Parking in Macroscopic Transport Models: Modelling Parking Capacities in Traffic Assignment

Dawn Spruijtenburg[1] (dawn.spruijtenburg@tno.nl), Erwin Walraven[1], Reinier Sterkenburg[1] and Marieke van der Tuin[1]

[1] TNO, Anna van Buerenplein 1, 2595 DA The Hague, The Netherlands

Abstract. Parking measures are typical for cities that aim to improve the liveability in terms of air quality, noise, congestion and space. The strategic transport models, used to determine the effects of (policy) measures, do not incorporate the effect of parking behaviour during the trip. The behaviour of parking the car near the destination, and walking the last bit, is not yet modelled in these models. In order to incorporate this behaviour in the static traffic assignment, a methodology is developed. Parking capacities are used in the traffic assignment, using parking and walking links. In this way, the extra search time for a parking space is modelled, as well as the diverting behaviour when (almost) all parking spaces are occupied. Simulations for a use case in Amsterdam show that the diverting behaviour is modelled and show possible effects of parking policies, for instance on the amount of car traffic in the city.

Keywords: transport modelling, static traffic assignment, parking capacities.

1 Introduction

Different cities are facing challenges with liveability, and sometimes (re)designing city centers to become more liveable. This means better air quality, less noise, more space for moving around and recreation, and generally less (car) traffic. In some cases, the measures taken impact parking, for instance when removing parking spaces, or providing only few parking spaces in newly developed areas. Some measures taken are specifically aimed at parking, such as (higher) parking fees.

Before introducing such measures in the city, it is good to study the effects of these measures to make sure the overall effects are positive (e.g. less car traffic) and not negative (e.g. same amount of car visitors but generating more traffic due to searching for parking spots). For this, typically strategic transport models are used. These models compute the destination choice, mode choice, route choice and resulting network flows in a certain region. In some cases, parking is considered in the destination choice and mode choice. The parking conditions (such as parking fee, walking time, (probability of) availability) are factors in the decisions made.

However, some parking behaviour only arises during the trip. For instance, when the location at which a person wanted to park has no available spaces. Then, this person might circle around to see and wait if a space becomes vacant, or drive to a next location at which parking might be available. This behaviour results in extra travel time and sometimes distance.

In this study, we propose a methodology that includes parking capacity in the static assignment of traffic, to get insight in the diverting behaviour and its effects. We do this by modeling a limited parking capacity per zone. The method builds upon existing knowledge and is incorporated in existing models.

2 Literature review

A strategic transport model typically consists of four steps (Ortuzár et al., 2011): trip generation, trip distribution, mode choice, and traffic assignment. The traffic assignment results in travel times (including congestion), which influences the mode choice.

The parking behaviour is mostly only considered in the mode choice, destination choice and sometimes time choice. Attributes of parking that are considered are: parking cost (parking fees), the (un)certainty of finding an available parking spot, estimated time searching for a parking spot, estimated walking time from the parking spot to the destination, and socio-economic characteristics of the driver (Chaniotakis et al., 2015).

However, also in the network assignment the parking behaviour can be taken into account. This is the part in which a specific parking location (spot) is determined (or assumed). The (un)availability of parking spaces causes drivers to circle around, or to divert to a different parking location and walk to the destination. As a result, travel times (by car) to certain destinations with limited parking availability will increase, which results in choosing different destinations or modes to reach the final destination.

This network aspect of parking is considered in several studies. For instance Lam et al. (2006) considers simultaneous departure time, route, parking location and parking duration choice in a network equilibrium model. Boyles et al. (2015) considers parking searching in a traffic assignment and considers uncertainty regarding the availability of vacant parking spaces. Leurent et al. (2014) use a static traffic assignment while taking into account route choice and parking location choice. Pel et al. (2017) introduces the concept of *parking search routes*, where a driver visits a sequence of parking locations until finding a vacant parking spot. Lam et al. (1999) use a user equilibrium assignment with departure time choice and parking location choice. In Lam et al. (2006) a travel time function is used to model availability of parking spaces.

Inspired by these approaches, and building upon modelling techniques developed previously and described by van der Tuin et al. (2021), we propose a method for incorporating parking behaviour into the static traffic assignment.

3 Methods

The basis of our work is a static traffic assignment. A volume averaging algorithm is used, a heuristic to approach an equilibrium situation where no one can improve their travel time by choosing a different route (Ortuzár et al., 2011).

To include parking in the static assignment, parking links are included in the network. Each zone (centroid) in the network gets one parking link with a set capacity, which represents the amount of parking spaces available. The more vehicles use a certain parking link (i.e. park in a certain zone), the higher the travel time (search time for a parking spot). At some point as the parking spaces fill up, the travel time becomes so high that it is quicker to park in a neighboring zone, and walk to the destination, instead of parking in the intended destination zone.

This mechanism is modelled by adding 4 different types of ‘parking links’ to the network: parking connector links, parking links, walk parking links and interzonal walk links. Figure 1 represents the situation where no parking links are added, and Figure 2 shows an example where the 4 types of parking links have been added.

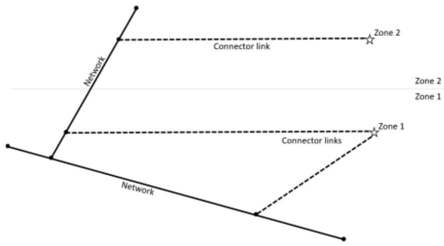

Fig. 1. Reference situation without parking links

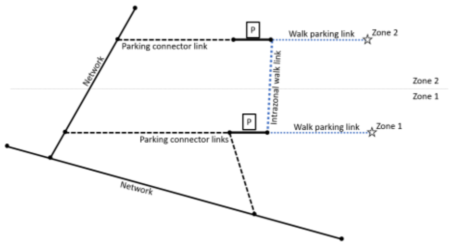

Fig. 2. Example of added parking links

The parking links have limited capacity and cause the extra searching time, by using a (BPR) travel time function. The walk parking links connect the parking links to the zones. The parking connector links connect the parking links to the car network, at the same locations as where the original connector links were connected. The interzonal walking links are used for connecting the ends of parking links with those of other zones, and allow people to park in one zone and walk to another for their destination zone, when two zones are within a realistic walking distance. These interzonal walking links are added between each two zones that are within a set distance of each other.

The method described above requires the capacity (maximum number of available parking spaces) per zone. Since such data is not readily available in the Netherlands, the amount of parking spaces is estimated using several data sources. The estimation uses GIS (Geographic Information System) techniques, with data from several sources: Dutch cadaster (*Kadaster*), road data from the executive agency of the Dutch Ministry of Infrastructure and Water Management (*Rijkswaterstaat*), and data from the Dutch national parking registry (*Nationaal Parkeerregister*). Three different types of parking are distinguished: parking on own terrain (for homes), parking on parking lots and parking garages, and street side parking.

4 Use case and modelling framework

The described assignment with parking links, using the parking capacities, is tested in a use case of the city of Amsterdam and surrounding areas. The model of Amsterdam is based on the *Verkeersmodel Amsterdam* (VMA), and contains 3035 zones and 77,668 links. The studied year is 2020, and the time period used is the morning peak period (7.00 – 9.00) (Gemeente Amsterdam, 2022).

The model is implemented in Urban Strategy (Lohman et al., 2023), a Digital Twin tool developed by TNO consisting of several models, such as an assignment module for car, freight and bike (Traffic+), for public transport (Public Transport), for mode choice (New Mobility Modeller), and modules for air quality, emissions and noise (Air and Noise). In this use case the module used is Traffic+. Although not demonstrated here, it is possible to use the methodology in a chain of modules, for instance running the assignment of cars in combination with (adjusted) mode choice.

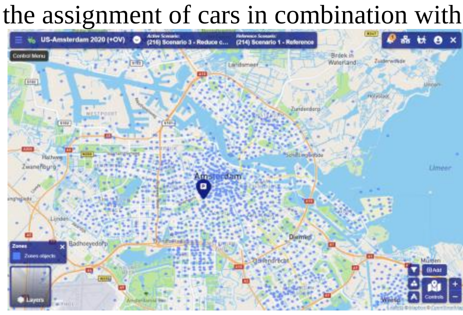

Fig. 3. Location of zone (parking marker) with reduced parking capacity in scenario 3

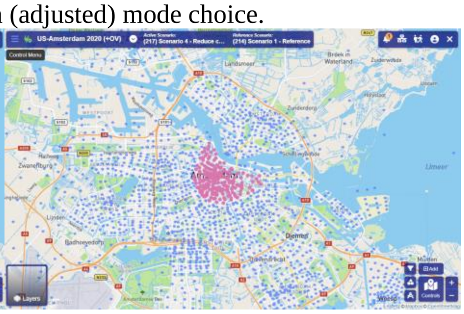

Fig. 4. Zones with reduced parking capacity in scenario 4 marked with pink dots

We present 4 scenarios for the city of Amsterdam. The first scenario is a reference scenario, where the assignment is performed without using the parking links and capacities. In the second scenario, the parking links are used with the parking capacities, such that the effects of the parking links can be studied. In the third and fourth scenarios, measures are applied to see the effect on the parking behaviour. In the third scenario, a reduction in parking capacity in a zone near the Vondelpark in Amsterdam of 1992 places (from 2042 to 50 parking spaces) is realised. See Figure 3 for the location, marked with the parking label (P). In the fourth scenario the parking space in the whole city center (within the ring road S100) is reduced by 75%. See Figure 4 for the zones for which parking capacity is reduced, marked with pink dots.

5 Results and discussion

In this chapter, the results of the 4 scenarios are presented. In Table 1 some results for the 4 scenarios are shown in terms of vehicle loss hours and vehicle kilometers driven. A distinction is made between the results for the total model (Amsterdam and surrounding areas), and just the city of Amsterdam. When comparing scenario 1 with scenario 2, it can be seen that the amount of vehicle loss hours and vehicle kilometers driven decreases. This can be explained by the fact that the introduction of parking links sometimes leads to shorter paths. This happens in the case where two zones are in close proximity to one another, but the car network between the two zones contains a large detour, for instance when one has to cross a bridge or park to get to the other zone. With the birds-flight distance that is assumed, this results in shorter routes.

Table 1. Results of the 4 scenarios in terms of vehicle loss hours and vehicle kilometers driven

	Vehicle loss hours (total)	Vehicle kilometers driven (total) (*1,000)	Vehicle loss hours (Amsterdam)	Vehicle kilometers driven (Amsterdam) (*1,000)
Scenario 1	22076.1	5024.7	1243.2	1493.7
Scenario 2	21928.9	4999.2	1173.9	1475.4
Scenario 3	21929.0	4999.2	1173.9	1475.4
Scenario 4	21930.4	4999.0	1176.5	1475.0

In Table 2 some results in terms of occupied parking spaces (distinguished between the whole model, and zones with reduced capacity in scenario 4), and the number of cars that parked in a different zone than the destination, and walked to the destination are shown. When comparing scenario 3 with scenario 2, an increase in cars parking in other zones can be seen. Since the zone with reduced capacity is on the edge (just outside) of the area in the city center, this causes increase in the number of occupied parking spaces in the city center, as this is (part of) the traffic that parks in a different zone.

Table 2. Results of the 4 scenarios in terms of occupied parking spaces and rerouting traffic

	Number of occupied parking spaces	Number of occupied parking spaces within city center	Number of cars parked in zones other than destination zone
Scenario 1	N.A.	N.A.	N.A.
Scenario 2	456313	8073	71958
Scenario 3	456313	8212	72015
Scenario 4	456313	6609	74352

We see larger effects when looking at parking capacity reduction for a larger area, i.e. the whole city center (scenario 4). Often driving to a nearby zone is not a solution, as these zones also have less capacity. Vehicle loss hours increase, since congestion occurs on the parking links when zones (nearly) reach their parking capacity.

The increase in vehicle loss hours is, even with a 75% reduction of parking capacity in the city center, quite limited. This indicates that the amount of parking spaces estimated is still quite sufficient. Additionally, when comparing scenario 4 with scenario 2, it can be seen that much less cars are parked within the city center (Table 2). This is to be expected due to the reduced parking capacity.

For running the traffic assignment of 10 iterations volume averaging with parking links, the model takes 92 seconds on a standard desktop PC.

6 Conclusion and recommendations

In this paper, a method is described to include parking capacities in a static traffic assignment. The usage of parking capacities in traffic assignment is demonstrated by application to a use case of Amsterdam, and it is shown to display realistic behaviour and fast computation times. This methodology allows for exploration of effects of parking measures on route choice, destination choice and mode choice, which is important if cities wish to be car-free without the possible negative effects of parking behaviour.

For future research directions, two main directions are proposed. The first is to study the behaviour and model equilibrium of combining the traffic assignment including parking links with other travel choices such as mode choice or destination choice. Parking measures are expected to have effects like modal shift, or choosing different destinations when travelling to locations with limited capacity. These combinations of choices can demonstrate new applications of the methods developed.

The second recommendation is related to the destination of trips. It is now assumed that each traveler has a fixed destination, and they know where to drive to. Even when parking in a different zone, they still walk to this destination. In reality, travelers sometimes drive to a certain area and park where they see a free spot. This behaviour of circling around is not yet explicitly modelled, but would be a next development.

Acknowledgements

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