The effects of parking measures on car use in the context of shopping trips

The Effects of Parking Measures on Car Use in the Context of Shopping Trips[1]

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Abstract

This paper presents an application of the parking analysis model ***Pamela***, a model that predicts parking consideration sets and combined travel choices in the context of shopping. The application was set up in the Eindhoven region and included three competing shopping centers: Eindhoven City Center, Veldhoven City Center, and Shopping Center Woensel. The model predicts that in the current situation for approximately 75 percent of the 5800 included non-weekly shopping trips the car is used. The use of cars results into 30,388 car kilometers.

Introduction

To estimate the effects of transportation measures, the Urban Planning Group of Eindhoven University of Technology has developed ***Pamela***; a Parking Analysis Model for predicting Effects in Local Areas (Van der Waerden, 2012). The model is able to predict the effects of various transportation measures (including parking measures) on destination, travel mode, and parking choice in the context of weekly and non-weekly shopping trips. To illustrate the working of the model, at the time of the development phase, the model was applied on a hypothetical situation including several shopping centers, parking facilities, and bike storages.

In addition to the application in a hypothetical situation, the model is applied in a real world situation. The real world situation was set up in the Eindhoven region, and includes three major and competing shopping areas: Eindhoven City Center, Veldhoven City Center, and Shopping Center Woensel. The three shopping centers and accompanying parking facilities and bike storages were specified in terms of the attributes that are included in the various

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models of ***Pamela***. Based on Dutch Mobility data, a number of non-weekly shopping trips was generated for the city of Veldhoven (approximately 45,000 inhabitants). This resulted into almost 6000 non-weekly shopping trips per day that were included in the simulation. The model predicts for each shopping trip the shopping destination, travel mode, and in the case of car trips, parking facility. The predictions are used to create an origin – destination (OD) matrix for car trips. This OD-matrix is included in a Geographic Information System to assign the trips to a road network and to calculate the distances traveled by car drivers.

This paper describes in detail the set up of the simulation for the real world case. It also pays attention to the results of the model simulation with a focus on car use that is expressed in terms of the number of car trips to each shopping center and the amount of car kilometers. The remainder of the paper is organized as follows. First, the included components of Pamela are explained in more detail. Next, the adopted research approach is outlined. This section also includes the specification of the real world situation in the study area. This section is followed by the simulation results of the current situation. In addition, the working of the model is illustrated by several transportation scenarios. The paper ends with the conclusions and some suggestions for future research.

Parking Analysis Model *Pamela*

The parking analysis model ***Pamela*** covers different travel and parking decisions from the moment an individual has decided to leave home for weekly or non-weekly shopping until the moment the individual has completed her/his activity, leaves the chosen parking facility and goes home. ***Pamela*** consists of three components (Van der Waerden, 2012). The first component of Pamela covers the generation of individuals' parking consideration sets. This consideration set is generated using eleven attributes of the parking facilities that are available in the vicinity of a shopping destination. The included attributes are: size of the parking facility (number of spaces); chance of finding a free parking space; parking costs per hour; maximum allowed parking duration; average time needed to leave the parking facility (egress time); availability of driving space in the parking facility; type of parking facility; type of security; the location of the parking facility vis-à-vis the individuals' residence; location of the parking facility vis-à-vis other parking facilities; and the distance to the closest supermarket or department store. Each characteristic was defined at three levels (see Table 1). The parking consideration set consists of all parking facilities an individual chooses from when arriving at a shopping destination with a car.

Table 1: *Attributes and attribute levels for the consideration set task*

Attributes	*Levels*		
Size of the parking facility	50 spaces	250 spaces	450 spaces
Chance of finding a free parking space	25 %	50 %	75 %
Parking costs per hour	free	DFL 1.00	DFL 2.00
Maximum parking duration	unlimited	max 3 hours	max 1 hour
Average egress time	0 minutes	2 minutes	4 minutes
Driving space in the parking facility	limited	average	spacious
Type of parking facility	parking lot	-	parking garage
Type of security	none	video	guards
Location in relation to residence	favorable	neutral	unfavorable
Location in relation to other parking facilities	close	neutral	at distance
Distance to supermarket/department store[1]	50 meters	150 meters	250 meters

[1]dependent on type of purchases: weekly (supermarket) and non-weekly (department stores) goods

The second component of ***Pamela*** deals with the combined travel choice of individuals. The component covers the choice of shopping destination, travel model, and parking facility or bicycle storage (depending on chosen travel mode). Shopping destinations are described by two attributes: supply and spatial distribution of shops (see Table 2). The travel modes are specified using travel time between home and shopping destination. The parking facilities are characterized by the following attributes: parking tariff, maximum parking duration, and maximum walking distance from parking facility to closest supermarket/department store (depending on type of shopping trip: weekly or non-weekly).

Table 2: *Attributes and attribute levels for the combined travel choice task*

Alternatives	*Attributes*	*Attribute levels*
Shopping destinations	Supply of shops	limited, average, broad
	Distribution of shops	scattered, concentrated, dense
Travel modes	Travel time Car	5, 15, 25 minutes
	Travel time Bicycle	10, 20, 30 minutes
	Travel time Bus	10, 15, 20 minutes
Parking facilities	Walking distance to final destination	50, 150, 250 meter
	Parking costs	free, DFL 1.00/hour, DFL 2.00/hour
	Maximum parking duration	unlimited, max 3 hours, max 1 hour
Bicycle stalls	Level of security	secured, unsecured
	Storage charge	free, DFL 0.50/time, DFL 1.00/time
	Walking distance to final destination	25, 75, 125 meter

The third component of ***Pamela*** focuses on adaptive parking choice behavior when a car driver faces a fully occupied parking facility. Car drivers can express five different adaptive choices. First, motorists may choose to wait until a parking space becomes available. Second, motorists may choose to park illegally, especially when they think the risk of being fined is small. Third, motorists may decide to go to another parking facility and continue their search for a free space at that parking. Fourth, motorists can decide to shop elsewhere a strategy that is most likely in the case of large congestion in the vicinity of the shopping center. Of course, the car drivers also can decide to terminate their shopping trip and return home. Because of the adopted approach (see next section), this component is not included in the current study.

For all components, discrete choice models of the mixed logit type were estimated to calculate the probability of each included alternative.

Research approach

The application of ***Pamela*** in a real world context consists of the three steps. First, a choice situation is defined and the current situation is specified using the attributes included in ***Pamela***.

Step 1: *Define the real world context*

Pamela is applied in the Eindhoven region where three major shopping centers are located (Figure 1): City Center Veldhoven (green), Shopping Center Woensel (blue), and City Center Eindhoven (red). The shopping centers are competing, especially in the context of non-weekly shopping.

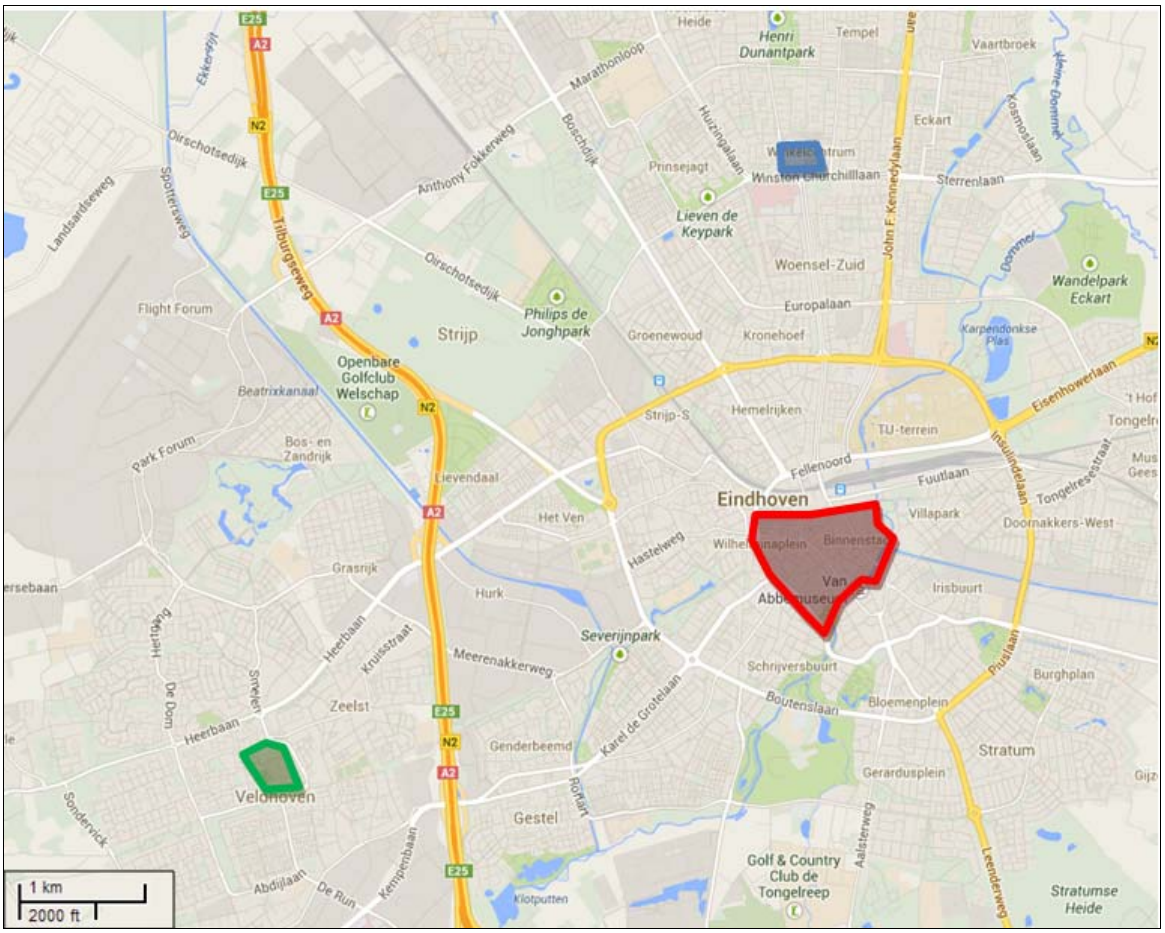

Figure 1 Three competing shopping areas in the Eindhoven Region (Ratgers, 2013)

The included shopping centers are surrounded by various parking facilities. In the vicinity of the Eindhoven City Center there are approximately 30 parking facilities. Not all parking facilities are available for shopper (facilities for residents or workers). This means that the set of available parking facilities is reduced to 15. Veldhoven City Center is surrounded by 8 parking facilities (Figure 2) while 4 parking facilities are located in the vicinity of Shopping Center Woensel.

Figure 2 Parking facilities in the vicinity of the Veldhoven City Center (Ratgers, 2013)

All shopping centers, travel modes, parking facilities, and bike storages are described using the attributes that are included in ***Pamela***. One example is shown in Table 3.

Step 2: *Determine the number of non-weekly shopping trips*

After the specification of the choice situation (supply side), the demand side is defined. For the purpose of this study only the residents of Veldhoven are included. Veldhoven is divided into 9 different 4 digit postal code zones (Figure 3). The number of residents in these zones ranges from 2431 (zone 5507) to 11123(zone 5508). Based on information of NBTC-NIPO (2006) the number of non-weekly shopping trips is determined. It appears that individuals make 0.1469 Non-weekly shopping trips per day. The total number of non-weekly shopping trips included in the simulation is 5841.

Table 3 Example of parking facility specification in Veldhoven (Ratgers, 2013)

Kenmerken	Parkeerfaciliteiten							
	1	2	3	4	5	6	7	8
Aantal parkeerplekken per parkeerfaciliteit	450	250	50	250	50	50	250	250
De kans op een vrije parkeerplaats	75%	75%	25%	50%	50%	25%	75%	75%
Hoogte van het parkeertarief per uur	1 euro	1 euro	1 euro	1 euro	1 euro	1 euro	1 euro	1 euro
Maximum parkeerduur	onbeperkt	onbeperkt	onbeperkt	onbeperkt	onbeperkt	onbeperkt	onbeperkt	onbeperkt
Tijd om uit de parkeervoorziening te komen	0 minuten	4 minuten	4 minuten	2 minuten	2 minuten	2 minuten	4 minuten	0 minuten
Ruimte	ruim	ruim	gemiddeld	ruim	ruim	ruim	ruim	gemiddeld
Type parkeervoorziening	parkeergarage	parkeerterrein	parkeerterrein	parkeerterrein	parkeerterrein	parkeerterrein	parkeerterrein	parkeergarage
Aanwezigheid van beveiliging	beveiligers	geen	geen	geen	geen	geen	geen	geen
Ligging ten opzichte van herkomst								
Postcodegebied 5501	gunstig	gunstig	ongunstig	ongunstig	ongunstig	ongunstig	gunstig	gunstig
Postcodegebied 5502	ongunstig	ongunstig	gunstig	gunstig	gunstig	gunstig	ongunstig	ongunstig
Postcodegebied 5503	ongunstig	ongunstig	ongunstig	ongunstig	gunstig	gunstig	gunstig	gunstig
Postcodegebied 5504	ongunstig	ongunstig	ongunstig	ongunstig	gunstig	gunstig	gunstig	gunstig
Postcodegebied 5505	ongunstig	ongunstig	ongunstig	ongunstig	gunstig	gunstig	gunstig	gunstig
Postcodegebied 5506	gunstig	gunstig	neutraal	ongunstig	ongunstig	ongunstig	gunstig	gunstig
Postcodegebied 5507	gunstig	gunstig	gunstig	gunstig	ongunstig	ongunstig	ongunstig	ongunstig
Postcodegebied 5508	gunstig	gunstig	gunstig	gunstig	ongunstig	ongunstig	ongunstig	ongunstig
Postcodegebied 5509	gunstig	gunstig	gunstig	gunstig	ongunstig	ongunstig	ongunstig	ongunstig
Ligging ten opzichte van andere parkeerfaciliteiten	dichtbij	dichtbij	dichtbij	dichtbij	dichtbij	dichtbij	dichtbij	dichtbij
Afstand tot warenhuis	250 meter	250 meter	150 meter	50 meter	50 meter	150 meter	150 meter	150 meter

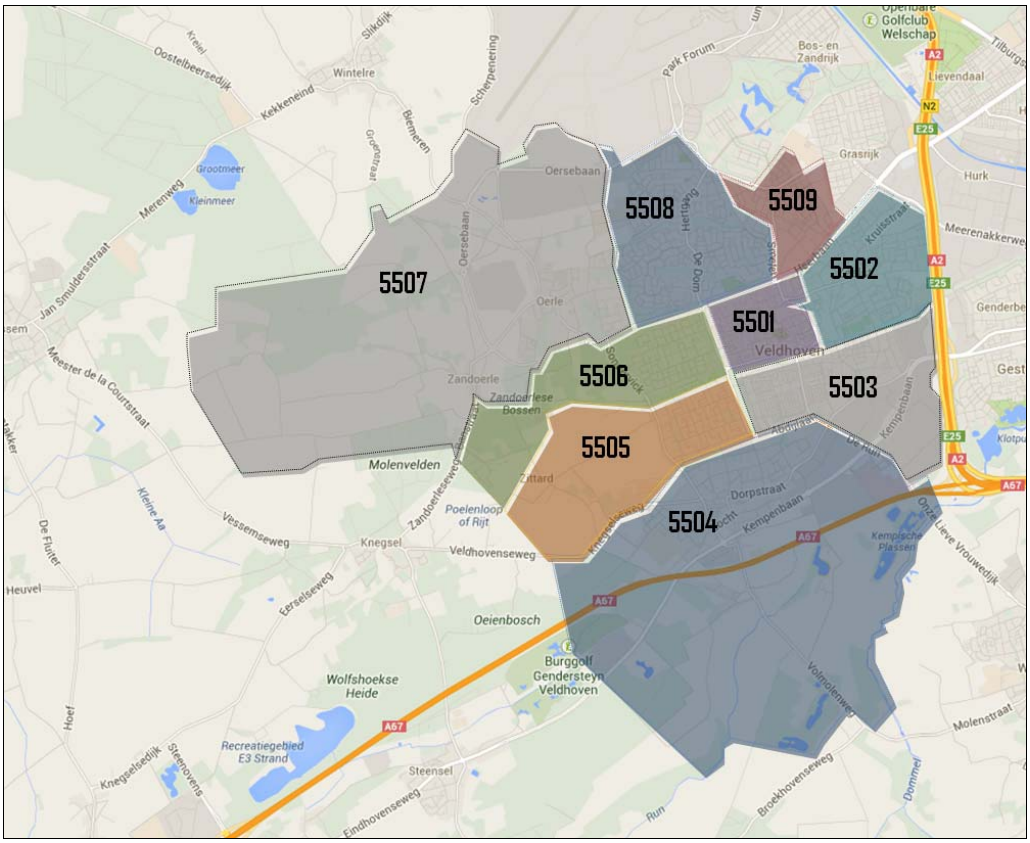

Figure 3 Origin locations of shopping trips in Veldhoven (Ratgers, 2013)

All the data are incorporated in the models to compose the individual's parking consideration set and his/her combined travel choice (see next section). The details of the various model parameters are described and discussed in Van der Waerden (2012).

Result of current situation

The first step of the simulation produces the composition of the individual parking consideration sets. This means that for each non-weekly shopping trip (conducted by a resident) a parking consideration set is composed. The total number of times that a parking facility is included in the individual consideration sets is presented in Figure 4. For example, the figure shows that parking facility 1 (De Geer) is included in the consideration set for almost all trips. Parking facility 6 (Braak Zuid) is only included in the consideration set for 2100 trips. Of course, this is strongly related to the attractiveness (expressed in the utility) of the various parking facilities.

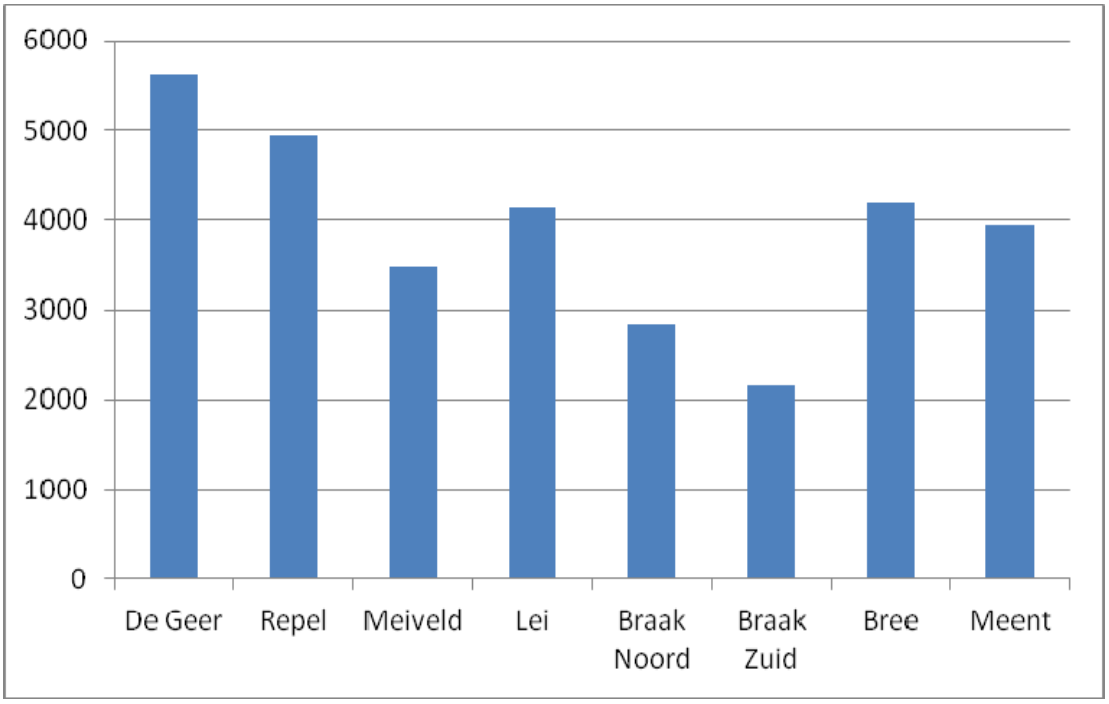

Figure 4 Aggregate results of the travelers' consideration set composition

This information is included in the simulation of the combined travel choice. This means that the attractiveness of a shopping destination and the travel mode car are also related to the attractiveness of the consideration set. The simulated parking choices are presented in Figure 5. Parking facilities 4 (Bijenkorf), 6 (Mathildelaan), and 13 (Deken van Somerenstraat) are most used by visitors who use the car for traveling to the Eindhoven City Center. Most car drivers who visit Veldhoven City Center park their car at parking facilities 4 (Lei) and 5 (Braak-Noord). The parking facilities in the vicinity of Shopping Center Woensel are more or less equally chosen by the car drivers.

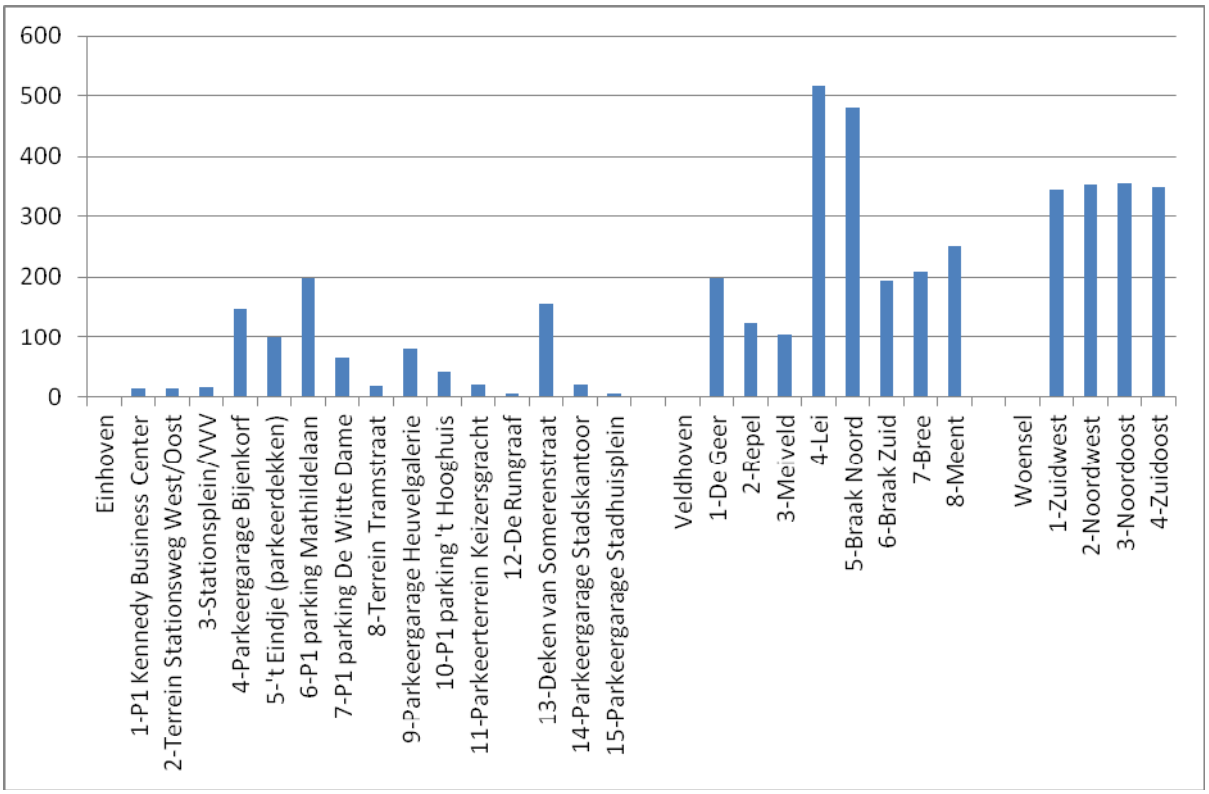

Figure 5 Overview of the parking choices

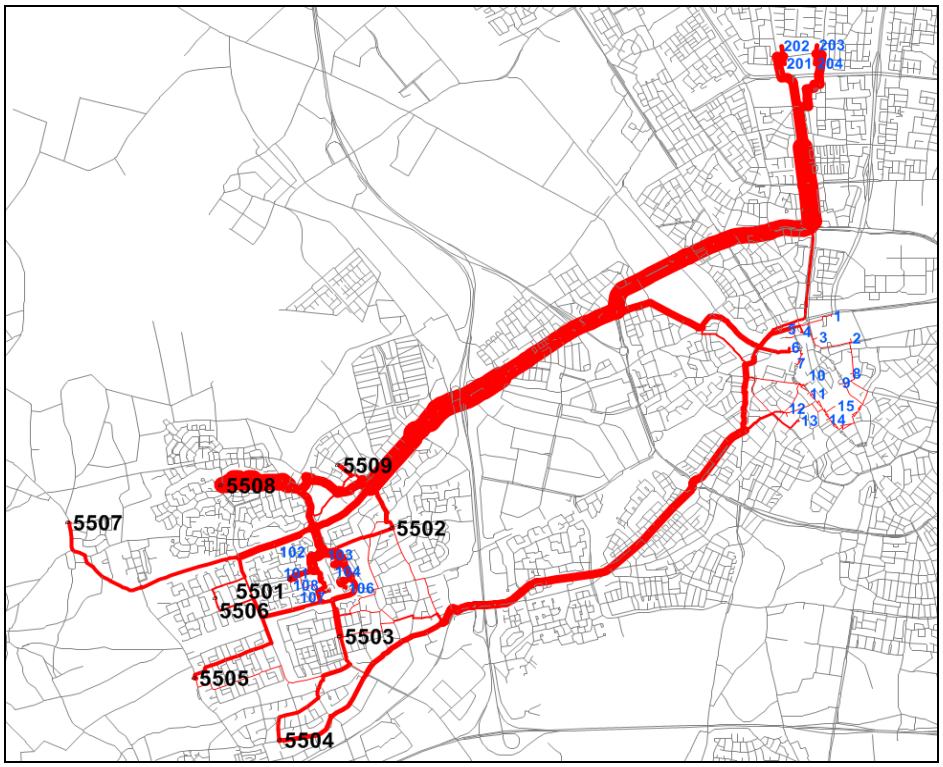

Figure 6 Results of the traffic assignment procedure in TransCAD (Ratgers, 2013)

All car trips are included in an Origin-Destination (OD) matrix where the postal code zones are the origins and the parking facilities are the destinations. This OD-matrix is used to assign the car trips to the road network as shown before (Figure 6). The traffic assignment was carried out using the Geographical Information System TransCAD (www.caliper.com). The routes between origin and destination on the road network are used to calculate the total and average distance traveled by cars (Table 4).

Table 4 Car use in current situation

Aspect	*Eindhoven City Center*	*Veldhoven City Center*	*Shopping Center Woensel*	*Total*
Number of Car trips	908	2074	1405	4387
Distance travelled (km)	8370	4976	17042	30388
Average distance (km)	9.22	2.40	12.23	

Transportation scenarios

To show the working of the model in more detail, four different transportation scenarios are evaluated. The scenarios are related to current developments in the Netherlands. The first scenario concerns an equalization of all parking tariffs at the level of Eindhoven City Center. This means that the parking tariffs in Veldhoven and Woensel are increased to 2.00 euro per hour. In the second scenario the travel time by car is equalized (for example due to infrastructural or speed regulation measures). This means that the car accessibility from each origin to all centers is equal. In line with some test areas in the northern part of Netherlands, in the third scenario free parking is reintroduced at all parking facilities. In the final scenario only free parking is introduced at the parking facilities in the vicinity of Veldhoven City Center. The parking tariffs at the other parking facilities are kept at the current level.

The main results of the simulations are presented in Tables 5 and 6. The Tables show the differences between the current situation and the various scenarios. First, the change in car use to travel to each of the shopping centers is presented. For example, the introduction of a high parking tariff level (scenario 1) results into an increase of car use to Eindhoven City Center (plus 545 compared to current situation) and a decrease of car use to Veldhoven City Center (minus 992). Most of the changes are as expected. Some changes are at least remarkable: the increase of car use to Shopping Center Woensel in the case of scenario 2 and the big increase of car use to Veldhoven City Center in the case of scenario 4. All changes found here can be related to increase or decrease of the demand for parking spaces at each shopping center.

Table 5 Differences in car use between current situation and scenarios

Scenario	*Eindhoven City Center*	*Veldhoven City Center*	*Shopping Center Woensel*	*Total*
1. High parking tariff level	+545	-992	+29	-418
2. Equal travel time, cars	-161	-836	+860	-137
3. Free parking everywhere	+1166	-279	-371	+516
4. Free parking Veldhoven	-329	+1668	-1019	+320

The changes in car kilometers between current situation and scenarios are presented in Table 6. The Table shows that the first three scenarios result into an increase of the total number of

car kilometers. Especially, the overall attractiveness of the shopping centers Eindhoven City Center and Woensel causes the increase of car kilometers for these scenarios. Only the fourth scenario results into a decrease of the total number of car kilometers especially between Veldhoven and the Eindhoven shopping centers.

Table 6 Differences in car kilometers between current situation and scenarios

Scenario	*Eindhoven City Center*	*Veldhoven City Center*	*Shopping Center Woensel*	*Total*
1. High parking tariff level	+4986	-2362	+354	+2978
2. Equal travel time, cars	-1520	-1934	+10374	+6920
3. Free parking everywhere	+10900	-672	-4508	+5720
4. Free parking Veldhoven	-3052	+4064	-12354	-11342

Conclusions

This paper presents an application of the parking analysis model ***Pamela***, a model that predicts parking consideration sets and combined travel choices in the context of shopping. The application was set up in the Eindhoven region and included three competing shopping centers: Eindhoven City Center, Veldhoven City Center, and Shopping Center Woensel. Special attention was paid to the use of the cars and resulting number of car kilometers. Based on the model prediction, the car use and the number of resulting car kilometers travelled are calculated for 5841 non-weekly shopping trips. The model predicts that in the current situation for approximately 75 percent of the trips the car is used. The use of cars in this application results into 30,388 car kilometers.

To show the working of the model in more detail, four different transportation scenarios are evaluated. It appeared that the introduction of a high parking tariff level results into the greatest reduction in total car use. However, the scenario in which the parking at the parking facilities in the vicinity of the Veldhoven City Center is free, results into the highest reduction of car use and car kilometers.

While setting up the application several assumptions had to be made. Future research can confirm the reliability of these assumptions. The most interesting challenges are:

- Investigation of the (shopping) destination choice set of individuals in Veldhoven;
- Investigation of the routes between home and shopping centers that will be chosen by travelers;
- Investigation of the public transport in the relation between Veldhoven and the Eindhoven shopping centers;
- Investigation of the number of shopping trips in the context of non-weekly shopping.

References

Ratgers, R. (2013) *Effects of Parking Measures* (in Dutch), Bachelor thesis NHTV/TUe, Breda, the Netherlands.

Van der Waerden, P. (2012) *Pamela, a Parking Analysis Model for predicting Effects in Local Areas*, Thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.