attention to the parking signage.

> Aurélie: "If it wasn't raining, I would go to see if there is some other parking signage but now I won't because besides that I stay here for less than half an hour." Interview of Aurélie, woman, 30 years old, Brussels.

At the time of her evaluation, the driver explains the way she understood the whole situation that has justified her choice.

> Aurélie: "A little further down, there was just a sign and, then, a pedestrian crossing. The prohibition seemed to stop at the level of this sign. And here, there isn't anything anymore. The place is perfect. It seems to me I am on a legal place." Interview of Aurélie, woman, 30 years old, Brussels.

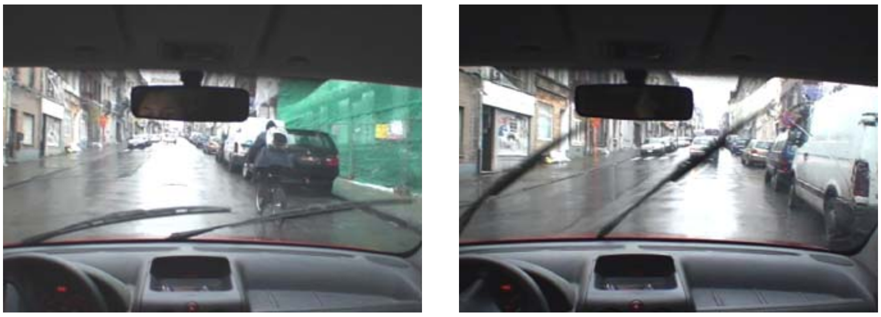


Figure 13: Videostills illustrating the parking search. In the still on the right, the driver decides to park, despite not knowing whether the place is legal. In the still on the left the van obscuring the second notice board is shown.

In her attempt to see the situation more clearly, the road work remained a bit disrupting but, nevertheless, they appeared to be not related to the prohibition.

However, after closer analysis, we can say that the first notice board extends the prohibition until the ending of the road work and that a second notice board, hidden by a van, actually indicates the end of the prohibition (a notice board that becomes visible only when the driver is leaving her place).

But in driver's perspective, while driving, the situation is fuzzy. Most of the signs are neither visible nor readable – hidden by an obstacle, too complicated to decode or yet, lacunal. Such situations call upon forms of investigation on behalf of the driver during which the most significant elements and the most approachable are articulated together so as to inform the situation as much as possible. But it is important to understand the influence of the context that plays a role in the investigation far more crucial than the abstract knowledge about traffic regulation and road conventions. It is always a set of constraints, inherent to the context of action, that will imply that some elements will be convoked by the driver. And these are the same constraints that will impose a way to articulate them. In the present illustration, we can see for example the importance of the rain, of the van that blocks the field of vision and of the length of the halt which is not long enough to incite the driver to check if the place is legal or not - and finally and more generally, the constant imperative not to stop the continuity of the course of action.

3.4.2.2 Momentary ambiguity on 'how to negotiate the prohibitions'?

The two following extracts illustrate different situations in which the traffic instructions, without being ignored, are not executed by the driver. Each time it is necessary to proceed to a form of judgment during which the relevance of the rules is assessed by the driver according to the situational elements. What also means for the driver to perform a kind of investigation. It is the case in the situations illustrated below in which the driver instructs a situation in which the outcome is uncertain.

> Thomas: "What we see here is a place that has just been left. There is a prohibitory sign from 07h to 20h. However, pragmatically, that doesn't seem to really disturb their working site. The place is perfect. I could stay here for one hour. They will never have more than one van. They can easily be placed in front of me. And as it is raining, they don't work so much [while smiling]. And also, I am right faced with my door. If I needed to spend the night here, I would have sought a place somewhere else." Interview of Thomas, man, 32 years old, Brussels.

Figure 14: Videostills showing the situation analysed in the box above.

After having evaluated the place with the help of several noticing and assumptions (the place was occupied earlier, the good progress of the road working does not seem to depend on this place, a short time halt is not much disturbing) the driver opts for parking there. Despite the obviousness of the prohibitory sign and the fact that this one seems justified, the investigation remains required. For that, the driver is making an inventory of all the present objects which are of some importance, examines them, and thus opens the possibility of a practical reasoning to be developed in spite of the traffic rules.

This situation is quite emblematic of the process of searching for a parking place. Indeed, many searches end similarly, especially when the area is saturated – what generally entails some illegal parking as the parking two abreast, on a corner, half on the pedestrian crossing, …

This point conducts to consider the search for a parking place as a routine action that, the most often, entails the driver to negotiate locally with rules and conventions seen as inadequate at a given time. It is then a justice of 'efficacité' [Jou2007] that is set up and for which what is 'good' does not necessarily correspond to the rules but, rather, corresponds to the guarantee that nobody (nor any other entity) concerned by the action will be impaired or injured.

3.4.2.3 Ambiguity of meaning covering signs

The last example illustrates again a situation with a driver's investigation and in which he negotiates the interdictions. But this time, the situation is ambiguous first of all because the driver is mistaken about the significance of the road signs, more precisely, about the line marking. After having turned, the driver decides to park in front of a 4X4 exactly where the yellow markings lines indicate an interdiction. At the analysis, we can observe the parking is forbidden all along certain sections of the street. What seems justified by the large entries of employment sites on both sides of the street and that must involve frequent and important manoeuvres.

The extract of the interview below shows the evaluation of a car driver concerning the space where he has just decided to park.

> Assen: "I feel a degree of anxiety because of the yellow marking lines. They tell me that the parking is forbidden because the guy, for I do not know what reason, thinks that he needs plenty of place to be able to leave his garage, which is 5 meters farther, to make his manoeuvre! It is my own apprehension. He is likely to call the police only if one touches the yellow marking lines. But, I make the evaluation immediately. For me, I don't disturb anybody if I park here. That doesn't prevent to enter the garage nor to leave the garage. The more, there is a car parked in front of the garage. Maybe it is the owner of the garage, in this case, there isn't any problem."
> Interview of Assen, man, 35 years old, Leuven.

Figure 15: Videostills illustrating the situation described in the paragraphs above.

We can notice that the yellow marking lines represent a prohibition for the driver. However, he is mistaken on their justification, what does not necessary prevent the application of the instruction. But most often, before being applied, the instructions are first situated into the context of the action in order to assess if the prohibition is relevant or not according to the specificities of the present context. With such an inquiry, the reasons justifying the prohibition are found out, what eventually leads the driver to revise its validity. The most important in this situation is not the exactitude of the justification that the driver gives to the prohibition but the possibilities he creates to make a more appropriate choice. We can see that the whole argumentation of the driver is articulated around the door of the garage allowing him to assess what is convenient. The latter is not so much convoked as the real true cause but rather as a pragmatic one to force the decision.

It is interesting to note that rules, as frequently negotiated, are highly situated. Furthermore, the exact knowledge about the signage is always linked to the knowledge concerning the area of the signage. This means that the specificities of a place give specific meanings to the sign. By knowing a place, one knows when and why rules are in force.

3.5 The organisation of space: zones of relevance

We saw that the environment of the action emerges with plenty of contrasts. There are a lot of nuances and qualitative disparities that are all relevant for the search of a parking space. In other words, we can say that, provided being able to detect the lines and the saliences, the environment is not passive. The detection of an affordance, as a specific practice, enables mobility in the city. It is a practice that enacts mobility. In the same manner, the organisation of space into different zones is also an efficient way to perform mobility. At the condition, this time, that this spatial organisation is made according to the objectives that are pursued. In this part of the report, we will consider another practice that also makes mobility possible: the activities of configuration of space. And for that, we use the notion of 'zone'.

Compared up to a certain point with the concept of 'paysage' (landscape) [Tro2001], we can say about the 'zone' that "*it [the landscape] supposes to have arranged a totality which is not the simple addition of the different parts that compose it […] and that the parts acquire their determination only in their relation with this totality.*" The configuration activities of space are all the visual and cognitive operations that allow the selection of the most relevant objects, their qualification and then their articulation into one entity.

This configuration of space is the next step after the detection of useful signs in the environment. Indeed, afterwards they are connected in order to constitute a zone of relevance. We will show some situations where zones of relevance are elaborated and we will see the strategic role they have in the search for a parking place. But before that, we need to add one theoretical precision about them. The emergence of a zone is linked to the specificities of a space-time that propose some opportunities for the configuration. But, at the same time, the zone is also the result of an action, the driver's one. As the landscape that appears in conformity with one's certain aesthetic preferences, the zones are drawn depending on the aims an individual is pursuing. The zone appears with forms that depend on the activities in which one is engaged. This means, once again, that the agent does not only analyse the situation but he truly contributes in making it [For1999].

3.5.1 Parking zones and disqualifying zones

Nathanael: "I think that it is more logic to search a place in a spiral, further and further away from the centre. This is what works best. But since I take a certain street, I am in another part of the city, another half-circle. And once I am in this other half-circle, it is very difficult to return here." Interview of Nathanael, man, 34 years old, Brussels.

Nathanael: "I am going to try to reach Solvay, it seems to me that there are more places in the street that are on this side of the Chaussée d'Ixelles that on the other side." Interview of Nathanael, man, 34 years old, Brussels.

Usually, inside the familiar areas, the drivers search a parking place through 'parking zones' which are relatively well circumscribed. Their qualification can be explained by a combination of reasons, the proximity to the destination, the potential in terms of places, the fact that it is a free zone, … But, above all, they have strategic functions. By the definition of one zone, it is at once a set of operations that are defined. First, they mark the spatial limits between an inside and an outside – where the search begins and where it ends. And secondly, the spatial characteristics of the zone impose a form or a direction to the routing, to the 'parking-routing'.

Choosing one kind of zone rather than another is strategic. Indeed, the choice for 'spiral routing', for example, allows the individual to stay into one same block of streets and to avoid losing himself. Instead of that, an 'erratic routing' allows reaching the main roads more quickly.

At the opposite, there are the 'disqualified zones', depreciated as a parking area. However, they have value for the search. More, they are likely to fulfill a variety of functions, in particular, the connection between two spatial points. This is the case with the 'lap'.

The disqualified zone is also disqualifying. First, the lap corresponds to a fast lane (ring road) which canalises the driver in only one way and on which it is difficult to turn to the right. This can indeed discourage the driver to go on for a third turn. He will probably prefer to park at the first or at the second opportunity instead of taking this road again that is so absorbing. So, we can say that the lap, in this situation, excludes the possibility of a second or a third turn. Second, this road disjoins the spaces as would a border do and, for this reason, can be seen as a point of no return. This lap-section dissuades those who want to make some round-trip between these spaces, what is a second manner to be discriminating. At the same time, we note that by the effect of this section of the road, it is as if the spaces were very distant from each other. However, it is not a Euclidean distance but more a distance we can call a 'cognitive distance'**.**

3.5.2 The qualification of space of connecting clues

The extracts of the journey below show the way a space is progressively qualified and obtains a particular function in relation to the search of a parking place. In the beginning, several isolated signs are convoked, as for an investigation, to provide punctual meaning. And then, gradually they are gathered, lose their independency and start getting significant for a larger space, the whole street in our example. Indeed, we can see that a number of empty places, first considered one by one by the driver, have finally given a global signification to the street. Put in relation to one another, these singular signs confer to the street a status of totality and, through it become relevant clues, useful for the search. Therefore, by a progressive assembly of isolated elements, it is a semantic of the street that is worked out.

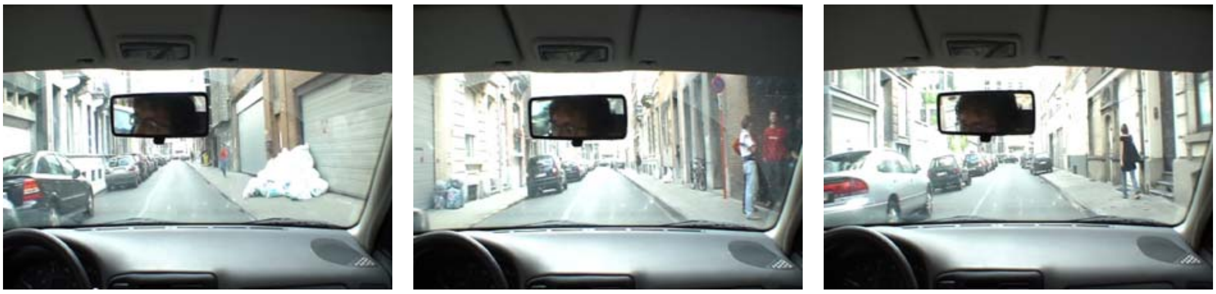


Figure 16: Videostills showing how a driver passes through a neighbourhood and decides that he is in an upper-middle class part of the city, with a lot of private parking garages.

At the first garage door, the driver slows down, look at his left and checks out:

> David: "That's a place…ho no!" Interview of David, man, 31 years old, Brussels.

At the second door garage, D already slows down less. He starts giving meaning to the street. At the third garage door, he does not pay attention any longer. He still looks a very little at his left but he continues at the same speed:

> David: "Here we are in an upper-middle class neighbourhood, everybody has his own garage." Interview of David, man, 31 years old, Brussels.

Now that the street is qualified, the attention of the driver changes in mode. The focus is not on the empty places anymore.

3.5.3 The buffer and retreat zone

We identified two other zones: the buffer zone and the retreat zone. Both play a specific role in the search for a parking place.

The 'buffer zone' corresponds to the space-time during which the parking situation is evaluated in order to determine exactly the limits of the parking zone. It is a buffer zone seen its intermediate position always upstream of the search zone. More precisely, while the driver traverses the buffer zone the threshold of the search zone is defined. So, the buffer zone extends while the search zone tightens itself or, depending on the characteristics of the situation, it can be the opposite. Finally, it is a phase during which the search is passive being given that the aims, at this moment, is not to find a place but to calibrate the search zone, to fix its limits.

For its part, the 'retreat zone' works as a back-up zone. It is where the driver knows that there are indeed some places available but without wishing to park within this area. Last in the hierarchy of preferences, the retreat zone serves as the ultimate recourse in case of an unsuccessful search. Reassuring in its function, the existence of this zone encourages the driver to go on his search towards other zones that are more convenient according to him – that, without fearing any failure.

3.6 The situational construction of the preferences

Following a pragmatic approach, we tried to unfold the complex processes by which the driver-car manages to adjust himself to the specificities of the environment. In such a perspective, the 'strategies' are all the actions that are made possible being given the different situational constraints on the one hand and the individual skills on the other. For that reason, we presented all the tactics and the skills necessary for carrying out an action – to find a place in this case. We have considered the use of the road network, the division of the action in temporal sequences, the negotiation of the field of vision, the qualification of space, and the identification of the clues. In this Section we will examine the way the decision relating to the suitability of the parking place is taken. For that, we introduce the notion of 'situated preferences' that comes to enhance the one of 'stated preferences'.

For the transport studies, the choice for a parking place is determined by a set of parameters corresponding to several fixed preferences. These preferences – concerning the cost of the place, the distance to the destination, and the length of the search – are stated off-situation and take different values according to a certain number of types of journey and types of individual profiles. While considering the importance of such preferences, we gave special attention to the situational dimension that influences the construction or the preference in context. In this Section, we will see the role of the perception within the process of definition of the preferences. Only, in our perspective, it is not question of preferences as general principles that are grasped but situated preferences, justified by the situation at a given moment.

3.6.1 Willingness to pay

If there is the willingness to pay, one still has to be able to distinguish a pay parking area from a free one. Indeed, it is still needed to detect the statute of the parking areas which one passes through. Of course, they are identifiable by the intermediary of official signs: a blue board P (for parking) in Brussels and a boarder, as well, in Leuven and also a small strip of blue plastic around some posts. However, at the analysis of the embarked interviews, we see that these signs are rarely mobilised. Often, the recognition of the pay parking areas passes through other signs.

A wide range of signs help the driver to identify the statute of the area – free or pay parking area. For the most familiar journey, several drivers admit not to have ever paid attention to the sign P. It is only after having been fined that they took note of the paying statute of the area. Of course, one can say that the willingness not to pay diverts the attention from these conventional signs. Nevertheless, it is not the only explanatory motive. They are not noticed because they do not enter into the field of vision. It is the case when an area changes of statute, becomes a pay parking area and, thus, obtains the conventional signs P. These are not seen because of the limit of the field of vision which has been forged by the visual routines that allow the driver to perform driving and parking in a 'cruise control' manner. The automatic gestures – the glance, the movement of the body or the head – are oriented towards the parking clues whereas other indications, like de P board, are left out of the field of vision.

We could also observe that there are signs which are not insistent enough. Or, we can also consider the hypothesis that it is due to the requirements of the driving as a multi-activity. It is the case with the more unusual journeys when the driver has less knowledge about the places he is passing through. Beside the concerns about searching for a parking place and staying on the road, the driver also needs to find his way or pay attention not to get lost. Divided in three, his attention filters the information leaving on side those of less importance at this time. It is only once he is parked, the statute of the zone can be finally examined. And actually, from this fixed point of perception, the parking signs are multiple and are not only conventional: the nearest parking ticket machine, the parking ticket set down inside the parked cars, the fines left on certain cars, …More often, these are configurations of signs that are noticed rather than singular signs. In addition, the qualification of the areas also entails the driver to assess their statute of free or pay zone free sometimes incorrectly.

> Brigitte: "I didn't even know that it was a pay parking area. I didn't really think that a street as small as this one was a pay parking street. There are only two shops. You can not imagine that it is a an urban centre, it is just a little section with few shops!" Interview of Brigitte, woman, 32 years old, Brussels.

And finally, it happens that these conventional signs do not enter in the field of vision because the driver is scrutinising, like a scanner, a very narrow perimeter of his environment, in a such manner that he doesn't see what is beyond it (for example, when he examines, one by one, each empty space of a street to be sure not to miss any opportunity). It is a kind of attention we call the 'attention zoom' which is characterised by a high perceptive investment and an eye that observes a tiny space in all its details. It is an attention that excludes all the elements of the environment that are not necessary for the immediate action. It is a fugitive attention; meanwhile, the decision to park can be grounded on it.

As a consequence, distinguishing the pay statute of an area is an operation which is not necessarily spontaneous. This is also the case with blue zones. Indeed, this operation of checking is not always inserted into the process of searching. Among other reasons, the checking can be heavy in terms of time and manoeuvring for the driver in certain circumstances. Therefore, it is often only after having parked that the point of view can be broadened for the operation of checking.

Of course, the willingness to pay and the willingness to check are intertwined. As for any type of action that has to be achieved, there are risks that are estimated. Namely, in this action, the risk is being fined. Not to check or not to pay mostly implies to have estimated this risk. This means that the driver needs to get the most appropriate clues for making this estimation. Very diverse, these clues are often official signs that have been diverted in their meanings (the presence of a police officer, the fines left on some windscreen). Or again, the consideration about the kind of area where the driver is:

> Tom: "There are parking ticket machines here, but in general I don't pay. Actually, it depends on the area I am in. In the centre, I am more inclined to pay because there are a lot of controls." Interview of Tom, man, 27 years old, Brussels.

So we see that the urban signs are multiple in the messages they deliver. There are full of meanings that are not absolutely intended or planned.

Concerning preferences, we can say that they are not completely correlated (willingness to pay, willingness to walk and the search time). For much people, there is a variable temporal threshold (5 minutes, 10 minutes, half an hour, one night, …) below which they don't pay. So the willingness to pay and the other preferences, in this case, are independent. But as soon as this variable threshold is exceeded, the preferences are changing and enter in a relation of a mutual dependency.

> Aurélie: "Beyond half an hour, I start to pay attention if it is a pay parking area or a legal place and only then I can imagine to search more and, eventually, farther for not paying." Interview of Aurélie, woman, 30 years old, Brussels.

It means that some parameters like the parking time – as we see – and some others – as the estimation of the risks for example – are likely to inflect the balance between the preferences.

3.6.2 Willingness to walk

Concerning the two other preferences – willingness to walk and search time – let's start by emphasising that the ideas of time and space are far less unequivocal and far more complex than is often taken into account. Firstly, we note that the perception of the distances is very variable since its measure is not only metric or temporal. For example, certain territorial ruptures that separate familiar zones from zones that are less frequently passed through, produce non-Euclidean or non-metric distancing that could be called cognitive distancing. A driver can then ignore certain potential parking spaces that are relatively close to the destination point. Thus, we can consider that the space is lived in a way that is much more wrinkled than linear.

Besides this point, the distance always has to be grasped within the trip chain in order to understand what is the relevant distance for the driver, the distance from which point. In some circumstances, the driver will prefer to be parked as close as possible of the main roads, staying linked to the traffic flow, so that he will be quickly able to go back to his car. At the opposite, one can make choices about a physical place because of series of particular activities, and not one sole activity. In this case it sometimes more convenient to be more anchored in a territory close to its different utilities (restaurants, shops, state-owned companies, …). So, a parking place becomes a centration point around which several activities can be combined.

And finally, the intensity of a distance will not be lived in the same way by someone who is going to an urgent appointment than by someone who is searching a parking place for a promenade. This is because the experience of the walking time is linked to the emotions and also because the driver's perception of the distance with the destination is fluctuating according the temporality of the next activities.

The same is true for search times. Although one unit of measure is time in seconds, minutes, and hours, other measurement units come into play during real-life searches. Comparable to what is said above on the notion of distance, the experience of time can change according to the situation. Here, we can think of situational (time) pressures that influence the experience a driver has of time. The stress resulting from a time constraint is in fact influenced by time becoming smaller than the objective measure would suggest (this means that the lived time is less than the objective time). On the other hand, when the driver has the time to search, time will be experienced in another way (lived time is greater than objective time). As Nathanael mentioned during his interview, when he is looking for a parking place with friends in the car when they go for a drink, "I don't mind looking even for 15 minutes or more!" (Nathanael, man, 34 years old, Brussels). This means that the search is to be considered in different ways, according to varying intensities.

Another remark to be made on the notion of time and consequently on search time, is the difference between time and times. In our interviews, time was almost more often made sense of in terms of times. That is the number of times a certain unit of a route was reiterated. Taking this street once, twice, a third time, and then it is time to switch to another way of doing the search. Or, in another example, taking a parking place that is less preferred in distance, but "I'm not going around that again!" (Nathanael, man, 34 years old, Brussels). It could be that times as parts of a route are only synecdoches, or semantic short cuts for the 'real time' they take. In this sense the driver doesn't count the seconds and the minutes, but he 'sees' how much time it is going to take immediately in the environment. Even if this is a plausible assumption, we should not overlook the content of the example just mentioned. For "I'm not going around that again!" does not only point to the time it is going to take, but also to the difficulty of the action it implies. So even if we accept the idea of displacement of units of time, we should also add another dimension to time, namely the action.

3.7 Conclusions

A novel way of looking at the search for a parking place is put forward. We have focalised on the pragmatic and ecological dimensions of actions, that is, the engagement of an agent in a dynamic environment in order to complete the task of finding a parking place. This engagement is embodied in the driver's driving and search itself. It consists of the reciprocal relationship between an affording environment and an agent trying to attune to this environment. Together with theories drawn from situational cognitive science – which are used to describe logics of routing of an agent – we have uncovered the dimensions of the parking search that hitherto have stayed black boxed in transport studies (off line accounts of actions). In the approach we propose decisive mutually interacting and creating roles by the momentum of courses of action. These are (i) the role of routing, (ii) the role of perception, and (iii) the role of situational constructed preferences.

(i) Considering **the role of routing**, we mention that the road network as a differentiated network serves as a physical and organisational mediator for the action of routing. With the differentiation of road types, a differentiation – that could be seen as allowing strategic conduct – of possibilities emerges. The agent making use of the road network can do so through an active or a more passive engagement. It can follow its own logic to reach the zones of choice, or follow the logic proposed by the road system. Together, the differentiation of the road network and the engagement of the agent construct a matrix of possibilities that could be said to be a matrix with strategic potential for its users. Certain combinations of roads that make up the routing can be considered as less or more strategic. However, in the latter, strategy is to be seen as strategic from a certain point of view. The values of the roads change according to the sequence in which the agent finds himself during a course of action. The uses of the roads are multiple in their answers to questions more or less stable in time, in the agent, and in his relation with the environment.

(ii) Considering **the role of perception**, we mention that it resides in a microscopic viewpoint of action (unlike the routing, which is more topologic). Its strategic role intervenes at points or moments in the ongoing action, points that are knots or joints wherein attunement between an agent and his immediate environment is produced. The attunement – all in the logic of a singular agent – allows him to know what is next or what to do next. As a result, the course of action can evolve through the mediation of a plan that is constructed in the process of adjustment or reaction to the situation. This perception is above all visual (at least for the task of the parking search). However, it has to be emphasised that the organs of visual perception are not limited to the eyes only. The whole body is engaged in the processes of perception, as well as the hybrid of the human body and the car. Seeing becomes seeing from within the car and seeing with the car. In the same respect as with the strategic possibilities of routing, the strategic advantage an agent can have, emerges from what the environment tries to show and how the agent is able to read it. In other words, the spatial and perceptual skills of an agent will facilitate him in recognising, deciphering, and interpreting general or idiosyncratic knowledge needed for pursuing and achieving the task of searching for a parking place. The size of detail and the ways in which the environment is able to affect a particular agent vary along with the (situational) emotional make up of the agent (i.e. the ways in which he is affected or not), and the experience accumulated in and through time in and through a particular space.

(iii) Considering **the role of the construction of situational preferences**, we did not refute the idea of the use of preferences as parameters in the final choice (in our case: of a parking place) proffered in most transport studies. We acknowledge that they can have a discriminatory function. However, it is important to take the situational dynamics and semantics/semiotics (i.e. indexical effects) into account. The latter are important because of their capacity to re-dimension the basic or initial preferences of an agent. Moreover, the languages in which the preferences are rendered intelligible, that is, the units of measurement, could be described in a different manner. Rendering the decisional processes intelligible should also comprise those that agents use (utterance instead of discourse).

If the outcome of this research seems difficult to place, if its register seems either too rich, detailed, or fluid, while at the same time not being completely ethnographic, this is in part due to the output it has to generate. In a multidisciplinary research context, we first put forward the translation of a policy and subsequent engineering question into socio-anthropological questioning. In order to re-translate the questions and possible answers, a boundary object in the form of a decision matrix is constructed. "*Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual use.*" So, the decision matrix or grid that serves as an output of our research, needs to serve as input for the other research teams.

4 Parking agents

In the previous Chapter, the behaviour of drivers wanting to park was examined. This Chapter discusses the modelling of the drivers and the translation of the behavioural research of the previous Chapter into the model. First, the concept of the model agents is introduced. In the second Section the essential features for the model of the behavioural research are given, while the third Section discusses the actual implementation in the model. The final Section describes the discrete choice models used in SUSTAPARK.

4.1 Model agents

The SUSTAPARK project adopts an agent-based model for the implementation of the drivers. This was motivated by the flexibility and interaction phenomena that agent-based models allow. Further motivation was provided by the idea that the psychology of the driver is important for the parking behaviour. Later in the project, it became clear that the SUSTAPARK model did not need the complete added complexity of agent-based modelling to have all the necessary features. Some of the related terminology continues to be used however.

The 'agents' in the SUSTAPARK model are in fact the cars of the drivers. The drivers themselves (i.e the people) are not explicitly modelled. This is because modal choice is not implemented and walking is not explicitly modelled. Extending the SUSTAPARK model with multi-modality and car sharing would require making the distinction between people and their mode of transport. The cars (or the agents, the two terms will be used interchangeably further on) are the entities that enter the cellular automaton, drive around in it, and compete for parking spots as near as possible to their desired destination.

4.1.1 Spatial location

Obviously, cars must always be located somewhere in space. Although this might seem a trivial issue, it deserves careful attention. The problem here is that, in general, cars can be either in the cellular automaton or outside it (either in a parking garage or outside the area of the city). A car that is outside the cellular automaton is no longer truly spatially located. This requires keeping lists at these locations with all the cars that are located there. An associated problem is that the cars are only located within the cellular automaton, for which the translation into real-world spatial coordinates is not straightforward.

Another aspect of the spatial location of the cars is that they all must have a location when the model starts to run. In order to prevent guesswork as to where driving cars are on the moment the model starts to run, we make the assumption that all cars are parked at the start of a model run (either in the city or on a gate). This implies that the starting time of the model is by necessity one with a traffic density that is as low as possible. The chosen time point was 4 AM, early in the morning.

The assignment of the cars to their starting parking places is only complex for cars that park in the city. Cars that start outside the city start at a gate. Cars that park within the city are placed on the parking places one by one. A car is first randomly selected and then placed on a free parking place as near as possible to its starting location (which is assumed to be the house of the driver). The places considered are first private parking places (if such a place is available to the agent) and then on-street parking places. Parking garages are not considered as they are closed for the night. If no free parking place can be found, the car is placed on the nearest gate.

4.1.2 Types

The population of the studied city and its hinterland is grouped according to 8 different types. Each of these 8 types corresponds to different mobility behaviour. While the group to which a person is assigned does not impact the parking behaviour, the different groups facilitate the estimation of the transport demand in the city, due to their differing mobility behaviour. The eight groups are:

- students,
- full time working in the household,
- unemployed or incapacitated for work,
- retired,
- employee,
- liberal profession,
- and other.
- visitors.

With the exception of visitors (from outside the hinterland of the city), each of the other groups can be residents or people coming from the hinterland of the city.

For the purposes of the model, each agent (i.e. car) is assigned to a group. Extending and refining the model will likely require adding parameters differentiating the groups (which is currently not the case).

4.1.3 Activities

The distribution of different types of activities is hetergeneous across a city. Some areas will be more devoted to shopping, others to work and still others to nightlife. Since these types of activities not only differ in their location but also in the time periods when they are in demand (and thus cause transportation trips and parking demand), it is important to make this distinction. The SUSTAPARK model implements 8 types of activities, namely:

- **Activities at home***:* These are the trips of people returning to their home (reason not specified).
- **Working***:* These are the trips towards the employment location.
- **Attending school***:* This represents going to school for under-age persons and taking courses at the university.
- **Shopping***:* These are the trips towards a shop in the inner city.
- **Services***:* These are trips to banks, public services, …
- **Business***:* Business trips represent work-related trips but not to the normal work location. They can be very diverse and are difficult to spatially distribute.
- **Nightlife***:* They include diffuse trips (visits to friends and relatives, …) and trips to more concentrated entertainment locations such as restaurants, cafés, movie theaters, …
- **Visits from outside the city as usual environment***:* These represent people coming to the city as a tourist and visiting the major points of interest. Although this can be substantial in some cities in the tourist season, this is thought to be negligible in most (average, Belgian) cities.

These eight types of activities are thought to be sufficient for the representation of realistic behaviour.

Based upon available data sources each street segment of the city is assigned a certain attractiveness for each type of activity. This attractiveness is used in assigning locations to the agents for the activities that the agents want to perform.

Note that in the current version of the SUSTAPARK model, the activities only have an impact on the parking behaviour through the choice model for the type of parking. In reality other differences might exist.

4.1.4 Activity schedules

4.1.4.1 Concept and motivation

In other transportation models much attention is devoted to the choice, sequence, and times of activities that the modelled people want to perform. Because this is a complicated issue outside the scope of the SUSTAPARK model, we adopted a simpler approach to assign activities to the different agents. This approach is termed 'activity schedule'.

Such an activity schedule is a sequence of activities with the locations at which and starting times when the agents want to perform them. The activities themselves are never performed; the cars simply try to park close to the location desired by their assumed drivers and wait there until it is time to leave for the next activity. In each activity schedule there is a one-to-one correspondence between the activities and the locations. The type of activity is of limited consequence for the model: a driver's parking behaviour will be determined by the local situation at the time he is looking for a parking place, his experience and knowledge of the area, his personality, and his driving attitude. The activity can indirectly influence the parking behaviour; for example, some activities will take place at times when parking is easier or more difficult, some activities will have a starting time that the agent will want to adhere to, and for some activities the willingness to pay for parking might be higher, …

Here we made the assumption that the activity pattern of an agent is fixed, in the sense that an agent does not need to choose the most desirable time to perform them. Instead, these times are drawn from a statistical distribution, introducing variability in the model. Note that this means that the model will not allow within-day re-planning of the activity schedules. It is thought that this omission does not meaningfully affect the parking dynamics within the city. An agent might skip an activity if he has not been able to find a parking place for a very long time and needs to start the next activity on its activity schedule.

4.1.4.2 Generation

Since the agents do not decide which activities they want to perform, the activity schedules are instead generated from a database of schedule bases. Such a base contains the fixed sequence of the different activities that compose the activity schedule and lists for each activity the mean and standard deviation of the time when the activity starts. When a schedule is generated for an agent the starting time for each activity is drawn from a normal distribution with this mean and standard deviation.

After this step the locations where the activities will be performed are filled in. As explained in Section 2.3.4, for each activity the street segments of the city have a certain (time-independent) attractiveness. This attractiveness is used to calculate the probability to select this particular street segment for this activity. The street segment is then chosen by a random draw. This choice is independent of the location of the previous activity and might therefore be located anywhere in the city. This might make some activity schedules look unrealistic and lead to more traffic than in reality. In the selection of the locations the model also does not contain any relation between the location and the socio-economic status of the model.

Some activities of the agents will be located outside the area under study. For example, people who live in the city and go to work somewhere outside the city. The trips that result from these movements are not disaggregated by purpose, but are listed in the activity schedules as activities elsewhere. Multiple consecutive activities are lumped together as one entry in the activity schedule. The gate by which the agents leave the city to go 'elsewhere' is selected randomly.

The model operates under the assumption that, at the start of the model run, no-one is in transit. Therefore everyone will always be at a certain location at the start of the model. This location is not noted as such in the activity schedule, but it is always the location of the last activity in the schedule. During a day agents are thus assumed to follow a cyclical routine, starting and ending at the same location. This location is assumed to always be their home. In reality it could also be that a person works at night, for example.

The previous paragraphs discuss how a single activity schedule is generated. The different schedule bases are stored in a database table, as stated above, with their sequence of activities and the mean and the standard deviation of the starting times of those activities. The form (sequence of activities) and the distributions of the starting times must be derived from external data, for example a mobility survey.

From such a mobility survey (or some other appropriate data source) the allocation of the different sample schedules over the different types of agents can also be determined. This data is stored in a table linked to the table with the schedule bases. The allocation table is the tool to control and modify the total number of agents, the number of agents of a specific type, and the number of agents that adheres to a specific schedule base.

4.2 Conceptual framework

In this Section a summary of the essential features of the sociologic results in Chapter 3 is provided (the description of parking behaviour). The parlance is also adapted to be more familiar to persons with a technical background. First 4 key concepts are explained; these are the 'propre', the centration point, planning and affordance. Then a summary of the behaviour of the drivers is provided, distinguished by their level of 'propre'. The behaviour of the drivers is further divided in three phases: the inception sequence, the preparation sequence, and the stake and trial sequences.

4.2.1 Concepts

The 'propre' designates the places that the car driver travels to under the assumption of availability (of parking places). It is also used to denote the expertise of the driver in relation to space, his knowledge of the area and its parking places. Essential is the familiarity of the driver with the parking possibilities in the city (encompassing on-street parking places, parking garages, parking pressure, possibilities for park-and-ride, …). The term 'propre' contains a morphological aspect as the propre can be a contiguous, circumscribed area, or it can be composed of unconnected zones (shattered) where the car driver sequentially goes to search for parking. The operational range of the propre is not defined (and therefore neither the area in which people search for parking). The knowledge contained in the propre allows the presumptions that allow the envisaging of a parking strategy.

The degree of propre can be viewed as a continuum. For practical reasons the SUSTAPARK model distinguishes two levels: high and low. Low means no or little knowledge of the area. High means full knowledge of the area. It is assumed that all visitors have a low level of propre and that all other categories of drivers have a high level of propre. The low level of propre of visitors applies throughout the entire city. For other drivers a high level of propre has been assumed throughout the city. In reality this assumption will not hold, especially in bigger cities. One way of implementing this aspect is to divide the city in zones (a somewhat arbitrary step) and give each agent an indicator whether he is familiar with this zone or not. The problem then becomes deciding for each driver which zones he is familiar with.

The 'centration point' denotes the parking place that fulfils the search criteria. It forms a connection between the search criteria. The search criteria are composed of the preferences of the car driver regarding parking choice, his activity schedules (and the constraints it imposes) and the local situation. It dynamically changes as the spatial position of the agent and the point in time change.

To treat parking strategy some understanding of planning is also necessary. Two different types of plan are distinguished. The plan as a program means strict, precise instructions that have to be executed (in sequence). The plan as a resource means looser guidelines that allow room for improvisation, greater use of the environment and the knowledge of the agent.

In practice, these two types of planning are intertwined and during the search the balance between them shifts back and forth as the parking search progresses. Therefore they are not modelled as separate concepts. Instead, the plan as a program is considered to be the actions that the agent actually executes in the model. The plan as a resource corresponds in the model to the actual parking strategy of the agent.

The concept of 'affordance' encompasses anything that is a resource of action or for information, as perceived by the driver in his environment. The affordances are not autonomous attractors that can take action by themselves. They are linked to the built environment, the social environment, or have a cultural dimension. Affordances can also be found in artefacts, i.e. objects and devices designed to be precursors to the realisation of certain actions. They are dynamically intertwined with planning as the plan depends upon the resources available. They are also linked to the level of propre as the familiarity of the drivers with a place or situation might determine which affordances they perceive, and are thus available to them.

Affordances are a very broad concept. The level of detail that they imply (which is as detailed as individual signposts and traffic lights) is not feasible in the modelling effort. The data required for such a detailed model would be humongous and running the model would require large amounts of time. What is feasible is to approximate some affordances as measurements of the local traffic situation and use these as decision variables in the choice models.

One other concept introduced is the idea of attention zoom, which is unfortunately not implementable in the current model. It is also noted that slowing down or low traffic speeds allow drivers to get a better look. The centration point in this phase evolves as the search evolves. Centration points are chosen by drivers with a high level of propre to be relevant.

4.2.2 Behaviour analysis

The sociologic analysis divides the search for parking into three sequential phases: the inception sequence (starting sequence), the preparation sequence (stabilising sequence) and the stake and trial sequences (executing sequence). In each of these phases the analysis further distinguishes between a high level of propre and a low level of propre, as this strongly determines the behaviour and its driving factors. The following paragraphs will first discuss the parking behaviour of drivers with a high level of propre and then the behaviour of those with a low level of propre.

4.2.2.1 High level of propre

During the inception sequence the goal is to drive towards the destination from the starting point. Therefore the driver adopts a plan as a program. A driver with a high level of propre follows a sequence of instructions that stem from their knowledge of the area. A driver switches to a plan as a resource if he encounters a contingency blocking his path or if the driver wishes to start looking for a parking place (which means the end of the inception sequence).

In the inception sequence a driver with a high level of propre looks for the most convenient way (as he already knows the 'right way') and, on ring roads, takes the gate nearest to his destination. A driver might also decide to take a shortcut; the motives for doing so are diverse. In this phase the driver also tries to position himself well for his subsequent parking search. The centration point has little to no influence at this stage.

During the preparation sequence the driver has four objectives: specify the threshold of the search area, measure the level of difficulty of finding a parking place, gather information needed for the actual search and adjust his parking plan to the local circumstances and position himself as good as possible for his parking search. The preparation sequence takes place in an area around the point of entry into the parking zone. A driver with a high level of propre will position himself with the aid of his high level of knowledge and has already decided upon his parking zone. To fulfill the objectives of this phase the driver with a high level of knowledge focusses on affordances that serve as informational support to determine the level of difficulty. However, the clues he uses for this, are neither established nor formal. During this phase the centration point becomes progressively more defined.

During the stake and trial sequence the driver aims to park. A driver with a high level of propre has at this stage a plan as a program. Such a driver also defines several preference zones for parking; the hierarchy of the zones depends upon the situation. The actions that the driver takes are specific routine forms. The affordances that the driver looks for are specific due to his knowledge of the area. If the plan as a program of the driver fails or if the occupancy is too high, then the driver switches to a plan as a resource and behaves similar to a driver with a low level of propre. If parts of the program fail, the driver experiences stress and negative tension. The stake and trial sequences are in the behavioural research mostly based on the affordances offered by the environment. As previously stated, it is not feasible to use these affordances in full in the model. Instead, simplified measures of the concept are employed.

4.2.2.2 Low level of propre

In the inception sequence a driver with a low level of propre follows the instructions coming from affordances. The attention of the driver is focused on finding the 'right' way and finding relevant cognitive artefacts (signposts). A driver with a low level of propre also picks the nearest gate to his destination but for different reasons than a driver with a high level of propre.

In the preparation sequence a driver with a low level of propre still looks for his destination and tries to outline the limits of the zone where he will search for parking. The driver tries to remain within this area, not too far from his destination. The parking zone emerges gradually and the evaluation of the parking plan of the driver is low (it is evaluated in the stake and trial sequences).

The attention of the driver is divided between looking for a parking place and looking for the destination. While searching for the destination the driver has a low speed to better catch the appropriate affordances. Parking is restricted to the available free spaces as the driver has no knowledge of nearby alternative parking options. If the driver gets too far from his destination then a new positioning sequence takes place.

In the stake and trial sequence the driver with a low level of propre focuses more on the affordances due to the small amount of information that he has available. The search is therefore based mainly on 'clues' in the environment. The centration point mainly depends upon the final destination.

4.3 Behaviour implementation

In this Section the parking behaviour in the SUSTAPARK model is described. A detailed description of the implementation is given. First a general overview is presented that gives the outline of how the parking behaviour works. After that the details of the implementation are described, giving the figures and checks that have been used in the model.

The initial choice of strategies, before the model is run, happens in the current version of the model by a fixed allocation over the four different initial parking strategies. Ideally this should happen by calling the model for parking choice, but this requires calculating expected values for the variables. This aspect proved too difficult to solve within the duration of the project.

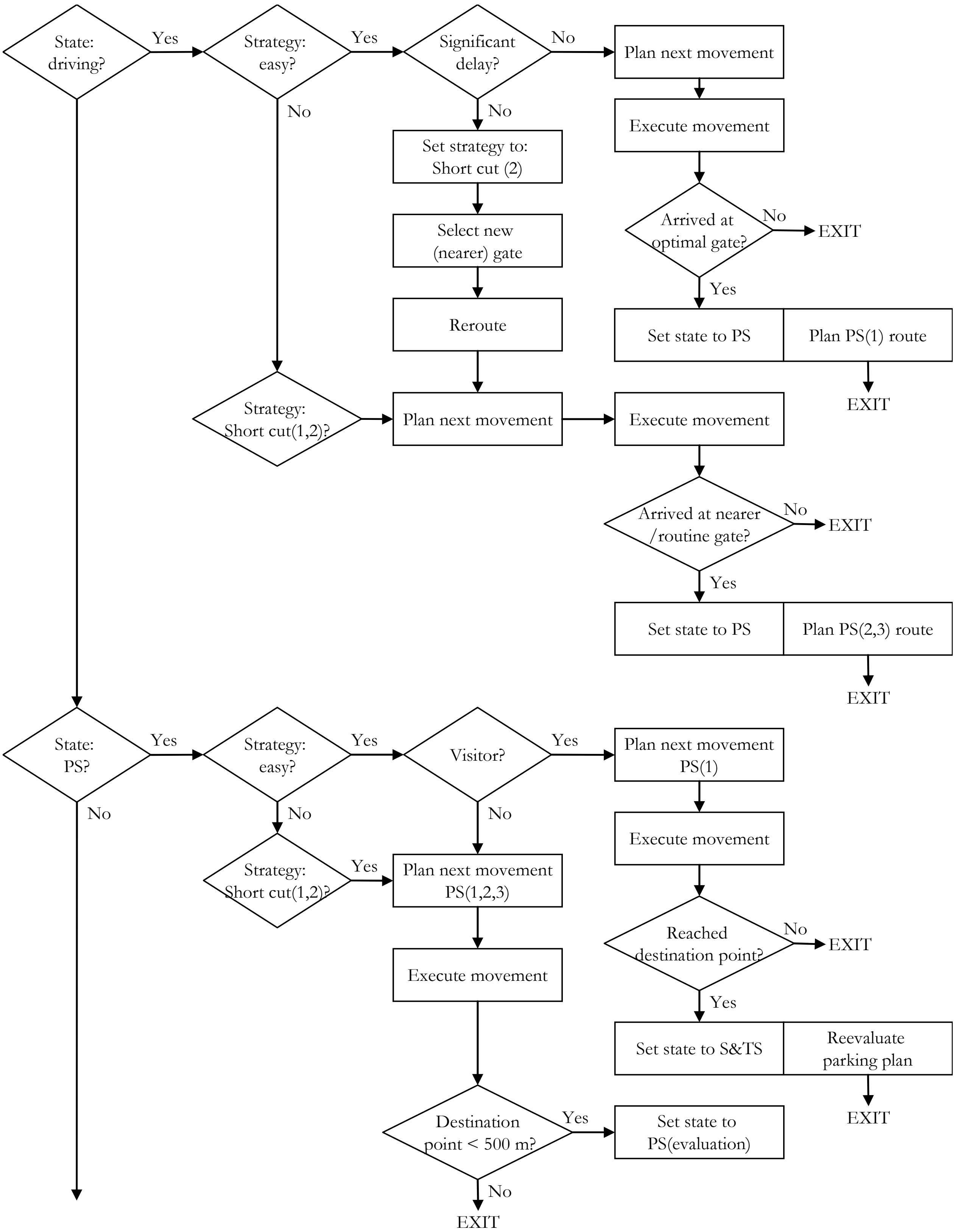


Figure 17: Diagram of the behavioural module of the SUSTAPARK model (first part). The arrow at the bottom-left goes to top diamond of figure 19. Further explanations are given in Sections 4.3.1 and 4.3.2.

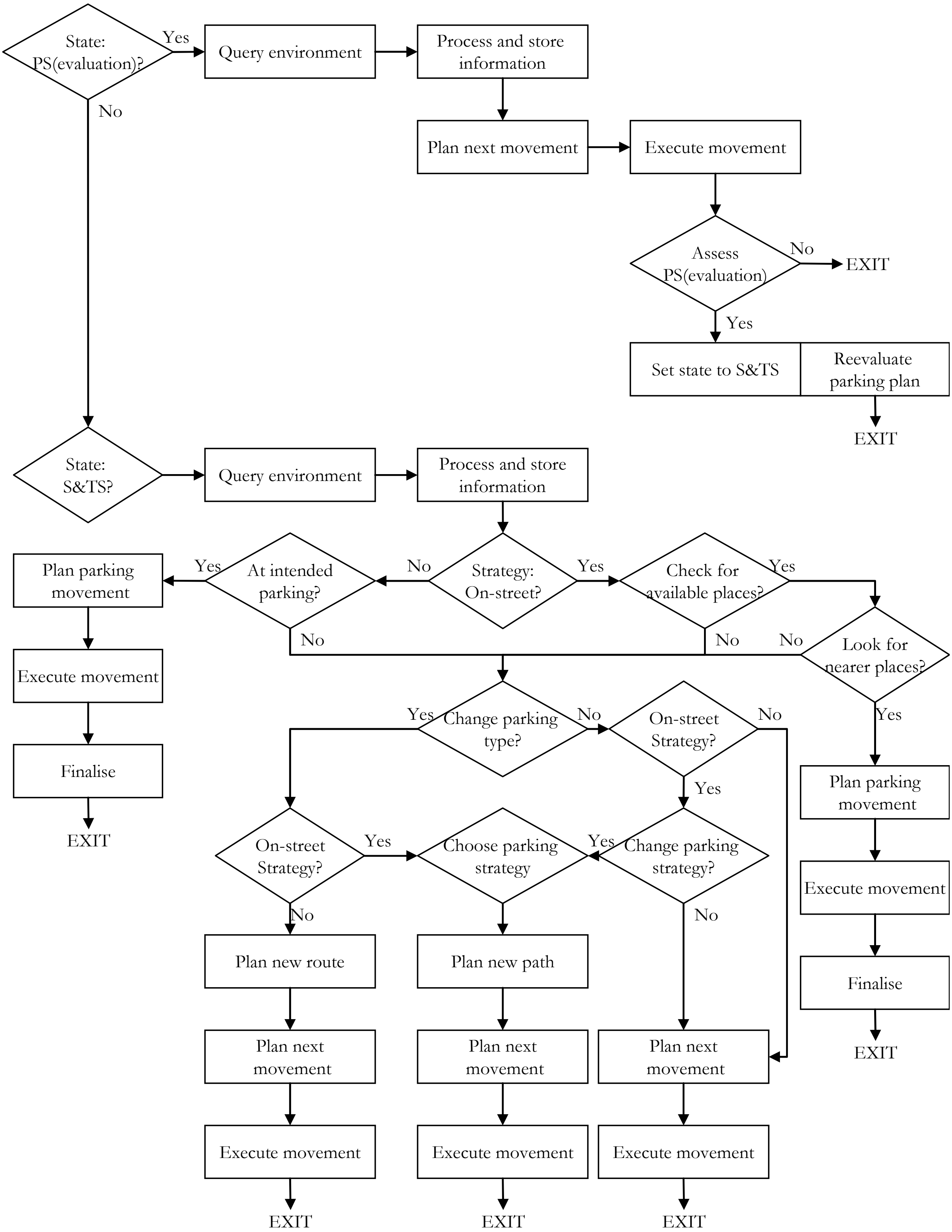


Figure 18: Diagram of the behavioural module of the SUSTAPARK model (second part). The diamond on the top-left forms the link to figure 18. Further explanations are given in Sections 4.3.1 and 4.3.2.

4.3.1 Overview of the structure

The previous Sections gave a more model-based rewording of the results of Chapter 3. This Section discusses the details of the parking behaviour that is implemented in the SUSTAPARK model. This implementation is based on tables giving a more 'component'-based view of the parking behaviour research (see Appendix A). A diagram sketching the behaviour is provided in figure 18 and figure 19. There, a diamond signifies a decision point and a rectangle signifies an action of some kind. EXIT means that no further steps in the decision tree must be taken during this pass through it.

In a nutshell an agent in the SUSTAPARK model decides on his preferred parking strategy before starting its trip. Once it arrives near its destination, the agent starts looking for a parking place, applying its chosen parking strategy. When it perceives that its current strategy is unlikely to succeed, the agent can change it. In principle, each agent that is active in the model should pass through the decision tree at every time step. In practice the produced computational load is too high. In particular, the model that decides whether to change parking strategy is run only once every 30 simulated time steps (i.e. seconds). When a route must be calculated standard shortest path algorithms are applied, taking the road level into account.

The behavioural research distinguishes three types of drivers: resident, commuter, and visitor. There does not seem to be a substantial difference in behaviour between residents and commuters. Visitors are different in that they first drive to their destination, only afterwards start looking for parking and never search for parking before arriving at their destination. Two general categories of strategy are defined: the 'easy' strategy (essentially following the ring of the city) and the 'short cut' strategy (going through the inner city). Two types of 'short cut' strategy exists: one for drivers who adopt this strategy from the start (denoted by 1 in the diagram) and one for drivers who first adopt the 'easy' strategy and take a short cut when delayed enough (denoted by '2' in the diagram). The initial distribution of drivers over the 'easy' strategy and the 'short cut' strategy is done by a fixed allocation.

In the decision tree the first phase a driver enters the model in, is the inception phase (top half of figure 18). During this phase the agent drives on the ring road until he arrives at his gate of choice. If a driver who follows an 'easy' strategy encounters a substantial delay, he changes to a 'short cut' strategy and enters the city proper sooner.

When the driver enters the city he enters the second phase: the preparation phase (PS in the diagrams, lower half of figure 18). If the driver is a visitor following an 'easy' strategy, he drives until he has reached his destination. Only then does he start looking for a parking place (this is due to the low level of propre in this case). In all other cases the drivers drive until they are sufficiently near their destination. At this point they enter the second phase of the preparation phase (top part of figure 19) and start looking for information necessary for the parking search. When the driver has gotten closer to his destination he starts looking for a parking place.

In the stake and trail phase (S&TS in the diagrams, bottom part of figure 19) the driver looks for a parking place. If the driver does not follow a strategy to park on-street, he will drive towards his intended garage or parking lot. If the driver follows an on-street parking strategy, he checks every time step if there is a suitable, free parking place nearby (suitability is determined by the choice model for a parking spot; see Section 4.4.3). If there is a suitable parking place he will park, if not the driver continues looking.

Every thirty seconds a driver in the S&TS phase reevaluates his current parking strategy (with the choice model for parking strategy (see Section4.4.2)) and changes to a new parking strategy if the choice model indicates so. A driver following an on-street strategy must also decide where he will look next. To make this decision, the behavioural research lists 5 possible searching strategies (see Section 3.2.3). Only one strategy is implemented in the model at this stage, namely the random searching.

Some caveats should be added to the above. The parking behaviour described is mainly valid for drivers looking for on-street parking. Drivers who are guaranteed to have a parking place, like drivers who park in their garage at home, who have obtained a parking place from their employer, or who have decided to park in a parking garage before they start on their trip, all drive directly towards their intended parking space (and not to their destination as such) and therefore do not need to search for a parking place. On the other hand, people with a residence permit are assumed to keep searching for a parking place when they return home.

It should be stressed that the parking behaviour, as implemented, takes no account of the parking duration or the time that a person is going to spend at a certain activity. This means that turnovers rates will be underestimated where limits on parking duration exists and that persons with a short activity spend more time searching (or more money on an off-street parking lot) for a parking place than they really would be willing to.

4.3.2 Details of behaviour

The following notes give some clarification of individual parts of the diagrams.

4.3.2.1 Significant delay

The following methodology is proposed in order to determine if a significant delay has been incurred. It is possible to determine the average speed of a driver on the part of the ring road that he has already driven on. With this the expected trip time until the chosen gate can be determined. If the time given by the start time of the trip plus the time already driven plus the expected additional time on the ring is greater than the intended arrival time (as given by the activity schedule) minus 15 minutes, then the driver decides he has incurred a significant delay and switches to a 'short cut' strategy. Note that this feature is not implemented.

4.3.2.2 Select new (nearer) gate

When a new gate needs to be selected during the inception phase, the gate should be selected that is nearest in the direction the driver is currently headed. A potential problem here is that the switch in strategy will occur to soon and that a gate will be selected, from which it is not really feasible to get to the intended destination.

4.3.2.3 Plan next movement

Where the diagram states 'planning route', this means the use of the shortest path algorithm. 'Plan next movement' means that a query is made to the stored route that previously was determined by the shortest path algorithm. The diagram also notes PS(1), PS(2) and PS(3). These mean that a modification is made to how the shortest path algorithm works.

- **PS(1)**: this routing is done by people following the 'easy' strategy. After taking the gate, they follow the major roads, only taking the minor roads if it is necessary to reach their destination.
- **PS(2)**: this routing is done by people who changed from an 'easy' strategy to a 'short cut' strategy (denoted by 'short cut(2)'). After taking the gate, they continue towards their destination along the shortest path. Major and minor roads are given equal value.
- **PS(3)**: this routing is done by people who adopted a 'short cut' strategy from the start (denoted by 'short cut(1)'). After taking the gate, they continue towards their destination, while staying as much as possible on major roads. A switch to a minor road happens only to get as quick as possible to another major road.

4.3.2.4 Re-evaluate parking plan

'Re-evaluate parking plan' means a call to the procedure that determines whether a change in parking strategy is necessary. If a change is required a call should also be made to the procedure that chooses a new parking strategy.

4.3.2.5 Assess PS(evaluation)

To assess whether the PS(evaluation)-phase should end, a distance travelled of about 200 m is proposed (or, alternatively, a distance of 300 m from the destination) . This length is the distance between the start of the evaluation phase and the maximum extent of the search area. Initial averages of the relevant parking variables in the area are gathered during these 200 m.

4.3.2.6 Query environment

'Query environment' means that drivers (actually their cars) check their environment for relevant information.

4.3.2.7 Re-evaluate parking plan

'Re-evaluate parking plan' is just a call to the start of 'change parking type'.

4.3.2.8 Check for available places

'Check for available places' means that the driver looks ahead a few places from where he is now to see if there are any free parking places available there.

4.3.2.9 Check to look for nearer places

'Check to look for nearer places' is a check to see if the driver will ignore an empty parking place and search further for a nearer parking place. For this decision the choice model for a parking spot is used (see Section 4.4.3).

4.3.2.10 Change parking type

'Change parking type' means that the logit model to choose between different types of parking (see Section 4.4.2) is called. The values for the model are collected from the surroundings during the 'Query environment' block.

4.3.2.11 Change parking strategy

'Change parking strategy' determines whether a driver wishes to switch strategies for looking for on-street parking places. The motivating factors for this are not specified in the behavioural research. As only one search strategy is implemented, this part is not implemented.

4.3.2.12 Choose parking strategy

'Choose parking strategy' is where the actual choice between the different search strategies is made. As only one search strategy is implemented, this part is also left unimplemented.

4.4 Choice models

This Section describes the discrete choice models that are the foundations of the choices the agents make in the model. First an introduction to discrete choice theory is given, then the model for the choice of parking type is given, and finally the model for the suitability of a parking spot is described. Note that these choice models assume rational behaviour and full knowledge of the drivers.

4.4.1 Discrete choice modelling

In discrete choice theory each possible alternative of the finite choice set is assigned a utility. This utility is a numerical value that represents how much the decision maker values that alternative. The scale of this valuation is of no importance, as long as the same scale is used for all alternatives. This also allows rescaling of the utilities so that numerical stability can be avoided when applying the theory.

After the calculation of the utilities, the decision maker compares these against each other and chooses the one with the highest utility. The comparing of the utilities implies that only differences in utilities matter, not the actual values of the utilities.

To calculate the utilities, a function is constructed in terms of the observed properties of the choice set. For example, the price of a trip and the time the trip takes can be two of the properties in deciding which transport mode to take. However, in practice there will always be unobserved factors and differences in the valuation of certain properties. This means that, instead of the deterministic method explained above, a statistical methodology needs to be used.

For the statistical method an appropriate error distribution (expressing the unobserved factors and uncertainty) needs to be specified and added to the observed utilities. Based on the assumptions made on the error distribution and the form chosen for it, a number of different statistical models can be derived, allowing a number of different choice behaviours to be simulated. The most widely used of these models is the multinomial logit (MNL) model, which is also the model adopted here (due to its simplicity and relatively low data requirements). The 'multinomial' part stems from the fact that the dependent variable is nominal during the regression. 'Nominal' implies a set of categories which cannot be ordered in any meaningful way; it is 'multi' because there are in general more than two categories.
After the selection of an appropriate choice model, the main task is to specify and fit an appropriate model for the observed part of the utilities.

Once this model is estimated, the values of the explanatory variables can be filled in for a decision maker. This results in choice probabilities that, for an appropriately specified model, can be interpreted as market shares. For further reading, see [Tra2003].

4.4.2 Parking type choice

In the parking model the following types of parking have been implemented.
Initially the following four search strategies are available:

- **OnStreet**: searching for an on-street parking places near the destination, with a mostly random route choice.
- **ResidentCard**: very similar to OnStreet, but represents residents with a resident card, which do not consider the price of a parking place and never switch to another search strategy.
- **Private**: residents who have their own parking garage and drive to it directly, without searching.
- **Complex**: drivers who go directly to the parking garage nearest to their destination that still has free parking places (this operates under the assumption of complete knowledge).

During the parking search drivers can also switch to two other strategies:

- **ComplexOnStreet**: originally these drivers followed the OnStreet strategy, but because the choice model indicated to switch to another type of parking they now have adopted a Complex strategy (i.e. driving towards a parking garage). While driving towards the parking garage the driver still checks the streets he passes through for free on-street parking places.
- **FixedOnStreet**: when there is no parking garage with free parking places available within a reasonable distance of the destination, a driver keeps on searching for an on-street parking place, despite having little success with it.

This model for parking type choice determines the type of parking place that the agent is searching for. This decision depends upon certain variables, such as the price of a parking place, the search time, … Note that for certain types of parking places no decision is necessary, such as drivers with a residence permit, who continue looking for an on-street parking place or drivers which have in some way a guaranteed parking place, like drivers parking at home. In this project, a model for parking type choice created by Hess and Polak is used [Hes2005].

The model considers four alternatives:

- free on-street parking,
- paid on-street parking,
- off-street parking in a parking lot,
- and off-street parking in a parking garage (both underground and aboveground parking structure).

Illegal parking is not considered in the current version of the SUSTAPARK model and is dropped (although the model of Hess and Polak does include it). Table 1 lists the numerical values of the coefficients. Note that the values depend upon the trip purpose.

Table 1: Table with the coefficients of the MNL model for the parking type choice [Hes2005]. The 'work' column gives the values of the coefficients if the trip has a 'work' purpose; the 'other' column if the trip has some other purpose.

VARIABLE NAME	NOTATION	COEFFICIENT	WORK	OTHER
ACCESS TIME [MIN]	AT	β_1	-0.0513	-0.0283
SEARCH TIME [MIN]	ST	β_2	-0.0632	-0.0589
EGRESS TIME [MIN]	ET	β_3	-0.0925	-0.0924
PARKING FEE [€/H]	FEE	β_4	-1.4104	-0.8267
ION-STREET (PAID)		$I_{ON\text{-}STREET\ (PAID)}$	-2.7628	-0.8126
IOFF-STREET (LOT)		$I_{OFF\text{-}STREET\ (LOT)}$	0.2830	-0.0913
IOFF-STREET(GARAGE)		$I_{OFF\text{-}STREET\ (GARAGE)}$	1.0614	-0.2140

A discussion of the variables in the table is given in the following paragraphs

- The **access time** is the expected time to drive to the area around the destination, which is the area where the driver intends to park. This value remains constant once the driver starts searching for parking.

- The **search time** is the time a driver is willing to search for a parking place once he has arrived at his parking area. Here it is assumed that the search time only applies to on-street parking places (both free and paid). This means that after a certain time spent searching, all drivers will want to park off-street.

- The **egress time** is the time a driver is willing to walk from the place he parked at to his actual destination. For the calculation of these times the assumption is made that the driver has full knowledge of the city, including roads, parking places and parking garages. As the search of an agent continues, his spatial location changes and so will this term.

- The **parking fee** is the amount of money the driver would have to pay for the time he spends at the parking place. This can be zero if the parking place is provided free to the driver.

Substantial differences can be seen between the coefficients for the 'work' purpose and for the 'other' purpose. In particular, commuters seem to have a strong dislike of paid on-street parking and seem to prefer garages. Hess and Polak note that the signs of the dummies for parking lot and parking garage of the 'other' purpose are wrong and should in fact be positive [Hes2005].

For the calculation of the expected values the assumption of full knowledge gives that the (expected) parking fee is the same as the true value. The access, search, and egress times are determined in iterative runs of the model until they converge to stable values. This means that for the search and egress times, the average is taken of all actual times experienced by the agents in a (small) zone of the city. For the access times the actual driving time is taken. Note that this represents traffic on a 'normal' day, i.e. without accidents or other disturbances. All these times are given a small random error to represent uncertainty.

It should be stressed that the coefficients used come from a study in a British city. The value of time that the coefficients implicitly contain is for this British city and might not be representative for the value of time in Leuven. Research has also shown that the value of time strongly depends on the purpose, which is only taken into account in a limited way.

The paragraphs below discuss the formulas used in the implementation of the model. As a first step the exponentiated utilities of all the alternatives need to be calculated. The free on-street alternative is the reference level and therefore has no dummy.

$$U_{\text{on-street (free)}} = \exp(\beta_1 . At + \beta_2 . St + \beta_3 . Et + \beta_4 . Fee)$$
$$U_{\text{on-street (paid)}} = \exp(\beta_1 . At + \beta_2 . St + \beta_3 . Et + \beta_4 . Fee + I_{\text{on-street (paid)}})$$
$$U_{\text{off-street (lot)}} = \exp(\beta_1 . At + \beta_2 . St + \beta_3 . Et + \beta_4 . Fee + I_{\text{off-street (lot)}})$$
$$U_{\text{off-street (garage)}} = \exp(\beta_1 . At + \beta_2 . St + \beta_3 . Et + \beta_4 . Fee + I_{\text{off-street (garage)}})$$

The choice probabilities (to be interpreted as the average probability that a specific alternative is chosen) are then given by:

$$P_{\text{on-street (free)}} = U_{\text{on-street (free)}} / (U_{\text{on-street (free)}} + U_{\text{on-street (paid)}} + U_{\text{off-street (lot)}} + U_{\text{off-street (garage)}})$$
$$P_{\text{on-street (paid)}} = U_{\text{on-street (paid)}} / (U_{\text{on-street (free)}} + U_{\text{on-street (paid)}} + U_{\text{off-street (lot)}} + U_{\text{off-street (garage)}})$$
$$P_{\text{off-street (lot)}} = U_{\text{off-street (lot)}} / (U_{\text{on-street (free)}} + U_{\text{on-street (paid)}} + U_{\text{off-street (lot)}} + U_{\text{off-street (garage)}})$$
$$P_{\text{off-street (garage)}} = U_{\text{off-street (garage)}} / (U_{\text{on-street (free)}} + U_{\text{on-street (paid)}} + U_{\text{off-street (lot)}} + U_{\text{off-street (garage)}})$$

By construction the sum of the probabilities is one. The probabilities form the parameters of a multinomial distribution. Draws from this distribution can be made with an random number generator (RNG) ranging from 0 to 1. The 'choice' is then made by comparing the value of the RNG with the range of the intervals:

- $[0 , P_{\text{on-street (free)}} [$ corresponds to a choice for free on-street parking.
- $[P_{\text{on-street (free)}} , P_{\text{on-street (free)}} + P_{\text{on-street (paid)}} [$ corresponds to a choice for paid on-street parking.
- $[P_{\text{on-street (free)}} + P_{\text{on-street (paid)}} , P_{\text{on-street (free)}} + P_{\text{on-street (paid)}} + P_{\text{off-street (lot)}} [$ corresponds to a choice for off-street parking in a parking lot.
- $[P_{\text{on-street (free)}} + P_{\text{on-street (paid)}} + P_{\text{off-street (lot)}} ,1]$ corresponds to a choice for off-street parking in a parking garage.

Because the driver in the model must make the choice for a parking type repeatedly, it is recommended that the value generated by the RNG is stored so that it can be reused. If not, the choices of the drivers will continuously switch between the possible alternatives, which is not desirable.

4.4.3 Parking spot model

This model is used by the drivers to decide whether they consider a specific, empty on-street parking place suitable to park. Because no studies or empirical data are available for this problem an ad-hoc model was constructed based on assumptions on which variables are relevant. Tests suggest that this model performs as expected.

The variables used are

- **Occupancy**: the fraction of the parking places in the street that is occupied.
- **Search time**: the time the driver has already spent searching.
- **Distance**: the current distance from the destination (measured along the routes).

Table 2: Table with the coefficients of the parking spot model.

VARIABLE NAME	NOTATION	COEFFICIENT	VALUE
INTERCEPT		β_0	5.88
OCCUPANCY [FRACTION]	OCC	β_1	8.789
SEARCH TIME [MIN]	ST	β_2	2.197
DISTANCE [METERS]	DIST	β_3	-0.05

The coefficients and the parameters are combined in the linear form:

$$U_{park} = \beta_0 + \beta_1 . Occ + \beta_2 . St + \beta_3 . Dist$$

The probability of parking in a given (free) on-street parking spot is then given by:

$$P_{park} = 1 / (1 + \exp(- U_{park}))$$

Because the driver in the model must make the choice for a parking place repeatedly, it is recommended that the value generated by the RNG is stored so that it can be reused. If not, the choice of the driver will be inconsistent.

5 Model use

This Chapter describes the practical use of the SUSTAPARK model, which data is needed to run it successfully and what can be expected in the way of output. A method to calibrate the model coefficients is also described.

5.1 Input data

To run the SUSTAPARK model a large amount of data needs to be gathered, described in the following paragraphs. The data needed for the calibration of the model is described in Section 5.4. The large data requirements are in fact prohibitive to the use of the model. Acquiring data at this level of detail is expected to be difficult. Even if the data is available, a large investment of time is necessary to process this data and prepare it as input for the model.

5.1.1 GIS data

As described in Section 2.3.1, the streets of the city in the model are represented as a network of cellular automata. To construct this network a digital representation of the street network of the city is needed. The SUSTAPARK model supports input for this in ArcGIS-format.

Three types of parking places (see also Section 2.3.2) are used as input: on-street parking places, parking garages, and off-street parking places (minus parking garages). On street-parking places can be available from the same GIS-data on which the street network is based. If not, an estimation based on the length of the streets will be necessary. Data on the capacity, location, and other relevant aspects of the parking garages is usually publicly available or can be easily acquired from the cities. Data on (private) off-street parking places will likely not be available. In the SUSTAPARK project these were estimated by calculating the number vehicles owned in the city (obtained from provincial averages) and subtracting the number of resident parking permits issued by the city. The relevant properties of all these parking places, like the parking fee, also need to be entered.

When the street network is read, the city gates (i.e. the entry and exit points of the city, see Section 2.3.3) need to be defined. It is sufficient to indicate which crossroads are to be considered as such.

The attractions (see Section 2.3.4) for the activities per street segment are calculated by adding together the floor surfaces of the buildings devoted to a certain activity in a street segment. Comparing the total floor surface for the activity of the street segment with the floor surface of other street segments gives a relative attraction for the activity. This measure is then used in the assignment of the locations to the activity schedules. A data source giving the detailed data with the floor surfaces and the type of activity needs to be available.

5.1.2 Activity schedule data

The generation of the activity schedules is described in detail in Section 4.1.4.2. The procedure requires the construction of representative sample schedules, with attached time distributions. A frequency table indicating the proportions (and absolute numbers) of the various identified (sample) schedules also needs to be constructed. A possible source of such data is a mobility survey that tracks which trips people make during a day. Such a survey might not be available, however. Even if it is, substantial analysis is required to construct the sample schedules from it and determine which schedules are the most prevalent.

It should be noted that in the current version of the SUSTAPARK model only one unspecified week day is implemented. Mobility might be (substantially) different during other days of the week (weekend, Wednesdays, Fridays).

Aside from data for the schedules, some statistics are also required about the population, the car ownership, and the number of people that make their trips by car. Currently the model assumes that all trips in a schedule are made by a single mode. The share of which persons do this by car needs to be derived. This allows for a fairly easy extension towards multi-modality.

5.1.3 Scenario setup

The data described above form the input for the baseline of the model. Scenarios need to be defined in order to evaluate different measures. This means that the baseline input must be modified so as to correspond with the situation envisaged in the scenario. This can mean adding a parking garage, closing down a street for traffic, or increasing the price of parking places.

5.2 Running the model

After setting up the input, the model can be run. First the database with the agents and their activity schedule is generated. This database is saved, so that it can be reused in different scenarios, allowing comparable model results. The locations where the agents go to are not saved, however, which is the cause of some fluctuations in the model. From the database the agents are assigned to their starting location in the model. Agents that come from outside the city are placed on a gate. Other agents are placed within the city. Agents with access to a private parking garage are placed there, otherwise they are placed on the street, as near as possible to their home.

After this assignment step, the model can be run. The activity schedule of each agent is checked to see if he should become active. If so, he starts driving in the cellular automaton towards his destination. As soon as he gets near his destination, starts executing the parking behaviour described in Section 4.3. Once parked the agent becomes inactive. In this way all the movements on the activity schedules of all the agents are simulated.

During the simulation various data related to parking is gathered and stored in csv-files. These files can be used in an appropriate application, like Microsoft Excel or Access. The data is then post-processed into the output of the model.

5.3 Output

The output of the model runs described above are database files that need to be processed to produce interpretable results. The following tools are adopted in the SUSTAPARK model in order to present the model results in a clear, concise, and informative way (note that this postprocessing needs to happen manually):

- **Maps**: due to the interface with ArcGIS, the model is able to write output directly to the data tables associated with ArcGIS layers. By applying appropriate graphical procedures (colouring et cetera) to the data, ArcGIS can display these on the maps in as many ways as can be desired. Due to the scalability maps in ArcGIS, the maps can also be produced at any spatial resolution desired, from the level of the individual streets to the level of the whole city.
- **Graphs**: aside from maps, graphs are also used to show how certain 'global' properties evolve through time or for a comparison of different zones/districts or different categories of parking space. This output is generated in Microsoft Excel.
- **Tables**: these serve mainly as a counterpart to the graphs. These are also made in Microsoft Excel.

By combining the output for various scenarios with the output of the baseline, comparative results can be obtained.

5.4 Calibration

A good calibration is essential in order to produce reliable, credible results in the baseline and in the scenarios. Model parameters that need to be tuned to the city under question are the parameters in the choice models, which might be city-dependent or change with time. Other parameters within the parking behaviour might also need adjusting. For example, in cities with a severe parking problem drivers might start looking earlier for parking place than in cities with only a moderate level of parking pressure.

Calibrating these coefficients requires re-estimating the choice models. For this, data needs to be gathered in an appropriately constructed and executed survey of parkers. Performing such a survey is inherently costly, especially since the estimation requires extensive data of high quality and level of detail.

It is also necessary to attempt to obtain as much verification of the patterns of activity that result from the activity schedules. The model results can only be trusted if the demand for parking places (and, in broader sense, for mobility) is reproduced with a degree of accuracy, both spatially and temporally. The best sources for this data are likely mobility experts of the city under study.

Some verification data needs to be gathered to confirm that the parking results (in the baseline) correspond approximately with reality. Obtaining this data will not be that difficult for parking garages. For off-street parking verification requires that counts are gathered in the streets of the city (by random sampling), as little or no data is available on this from the cities. Calibration of the off-street parking places will in reality likely be impossible. Although traffic modelling is not the main focus of the SUSTAPARK model, some verification of the traffic flows in the model to reality is needed.

Validation of the model would mean that the calibrated model is transferable to other cities. Due to the specifics of the model, as explained in the preceding paragraphs, this transferability will be low. The approach of the problem can be applied to other cities, however. Mind the caveat that the model as developed assumes a city with a ring road.

6 Case study: the inner city of Leuven

6.1 Introduction

As case study to test the SUSTAPARK model the inner city of Leuven, a city in Belgium, was chosen. Leuven is fairly small city with a dense centre. The inner city has a reputation as an area where it is difficult to park and was therefore of interest for the model. It was also the city where many of the interviews for the behavioural research took place.

The study area is the inner city of Leuven, the part within the ring road (the former ramparts) (figure 20). This is the zone where parking is modelled spatially. It is in this model that model agents look for parking. Demands in the model are based on the level of the street segments. The resolution to the level of the street segments is justified by the short streets within the historic city (average: 73 m, median: 61 m, standard deviation: 65 m). This is less than 200 m. On average in the province, 79.80% of trips shorter than 200 m are walking trips [Zwe2005].

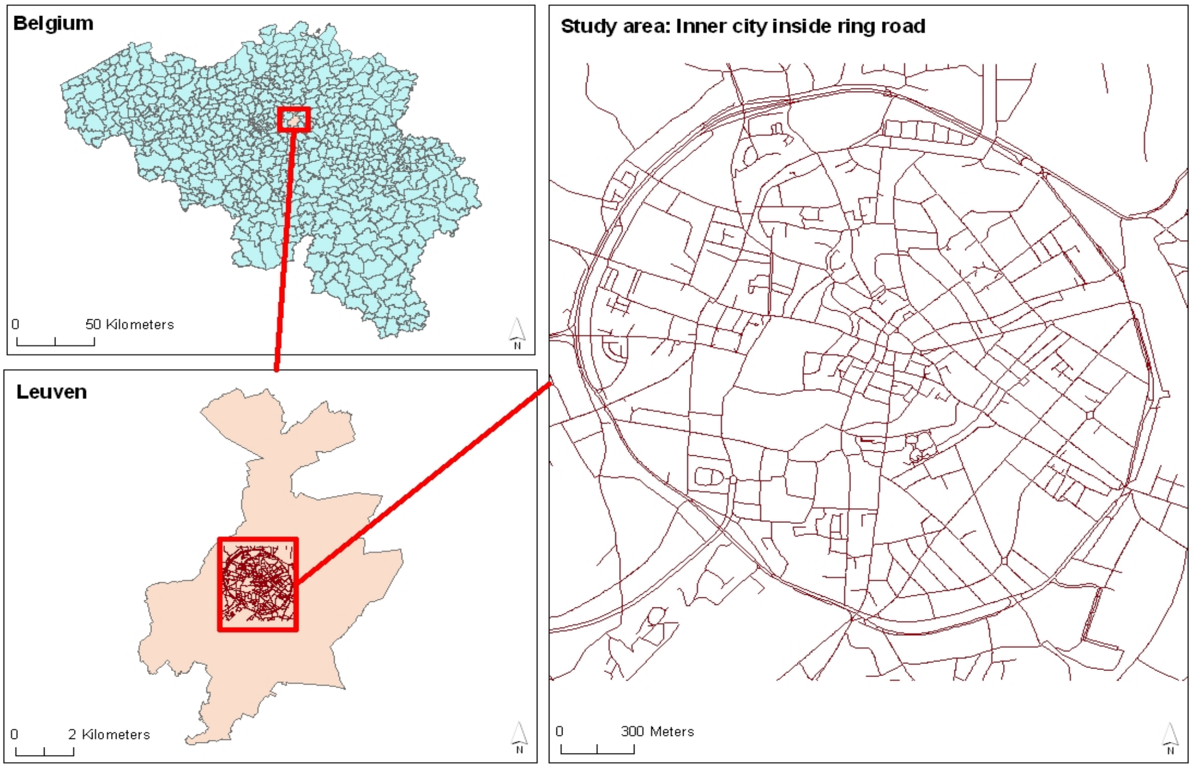


Figure 19: Study area of the spatial model.

Figure 20: Map of the inner city of Leuven, showing the names of the more important streets. The ring road is marked in yellow. ©2009 Google – Map data © 2009, Tele Atlas.

6.2 Data description

Most of the input needed for the SUSTAPARK-model is city-specific as parking is a spatially-related phenomenon. So for the case study of Leuven, the input of Leuven city services is of great importance. In case where no data is available due to rights or due to missing data, general input data is used to make estimations for these factors. The main input data is described in the following paragraphs.

6.2.1 Street network

A map of the inner city of Leuven is shown in figure 21. The network data used for the case study are obtained from the G@lilieo GIS service of Leuven (2008). Based on this the cellular automata is constructed. The details of the implementation are described in Section 2.3.1. Figure 22 shows the street network as it is implemented in the case study.

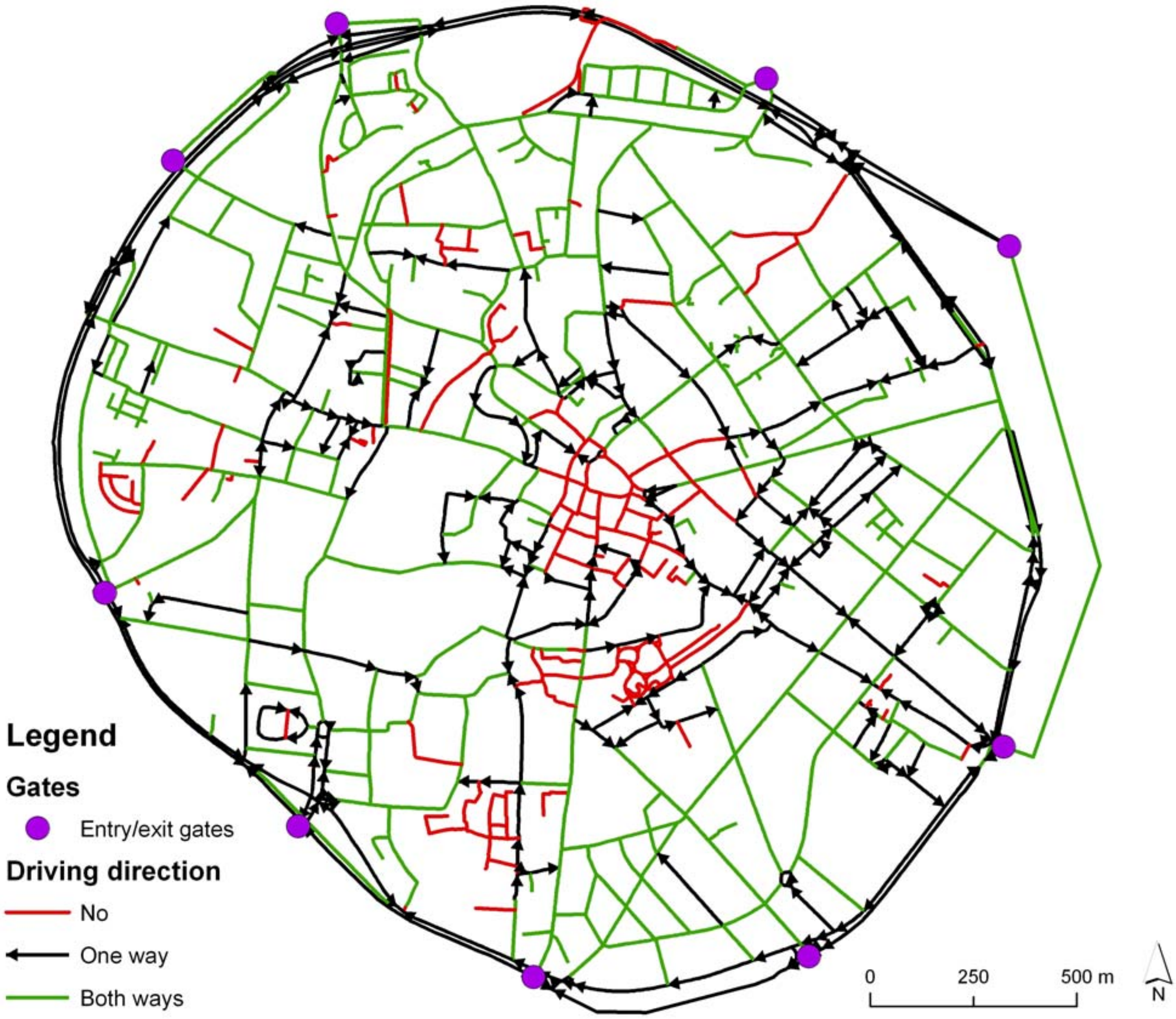


Figure 21: Street network of the inner city of Leuven, as it is implemented in the case study. One-way streets are indicated, as are pedestrian streets. Red lines indicate pedestrian-only streets. Note that the centre of the city is car-free. The ring road is in fact implemented as 2 roads with opposite driving directions. Network data source: G@lileo Leuven.

6.2.2 Parking places

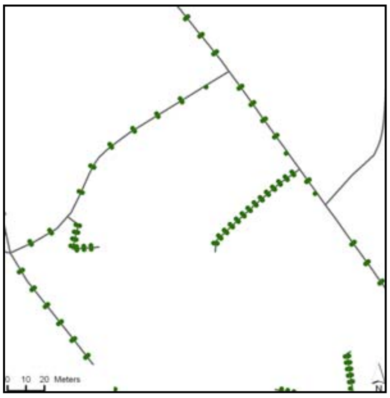
The generation of the parking places in the model is described in Section 2.3.2. The data sources used for the parking places in the case study are described below, with comments where needed.

- **On-street parking**
  Source: Traffic Organisation and Mobility service Leuven, 2007.
  Description: Number of on-street parking places per street. As these data are provided per street, the parking places have to be allocated for every segment of the street in the network. As no additional information is known, the best method is to allocate the number of parking places proportional to the length of the segments. Leuven uses a system of street zoning that determines the duration and fee of parking. This information is also included.

- **Resident parking cards**
  Source: Traffic Organisation and Mobility service Leuven, 2008.
  Description: Number of resident parking cards per street. The same allocation technique is used as for the on-street parking data to scale the data up to street segment-level.

- **Public parking areas**
  Source: Leuven official website, 2007.
  Description: List of public parking areas in Leuven. The location, opening hours, and amount of parking places is given.

- **Private parking residents** (garage boxes, private area, …)
  Description: No information is directly available by city services. Therefore an estimation has to be made. This is done based on the number of residents and resident parking cards per street. From national statistics it is know that the car-ownership for Leuven equals 396 cars on 1000 inhabitants, the number of cars per street can be calculated based on the number of residents. The difference of the cars per street and the resident parking cards is the amount of cars that must have another solution for parking in the city (like a private parking or parking outside the inner city). This estimation is therefore used.



As on-street and private parking places are given as tabular data, they have to be converted to spatial data. These parking places are placed at equal distances along the road. Road ID, distance from start point, and side of the road are stored as attributes so they can be referenced to a lane (see figure 23 for an example).

Figure 22: Parking places are placed on equal distances along the road. Network data source: G@lileo Leuven.

6.2.3 City gates

In figure 22, the 9 city gates in the model for Leuven are shown as purple dots. These are the places where agents enter and leave the city.

6.2.4 Activity schedules

For the construction of the activity schedules required by the model, detailed data from the comprehensive mobility study 'OVG Vlaams-Brabant' [Zwe2005] was used. In this database respondents listed all the trips they made in two days, along with many details about those trips like the origin and destination, the main transport mode, and arrival and destination time. By analysing the trips that come and go to Leuven, along with the trips that remain within Leuven, it is possible to obtain an image of the mobility demand and the underlying motives. With the weights that are included in the OVG data it is possible to weigh the results so as to obtain representative frequencies.

Some of the sequences of activities that were found only occurred rarely. These trips were dropped, so as not to burden the model. Sequences of activity representing about 60% of the total number of trips were retained. After the analysis of the sequences of activities, the accompanying start and end times of the trips were analysed per motive and the parameters of normal distributions fitted to these times were determined. Together the sequences of activities and the time distributions form the database on which the activity schedules in the model are constructed.

The locations in the activity schedules need to be filled in after constructing the activity schedules themselves. This is done according to the procedure outlined in Section 4.1.4.2. Some of the relative attractions used for the city of Leuven are shown in figure 24.

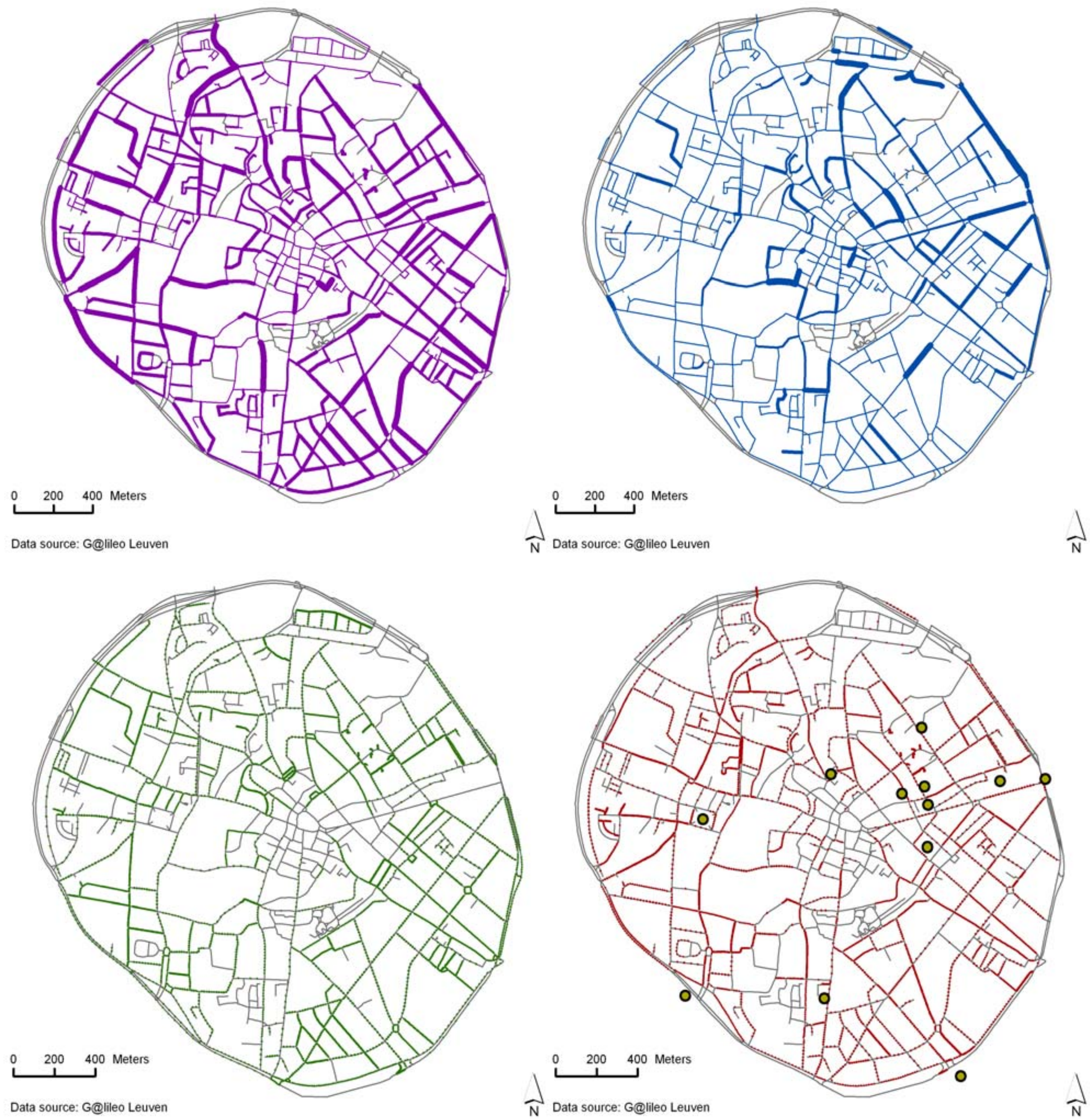


Figure 23: Maps A and B show the relative attractions for the baseline of the case study for the city of Leuven. Thicker lines imply a higher attraction. C shows where in the model city the on-street parking places are located. D shows the estimated private parking places and the parking garages (the dots). Network data source: G@lileo Leuven.

6.3 Case study baseline

This Section discusses the results that have been derived from the model runs of the baseline for Leuven. We would like to stress that these are all model results, stemming from a computer simulation. The goal is to show whether the results are believable and correspond to reality, although no calibration of the model coefficients for the city of Leuven happened.

Figure 25 shows a graph of all the agents that are active at any given time in the model and which fraction is driving and which fraction is looking for a parking place. The shape of the curve corresponds with the one found in other studies: a sharp peak in the morning and a broader and lower peak in the evening. The peak around noon is caused by agents going out or going back home for lunch. During working hours almost half of the drivers are looking for a parking place, which suggest that the parking problems are in part caused by too much commuters coming by car.

The total number of agents active at any one time in the model seems a bit low (never higher than 400, as shown in figure 25). It should be noted however that the ring road of Leuven is not modelled realistically and that the inner city of Leuven (minus the ring road) does not suffer from congestion (in part because a large part of the traffic is directed towards the ring road). The ring road is used more for routing purposes, and is not meant to be representative for the travel times within the city centre. Assuming a road network of 40 km in the inner city, the highest number of agents still means one driver per 100 m of road. The figure of 400 active agents might therefore not be so unrealistic, as many of these roads are little travelled secondary roads, meaning the traffic is in fact concentrated on much less than 40 km of roads.

In figure 26 a map shows the average parking distances (distance measured along the network, averaged over the whole of the day and all the cars that have this street segment as their destination). It is clear that the parking pressure is the highest around the traffic-free centre, which is also the area with the highest attraction overall. Away from this core, agents can usually park near their destination. This shows that parking is often a very localised problem. A caveat to this is that the model does not include modal choice and that therefore car users have the same modal share in every part of the city. It is likely that in reality the share of car users for the agents with their destination in the city centre will be lower than in other parts of the city where the parking demand is more spread.

In figure 27 the average time spent by agents searching for a parking place (averaged over all agents and all times of the day) is shown. Again the parking pressure around the city centre is clearly visible. In the eastern part of the city the 'Bondgenotenlaan' also stands out. This is a street with many shops, but no on-street parking places. Drivers must therefore search for parking places in adjacent streets. Search times of 10 to 15 minutes are likely not realistic; they do mark areas with a serious parking problem.

Figures 28, 39, and 30 give an overview of the use of the different types of parking places throughout the day. The occupancy of the 9 parking garages that are accessible to the public is shown in figure 28. Since the garages are closed for the night in the model, they are empty at night (in reality, not all of them are always closed at night). They fill up during the day, but at a later time than the morning peak. This is because drivers (in the model) first saturate the available on-street parking places within a reasonable distance of their destination and only after this opt for the parking garages. Noteworthy is that the peak use only occurs in the afternoon, probably due to shoppers. It is also noteworthy that the parking garages are never completely filled. Analysis suggests that this is due to the Ladeuze parking not being fully used. Most other parking garages are saturated for most of the day. Places in the garages rented to companies or private individuals are not taken into account.

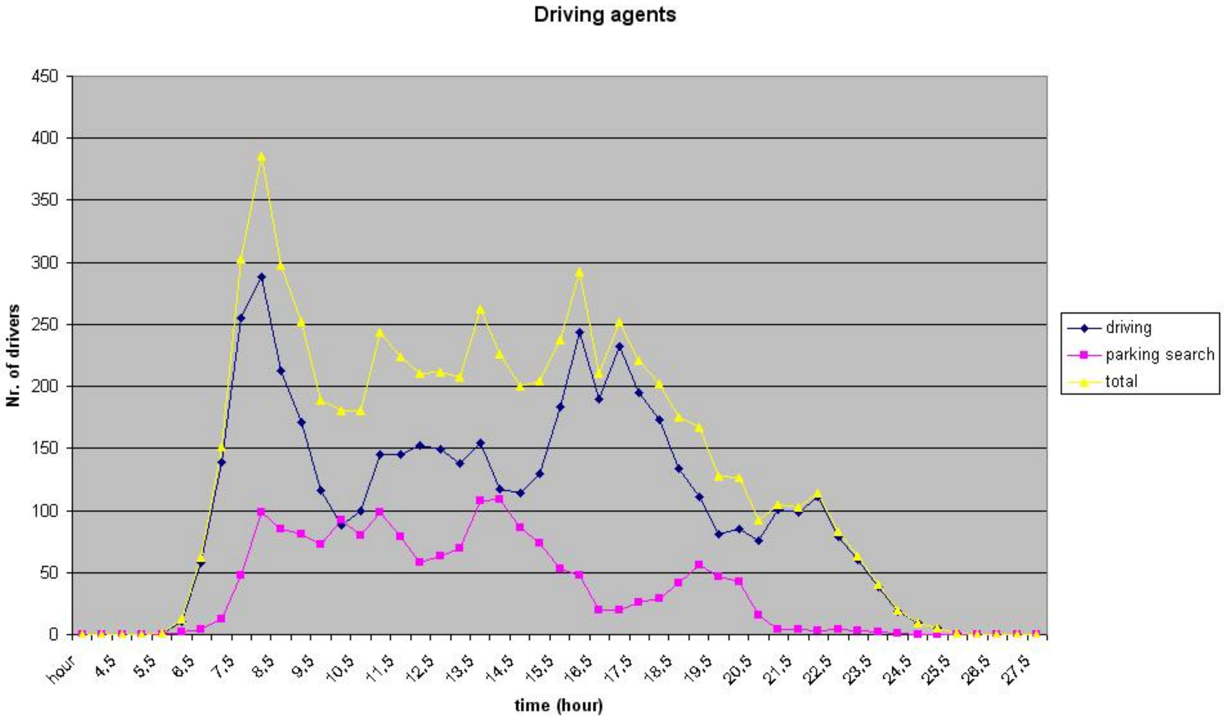


Figure 24: The number of agents simultaneously active in the model at specific times. The shape corresponds to that found in other studies. The total number of active drivers seems a bit low.

Figure 25: Map of the average parking distance (average over all agents and all times of the day, distance measured along the road network) for the baseline of the case study for Leuven.

Figure 26: Map of the average parking search time in the model (average over all agents and times of the day).

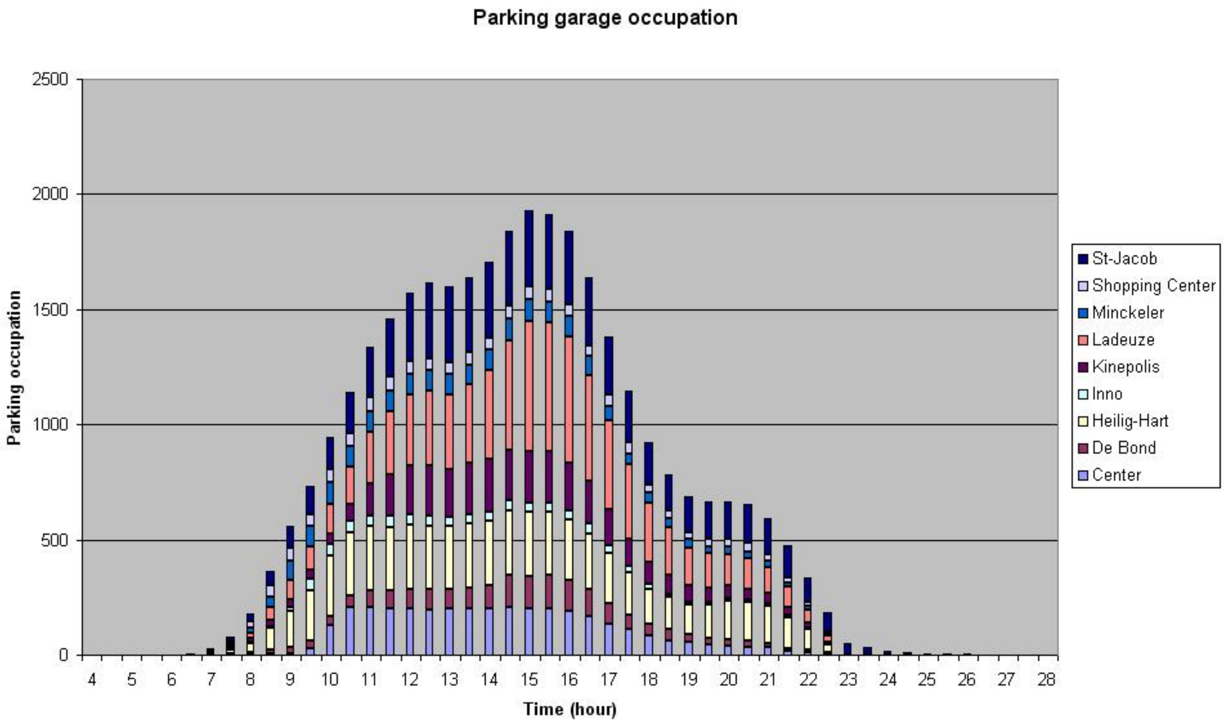


Figure 27: Evolution throughout the day of the total occupation of the parking garages in the baseline of the case study for Leuven. The maximum capacity is 2162 places.

The evolution of the total occupation of the on-street parking places in the baseline of the case study is shown in figure 29. In accordance with the model assumptions, the occupation is the same at the start of the model (4 AM in the morning) as at the end of the model. Since every agent is assumed to start and end at its home, this is to be expected. Occupation starts to rise as commuters come to the city. The same peak in the afternoon is observed as in the parking garages (figure 28). In the evening there is another peak as people come to the city for recreational purposes. The peak occupation is more than twice that in the parking garages.

The evolution the total occupation of the private, off-street parking places is shown in figure 30. The maximum capacity of 3000 places is completely used at the start of the model (a result of the way the initial distribution of drivers happens). The lowest occupation is found around the same time as the maximum occupation in the parking garages (figure 29) and on-street parking places (figure 28).

Figure 28: Evolution throughout the day of the total occupation of the on-street parking places in the baseline of the case study for Leuven. A model run starts at 4 AM in the morning.

Figure 29: Evolution throughout the day of the total occupation of the private (off-street) parking places in the baseline of the case study for Leuven. A model run starts at 4 AM in the morning.

Figures 31 and 32 show the evolution of parking strategies in the baseline of the case study. An initial strategy to look for an on-street parking place is followed by the large majority of the drivers. During more than 20% of their trips they are unable to find an on-street parking place within a reasonable amount of time and switch to a strategy aimed at a parking garage. As it is defined in the parking behaviour, drivers who go to their private parking place or who have a resident card do not change strategies. Some drivers who initially intended to park at a parking garage failed to find a parking place there and had to park on-street. The location of these agents and the time of day is not clear. It is also interesting to note that the number of drivers who wind up in a parking garage after first looking on-street for a parking place is higher than the number of drivers who go directly to a parking garage. This is indicative of the great reluctance of the agents to go into a parking garage, which is built in the choice model.

When the distance between the eventual parking place and the destination is studied (figure 33), it is clear that two thirds of the drivers find a parking place within a reasonable distance of their destination (less than 300 m). In fact, one third of the drivers manage to park within 100 m of their destination. In contrast, the fraction of drivers who park at a much farther distance than 300 m is very large. It is not known whether this is realistic.

A graph of the average search times for a parking place, stratified by distance between the eventual parking place and the destination, (figure 34) shows that the drivers who park close to their destination spend substantially less time searching for a parking place than drivers who find a parking place further away. The agents who manage to park within a short distance have a large share of drivers who park in a private parking garage or enjoy a residence permit. Drivers who park a further away are frequently drivers who first searched for an on-street parking place and then switched to a parking garage, which are on average further away from the destinations.

Comparing figure 33 and igure 34 shows that a limited group of agents experiences more than two thirds of the total time spent searching. Further analysis is required to determine whether this is realistic or is a model artefact. It might be the case that the model circumstances during the time of largest demand do not correspond to reality and that drivers in fact choose much faster for an off-street parking place (i.e. a parking garage) or on-street parking much farther away as soon as they notice that on-street parking is going to problematic in the area where they intended to park.

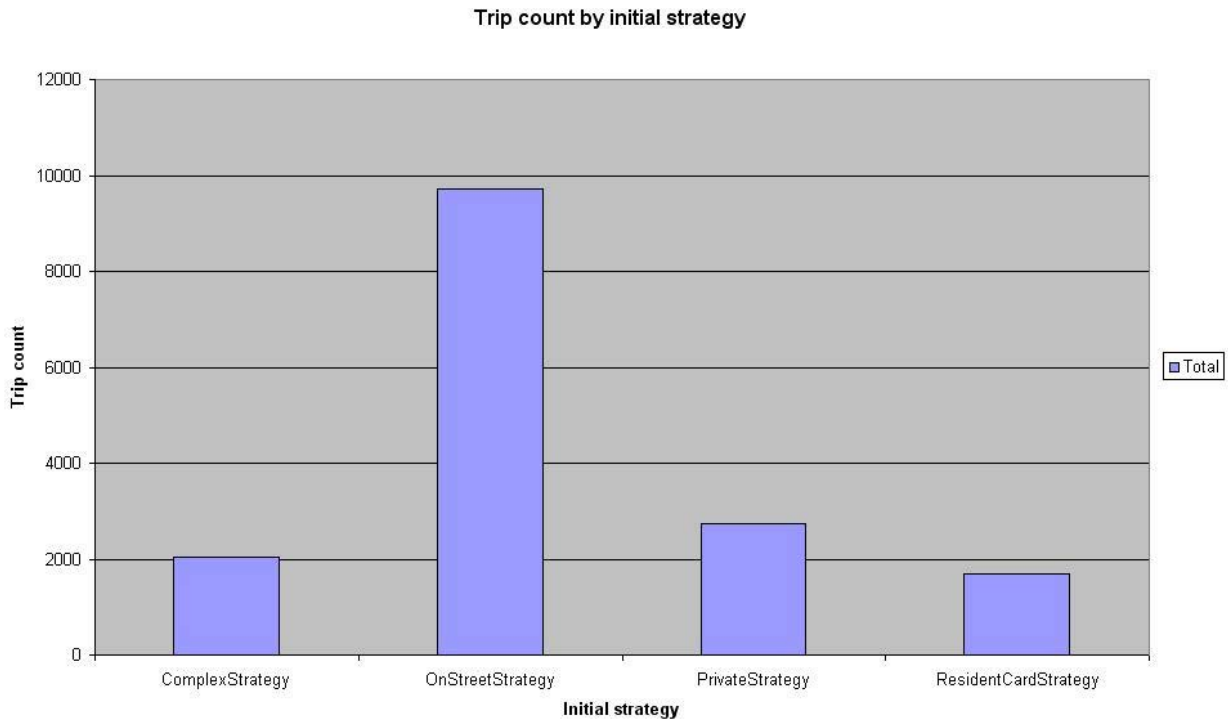


Figure 31: The total number of times a trip is started with a specific parking strategy in the baseline of the case study for Leuven.

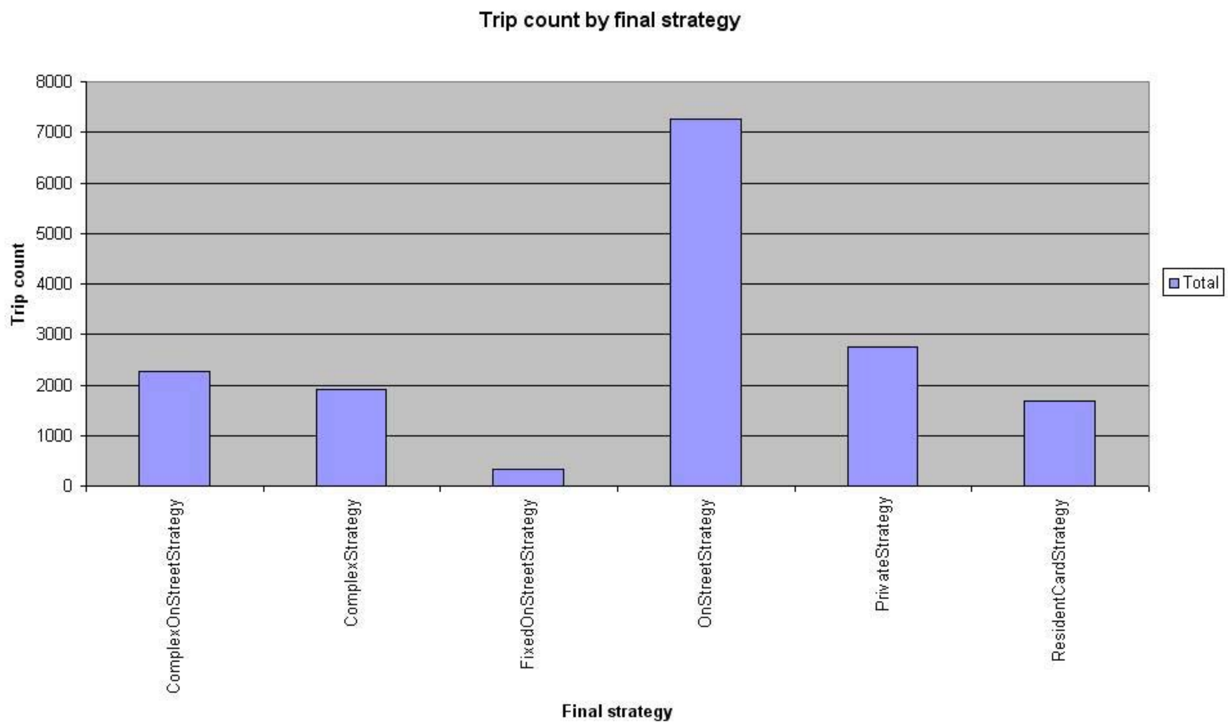


Figure 30: The total number of times a trip ends (an agent parks) with a specific parking strategy in the baseline of the case study for Leuven.

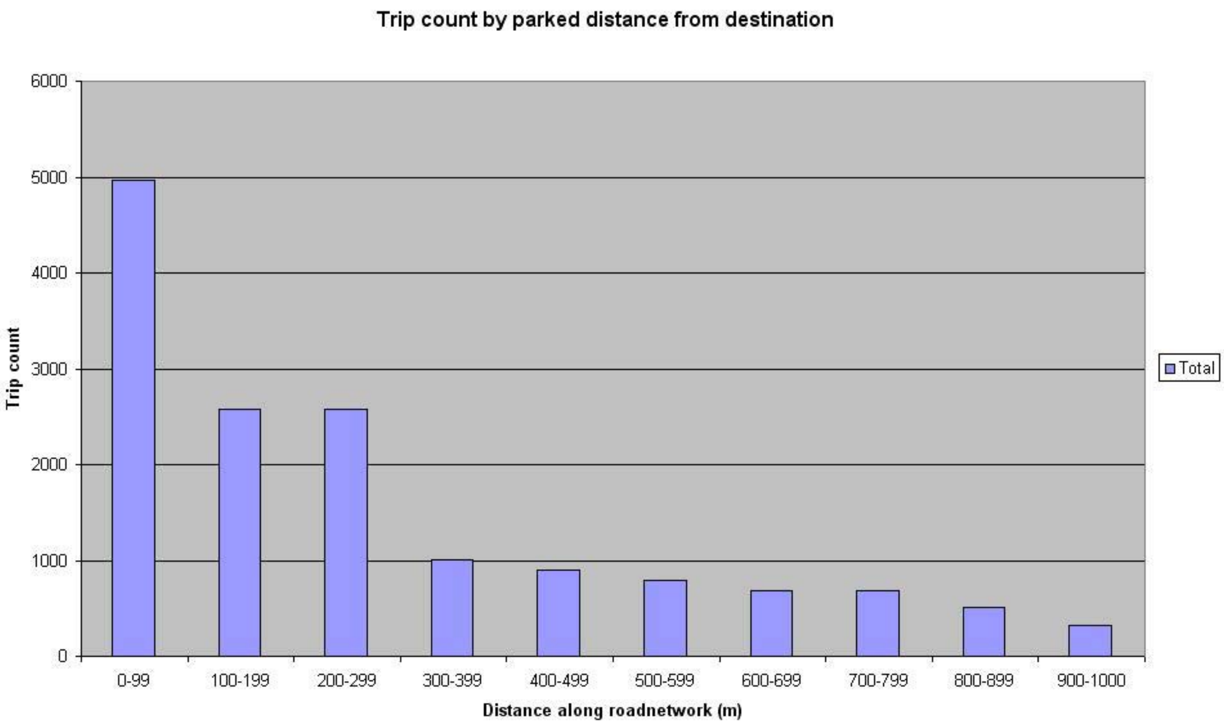


Figure 32: Total counts of the number of trips/parking searches that end within a certain distance interval of their intended destination (distances are measured along the roads). Two thirds of the trips park within 300 m of their destination. Figures for the baseline of the case study of Leuven.

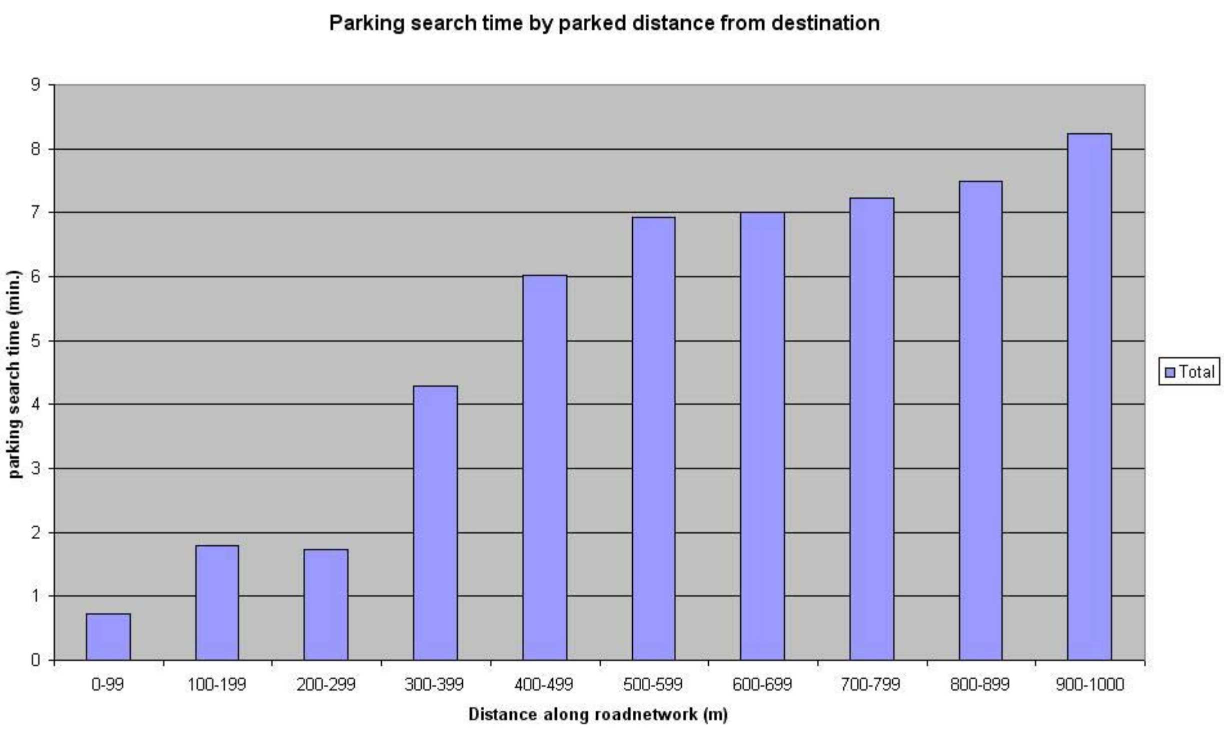


Figure 33: Average search time for a parking place, stratified by the distance interval of the eventual parking place from their intended destination (distances measured along the roads). Figures for the baseline of the case study of Leuven.

6.4 Scenarios

Three scenarios were run for the city of Leuven (based on their suggestions) to further verify the model. The three scenarios are:

- the addition of a parking garage,
- the special event of the Christmas market,
- and the impact of making a part of a street car-free.

6.4.1 Scenario 1: parking garage Kapucijnenvoer

In this scenario a large parking garage (1000 places) is added at the Kapucijenvoer. Some of its capacity is rented to residents (500 places) and the other places (500 places) are paid off-street parking places, usable by residents and visitors alike.

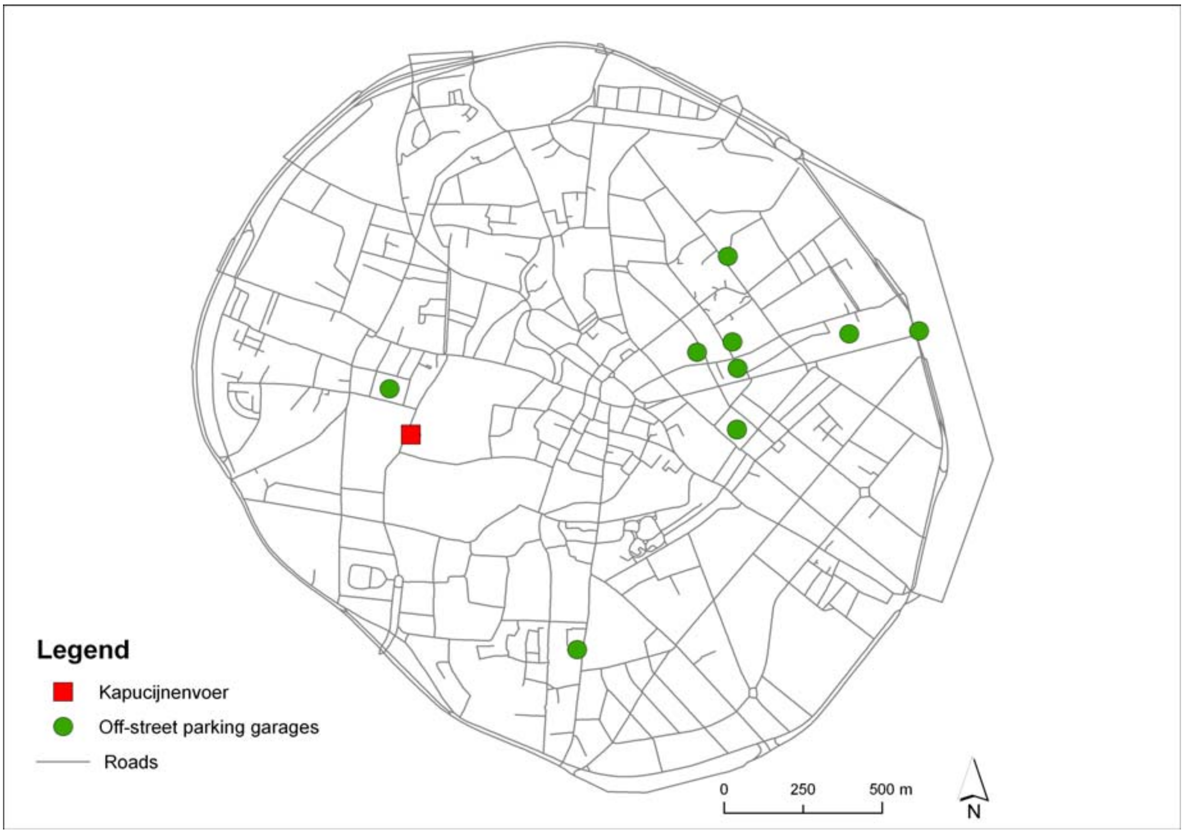


Figure 34: Map of the first scenario, showing the location of the new parking garage (red square). The green dots show the locations of the current parking garages.

6.4.1.1 Scenario setup

- Adaptations to agents:
    - Based on the agents in the baseline scenario: idem.
- Adaptations to network:
    - Based on the network in the baseline scenario: idem.
- Adaptations to parking places:
    - Based on the parking places in the baseline scenario.
    - Addition of parking garage Kapucijnenvoer (1000 places total, 500 available for all parkers, under the same conditions as places in other parking garages).

- Maximum number of private parkers is increased from 3000 to max 3500. This represents the 500 places rented to residents. It is assumed that all places are rented out.

6.4.1.2 Results

As is inherent in creating 500 extra 'private' places in the model of the city, a shift occurs in resident parking (trip motive home) from on-street parking towards private parking, as is clear from the occupation at night when comparing figure 46 and figure 45. But from the results in the baseline it is clear that parking at night is not the major problem. It does place a constraint on car ownership for people living in the city centre, but this aspect is not modelled.

The new parking garage also provides 500 extra places for paid off-street parking. Comparing figure 37 and figure 28 shows that the total occupation of all the parking garages changes little. The same is also shown in figure 44. What does happen is a large shift towards the new parking garage from the other parking garages (the influence is the largest on the Ladeuze and St. Jacobs parkings, which lose the most parking places to the new garage). This shift causes a substantial reduction in the average distance drivers park from their destination (shown in figure 36), but not in the search times (graph not shown), as more than half of the off-street parkers are originally people who look for an on-street parking place. This means that the main effect of the new parking garage is that some parkers can park closer to their destination if they decide to park off-street. However, this is only a substitution and does not attract (or only very little) drivers who currently park on-street.

It should be stressed that this is partly the effect of the way the (uncalibrated) model works and is in no way guaranteed to resemble reality. However, the result could hold some validity, as the current capacity of the parking garages in Leuven is known to be never fully used. Adding additional off-street parking places are likely to attract more drivers to the city, causing a shift from other transport modi for people who now find it more convenient to come by car. These effects are not modelled, however. Under the model assumptions, that demand does not change and the new places have the same price structure as the other parking garages. It is likely that the current drivers will not park more off-street than they do now. A shift to the new parking parage, without a substantial increase in the number of (current) off-street parkers, therefore does not seem an improbable result.

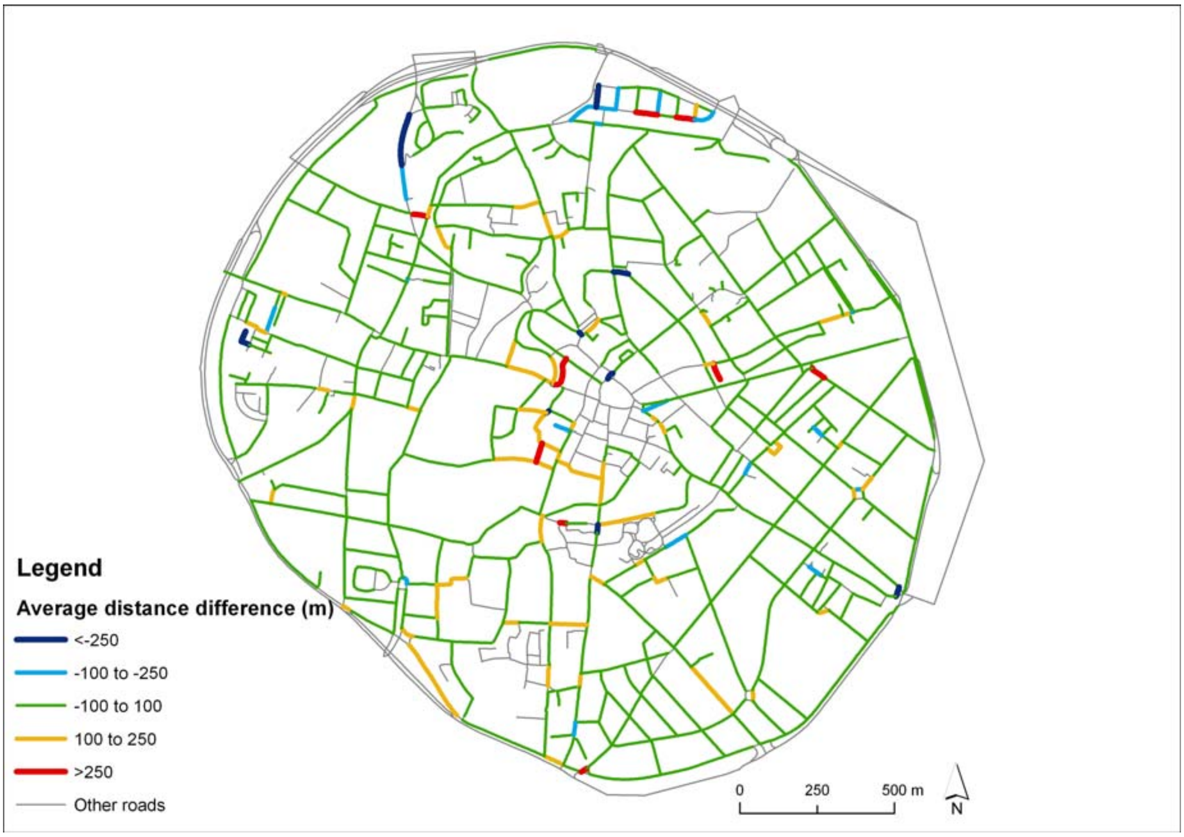


Figure 35: Map of the average parking distance (average over all agents and all times of the day, distance measured along the road network) for the scenario 'parking garage Kapucijnenvoer'.

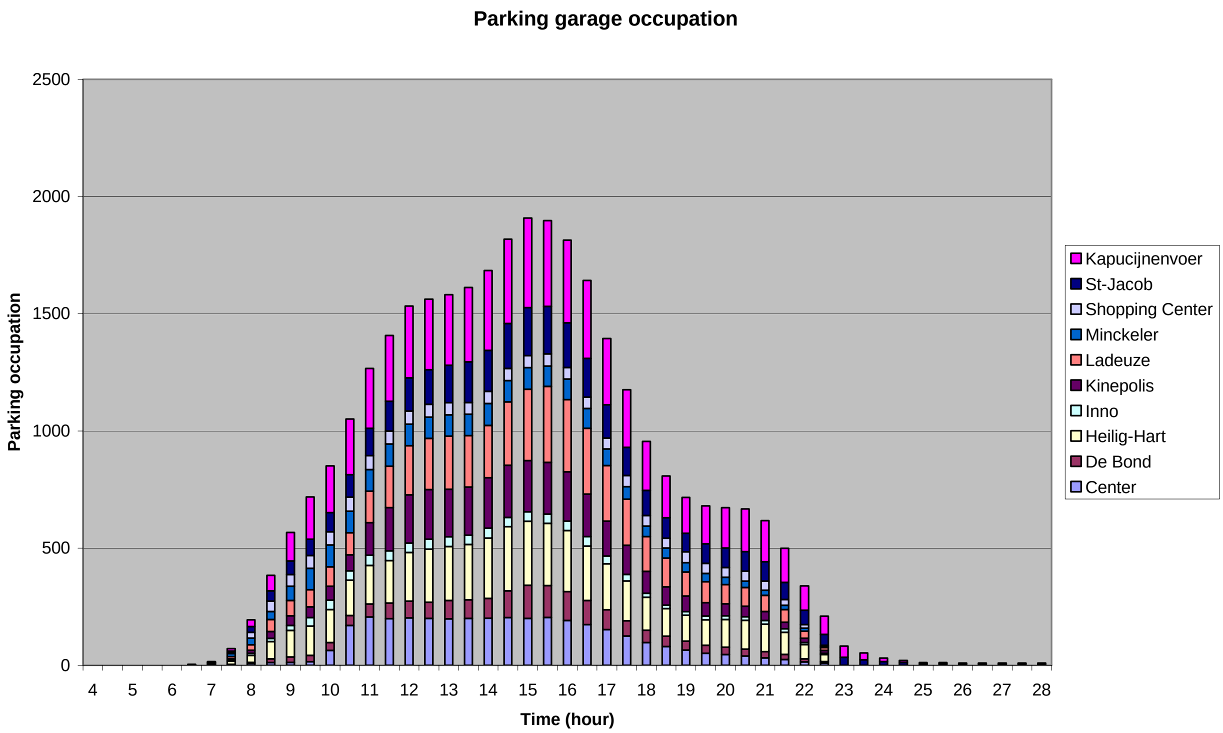


Figure 36: Evolution throughout the day of the total occupation of the parking garages in the scenario 'parking garage Kapucijnenvoer'.

6.4.2 Scenario 2: Christmas market

In this scenario the impact of the Christmas market in the city of Leuven is simulated. The market takes place on the Ladeuze square and Hoover square. Some additional demand in the bars and restaurants of the Old Market and Great Market is also taken into account.

6.4.2.1 Scenario setup

- Adaptations to agents:
  - Based on the agents in the baseline scenario.
  - Number of agents with motive recreation increased (about 1000 extra)
  - These additional recreation activities start in the evening
- Adaptations to network:
  - Based on the network in the baseline scenario.
  - Increased attraction for recreational purposes around Ladeuze square, Hoover square and the Great/Old Market.
  - Street around Ladeuze square is not shut down.
- Adaptations to parking places:
  - Based on the parking places in the baseline scenario.
  - Parking places around Ladeuze/Hoover square are not removed.

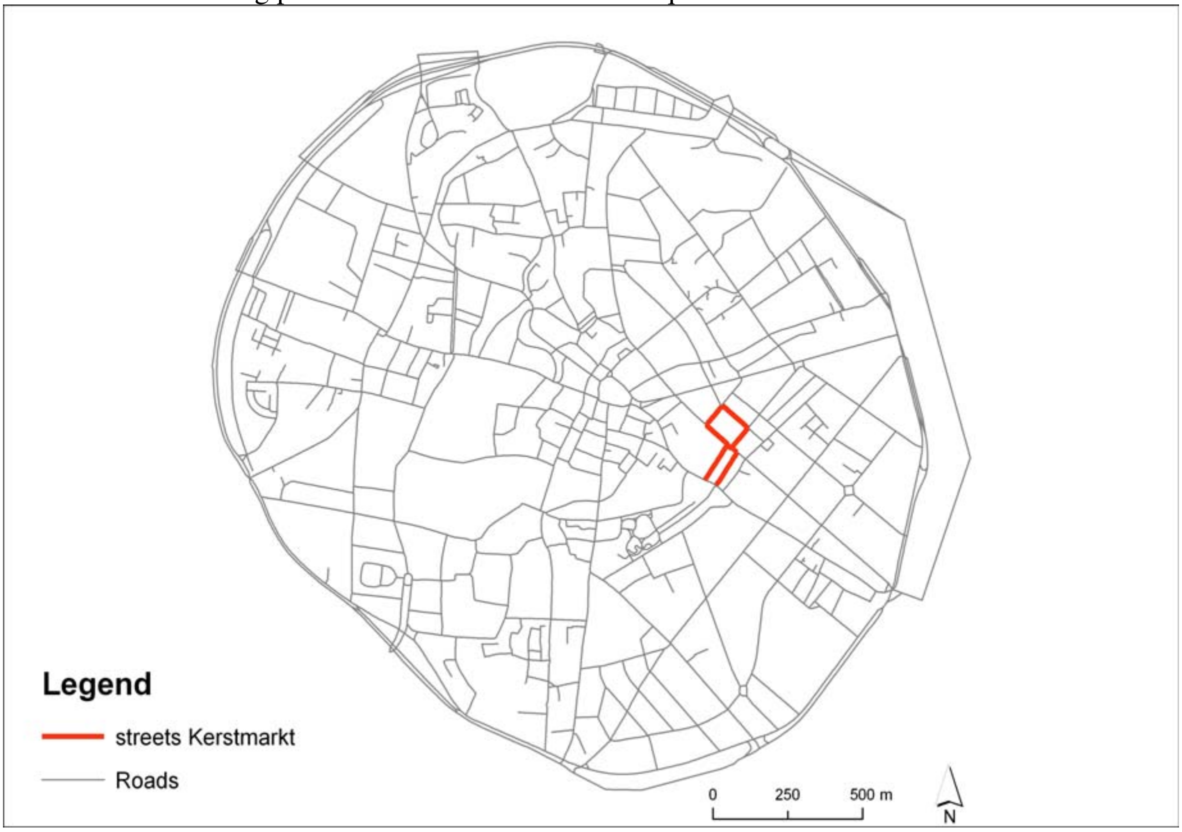


Figure 37: Map of the second scenario, showing the streets affected by the Christmas market. The rectangle is the circumference of the Ladeuze square, under which the Ladeuze parking is located.

6.4.2.2 Results

The Christmas market leads to a large additional evening demand in the relatively small area where it is organised. This leads to a large increase in average search times (figure 39), but only a moderate increase in the parking distance (not shown). This is because a lot of the visitors first spent considerable time looking for an on-street parking place, which is not available, and then switch to a parking garage. The nearest garage is Ladeuze (figure 40, compare with figure 28) which is right under the Christmas market, hence the lack of increase in parking distance. The large number of drivers who spent considerable time looking for a parking place is also evidenced in the number of agents active in the model and looking for a parking place (figure 43).

This result is a direct consequence of the way search behaviour is implemented in the model. In reality drivers looking to park will switch much sooner to off-street parking as soon as they notice (or even expect) that on-street parking is unlikely to succeed.

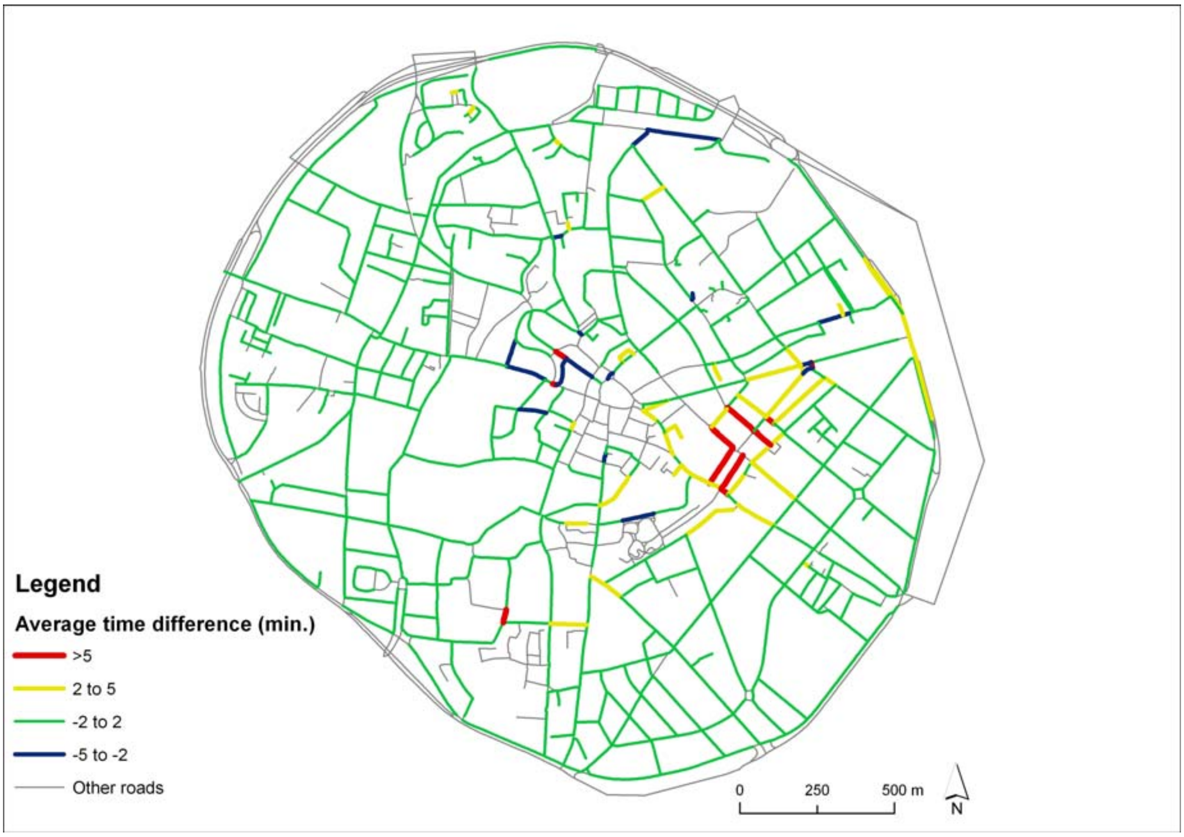


Figure 38: Map of the average parking search time (average over all agents and times of the day) for the scenario 'Christmas market'.

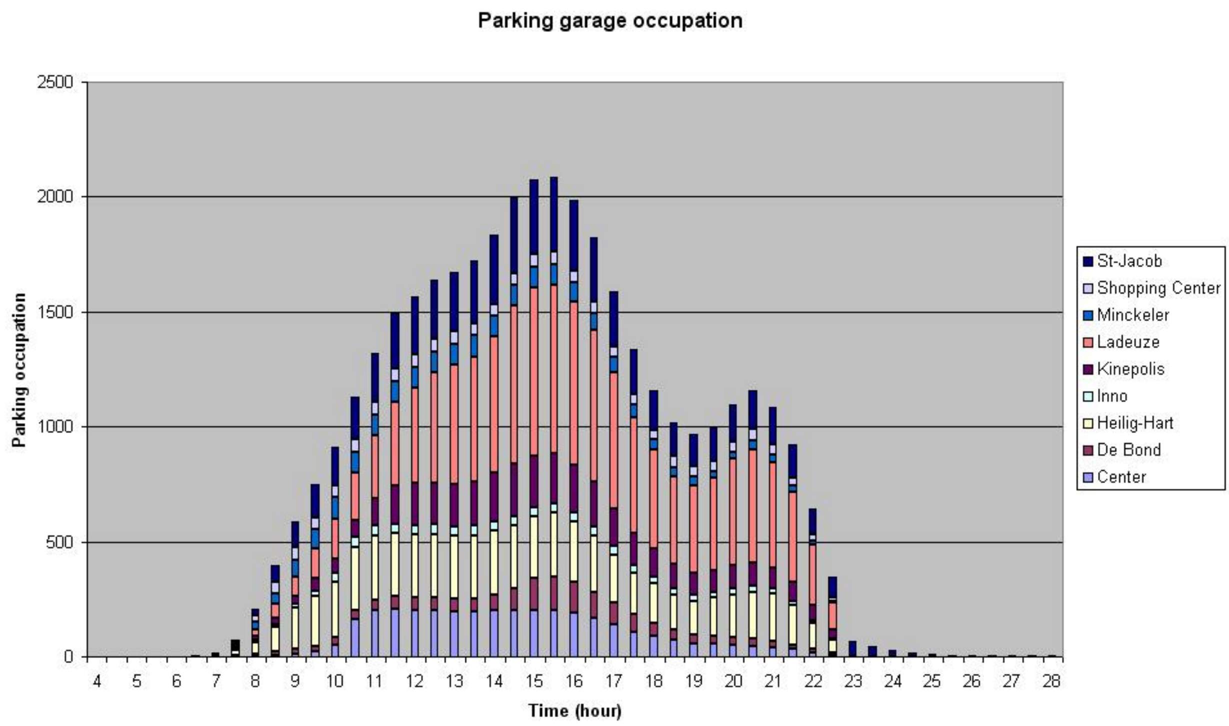


Figure 39: Evolution throughout the day of the total occupation of the parking garages in the scenario 'Christmas market'.

6.4.3 Scenario 3: Tiensestraat partly car-free

In this scenario the part of the Tiensestraat between the centre of the city and the Hoover square is made pedestrian only. Cars can no longer pass through this part and also no longer park here.

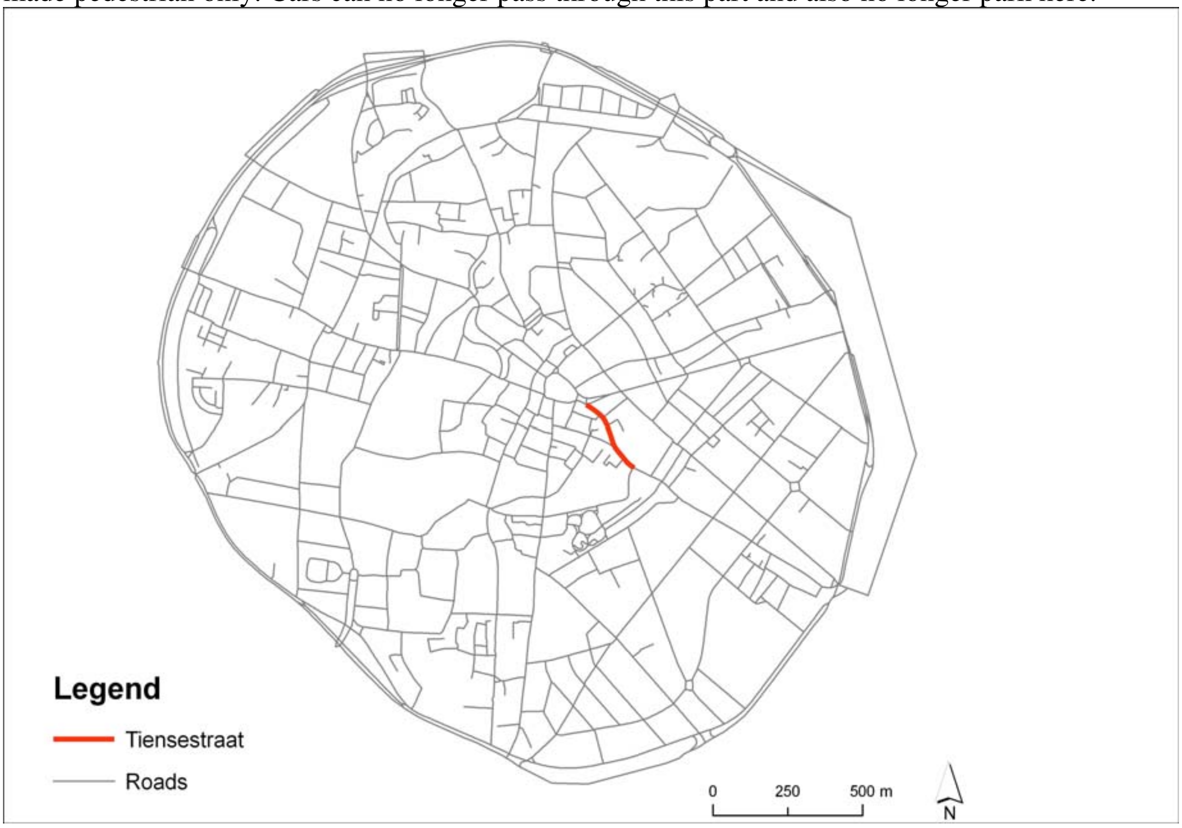


Figure 40: Map of the third scenario, showing the part of the Tiensestraat that is closed off.

6.4.3.1 Scenario setup

- Adaptations to agents:
  - Based on the agents in the baseline scenario: idem.
- Adaptations to network:
  - Based on the network in the baseline scenario.
  - Part of the Tiensestraat no longer can be driven through.
- Adaptations to parking places:
  - Based on the parking places in the baseline scenario.
  - Private parking places lower part of the Tiensestraat displaced.
  - Removal of on-street parking places on this part of the street.

6.4.3.2 Results

The results from this scenario suggest that the closing off of the street will have little impact upon the parking situation. Figure 41 shows some fluctuations in the average parking distance, but these fluctuations are spread out over the entire street network and show no systematic difference with the baseline scenario. Looking at the figures of the evolution of parking occupation throughout the day (figure 45 and figure 44) further confirms that there is little impact on the parking situation. Figure 42, showing the total number of agents active in the model, again has fluctuations around the baseline scenario, nut no systematic difference. Therefore it is concluded that this scenario has no significant impact on the parking situation.

The scenario does show in the fluctuations in Figure 41 and Figure 42 that the model generates substantial variation in the results, even when two scenarios are comparable. This is caused by the random components built in the model, as noted in 5.2. Alleviating this requires performing multiple runs and averaging the results.

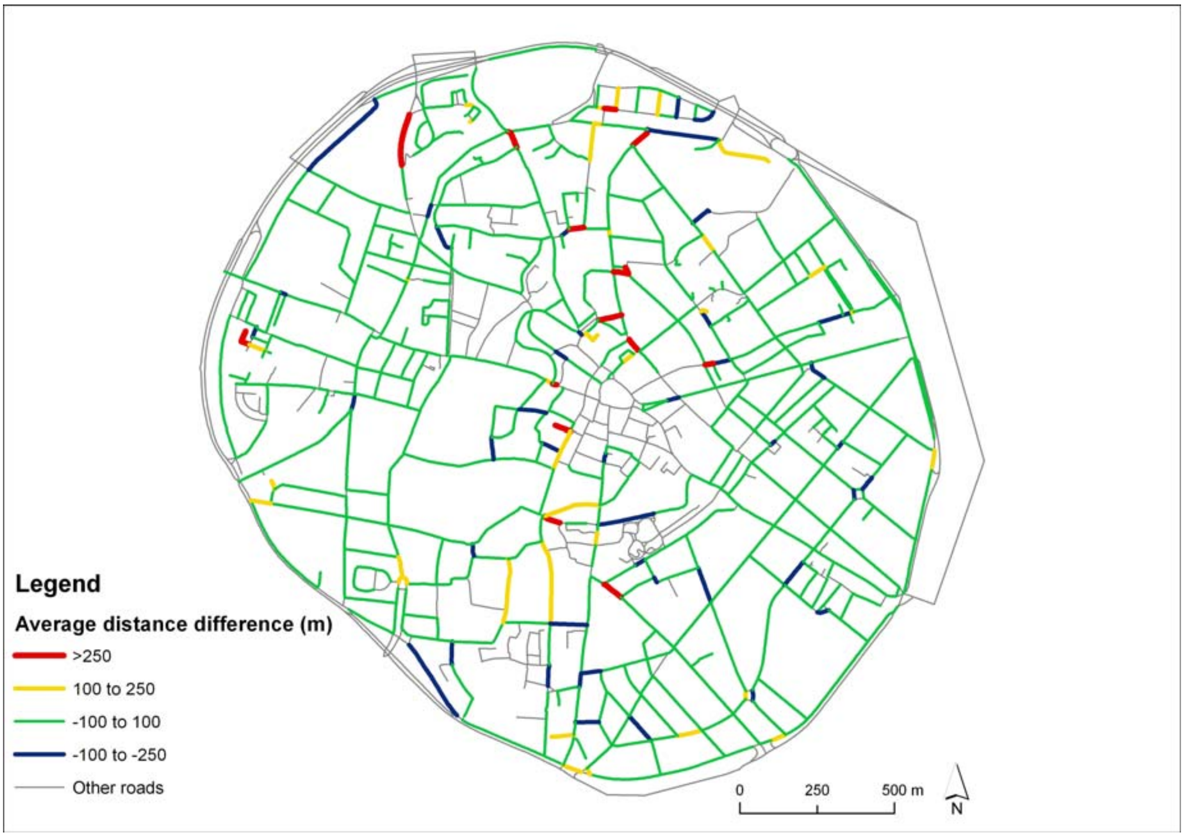


Figure 41: Map of the average parking distance (average over all agents and all times of the day, distance measured along the road network) for the scenario 'Tiensestraat'.

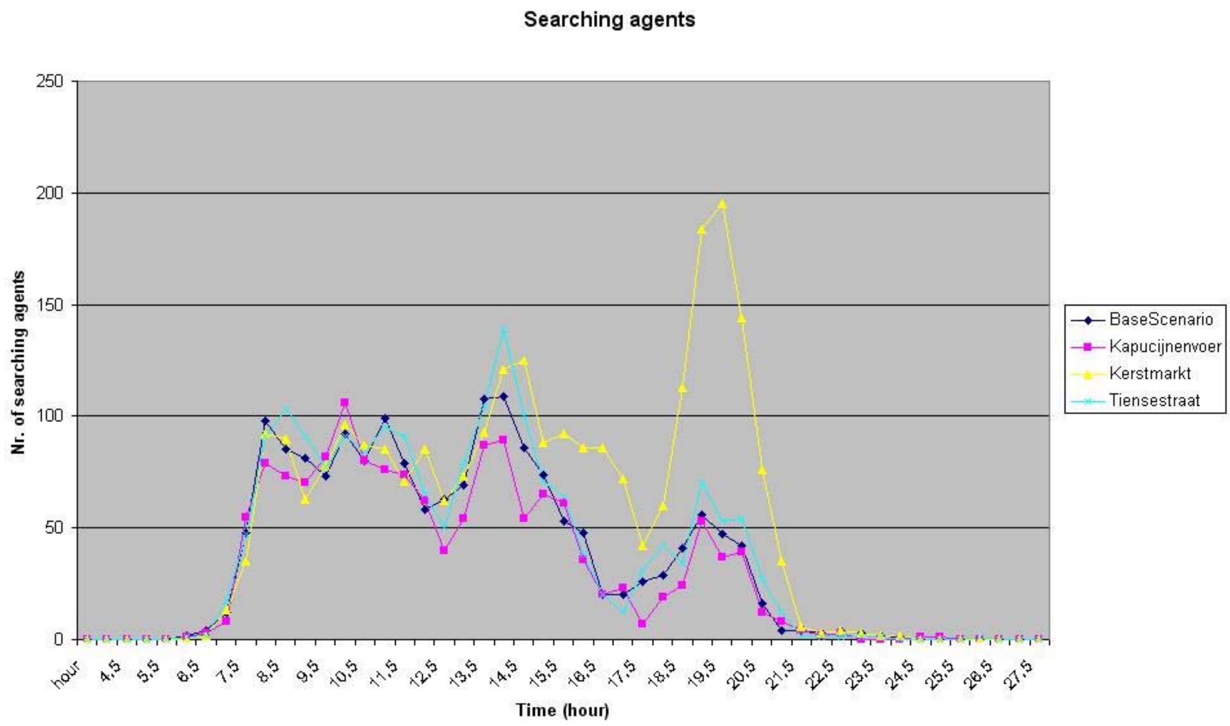


Figure 42: The number of agents simultaneously active in the model at specific times, shown for the baseline and the three scenarios. A model run starts at 4 AM in the morning.

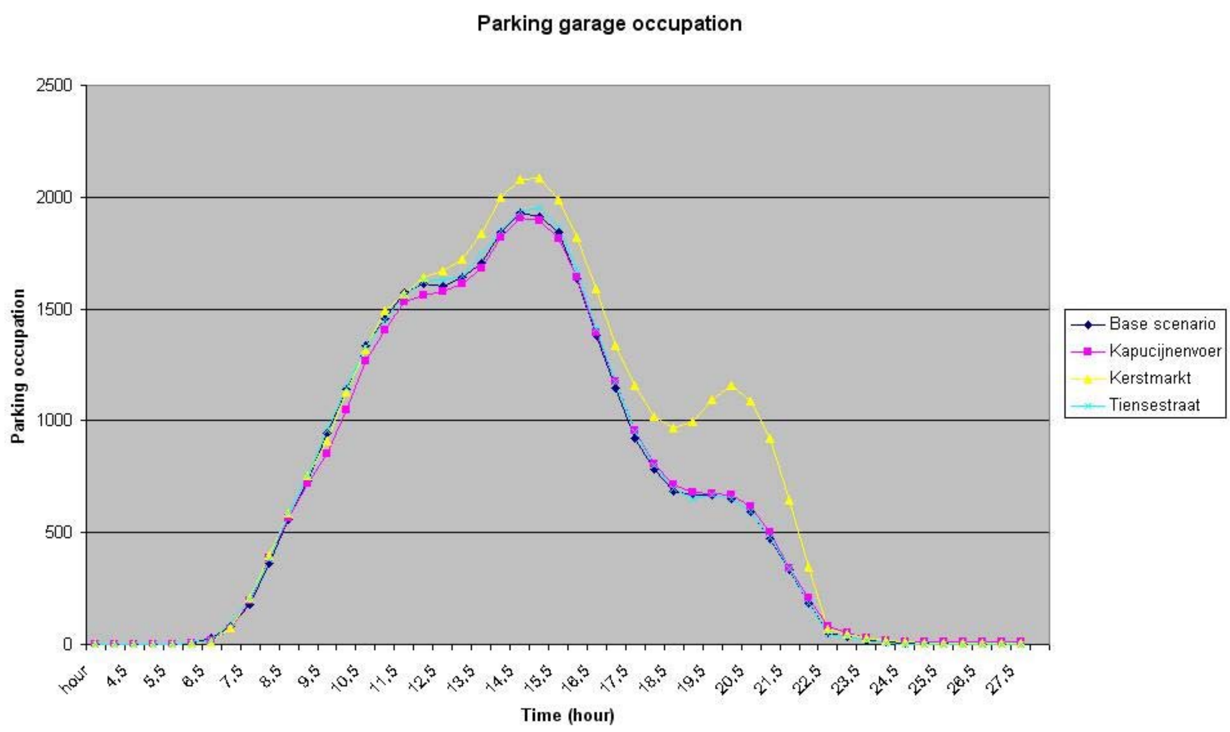


Figure 43: The evolution of the total occupation of the parking garages throughout the day, compared for the baseline and the three scenarios. A model run starts at 4 AM in the morning.

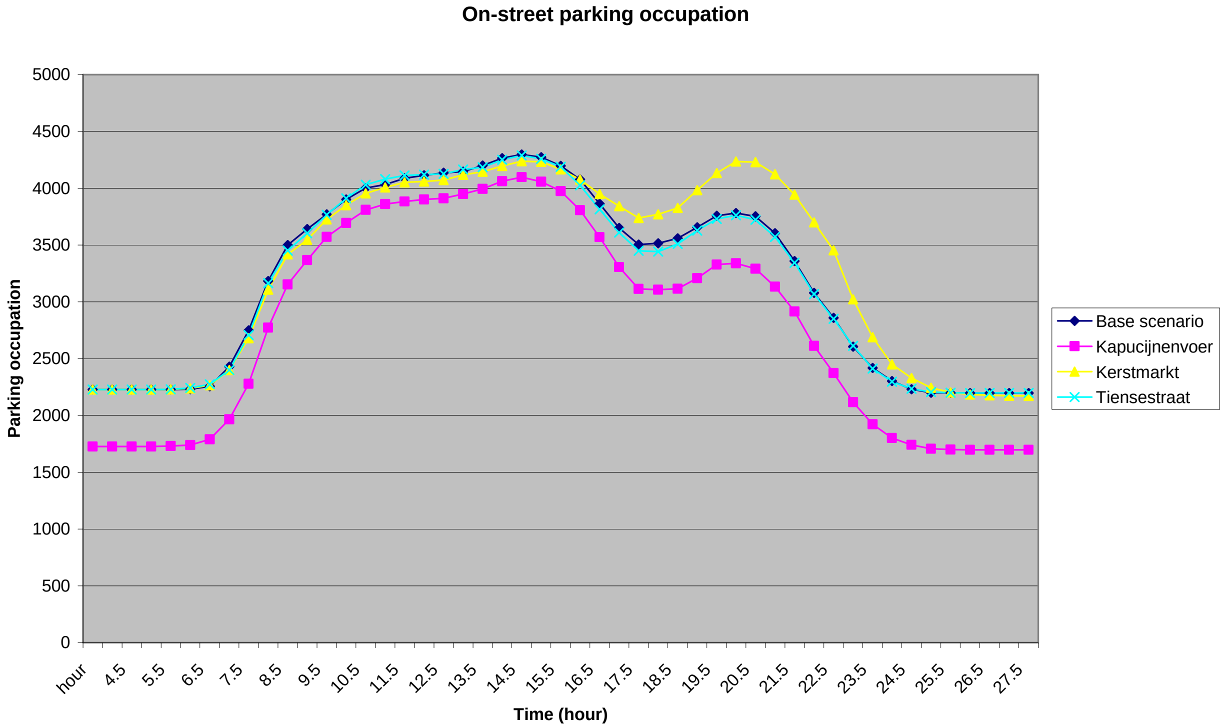


Figure 44: The evolution of the total occupation of the on-street parking places throughout the day, compared for the baseline and the three scenarios. A model run starts at 4 AM in the morning.

Figure 45: The evolution of the total occupation of the private (off-street) parking places throughout the day, compared for the baseline and the three scenarios. A model run starts at 4 AM in the morning.

7 Conclusions

7.1 Project conclusions

The previous Chapters of the report discussed the theoretical background and implementation of the SUSTAPARK model. A case study for the inner city of Leuven was also presented, showing the capabilities and some of the limitations of the model. The model itself is the main output of the project. In this Chapter a summary is given of what was learned during the project and a discussion is presented of the model strengths and weaknesses.

In the course of the project it became clear that parking is a very complex issue that touches on many levels of city planning and mobility. This complexity was initially underestimated in the project. It seems unlikely that all of these aspects can be captured in one model, and that a full parking model should in fact consist of several models that operate on different levels and treat different aspects. SUSTAPARK is focussed on the transport side of parking, whereby land-use issues are entirely ignored. The model has a very high level of detail and enables the modelling of interactions at a very low level. Due to the model structure, it can be easily extended and improved with additional features. As shown in the case study, the current model can be used to simulate effects of the addition and removal of parking places.

The current model and the methodology adopted do have many limitations at this point, marring its usability. One major limitation is the used agent methodology. While it enables a high level of detail in the model, it comes at a price of severe data requirements. The model also has many uncalibrated coefficients at the end of the project, while the agent behaviour and the model results are clearly very sensitive to them. Furthermore the coefficients are likely not transferable to other cities. This means that the time-consuming and costly calibration procedure needs to be repeated for each city that the model would be applied to. The costs and availability of the data limit the usability of the model. It should also be noted that a significant amount of time needs to be invested to process the data and prepare it as suitable input for the model.

As the model is now, it lacks some essential features to function as a full parking model. Especially the absence of modal choice that takes into account the price and availability of parking is problematic in this regard. Also the lack of a model for trip choice is a serious issue. Together this means that two of the most important effects of parking policy and policies aimed at a more sustainable city cannot be modelled.

The model does not take short consecutive trips into account, or the fact that people plan their trips so that their activities are located in each other's vicinity. This will also have an impact on the modal choice as people might go to their different activities by another mode, rather than always taking the car for each trip to each activity, as it is now in the model.

As evidenced from the case studies, the behaviour of the model agents is not very realistic in situations where parking pressure is very high. Instead of immediately switching to some other form of parking or go looking for parking places elsewhere in the city, drivers search overly long for on-street parking places where they have no realistic change of finding a free spot. Also, most of the search strategies that were found during the behavioural research are not implemented. The end result is that search times in the model are (severely) overestimated.

Another issue is that the model was developed and tested on the city of Leuven. Most of the behavioural research related to parking also happened in Leuven. An important feature of Leuven related to the modelling of the city, is that it has a clearly defined centre, surrounded by a ring road. For several years now the city council of Leuven has maintained the policy of keeping the traffic pressure in the centre of the city as low as possible and directing much of the through traffic to the ring road. The city of Leuven is also well known for its parking problems and has the reputation of strong enforcement of parking regulations. These factors might skew some results of the research and may mar the applicability of the SUSTAPARK model to other cities. Other cities might lack a ring road, a well-defined centre, or might have a less strong stance on car use in the city.

It is clear that much research remains to be done in the field of parking. In this respect, the SUSTAPARK project will contribute to the scientific body of knowledge on parking and better and more sustainable policies for out cities.

7.2 Future research

In this Section we discuss possible extensions and improvements for the model. Some ideas for further research are also suggested.

Features which are fairly straightforward to implement:

- **Better parking search algorithms**: many algorithms found in the behavioural research were not implemented due to time constraints and implementation difficulties.
- **Improved searching algorithm**: so that drivers searching for parking, shift sooner to an off-street parking strategy once they notice that on-street parking is saturated in the area where they are looking for a parking place.
- **Calibration and validation of the model coefficients**: currently no calibration happened of the model. This should be done, together with case studies in other cities so as to validate the model.
- **Improve current choice model for parking type**: the current discrete choice model does not directly take into account some relevant factors like the occupancy of the parking places et cetera. The coefficients also need to be re-estimated for the cities where the model is applied.
- **Parking place evaluation model**: replace the current ad-hoc model for the evaluation of a parking place with one based on real-world data, with actual variables and estimated coefficients.

Features requiring substantial further work and model development:

- **Number of private off-street parking places**: currently the number of private off-street parking places is estimated. There is however much uncertainty about the results. A validation of these estimations and perhaps a more refined estimation methodology would benefit the model.
- **Number of on-street parking places**: the number of on-street parking places is calculated based on the length of the streets. This might be an imperfect reflection of reality, as illegal places are not taken into account, nor the specific local circumstances in streets, nor the loss of parking places due to curb cuts for the exits of garages.
- **Sensitivity analysis**: currently is unknown how responsive the model is to changes in parameters and scenario setup. A sensitivity analysis needs to be performed.
- **Output**: the model could be expanded with indicators like turnover rate, allowing a more comprehensive analysis of the model results.
- **Improve setting up scenarios**: currently setting up scenarios is an involved process where data needs to be modified directly. Options to make this easier can be explored.

Features requiring substantial further effort to implement and likely additional research:

- **Improve input requirements**: the current data requirements of the model are very large. Ways to reduce or simplify these should be researched. The methodology of the activity schedule might have to be replaced with something easier to obtain and validate.
- **Modal choice model**: modal choice is currently not implemented in the model. To improve the functionality as a policy model, a model for modal choice should be added, one that explicitly takes the price and availability of parking into account. This might require new research.
- **Model for the choice to make a trip**: the effect of parking price and availability on the number of trips that people make is another aspect of parking policy. A model for the trip choice should be implemented.
- **Trip chaining**: related to the choice whether to make a trip or not, is the decision how to connect trips to each other. A model for this should be implemented, also taking into account the possible locations of the activities and the choice of mode to move between these activities.
- **Time limits**: currently in the choice behaviour there is no impact of time limits on parking duration. The model should be further developed in this area.
- **Vehicle occupancy**: currently the model has only on driver per car. This prevents the modelling of policies like car pooling, or that drivers might bring someone to drop them off at an activity they are not attending. Negotiation between the model agents would be necessary for this feature.
- **Heterogeneous population**: the population in the model is now identical. Eight categories of drivers are distinguished, but the only impact is that drivers of the employee category use slightly different coefficients for the decision which type of parking to take. More differentiation between the agents would be interesting, although this would further increase the data requirements.
- **Other parking types**: certain types of parking are currently not implemented in the model. For a complete parking model, novel types of parking like 'park and ride' should be implemented. Illegal parking should also be implemented, both in the sense of drivers not paying for a legal place, as drivers parking where this is not allowed.

7.3 Recommendations

The merits of the model for parking in the city, developed during the SUSTAPARK project, were previously discussed. In the course of the project it became clear that parking issues are related to more and more diverse aspects than assumed at the start of the project. At the end of the project, the focus on only mobility and transportation in the project seems rather one-sided and limited. In the following paragraphs we discuss other aspects of parking and place them in a broader context.

Parking is not only an important aspect of the transportation system, but, by its nature, has also a strong impact on land use. Every parking place takes up land that cannot be used for other purposes. If no parking places are available at all, a site becomes unreachable by car and unattractive to potential users. But in areas with high land rent, parking places are often an economically unattractive land use. For these areas novel parking and mobility solutions are needed that maximise the benefits from the land use while preserving accessibility of the areas.

One approach to achieve this is the pricing policy for parking places. Currently parking is often provided at no cost to the parker (but eventually someone else pays for it) or at a price that is (much) lower than the market price of parking places, as evidenced by the large number of drivers who keep coming to the city by car, despite the disadvantages of congestion and difficult to find parking places. Charging a fair market price for parking places (both on-street and off-street) is a necessity to let the demand meet the available supply.

Currently cheap (free) parking is often nothing more than a heavy subsidy for car use, encouraging car use, and contributing to mobility problems. Many trips made by car are fairly short (less than 20 km) and the true cost of a parking place is in fact the dominant cost factor for the trip. However this cost is not charged directly to parkers (due to the low prices). Instead everyone pays indirectly for parking, with little choice, through higher prices for other goods. Land rent is increased for everyone, shop keepers charge the cost of their parking places to all shoppers through the prices of their products, residents pay taxes to finance public parking places that are used by people from outside their city, …

A higher price for parking places might therefore contribute to a better car use. It has been proven that higher prices lead to higher occupancy rates for the cars that come to the city centre. Prices can therefore be used as an incentive to carpool or to shift to another mode. It can also stimulate the development of car sharing schemes such as Cambio.

Raising the price of parking places is likely to meet with resistance from residents, local shop keepers, employeesn and employers. They have grown used to free or cheap parking, often even viewing this as a right instead of a service provided. One counter-argument to this is that parking problems in many cities have now become so large that 'drastic' solutions are needed. Raising the available supply will in the long run only attract more drivers and not provide a true solution. Another way to increase public support is to earmark the parking revenue. If the revenue is invested in maintaining and improving the streets in the districts that generated the revenue, support by residents and shop keepers is likely to increase. The revenue can also be used to finance alternative long-term parking some distance away to commuters and provide a park-and-ride facility.

Communities are often reluctant to raise the price of parking or to limit the accessibility for cars to the city centre in some other way. They fear that by doing so the centre will become less attractive compared to other local centres and that as a result shopping, recreation, and employment in the city centre will decline. As this fear is not unfounded, it is recommended that cities are encouraged or enabled to confer with each other in order to come to an agreement with regards to pricing and other 'competitive' aspects of parking. A broad movement to charge correct prices for parking is also more likely to gain popular support.

Charging the market price for parking is easily said, determining it is another issue. Through trial and error this can be determined. At the market price of parking there will be just enough free places so that drivers find a place quickly and do not have to cruise for parking. An occupancy of 85% is suitable for this purpose. However, demand for parking also differs strongly within cities and throughout the day. A good pricing policy should reflect this. By charging a correct price throughout the city, spill-over into districts with a lower price can be avoided. Novel technologies like SMS-parking might provide a substantial aid in implementing such more complicated pricing schemes.

In this regard it should be noted that there remains a strong dislike for off-street parking with the drivers. The reasons for this are not known, but partly the perception that one can get away with not paying for an on-street parking place (since absolute coverage of all places is impossible) does play a role. The convenience of a car as a door-to-door means of transport is also important. Those who really want this convenience will be willing to pay a premium for it. A higher price for on-street parking than for off-street parking could therefore lead to a higher use of parking garages, which are now frequently under-used. To make this work private parking garages should obviously be prevented to match their price to the price of on-street places.

Another approach towards better parking policies is to more efficiently use the existing capacity. One avenue for this is to unbundle parking. When someone rents an office, an apartment, or a house, parking is frequently provided without choice in the matter. By unbundling parking, renters (or buyers) have the choice to only take the number of parking places that they want. They also become more aware of the cost of parking places since they are now paying separately for them. In effect, these measures create an improved market for parking places. Other means of improving this market are possible.

It should be stressed for the above that parking policies should never be implemented alone. New parking policies need to be part of a larger plan for mobility in the city. Parking policies aimed at reducing cars in the city centre means a reduction in mobility and accessibility. This will hurt the city centre in the long run as the city becomes less attractive for all types of activity. Therefore accompanying measures need to be taken that compensate for the loss in car mobility by increasing the quality and availability of other modi.

This is corroborated by examples from reality which show that where parking policies were implemented in isolation, their negative effects frequently outweighed their positive effects. Where parking policy was part of a wider mobility plan, the reverse was often true [CRO2001]. These examples also show that in the provision of parking places and the implementation of a new mobility plan great attention to details must be paid.

As already touched upon above, merely raising the supply of parking places is not a solution in the long run, as the demand for parking is likely to increase to the point where the parking problems are as large as before (with the caveat that more people are coming to the city centre). This illustrates the little researched connection between parking places, car use, and car ownership. There exist connections between these three aspects that are important for policy making. Do parking places cause car use and car ownership? Or vice-versa? Does car use eventually lead to more parking places? Or is the connection between parking and car use an autocatalytic one where each encourages the growth of the other?

Related to this are the connections between parking places, land use, and the transportation system. In short, these connections can have a defining impact on the urban form. More parking places means less dense land development, which in turn encourages car use. More car use increases the demand for parking and the construction of parking places. In some American cities this process has lead to auto-cities where all transport happens by car, the landscape is marred by the many parking lots and garages, and walking and cycling have been abandoned as modes of transport. This suggests that there is a point where there is too much parking. Determining this point is paramount to find the right balance between accessibility and sustainability.

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Appendix A Decision matrices behavioural research

Strategy #1 IS [EASY]

	Routing	Justification	Contingency/ Affordance	Operation/ Transition
Visitor #1	Follow RT1 (ringway) to gate closest to destination point.	Following the right way.	Affordance = optimal gate	When arrived at optimal gate: switch to strat #1 PS [EASY] visitor #1.
Visitor #2 ¬	Follow RT1 (ringway) to gate closest to destination point.	Following the right way.	Important delay (define delay through access time, 'other' category)	If contingency = delay: switch to strat #2 IS [short cut] Visitor #2.
Resident #1	Follow RT1 (ringway) to gate closest to destination point	Heads free.		When arrived at optimal gate: switch to strategy #1 PS [EASY] Resident #1.
Resident #2 ¬	Follow RT1 (ringway) to gate closest to destination point	Heads free until traffic jam.	Important delay (define delay through access time, 'work' category)	If contingency = delay: switch to strat #2 IS [short cut] Resident #2.
Commuter #1	Follow RT1 (ringway) to gate closest to destination point	Heads free.		When arrived at optimal gate: switch to strategy #1 PS [EASY] Commuter #1.
Commuter #2 ¬	Follow RT1 (ringway) to gate closest to destination point	Heads free until traffic jam.	Important delay (define delay through access time, 'work' category)	If contingency = delay: switch to strat #2 IS [short cut] Commuter #2

Strategy #1 PS [EASY]

	Routing	Justification	Contingency/ Affordance	Operation/ Transition
Visitor #1	When gate is taken, follow RT2 as far as possible to the destination point, then continue to destination by RT3 (if necessary) [RT2 > RT3]. Follow up to destination.	Following the 'right' way to the destination point.	Affordance = destination point	When passed the destination point: switch to S&TS [].
Resident #1 Positioning	When gate is taken, follow RT2 as far as possible to destination and continue by RT3 (if necessary) [RT2 > RT3] until 500 m before the destination.	Taking an 'easy' way to the destination point.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
¬ Resident #1 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).
Commuter #1 Positioning	When gate is taken, follow RT2 as far as possible to destination and continue by RT3 (if necessary) [RT2 > RT3] until 500 m before the destination.	Taking an 'easy' way to the destination point.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
¬ Commuter #1 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).

Strategy #2 IS [SHORT CUT]

	Routing	**Justification**	**Contingency/ Affordance**	**Operation/ Transition**
¬ Visitor #2	Follow RT1 (ringway) to gate less than optimal from the point that delay occurs. The first (possible) gate after contingency point will be taken.	City is entered sooner than foreseen because of unwanted delay on ringway.	At the moment where the delay (actual access time > preferred access time; 'other' value) occurs.	When arrived at 'new' gate, switch to strat #2 PS [short cut] Visitor #2.
¬ Resident #2	Follow RT1 (ringway) to gate less than optimal from the point that delay occurs. The first (possible) gate after contingency point will be taken.	City is entered sooner than foreseen because of unwanted delay on ringway.	At the moment where the delay (actual access time > preferred access time; 'work' value) occurs.	When arrived at 'new' gate, switch to strat #2 PS [short cut] Resident #2.
Resident #3	Follow RT1 (ringway) up to a given gate (reasons to be clarified, thereby gates to be clarified).	Routine itinerary (fixed short cut). Either because of association with a certain gate, either association with a certain activity (coming home).	Affordance = 'routine' gate.	When arrived at 'routine' gate, switch to strat #2 PS [short cut] resident #3.
¬ Commuter #2	Follow RT1 (ringway) to gate less than optimal from the point that delay takes place. The first (possible) gate after contingency point will be taken.	City is entered sooner than foreseen because of unwanted delay on ringway.	At the moment where the delay (actual access time > preferred access time; 'work' value) occurs.	When arrived at 'new' gate, switch to strat #2 PS [short cut] Commuter #2.
Commuter #3	Follow RT1 (ringway) up to a given gate (reasons to be clarified, thereby gates to be clarified)	Routine itinerary (fixed short cut). Either because of association with a certain gate, either association with a certain activity (work).	Affordance = 'routine' gate.	When arrived at 'routine' gate, switch to strat #2 PS [short cut] Commuter #3.

Strategy #2 PS [SHORT CUT]

	Routing	Justification	Contingency/ Affordance	Operation/ Transition
Visitor #2	When gate is taken, continue to destination point by shortest path. The road type is equalized [RT2 = RT3]. Follow up to destination.	Following the shortest way.	Affordance = destination point	When passed the destination point: switch to S&TS [].
Resident #2 Positioning	When gate is taken, continue to destination point by shortest path. The road type is *equalized* [RT2 = RT3]. Follow until 500 m before the destination.	Taking the shortest way.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
Resident #2 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).
Resident #3 Positioning	When gate is taken, continue to destination point, staying as *much* as possible on RT2. He will switch temporarely to RT3 but only to get as quick as possible on another RT2 [RT2 ≥ RT3]. Follow until 500m before the destination.	Taking a 'routine' way.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
Resident #3 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).

Commuter #2 Positioning	When gate is taken, continue to destination point by shortest path. The road type is equalized [RT2 = RT3]. Follow until 500 m before the destination.	Taking the shortest way.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
Commuter #2 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).
Commuter #3 Positioning	When gate is taken, continue to destination point, staying as *much* as possible on RT2. He will switch temporarely to RT3 but only to get as quick as possible on another RT2 [RT2 ≥ RT3]. Follow until 500m before the destination.	Taking a 'routine' way.	Affordance = 500m from destination point	When arrived at 500m: switch to PS evaluation mode []
Commuter #3 Evaluation	Continue current path.	Evaluating the parking volume, and anchoring CP.	Affordance = Quantity of empty places during 100m	In function of evaluation, determin threshold and CP (first 're-fixing' of initial preferences).

Strategy S&TS [MAIN]

Visitor	Routing	Justification	Contingency/affordance	Transition
Erratic	The agent looks for a place moving away from the destination point. Then, one after the other, the streets perceived as most empty are taken, with the RT being equal [RT2 = RT3]. He moves away from the destination point until he reaches the 500m perimeter.	Searching for a parking place.	Affordance = RT2 empty street & RT3 empty street. Choice between RT2 and RT3 also depends on the one-way streets or direction to be followed signs.	Inspection of empty parking places. When an empty place is encountered, switch to erratic evaluation/ decision.
Erratic Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue erratic strategy, or switch to new strategy and/or re-fixing preferences.
Cascade	The agent looks for a place moving away from the destination point. He follows RT2 as much as possible, taking RT3 streets to get to the next RT2 street. He moves away from the destination point until he reaches the 500m perimeter.	Searching for a parking place.	Affordance = RT2 & RT3.	Inspection of empty parking places. When an empty place is encountered, switch to cascade evaluation/ decision.
Cascade Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue cascade strategy, or switch to new strategy and/or re-fixing preferences.
Ilôt	The agent looks for a parking place by taking by preference RT3 streets, avoiding RT2 streets as much as possible [RT3 ≥ RT2]. If he reaches the 500m perimeter, he will return to the destination	Searching for a parking place.	Affordance = RT3 & RT2 Choice between RT2 and RT3 also depends on the one-way streets or direction to be followed signs.	Inspection of empty parking places. When an empty place is encountered, switch to ilôt

	point. The agent starts his search from the destination point.			evaluation/ decision.
Ilôt Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue ilôt strategy, or switch to new strategy and/or re-fixing preferences.
Block	The agent looks for a parking place by going around the block. The agent starts his search from the destination point.	Searching for a parking place.	Affordance = street corners	Inspection of empty parking places. When an empty place is encountered, switch to ilôt evaluation/ decision.
Block Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue block strategy, or switch to new strategy and/or re-fixing preferences.
Spiral	The agent looks for a parking place by circling around the destination point, progressively enlarging the circle of blocks until the 500m perimeter has been reached. The agent starts his search from the destination point.	Searching for a parking place.	Affordance = street corners	Inspection of empty parking places. When an empty place is encountered, switch to ilôt evaluation/ decision.
Spiral Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue spiral strategy, or switch to new strategy and/or re-fixing preferences.

Strategy S&TS [MAIN]

Resident/ Commuter	**Routing**	**Justification**	**Contingency/affordance**	**Transition**
Erratic	The agent looks for a parking place while approaching the destination point. After passing it, one after the other, the streets perceived as most empty are taken, with the RT being equal [RT2 = RT3]. He moves away from the destination point until he reaches the 300m perimeter.	Searching for a parking place.	Affordance = RT2 empty street & RT3 empty street. Choice between RT2 and RT3 also depends on the one-way street or direction to be followed signs.	Inspection of empty parking places. When an empty place is encountered, switch to ilôt evaluation/ decision.
Erratic Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue erratic strategy, or switch to new strategy and/or re-fixing preferences.
Cascade	The agent looks for a parking place while approaching the destination point by following RT2 as much as possible, taking RT3 streets to get to the next RT2 street. After the destination point, he moves away from the destination point until he reaches the 300m perimeter [RT2 ≥ RT3].	Searching parking place	Affordance = RT2 & RT3	Inspection of empty parking places. When an empty place is encountered, switch to cascade evaluation/ decision.
Cascade Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue cascade strategy, or switch to new strategy and/or re-fixing preferences.
Ilôt	The agent approaches to the block/ street of the destination point. He then looks for a parking place by taking by preference RT3 streets, avoiding RT2 streets as much as possible [RT3 ≥ RT2]. If he reaches the 300m perimeter, he will return to the destination point.	Searching parking place	Affordance = RT3 & RT2 Choice between RT2 and RT3 also depends on the one-way streets or direction to be followed signs.	Inspection of empty parking places. When an empty place is encountered, switch to ilôt evaluation/ decision.
Ilôt Evaluation/Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue ilôt strategy, or switch to new strategy and/or re-fixing

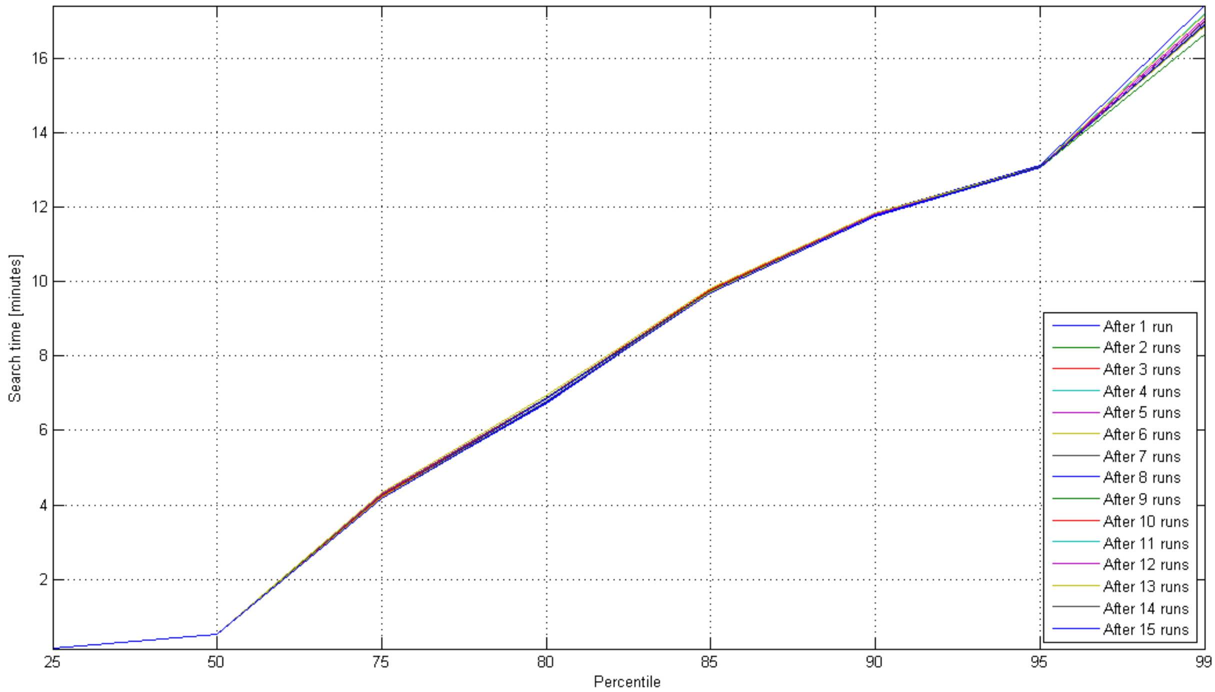
				preferences.
Block	The agent approaches to the block/ street of the destination point. He then looks for a parking place by going around the block.	Searching for a parking place.	Affordance = street corners	Inspection of empty parking places. When an empty place is encountered, switch to block evaluation/ decision.
Block Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue block strategy, or switch to new strategy and/or re-fixing preferences.
Spiral	The agent looks for a parking place by circling around the destination point, progressively enlarging the circle of blocks until the 500m perimeter has been reached.	Searching for a parking place.	Affordance = street corners	Inspection of empty parking places. When an empty place is encountered, switch to block evaluation/ decision.
Spiral Evaluation/ Decision		Evaluation of empty place.	Affordance = in function of preferences (discrete choice).	In function of discrete choice: park, continue spiral strategy, or switch to new strategy and/or re-fixing preferences.

Appendix B Stochastic fluctuations in SUSTAPARK

Because SUSTAPARK is a model that is based on stochastic draws with a random number generator (RNG), we expect fluctuations in the end results. The question then is, how severe are these fluctuations? For example, how large is the difference between consecutive runs of the model, and how comparable are the results for the same scenarios?

In order to try to answer this question, we ran the SUSTAPARK model 15 times on the same base line scenario (see also Section 6.3). During each run, we collected all the vehicles' search times on all the roads, and this for each block of 5 minutes during the day. In total, this gave some 16,000 data points for each runs, with a grand total of some 80,000 data points for the entire exercise.

Consider the results of 1 run, we can estimate the percentiles from the distribution of the vehicles' search times (the 50 percentile corresponds to the median). Each time a new run is executed, we combine its results with those of the previous set of runs. This systematically increases the population size, giving a better estimation of the true distribution of vehicles' search times. The following figure shows the results when calculating the percentiles after each set of runs:



As can be seen from the graph, we note that it seemingly does not matter how many runs of the SUSTAPARK model are executed. Each time, the percentiles lie closely to each other. Only for the very high percentiles (i.e. 99 and above), there is some variation in the results. This means that for the extreme values of the search times (i.e. exceptions such as small streets where only one car is slowly searching), increasing the number of model runs may stabilise the result. All in all, the previously sketched experiment seems to indicate that **each run of the SUSTAPARK model is quite stable in itself**, implying that no averaging of consecutive runs is necessary. One caveat to keep in mind however, is that we only considered 15 runs, whereas for a set of some 16,000 datapoints it would be necessary to execute a multiple of some 1000 runs in order to be statistically relevant. This is however impossible, as each model run took some 6 hours to complete.