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Too much of a good thing? The case of car parking in Rotterdam

The influence of parking policy and parking distribution on mode share

Reuben van Bemmel-Misrachi 900803048080

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Abstract: In recent years, there has been a renewed focus on car parking policy as a facilitator of automobile use. This thesis examines the policies and legislative requirements concerning car parking in the municipality of Rotterdam and the province of South Holland. This thesis will then analyse the composition of car parking in six key locations within the city of Rotterdam, substantiating the question of whether or not proximity to public transport and distance from the city centre matters in terms of car parking quantities. The results of this paper indicate that there are no clear patterns of car parking composition in Rotterdam in spite of what policies the municipality deploys to ensure a set quantity of car parking. Indeed, there is little evidence to suggest that either the current car parking policy nor the composition of the car parking itself is consistent with the need to curb car use in Rotterdam. This thesis concludes with recommendations on how the municipality and province might better approach car parking management in the future with an eye to effect a mode shift away from the automobile.

Acknowledgements

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Contents

Introduction:

Background

The role of car parking in urban transport has, until recently, been assumed as a natural requirement of the modern city. As with the use of roads by automobiles, the need for urban space to accommodate cars while parked has been considered a pre-condition of urban design, and residential and commercial development. This has resulted in considerable demand on governments (both local and national) to enact legislation for car parking to be included in building codes (Shoup, 1999) as well as construct and maintain (road and parking) infrastructure to cater for the road-space demand resulting from growth in automobile use in cities worldwide.

Even before environmental awareness became embedded in transport planning discourse, the negative consequences from growth in automobile use were being experienced in the form of localised traffic congestion. This developed primarily in the 1960s during a period of unprecedented motorway expansion across much of North America and Western Europe (Hutton, 2013). Since this road expansion, traffic congestion has been lauded as a by-product (and thus evidence) of a growing economy (see, for instance, Litman, 2014), and the car itself has been seen as the provider of unrestricted freedom of movement and as a status symbol in some cases. On the other hand, this indicator of growth is itself recognised as an impediment to further economic growth as it leads to traffic-saturated roads and further congestion. Economic growth and its resulting urban expansion both cause and is hampered by congestion (Sweet, 2014). This has become particularly severe in fast-growing cities where infrastructure development has not kept pace with demand. Environmental concerns about automobile use, oil security, and the role of the automobile in increasing greenhouse gas emissions have since added to the volume of concerns about our reliance on cars.

As a result, there has been a separate but growing call for governments to address the issues and environmental effects brought about by a reliance on private vehicles, and in particular for urban planners and city administrators to take an active role in managing and mitigating the threats posed by climate change (Reckien et al., 2014). The present threats of climate change, air pollution and peak oil are some examples where expertise in urban planning is critical, especially as urban areas are where the impacts of these challenges are to be felt the strongest. In terms of municipal climate policy, the Netherlands began initially with an active role, but to this day still lacks integration with other municipal divisions within local government organisations (den Exter et al., 2014). Urban transport decision-making is no exception to this.

In the last half-century, a theoretical focus on car parking’s role in the urban fabric developed in an attempt to explain travel behaviour. Ongoing concerns for the environment and the substitutability of sustainable modes in place of the automobile has helped shift the focus to discussions of parking as a significant facilitator of automobile use (see Hess, 2001 as an example). This thesis looks at the role of car parking as a facilitator of automobile use and whether the municipality of Rotterdam manages car parking with the higher objective of regulating automobile use in mind.

Research motivation

There is now a sizeable body of research that has examined the hidden costs of car parking (see, for example, Shoup, 1999 and Willson, 1995) with respect to zoning legislation, as well as the effect of negative on-street parking outcomes such as cruising and spillover (see Pierce & Shoup, 2013 and Millard-Ball et al., 2014). However, only a moderate amount of literature exists on symmetries of car parking and public transport supply, the focus of this thesis. Much of this literature is based on North American case studies, where car use is largely ubiquitous; conversely, little research exists in European cities (Schwanen et al., 2004).

In the Netherlands, some studies (van Ommeron et al., 2011 and Mingardo & Meerkerk, 2012) have looked at the question of car parking as a mode choice factor against different land uses, but the focus of Dutch urban planners has largely been on the provision of modes such as public transport and cycling, the latter for which the Netherlands is renowned. Nevertheless, alongside the provision of infrastructure for cyclists and public transport users, there is also extensive infrastructure provision for private automobiles in the Netherlands, and especially in Rotterdam (de Graaf, 2012). This tension in infrastructure provision between the supply of infrastructure for cars and infrastructure for cyclists and public transport users is central to this thesis, and raises some important questions about how public transport is perceived and how it may be possible to reduce automobile dependency in a large metropolitan area.

The case study of Rotterdam is interesting. Rotterdam has a very different urban structure to that of similarly-sized Dutch cities as its old city centre was destroyed during WWII. Rotterdam was rebuilt (in the 1950s through to the 1970s) at a time of unprecedented growth in car use and these values were reflected in the design of the city (McCarthy, 1998). Consequently, the city is now highly dispersed with a dense inner core surrounded by industrial harbour areas and low to medium density suburbs. This was fashioned in the urban design ideas of the times — the (suburban) garden city and modernism for the suburbs and inner city, respectively (Mashhoodi & Berhauser Pont, 2011).

In spite of awareness of the issues of car use, both environmentally and economically, car use is still significantly supported in the form of car parking in Rotterdam. It is this tension which underpins the motivation of this thesis.

Problem description

Transport is a large and rapidly growing source of greenhouse gas (GHG) emissions in Europe, and the Netherlands is no exception (Deetman et al., 2013). Of all transport emissions in the Netherlands, private automobiles are the greatest contributors to emission output, forming 51% of all transport emissions (Passier et al., 2008; KIM, 2012). A significant mode-share shift to public transport has been estimated to contribute a 32% reduction in national emissions according to research from the TU Delft (Den Boer et al., 2011). According to this research, to reduce annual transport emissions by 236 megatonnes of CO2, a reduction in car travel of the magnitude of 20% percent would be required. A similar analysis by Cuenot et al. (2012) showed that an average 25% reduction in car travel in OECD countries would equate to a 20% reduction in GHG emissions while Deetman et al. (2013) believe that greater subsidies for high speed rail are an appropriate response. All four articles designate public transport, in particular rail, as the appropriate substitute for private automobile use, as it offers comparable average trip length in urban areas. A mode shift away from the automobile would help mitigate the other problems: traffic congestion, localised air pollution, obesity, and stress and road trauma to name a few (Hutton, 2013).

The approach to managing transport infrastructure adopted by the three levels of government in Rotterdam (national, provincial and municipal) is supply-led. This means the nominated response to traffic congestion has been (and still is) to expand road capacity or somehow regulate its movement rather than seek to restrict automobile use itself. This is seen in the municipality's 'Green Wave' program, designed to give consecutive green traffic lights for consistent traffic flow. This circumvents the need to apply brakes and accelerate, the acts of which increase emission output (Madireddy et al., 2011). The supply-led approach is also visible in the ongoing support of municipality-built and subsidised car parking garages in congested areas, and the historical approach of expanding roadways at points of congestion, which has actually resulted in increased congestion (latent demand) for the most part. In reality, a 10% decrease in travel time has resulted in a subsequent increase of 11% in car mileage, while train mileage and that of other public transport modes declined by 2.4% and 1.8%, respectively, in the Netherlands (van der Loop., 2014). This seems to be at odds with claims that an increase in road capacity will reduce travel time over the long term, and suggests the negative influence road expansion has on public transport usage. The supply-led approach reinforces a dependence on the automobile for mobility.

Almost all residents of Rotterdam are connected to the road network. By contrast, not every resident has access to good quality public transport. In order to effect a mode shift away from the car, both expansion of public transport and restrictions (or penalties) of automobiles are policy options, but there has been notably little focus on the idea of reconfiguring car parking in Rotterdam to maximise a mode share shift. In the past, recognition of influential factors in mode share has often focused on the journey itself, not the destination or origin conditions, and this has been limiting. To this, a focus on car parking is necessary. Coevering (2008) has found that proximity to a public transport mode has negligible effect on the choice to drive in the Netherlands and that car ownership is generally location blind. International research by Shoup (1999), Guo (2013a, 2013b) and Weinbergen (2012) all confirm that a key determinant in choosing to drive is car parking itself – both off-street and on-street — and the costs and certainties of being able to park, rather than the provision of public transport itself. This merits a rethink of the supply-led approach of the municipality and province as well as the conditions of both public transport and car parking in Rotterdam.

A further concomitant problem of the supply-led transport approach has consequences for parking itself — the related problems of spillover and cruising. Spillover is when a shortage of parking in one location pushes drivers to congest adjoining areas, even if their activities are not situated in that location. A classic example of this is during sporting events whereby streets near to the event are found to be excessively congested. This phenomenon tends to have a cascading effect whereby residents of the congested streets seek a parking spot even further out from their homes - expanding the spillover (van Ommeron et al., 2012). Cruising is an issue whereby local streets become congested with slow moving cars seeking a car parking spot, often to the detriment of traffic major arterial roads (Anderson & De Palma, 2004). New technologies enabling in-car navigation to available parking spaces has been used but with limited success (Tasseron et al., 2014). Often solving these 'symptoms' disrupts policy making by supplanting a long-term comprehensive vision for short-term solutions that appease localised residential concern. For instance, increasing the turnover (decreasing occupancy time) of parking spaces may offer a limited resource to more drivers. But it may also act as an incentive to drive more as drivers are encouraged to search for further parking in the knowledge that the turnover rate is high.

Motorists are largely motivated by convenience. In spite of the environmental and social consequences of proliferate car use, research by Gardner & Abraham (2008) indicates that few motorists actively consider the side effects when selecting their mode of travel. Most motorists are concerned with reliability, the financial cost, time cost and the ease of movement of their vehicle of choice, though Beirao et al. (2007) point out that motorists regularly underestimate their journey time while in a car compared with public transport users. Likewise for drivers, price and availability (not average occupancy, as often modelled) are signals as to where they best can park (Millard-Ball et al., 2014). Coevering (2008) confirms this situation for the Netherlands too, adding that parking availability is almost always cited as the most common frustration residents experience in Dutch cities.

Research questions

This thesis does not assume there is an oversupply or an undercharging of car parking. Rather, it seeks to explore contradictions and inconsistencies in government policies, and suggests alternatives to the current approach.

The main research question is: **What strategies could generate further mode shifts to public transport with respect to parking strategy?**

The secondary research questions are:

1. **What are the policies governing the availability and pricing of car parking and providing incentives for travellers to use alternative travel modes?**
2. **How is car parking distributed at different distances from Metro Stations and Rotterdam's urban centre?**

Outline of structure

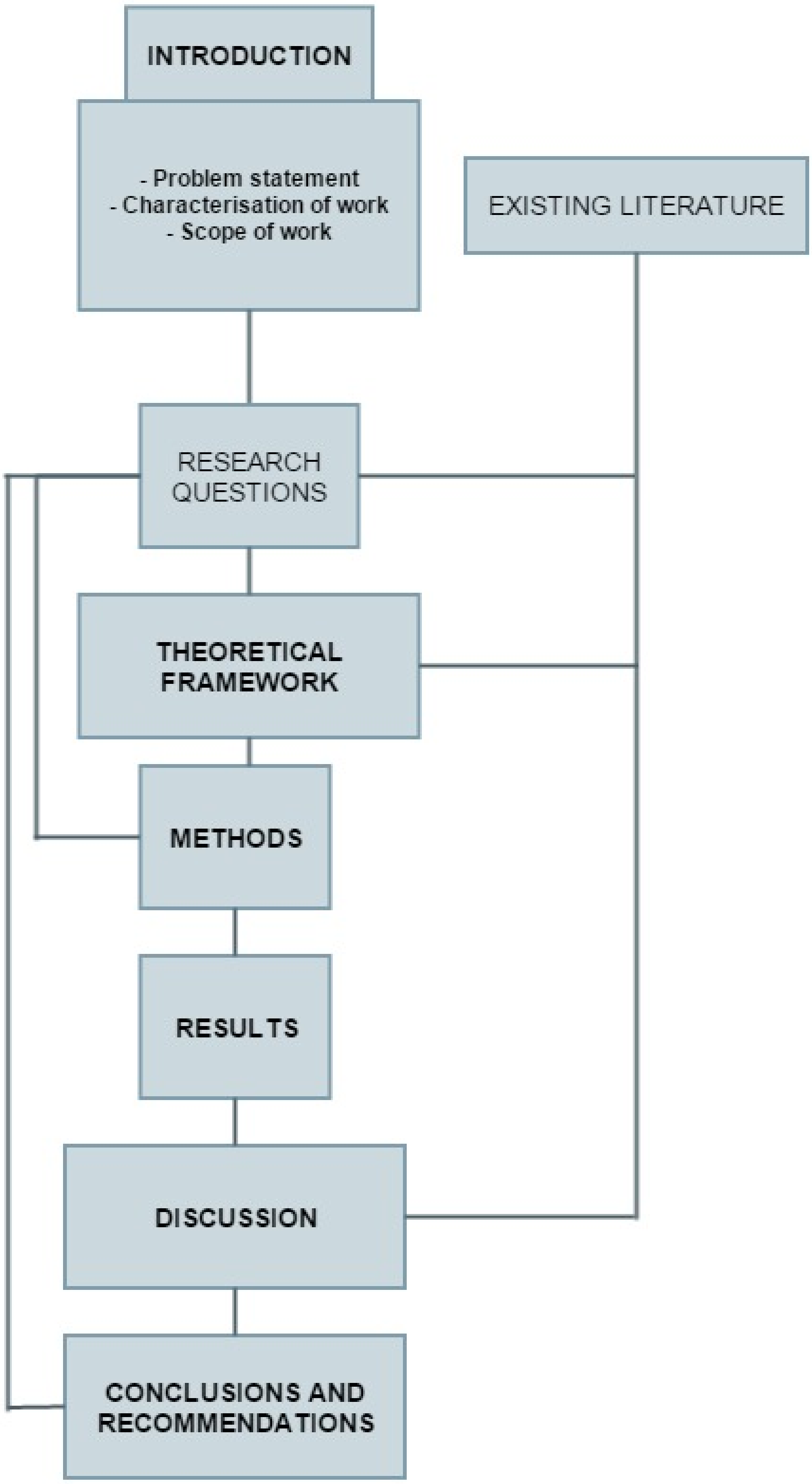


Figure 1: Outline of thesis

Theoretical framework and literature review

Non-vehicular mode share: land use factors

In discussions on what makes transport environmentally friendly and affordable, the indicator of mode share is highly relevant. Mode share depicts the proportion of users who opt for a specific mode in their travel routine (Hutton, 2013) and is useful for making model predictions (an oft-used tool in transport agencies) and scenarios about what a future transport mix could be composed of. Mode share gives an indication of the success of programs, projects and policies for public transport and cycling modes, drawing a link between the infrastructure conditions and the people who use it. It helps identify determinants of what makes an ideal transport mix. A contemporary example of this is analysing intergenerational transport choices, to determine what demographic groups use which modes (see Grimsrud & El Geneidy, 2014). However there are limits to the usefulness of mode share. A mode share sample finding a large proportion of residents of a suburb commuting to work using public transport might also neglect the fact that most of these residents also own cars which they use for non-work trips.

The three key land-use use elements that have been found to influence mode share are *urban density* (usually measured as people per square kilometre), *urban diversity* and *accessibility* (Vale, 2013). These are also referenced in the Dutch government's Mobility Index as being significant factors in mode share composition (Mobiliteitsbalans, 2012), yet remain overlooked in conventional traffic modelling which often focuses exclusively on historical traffic data – reinforcing path dependency to the detriment of different alternatives or a specific transport agenda aim (Curtis et al., 2010).

The role of greater population density in facilitating public transport and cycling mode shares is well documented, but remains controversial. It is argued that areas with high urban density facilitate lower energy demand, petrol use and, inversely, greater public transport use (Liddle, 2013). Such areas are frequently termed Transit Oriented Developments (TODs). TODs are not without criticism; some argue that urban density results in increased traffic intensity on surrounding streets, and the fact that higher densities are correlated with lower private automobile kilometres is just that: a correlation. The relationship of density to mode share is far from straightforward and the assumptions of the correlation ignore other factors that play a role, such as the quality of the public transport network in terms of its operational efficiency (transfer timing and reliability being just two examples), not just its coverage (Dodson, 2010).

The diversity of an urban area is recognised as important, too, and in recent years the term 'mixed use' has been used to describe urban areas where such diversity is high. In this instance, diversity refers to the balance of land uses in an area so that in order to reach local amenities, residents and workers do not need to travel as far and where public transport, walking and cycling are attractive (Marshoodi & Berhauser Pont., 2011). For land use planning, this means that residential and commercial zoning, as well as public amenities, are all located within reasonable proximity of each other—that they do not take much effort to access on foot or on bike.

Urban design influences the accessibility of an urban area. Rotterdam's outer suburbs (*wijken*) consist of many dead-end streets and circular feeder-roads — typical of the so-called 'Cauliflower Neighbourhoods' (*Bloemkoolwijken*) approach to urban design. This urban layout is highly conducive to car use due to its poor walkability and prolonged journey distances; this makes these neighbourhoods relatively less accessible for non-automobile modes (Frumpkin, 2002) for which longer distances are more arduous to travel. For residents of *Bloemkoolwijken*, public transport can be accessible, but it often doesn't work as effectively as it potentially could due largely to the low frequency (presumably brought about by low demand) and indirect routing of bus lines as a consequence of the aforementioned urban design (van Bemmel-Misrachi, 2014; Walker, 2012). Correspondingly, this has led to the generation of automobile congestion and the past (and still present) solution of expanding roads to funnel traffic off major streets.

SNAMUTS – public transport quality

Mere accessibility to a service or infrastructure does not guarantee it is of sufficient quality; the presence of public transport infrastructure does not guarantee it will be used or that it is efficient. Work by Curtis and Scheurer (2010) looked at what constitutes a high grade of public transport and their research has since culminated in the SNAMUTS (Spatial Network Analysis for Multi-Modal Urban Transport Systems) approach for public transport systems. Their methods are premised on the idea that mode share, travel distance and land use are all interconnected and that the outcome of infrastructure hinges on what infrastructure is provided. The authors thus seek to break away from a path-dependent focus of predict-and-provide transport modelling and move towards an agenda-setting one—one where sustainability is paramount (Curtis et al., 2010). They focus on six key indicators of public transport quality:

1. *Closeness Centrality*: a measure of speed (travel time between stations) and frequency. Compares each node to every other node in a chosen network.
2. *Degree Centrality*: a topological measure of the minimum number of transfers required between nodes.
3. *Contour Catchment*: this measures both public transport speed and land use intensity by calculating total numbers of residents and jobs within 30 minutes of travel time and walking distance.
4. *Network Stress*: this examines the ability of public transport to move passengers along each segment, determined by frequency, speed and vehicle capacity.
5. *Betweenness Centrality*: this measures the geographical distribution of attractive travel routes between each node pair. Effectively, it shows spatial activity concentration across public transport access paths. The Rotterdam Metro station of Beurs is an example of a high concentration of both public transport paths and activity.

6. *Nodal Connectivity*: This measures the strength of each activity mode in terms of integration of services. It multiplies the number of converging (to a node) route segments by the amount of departures (from the node). It is weighted by average occupancy rates of each mode.

Non-vehicular mode share - human factors

Attempts to expand road networks to alleviate congestion and stop-start traffic patterns (which increase pollution from constant slowing down and subsequent re-acceleration) have typically involved road expansion — a physical intervention. The basis for road expansion is found usually in computer modelling of traffic, focusing usually on congestion at specific points of the road network. However, this is a problematic approach. By not examining the sources of traffic (looking at land use in a particular area) and driver behaviour, the solution becomes one-sided and risks a repeat of past mistakes (Curtis, 2010).

Road expansion, as a policy instrument, is compromised by the consequent induced demand. Induced demand is the effect of a net increase in traffic after road expansion in the long term by the generation of new traffic responding to the initial increased road capacity. This can come from a number of causes and individual decisions, including drivers switching the time at which they travel, the route which they travel, or public transport users switching to the car. Empirical literature has shown a statistically significant correlation between an increase in lane-kilometres of road capacity and vehicle-kilometres of travel by motorists (Nolan & Hanson, 2013). Work by Barr (2001) revealed an elasticity[1] of between -0.3 and -0.5 units of post-road expansion vehicle mileage, implying motorists will spend between 30% and 50% of their time savings on additional road travel. Cevero (2002) confirms this but notes that in some settings, the induced demand effect is not so strong, an example being when an existing road is expanded compared to when a brand new road is built. This is due to the fact that a brand new road attracts additional traffic through all hours of the day, not just in peak hours where congestion is felt strongest. In their extensive evidence review, Nolan & Hanson (2013) concluded that “theoretically, one cannot reduce congestion through new road projects, and building new roads that access undeveloped land will result in increased vehicle travel” (p. 81).

Public transport mode share is negatively impacted by road expansion. Hutton (2013) observes this, as do Curtis (2010) and Hess (2001): public transport loses ground in mode share, which results in the positive feedback cycle of public transport operators needing to raise fares or cut back services which, in turn, have the effect of turning people away from public transport and back to their cars (see figure 2). Inevitably public transport becomes inconvenient for the vast majority of commuters and too expensive to expand to where it might later attract more patronage.

[1] Elasticity is a measure of how responsive one variable is to another in economics.

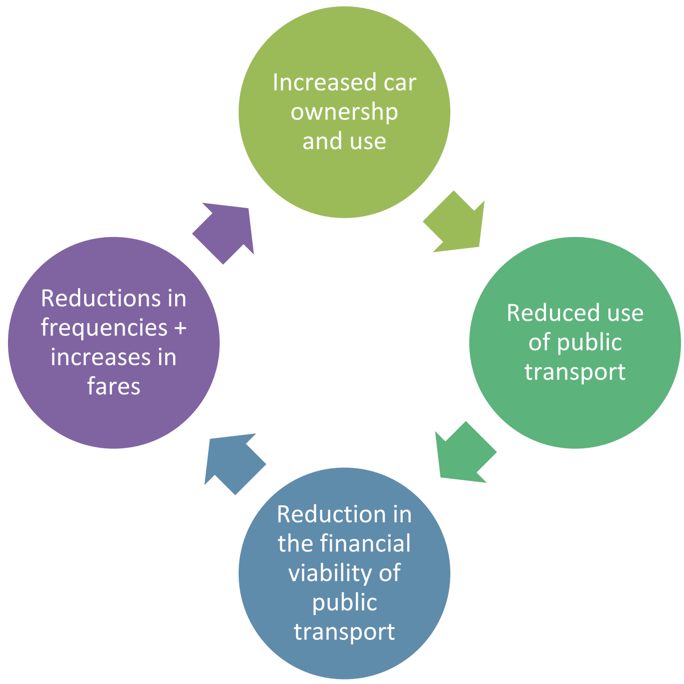


Figure 2: The cascading effect of declining public transport mode share (Hutton, 2013, p. 284)

Road pricing is seen as one solution to the problem of traffic congestion, but it too is not without criticism. The logic of road pricing is that (1) road users are consumers who are rational and make discrete decisions – termed the Theory of Planned Behaviour (Gardner & Abraham, 2007); and that (2) they respond to prices by either spending more money for a service (e.g. road tolls) after a price increase or switching to alternatives (e.g. driving and then choosing to cycle instead). Commuters choose the decision that suits them the best.

A major critic of this conceptualisation is Hutton (2013), who argues that the framing of roads and proposed road tolls is not akin to decision-making models recommended by proponents of demand-based solutions. Instead, he argues, travel choices are made by sifting through possible destinations and selecting the appropriate mode based on a number of different criteria; consequently, an increase in travel price may actually act to penalise individuals who seek to fulfil what is still the most rational choice for their travel needs based on all criteria other than cost. Hutton claims that a structural (infrastructure-based), not psychological (pricing or campaign-based approach), dimensions are what makes commuters opt for one mode over the other. Graham-Rowe et al. (2011) give substance to this criticism and found that most effective interventions have indeed been structural, not psychological.

There are affective responses towards regulating car use too. Jakobsson et al. (2000) looked at the responses to a proposed road tax in Sweden and found that low income earners were less likely to be supportive of financial penalties for driving as it would affect them the most. Almost all respondents (owners and users of private vehicles) lamented taxes while many saw it as an infringement on personal freedom, fairness and self-interest rather than a policy tool to benefit the environment. Interestingly, Schade & Baum (2007) found that reactions varied according to with how much certainty a demand focused intervention was certain a demand-focused intervention was intended to be; respondents who were told that road pricing was inevitable reacted less negatively and “reported lower levels of infringement of personal freedom”, stating “weaker motivation to restore personal freedom than persons who got the impression that the introduction of road pricing is rather uncertain.” (P. 45). The authors note that this is in line with ‘reactance theory’: people tend to cope with unavoidable events by viewing them more positively. This provides an idea on how potential restrictions on car parking might be implemented – through forewarning of potential shifts to give commuters time to consider how to respond when the restriction is indeed implemented.

Car parking - the missing factor

The provision of high quality public transport and cycling infrastructure is important but alone may not induce significant mode shifts. Even in areas of high public transport accessibility (where public transport itself is of high quality) and substantial population density, it has been shown that car parking is a greater decider of mode choice (see Weinberger, 2012; Willson, 1995; Su & Zhou Zuo & McDonnell, 2013). The work by Weinberger (2012) is particularly instructive as it explicitly looks at proximity to subway systems in New York as an influencing variable (no significant relationship was found). These studies all agree that – cars – despite their high running costs – are still subsidised when it comes to parking given the amount of space they take up. Motorists are, in fact, often subsidised in the form of public parking garages (Rotterdam has many such garages) for residents and visitors, and in parking fee structures that fail to take into account variations in demand (parking permits are an example of this). This is, of course, incongruous with the intention to shift to sustainable mode share. The diagram below gives an outline of the relationships between car parking and mode share (as a part of the broader mobility picture).

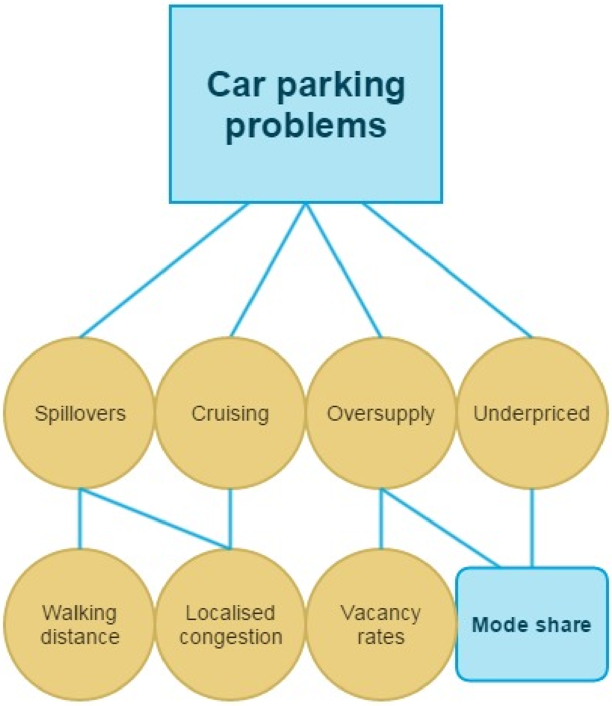


Figure 3: Common problems with today's car parking.

Early concerns about car parking

Alongside environmental issues relating to car use, the management of car parking supply is itself already problematic. The issues of cruising (slowing down on a thoroughfare while searching for free parking spaces) and spillovers (parking congestion in one area pushing into adjoining areas as people park further and further away from their intended destination) are also of consequence (as shown above in figure 3). Spillovers and cruising both contribute to localised congestion while spillovers also increase the walking distance for commuters.

Arnott et al. (1991) believe spillovers (also known as 'intrusion') results in on-street parking spaces being decreasingly congested as one moves away from the desired location and conversely increasingly congested as one moves towards it. This is due in part to commuters valuing walking time savings two to three times more than in-car time savings. The authors recommended that locations of the greatest convenience to the motorist (e.g. in terms of walking time) should be priced in order to achieve an appropriate level of demand (reducing demand for parking spaces at desirable locations). This would regulate what small on-street parking exists appropriately. Measuring spillover is difficult, as obtaining specific data would necessitate determining to which household a car parked on the street belongs and measuring the distance from that car to its place of ownership.

One solution to spillovers is dedicated parking permits for residents, which effectively 'lock out' visitor's cars that would otherwise force residents to park further (Zuo & McDonnell, 2013). However, Pierce & Shoup (2013) are critical of parking permits, claiming that they may encourage car use among residents; instead, they propose that parking prices be set at such a level as to encourage a certain number of spaces to be left –vacant and in a state of constant turnover.

Cruising is a related problem to that of spillovers but one with a more direct impact through the slowdown of through-traffic in the car lanes behind. It is usually calculated by looking at availability of car parking and its relationship with pricing. For the driver, there is little probability of finding a block of on-street parking spaces when spaces are close to full (Millard-Bell, 2014). There is little that can be done about this except in the realm of road design; the use of 'slip lanes' – a separated lane for local traffic along major roads – is one approach to mitigate the problem.

In many urban areas, including Rotterdam, the response to spillovers and cruising has been the construction of car parking garages, particularly in areas of higher density, to absorb the increased pressure that is exerted on on-street parking. As with on street-parking, public parking garages also face congestion, especially if on-street parking fees are raised (Arnott et al., 1991). To address congestion, several technical solutions have been recommended, including 'intelligent parking systems' that tell searching drivers if a space exists. However, their effectiveness is limited; guidance to a free space is possible only if that space does not get taken before the driver arrives (Tasseron et al., 2013). There are further problems with managing demand here: many drivers wish only to park in a certain location but if that location remains full, then the guidance system will lead drivers to a free space with a high walking distance regardless. Some newer approaches have adopted 'fuzzy logic' intelligent guiding systems whereby all uncertainties and real-time changes are factored into the guidance system which, in turn, provides feedback for the driver (Teodorovic & Lucic, 2006).

Off-street private parking - reinforcing driving

On-street residential car parking and off-street residential car parking have different and somewhat contradictory effects on the choice to drive, and there is already evidence that off-street parking results in greater use of the automobile by commuters. Work by Weinberger (2012) demonstrates a clear relationship between proportion of off-street parking in a neighbourhood and the propensity to drive. The author notes "where on-site parking is relatively scarce there is likely competition for curb-space which implies search costs and additional effort to walk from the parking spot to the home or other destinations." (p. 100). In this sense, the provision of off-street parking makes parking (and thus driving) 'easy' and requires little time sacrifice (searching for a free space and then walking).

Following on the work of Weinberger (2012), Guo (2013) looked at different conditions within off-street parking, examining further elements such as parking *certainty* (the ability to have a guaranteed vacant parking space) and parking *ease* (the ability to manoeuvre the vehicle in and out of the off-street parking space). Large multi-storey developments, where each household has a guaranteed but unreserved parking space, are an example where parking ease is low (as it would involve driving up several levels and then walking from the car) and parking certainty is intermediate (spaces are guaranteed, but not reserved). These are conditions which affect which mode is to be used.

In his study, Guo (2013) sought to classify *ease of parking* as existing where *certainty of parking* is also constant. If houses do not have the same set of parking options (can equally park on street as well as off street), then the study would suffer from selection bias. There is also endogeneity associated with car ownership. The parking ease itself may influence whether the household owns a car. Guo measured ease according to five key variables: (1) location of garage (close to the street or at the back of the building, for instance), (2) the presence of a narrow driveway to the garage, (3) the presence of a carport abutting the street, (4) ownership of the property and (5) housing type (p. 100). The first three factors directly relate to the ease. The fourth and fifth reflect on whether a household can block the driveway for a temporary pause between trip events or not, or whether modifications could be made to the building to make parking more convenient. Guo found that those residents enjoying high parking ease parked in the driveway or on the street more often (greater parking ease) and made more frequent trips with their vehicles. The average time spent by on-street and driveway-parked cars was less than those in garages. Guo concluded that, indeed, parking ease and the certainty of having a designated private parking space leads to people drive more often. .

For off-street parkers, the financial costs of yearly, monthly or even hourly fees that would ordinarily be associated with public or on-street parking are not consciously considered. This is because such fees have been bundled into the costs of housing (Cutter & Franco, 2012) where it is difficult to isolate their contribution to overall costs. It could very well be cheaper to park on the street, but it will not necessarily *feel* like it if one has to spend money for each parking event. Residents thus tend to underestimate the actual costs of their driving in a residential setting and think only in terms of the more visible costs of operating their vehicle.

While present availability, ease of access and certainty of off-street parking is seen to influence overall mode share and the propensity to drive, there are also other costs to off-street parking that are often overlooked. Work by Shoup (1999, 1995, 2005) and Willson (1995) have shown that construction costs are inflated when minimum parking requirements exist for dwellings and commercial buildings. This is especially so in urban areas of higher density where the spatial requirements (of the minimum parking requirements) demanded of car parking force developers to build multi-story or underground car parking. This costs more in construction and maintenance (the need to excavate, install elevators, fire escapes etc inflates the cost severely). Shoup (1995) estimates that the construction cost per additional parking space built in subsequently expanded multi-storey parking garages was approximately $US55,700 (€60349.42) in 1991, up from $US1,170 (€1074) in 1960 (p.7) (all figures in 2015 dollars). In highlighting one example, Shoup (1999) suggests underground parking (the most costly to construct) costs US$25,000 per parking space while above ground parking structures cost about US$10,000 per space. As mentioned earlier, these sorts of costs are not fully considered by residents, commercial tenants or users of parking garages as they are embedded into the costs of construction of the building, but are inevitably paid for through a mortgage, rent or through a municipal subsidy as in the case of Rotterdam (Tarievenoverzicht, 2015).

Barter's typologies of parking

Existing parking policies and the question of who pays for their provision, fees and maintenance have been examined in work by Barter (2013, 2014). In his '*A parking policy typology for clearer thinking on parking reform*', three main paradigms of parking policy are identified, plus a fourth for which no real case studies exist yet: (1) all sites (addresses) to be served by car parking - *as infrastructure* (this is the most common, represented in the form of minimum parking requirements for each dwelling); (2) all sites form together a 'parking district' wherein parking is supplied *as infrastructure* to serve the entire district (this is also known as 'area management') but not for specific sites; (3) a responsive, market led approach developed at the district level and where parking is *not* considered infrastructure but rather a *market good*; and (4) a per-site emphasis, similar to (1), but where parking is not infrastructure but a *market good* instead (no current examples exist). These are shown in the diagram below:

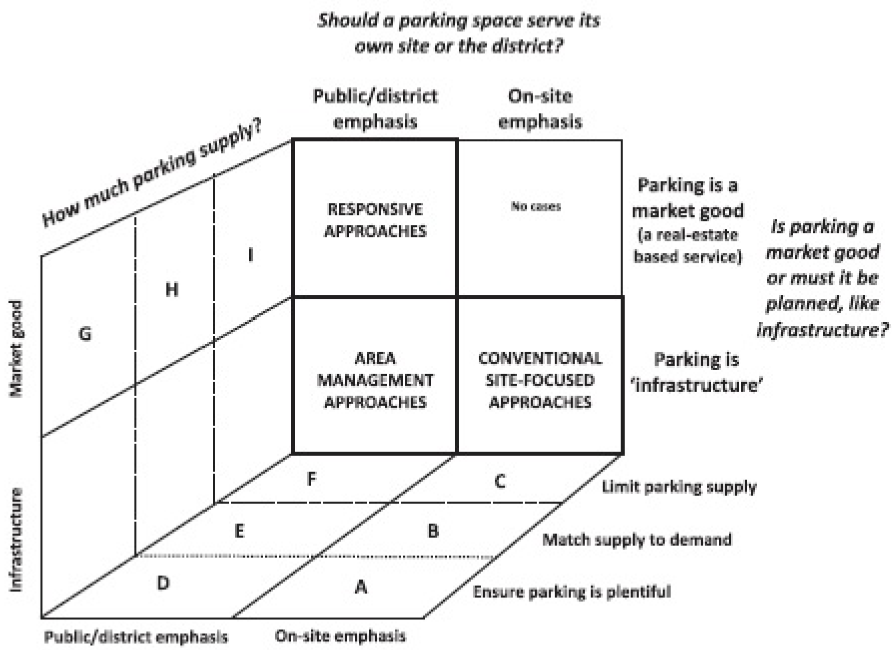


Figure 4: Barter's typology of car parking - how to conceptualise car parking. (Barter, 2014)

Barter (2014) believes that these parking typologies are underpinned by normative beliefs about how parking should be realised but only emerge as such in the context of policy conflicts. There is a particular division between market-led and infrastructure camps. Those who view parking as infrastructure would argue that a government-led supply of parking is necessary to reduce spillovers and cruising, and for the purposes of equity (most of Western Europe adopts this approach, including Rotterdam). Those in the market-led camp tend to argue that there is an oversupply of parking infrastructure that is tantamount to a market failure, and that the maintenance and construction of such infrastructure is an unacceptable cost to the government.

Barter concludes by comparing other authors' views including those of Shoup (2005) and Litman (2006), and asks the question 'What is the right amount of parking?' He posits a variety of shifts in parking policy over the years, including a shift from site-focused approaches to area-management approaches as seen in denser urban regions. Rarely, however, do municipal and other government authorities effect a transition of parking policy from infrastructure to market good. This, believes Barter (2014), results in an inevitable oversupply of car parking and a definite shift of mode share towards the automobile. Barter's framework will underpin the discussion section of this thesis.

Self-selection and land use

A concern raised by authors such as Guo (2013) and Weinberger (2012) is the confounding variable of residential self-selection. Self-selection, in this case, refers to the process of residents with pre-existing transport (mode share) preferences influencing correlational studies between land use and travel mode. In effect, it is the inability of researchers to separate the effect of land use on travel behaviour from that of preferences of the individual resident who travels a certain way based on personal factors (such as income) . There is much literature and research energy spent on trying to separate the two, however the question remains problematic.

In spite of this, the work of Chatman (2014) is instructive. He argues against the importance of self-selection for three reasons:

1. The so-called 'treatment effect' of land use can vary as sampling groups are heterogeneous. Chatman (2014) believes that "responsiveness [to the built environment] varies according to preferences, the built environment, and the combination of the two" (p. 55), which makes the process of trying to isolating the built-environment effect as problematic.
2. Residential self-selection is "the name of the game" (Chatman, 2014, p. 47); built environment-travel relationships necessarily involve some sorting by definition as each location contains certain proportions of certain types of households. The focus should thus be on the effect of an altered built-environment on the group that will experience that change. In other words, people's preferences and attitudes may change once they move to a neighbourhood with a different set of

built-environment characteristics or once their neighbourhood experiences a change itself (such as a train station opening).

3. There is not proper examination of how population compositions can differentially influence elasticity of demand (for a railway station, as an example). This demographic variability can have considerable potential to influence travel behaviour. As with (2), one cannot formulate a correct assumption about travel behaviour without considering groups within the population sample.

The image below illustrates the interaction effect as indicated by Chatman's first point.

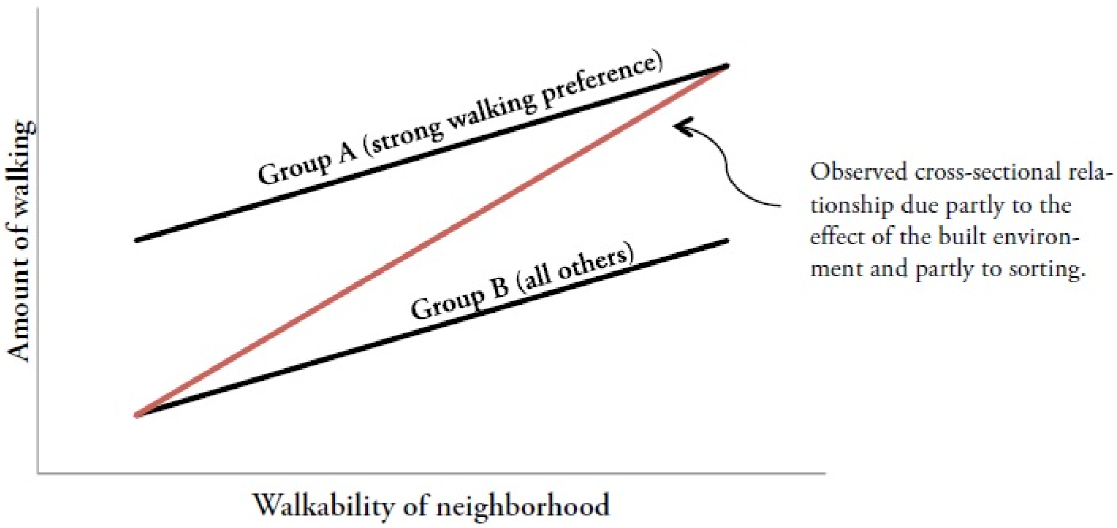


Figure 5: In this diagram, Group A and Group B respond to the environment at the same rate but at different initial (low walkability) and end (high walkability) levels. The red line shows the total outcomes of an increase in walkability (Chatman, 2014)

Scheiner (2014) believes that a longitudinal study, tracing residents 'life courses' might be the best way to settle the finer aspects of the questions of preferences. For Naess (2014), the picture is clearer: transport based self-selection is already evidence of the effect of residential location on travel behaviour. If it were otherwise, he believes, we would expect those with a preference for walking to also settle into neighbourhoods with poor walkability. Naess believes that the focus should be on how, why and when residential location influences travel differently, and that rationales of travel behaviour must be investigated to find out if residential location affects it.

From this ongoing discussion, it is clear that a more comprehensive analysis of residents' preferences (before and after a house-move or a new transport-related development), their demand elasticity (in relation to a particular transport mode) and the demographic composition of resident populations is necessary to establish (with certainty) causal links between the different variables.

The case of Rotterdam

Land use and urban structure

There has already been some work done on analysing the land use of Rotterdam and its impact on mobility. One metric that has already been employed in Rotterdam is the Spacematrix model designed by T.U Delft professor Berghauser Pont (mentioned in the previous section). It measures the amount of commercial destinations reachable within set distances from each residential dwelling. It is further applied to other nearby facilities such as schools or doctors' clinics. With the Spacematrix model, Pont is measuring the potential trip events of each resident to those facilities within the aforementioned 'reasonable distances', and thus the diversity of the neighbourhood (Mashhoodi & Berghauser Pont, 2011). The spacematrix shows a clear radial pattern for accessibility to non-residential land uses (as shown below). Those who live closer to the centre have greater accessibility to the wide range of non-residential land uses. This declines with increasing distance from the centre.

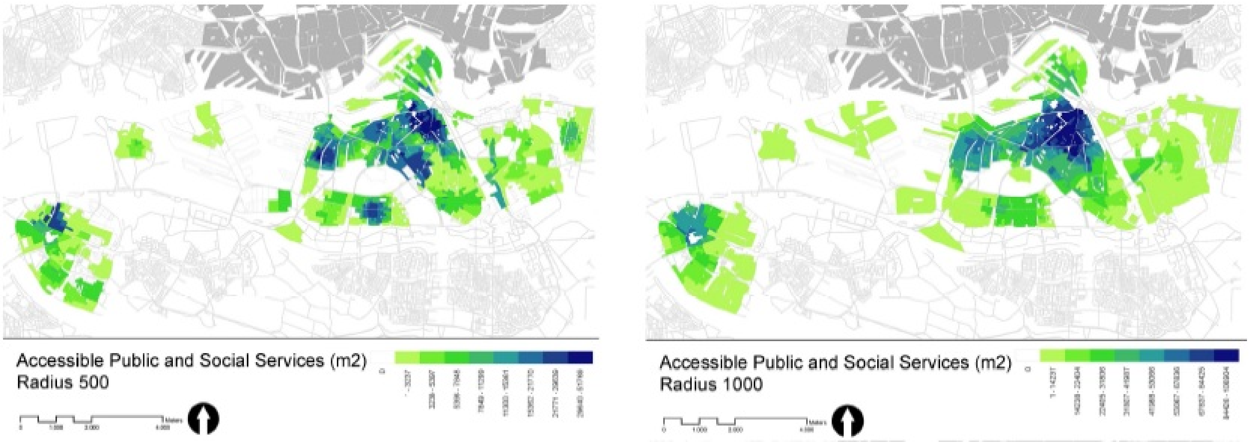


Figure 6: Accessibility as depicted in the spacematrix. The more 'blue' the area is, the greater access there is for residents to social services (Mashoodi & Berghauser Pont, 2011).

In terms of accessibility, De Vos (2015) has compared the node clustering seen in the Netherlands and the comparatively ad-hoc urban structure in Flanders, Belgium. His conclusion was that Dutch cities, particularly in the Randstad region, are seen to be more accessible for public transport users compared with those in Belgium. This is confirmed by the work of Schwanen et al. (2004) who note historical trends of node-based urban clustering in the Netherlands and the protection of rural areas such as the Green Heart (*groene hart*) of the Randstad. From this it is clear that specific patterns (clustering) and composition (diversity and density) might indeed have an influence on travel patterns.

In terms of SNAMUTS, this thesis considers Closeness Centrality, Degree Centrality and Contour Catchments in particular to be important, as these are what most commuters intuitively consider before making their journey, as well as being of the most manageable adjustments that government bodies can make to improve the quality of public transport. It is clear that in Rotterdam, those residents who live near a Metro station do far better than those who do not, despite the prevalence of bus routes in most areas of Rotterdam (as shown in figure 7). This disparity is quite large.

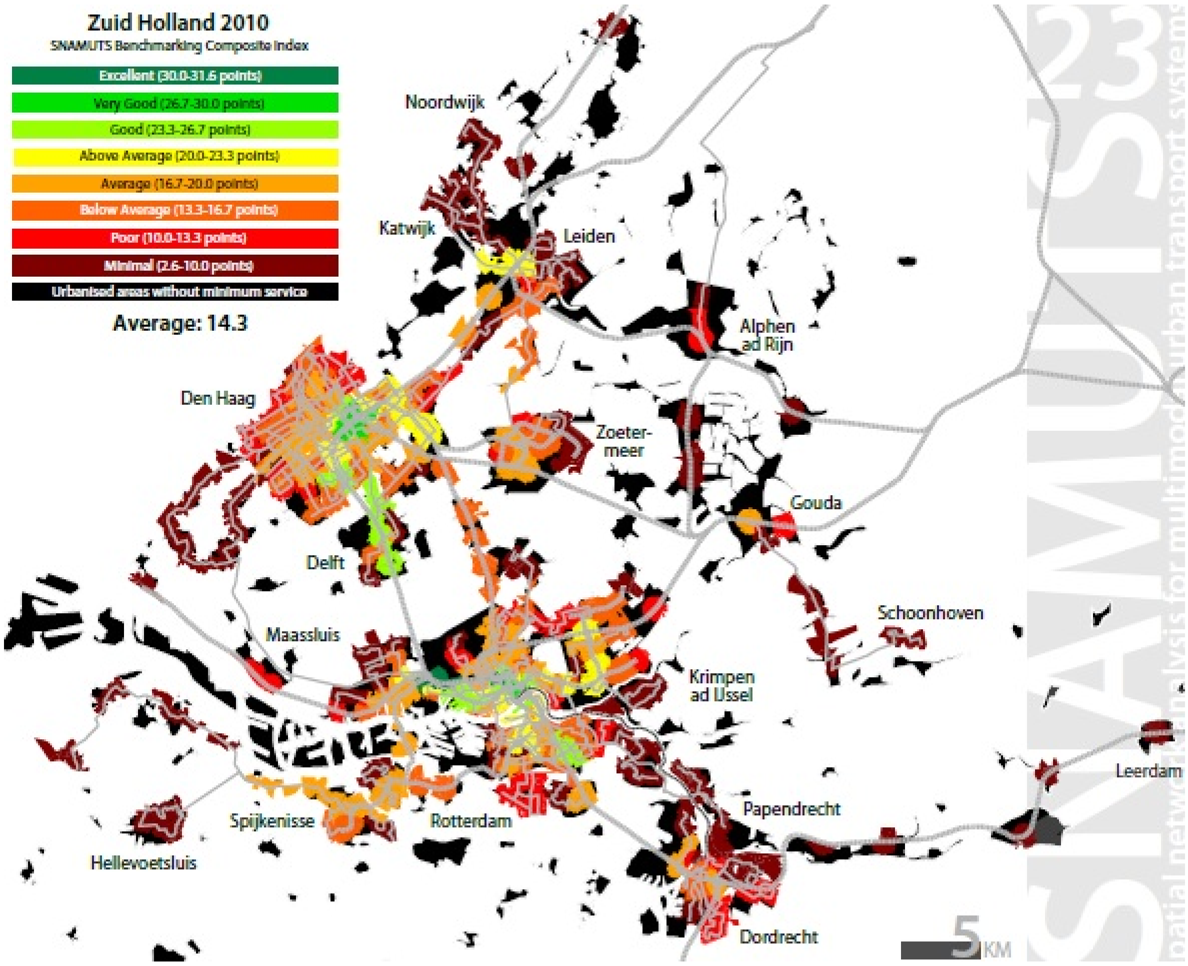


Figure 7: This map shows the 'quality' benchmark for public transport in South Holland. As is seen, the 'quality' of the public transport service declines with distance from Stadscentrum (SNAMUTS, 2014).

Rotterdam and mode share

In Rotterdam in 2012, mode share favoured cars compared with other Randstad cities - sitting at 27% compared with that in Amsterdam, Den Haag and Utrecht at 17%, 25% and 22%, respectively (de Graaf, 2014). As a whole, the rate of car ownership has increased in the Netherlands – a trend which looks to be declining slightly in recent years (see figure 10).

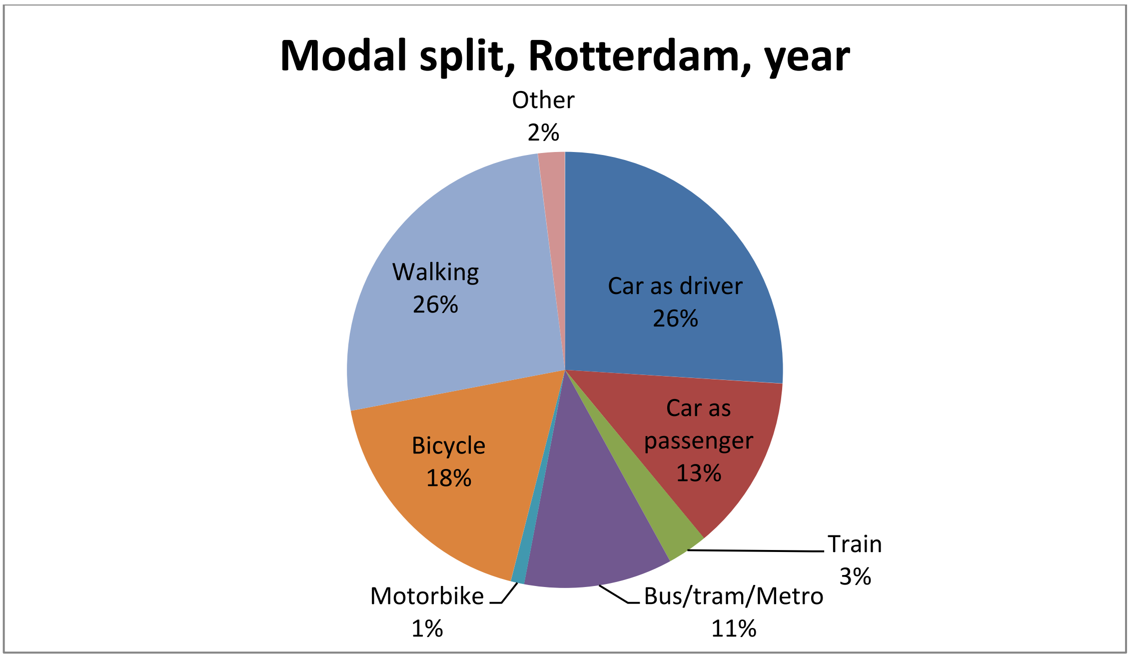


Figure 8: Mode share breakdown of metropolitan Rotterdam, 2012 (de Graaf, 2014).

However, Rotterdam, when compared with the national average has fewer cars per household with 0.73 vehicles per household in 2012 (down from 0.75 in 2010), against the national average at 1.08 (an increase from 1.07 in 2010; de Graaf, 2014). Interestingly, Rotterdam experienced a slight decline in car use from the years 2004-2009 when private automobile mode share sat at 26%, to 2010-2012 where it was 25%. From the data, it is clear that while long-distance travel (15 km or more) increased, there was a larger decrease in short-distance travel. The distances have increased but the proportion of residents who travel at such distances in private vehicles actually declined from 11.6% to 11.1% over the same time frame (de Graaf, 2014). Train travel (Nationale Spoorwegen – National train services) declined too, from an average of 3 kilometres per person per day to 2.4, while it is also apparent that the average distances of the train journeys also declined.

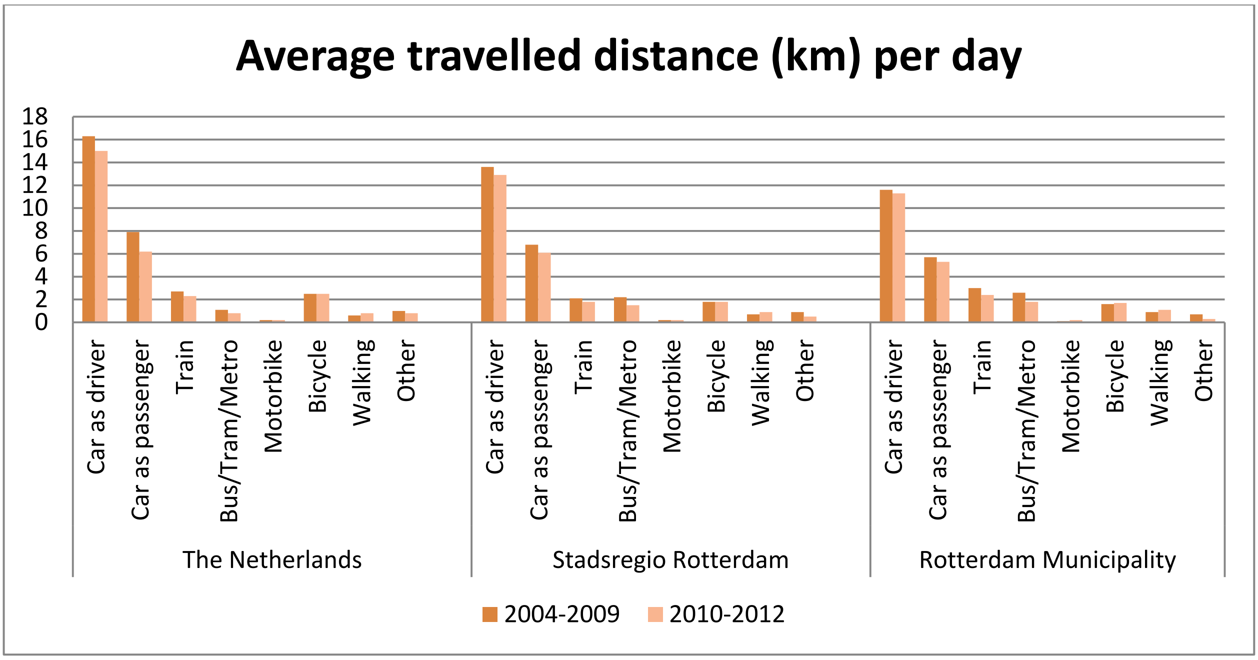


Figure 9: As might be expected for a large city, VKT for cars is lower than the national average and declines when the parameters are shifted to the main urban area (de Graaf, 2012).

Across the Netherlands, there has been an increase in the rate of growth of households with one or two cars, having been growing steadily since the 1980s (KIM, 2012), as shown by figure 10. So, too, in Rotterdam, there has been an increase in car use (de Graaf, 2014) and this has inevitably brought further pressures on car parking. In Rotterdam, the amount of people with a car has increased in the last two decades too, as shown by figure 11.

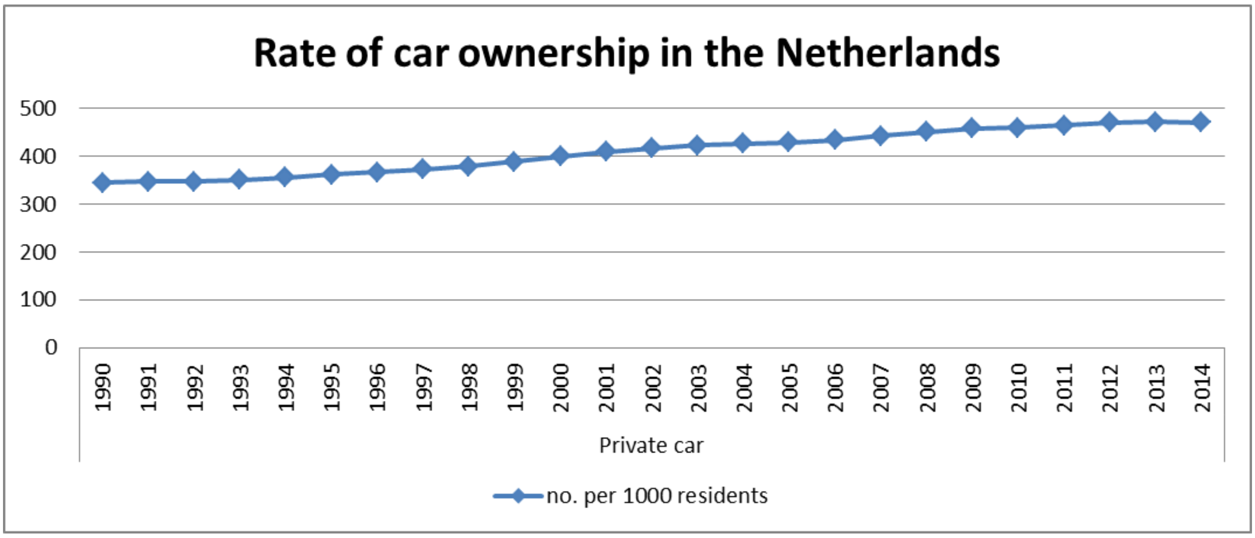


Figure 10: There has been a sizeable per capita increase in car ownership in the netherlands (CBS, 2014).

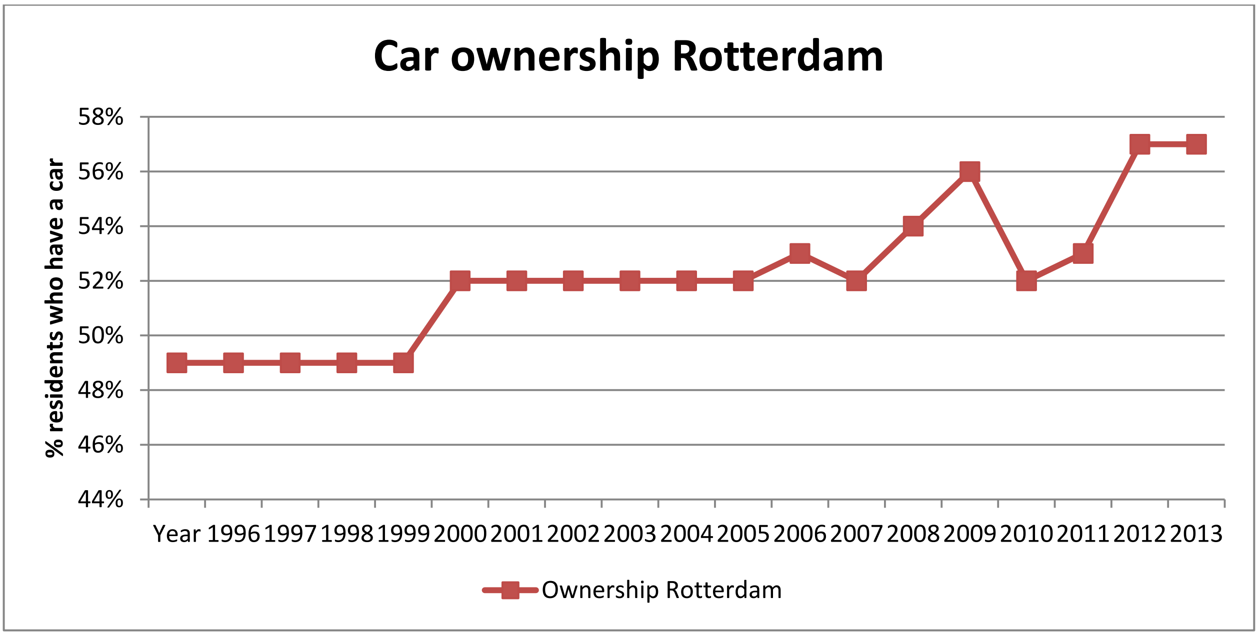


Figure 11: Again, a similar trend for Rotterdam (de Graaf, 2014).

For a Dutch city, Rotterdam has low bicycle mode share. In Rotterdam, 70% of residents own a bicycle compared with the national average of 86% (de Graaf, 2014). This parallels the amount of bicycle trips per person per day, sitting at 0.48 in Rotterdam in 2012 compared with the national average of 0.74 over the same year. Rietveld and Daniel (2004) believe that the low cycling rate in Rotterdam (when compared with other Dutch cities) is attributable to the long delays in travel time and the urban layout of the city. Much of these delays are likely a result of traffic light cycles favouring cars, including the much-vaunted 'Green Wave' - a traffic light priority system to maintain vehicular traffic flow.

There are some historical reasons why mode share in Rotterdam is the way it is today. In the past, the Dutch government had a centralised comprehensive planning approach with a delineated hierarchy of government, but this changed by the 1990s (Dijst & Vazquez, 2007). The deconcentration involved categorisation of relocations based on accessibility: *A locations* (those adjoining railway stations, in keeping with the aims of TODs), *B locations* (development sites outside the city centres, but with good public transport and easily accessible by car) and *C locations* (locations with excellent motorway access). The categorisation was not successful and resulted in most firms opting to locate at C locations where parking was plentiful and inexpensive, while local authorities encouraged them. These authorities were keen to see growth in their jurisdictions despite many such developments at these C locations being mono-functional as per the definition of urban sprawl (Bogaerts et al., 2007). This had come to be seen by some as an abandoning of the compact city principles the Netherlands had long established (Dijst & Vazquez, 2007) and the encroachment of a free-market focus (neoliberalism) – a process that has continues strongly to this day (Gerrits et al., 2012).

Already some policy responses have been tried within the municipality (Gemeente Rotterdam). These mainly consist of methods to reduce the environmental impacts of driving, rather than arresting the proliferation of congestion and car use in the first place. An example of this is the municipality's Green Wave programme (also adopted in other cities in the Netherlands and Europe) as mentioned earlier. Mingardo (2013) observes the introduction of P+R (Park and Ride), originally intended to stop outer-city traffic from penetrating into the city by allowing drivers to park safely and switch to public transport. This, however, has not been successful and with the 2015 introduction of a parking fee (Tarievenoverzicht, 2015), its original intention is likely to be rendered less effective.

The Dutch Knowledge Institute for Mobility Policy report on Sustainable Traffic concluded that most policy makers in the Netherlands view mode share shifts as theoretically possible but realistically impossible to dissuade commuters from their cars (Kennisinstituut, 2011). While not abandoning improvements in public transport, the report recommended that in order to satisfy the need to reduce GHG emissions, focus should be placed on reducing traveling kilometres and promoting use of energy efficient vehicles. Again, the focus turns on technical solutions rather than spatial or behavioural solutions.

Rotterdam resident views

Some interesting trends and view about transport and traffic can be found in the report Rotterdam talks traffic' (*Rotterdammers over het verkeer*; 2014). Of note was the slight increase in people with a driver's license and access to a car. Here, 66% of people have car access while the same proportion of sampled interviewees use a car (as either driver or passenger) to get to work.

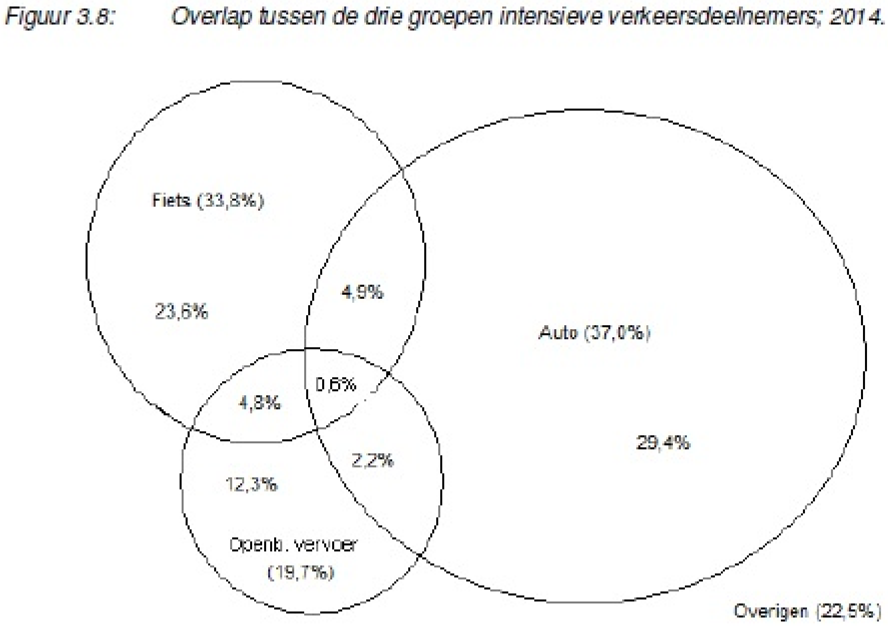


Figure 12: As one might expect, overlap exists between mode share users. (de Graaf, 2012).

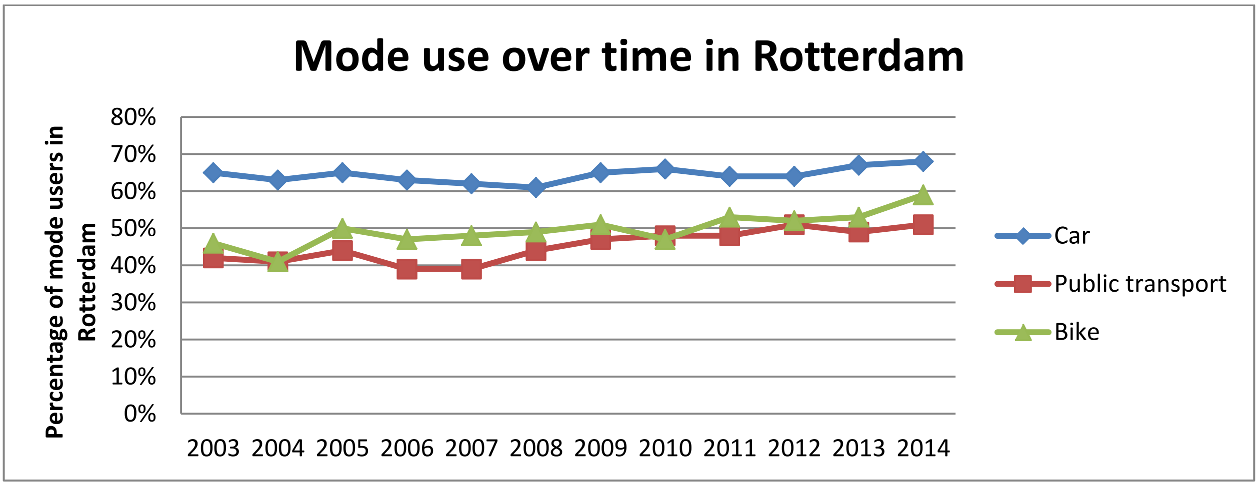


Figure 13: As can be seen, the growth in bicycle and public transport use is slightly steeper than car use. It is observable too that the growth in these sustainable modes does not come at a cost to car use. (de Graaf, 2012).

The report notes that increases in bicycle and public transport use do not come at the cost of car use. Car use itself, as shown in figure 13, is seen to be growing albeit at a slower rate than that of public transport. For peak hour travel, it is also evident that certain groups tend to use certain modes. Those in salaried work are more likely to drive (46%) than those on welfare (24%); meanwhile, while no students drove, 75% of them have access to a car. The financial costs and psychological burdens (e.g. sitting in traffic) of driving seem more associated with commuters who have salaried employment. This is confirmed by a survey on willingness to reduce car use, with 35% of regular automobile users declaring that they have no intention to reduce their general car use, 18% declaring they would do so but not at the present moment (when the survey was taken, 2014), 5% stating they would but not knowing when or how, and 2% declaring they intended to reduce their vehicle use. By contrast, 25% responded that they only try to avoid driving during the peak hour.

Responses in 'Rotterdammers over het verkeer' concerning the status of mobility and accessibility in Rotterdam indicated that people were far less satisfied with automobile traffic flow and movement than public transport flow and movement. Indeed, 42% of respondents gave a negative assessment of traffic flow while 9% gave it an extremely negative assessment, in contrast to 8% and 2% of negative and extremely negative assessments about the tram network (figure 14). Similar results were found for bus services and for cycling infrastructure. Only in perceptions of safety did Metro and NS Train stations elicit a 36% negative response compared with a 64% positive response. Of particular interest were responses to parking pressure, with 23% of people giving an extremely negative assessment and 39% giving it a generally negative assessment. This is in marked contrast to assessments on car parking around homes, with only 10% and 16% of respondents giving an extremely negative and generally negative score. Commuters are clearly happier with parking at home than parking in the inner city, though this should come as no surprise given the assessments for traffic flow and the fact that the inner city is much more crowded and less friendly to automobiles.

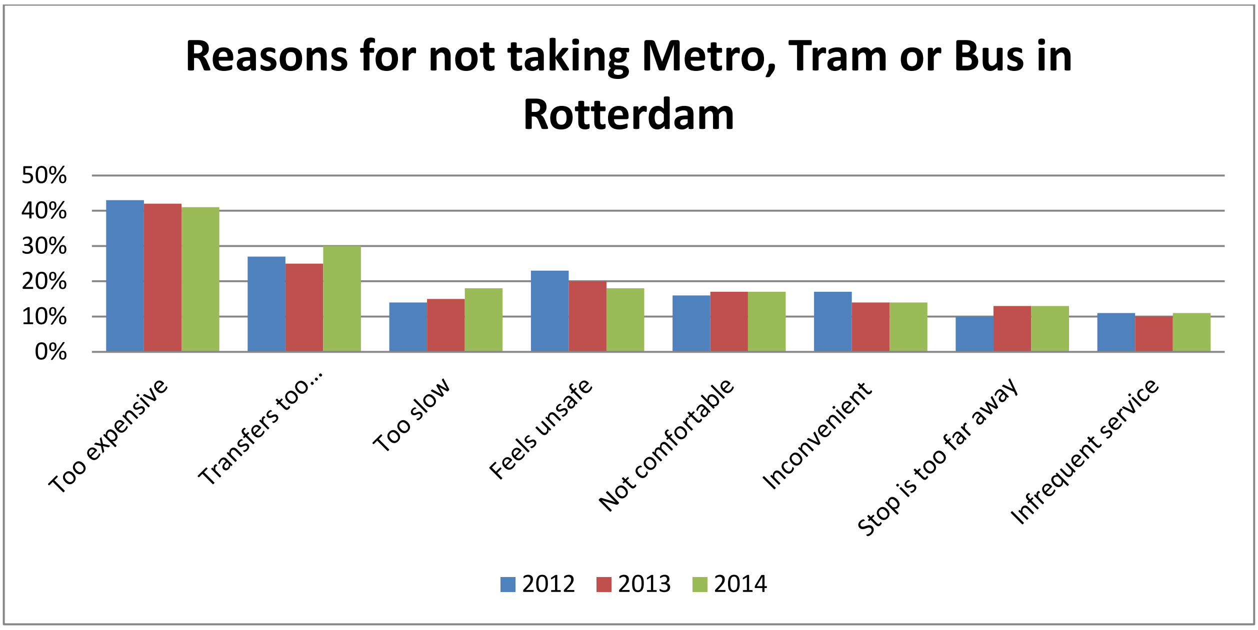


Figure 14: Cost and time cost stand out as being key deterrents to greater public transport uptake (de Graaf, 2014).

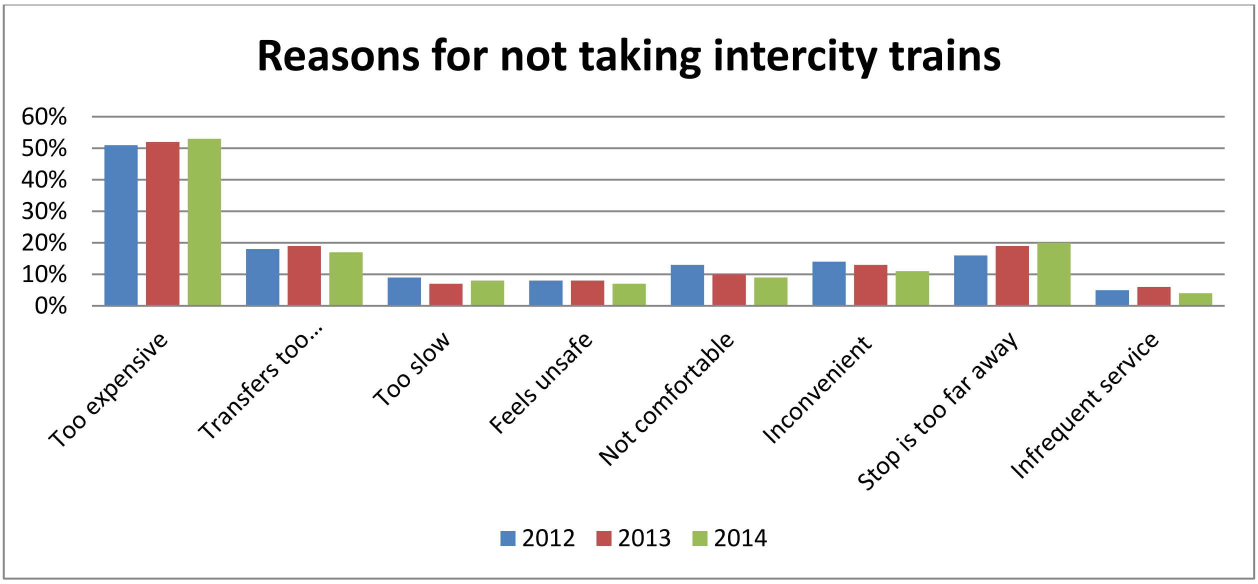


Figure 15: By far the most pronounced and consistent reason for avoiding intercity trains is the costs. (de Graaf, 2014).

When it came to self-awareness about how best to reduce one's transport GHG emissions, 77% of respondents agreed more cycling was the best approach followed by 66% of residents declaring more use of public transport was key. Interestingly, 60% thought that a more efficient car was a good measure to take with slightly less (58%) believing less car use was the best approach, despite the fact that it largely is (Cuenot et al., 2012), as it negates emissions output in the first place.

From these survey results, it is clear that costs and transfer times (known as Degree Centrality in the SNAMUTS analysis) stand out as large limiting factors to greater uptake in public transport use as a whole (figures 14 & 15). In any case, it is clear that car journeys make up the vast majority of total trips in Rotterdam, especially for longer distances. It is also observable that in the Netherlands as a whole, more people own cars. In general, there is a small shift towards cycling but public transport mode dominance remains static, similar to car use (despite there being more cars owned). If the municipality and other governing bodies are to effect a mode shift, these trends would suggest the current approach may not be effective.

In 2012, some 44% of Rotterdam residents experienced no issues with parked cars obstructing their way (de Graaf, 2014). Whether a resident had driver's license or not was not a factor in whether they found this obstruction to be more frustrating. What is interesting, however, is the locations of where people park. As can be seen from graph 16, more residents are parking on their own property; for those who park on the street, there is an increase in those who park further away from their homes.

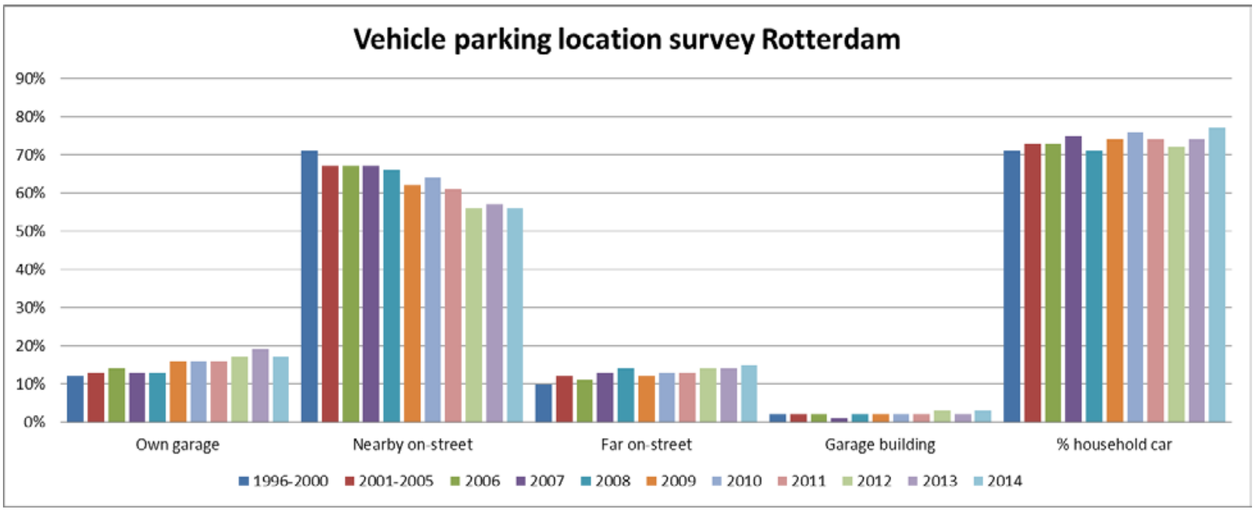


Figure 16: The data here suggests parking pressure has increased. People are parking further away and more residents have (or use) their own garage. (OBI Rotterdam, 2012).

Clearly there is a per-capita increase in car ownership or at a per household one, but this data also suggest that congestion on the street has increased as more people park further away from their house on the street due to crowding (the spillover effect). The data also implies more houses have off-street parking and that residents have their own private parking spaces.

In Rotterdam, the availability of car parking and car parking policy mainly fall under the responsibility of the municipality (Gemeente Rotterdam) who set prices and manage the public neighbourhood car parking garages (*wijkgarages*) which are designated for residents exclusively. Most of these have waiting lists but for those which do not, special circumstances may allow visitors to park cars there. The municipality also operates public garages which are dotted throughout the city but are mainly concentrated in the 'Stadscentrum' Neighbourhood.

Methods section

The methods section will explain how the main research question, and the three secondary research questions, will be answered. To recap, the main research question is:

What strategies could generate further mode shifts to public transport with respect to parking strategy?

With two secondary research questions:

1. **What are the policies governing the availability and pricing of car parking and providing incentives for travellers to use alternative travel modes?**

2. **How is car parking distributed at different distances from Metro Stations and Rotterdam's urban centre?**

Implicit within each of these research questions is a series of sub-research questions and specific data requirements, the methods of which are indicated below. This required a quantitative approach – a cross sectional analysis – that sought to describe and analyse car parking in Rotterdam and how it is managed.

This thesis examines different categories of car parking, including residents' parking garages, and public municipal and privately-run off-street parking (short-term parking garages such as those run by QPark). The categories of different types of car parking are conceptualised in the table below. (See the glossary section for definitions of key terms.)

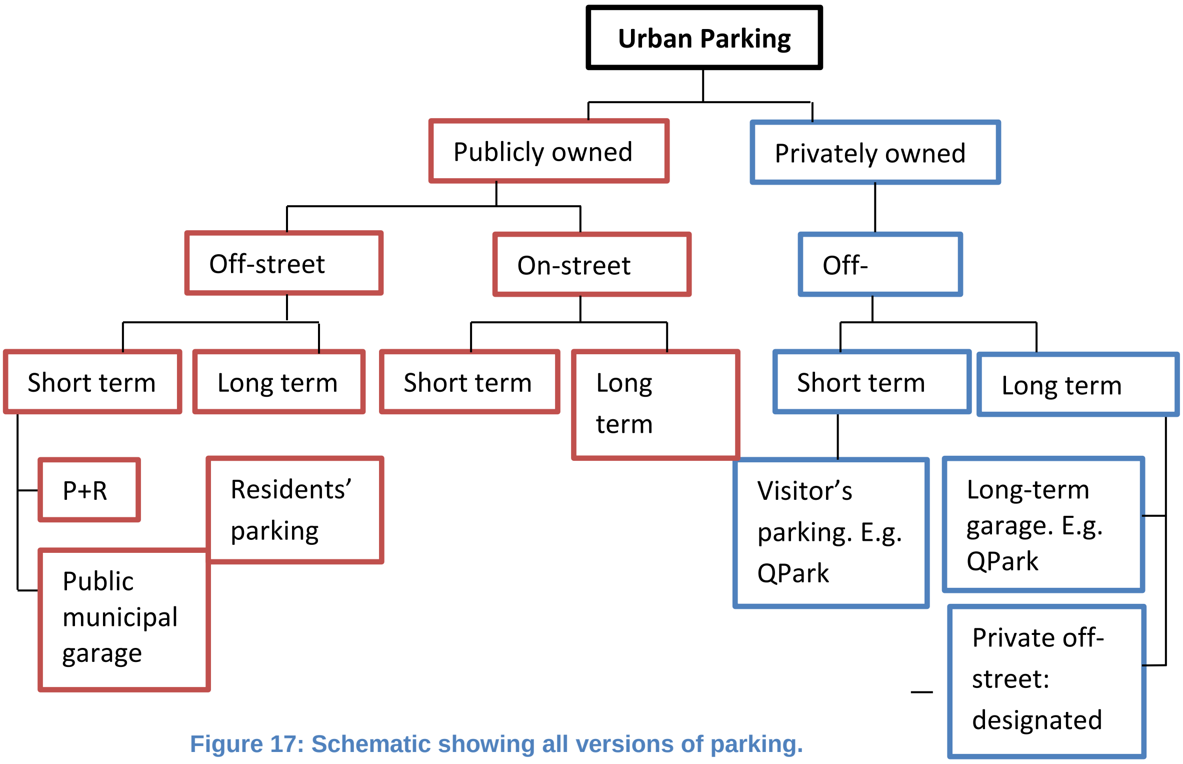


Figure 17: Schematic showing all versions of parking.

Given the enormity of the city and time constraints, six sampling zones were selected to try and capture different parts of the city. The six sampling zones were differentiated on the basis of two primary variables: proximity (within 500 metres) to a Metro station and distance from Stadscentrum (the centre of the city).

The table below summarises the six catchment zones. The first three in the list refer to catchments within a 500 metre radius of three Metro stations (at respectively increasing distance from Stadscentrum). The latter three are catchments of the same approximate distance from Stadscentrum but without a Metro station. The municipality divides the city into specific parking zones for residential areas (denoted R) and non-residential areas (denoted NR) with different codes for both (residential areas use numbering 1-4 for the different sectors, while commercial areas use letters A-C). For maps of the zones, see the annex.

Catchment + Distance (km)	Neighbourhood(s)	Public transport	Description	Parking sector R	Parking sector NR
Beurs Metro Station 0	Cool Stadsdriehoek	**5 metro lines** 2 tram lines	High density, mixed use and with high pedestrian traffic.	**1**	**A**
Voorschoterlaan Metro Station 2.37	Kralingen Oost Kralingen West	**3 Metro lines** 2 tram lines	Medium density, predominantly residential inner city	**2**	**B**
Alexander Metro Station 6.15	Ommoord Het Lage Land Oosterflank	**2 Metro lines** Intercity/Sprinter services Multiple bus lines	Large interchange with high density commercial zones and low density residential zones. High pedestrian traffic	**4**	**B**
Agniesebuurt 1.43	Agniesebuurt	1 tram line 1 bus line	Medium density, predominantly residential inner city	**1**	**B**
Oud Crooswijk 1.95	Oud Crooswijk	1 tram line 1 bus line	Medium density residential neighbourhood, low pedestrian traffic	**2**	**B**
Terbregge 4.72	Terbregge	1 bus line	Low density residential neighbourhood with low pedestrian traffic	**4**	**C**

Figure 18: The six catchment zones, their public transport and respective parking sectors.

The spacing of each catchment zone was not able to be precisely ascertained due to the irregular boundaries of some of the neighbourhoods. As highlighted previously, Rotterdam exhibits a radial pattern of development tempered only by the geography of its river systems and some industrial zones. Thus, as a general observation, the amounts of mixed-use land and high-to-medium population density declines, the further from Stadscentrum one travels (Marshoodia, 2011). It was on the basis of this pattern of development that the six catchments were chosen. Stadscentrum has the highest density, mixed-use land and public transport accessibility.

High quality public transport, as mentioned in the literature review, was based on a component of the SNAMUTS analysis (SNAMUTS, 2010) with a focus on the pre-trip considerations of frequency, speed and the amount of changeovers necessary (Walker, 2012). From this it was evident that the Metro system would be the key sampling component for ‘proximity to a high quality public transport mode’. Metro services run at a general frequency of every 10 minutes, with greater frequency in peak-hour and slightly lower frequency on the weekend (every 15 minutes on most lines; RET, 2015). Trams also run at a high frequency but are comparatively slow and require greater transfer times than do Metros (van Bemmel-Misrachi, 2014). Buses are both slow and infrequent, and despite their presence, many parts of Rotterdam still score poorly in the SNAMUTS analysis.

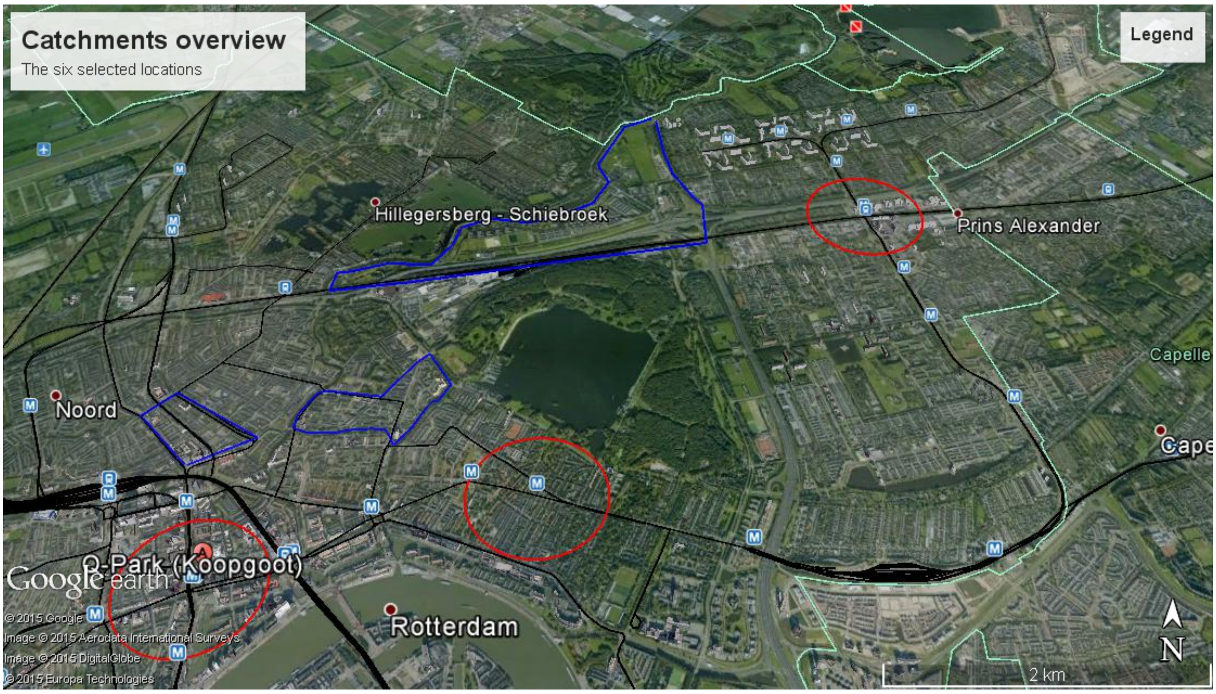


Figure 19: Blue outlines mark non-Metro catchments while red circles show 500m radii containing the Metro catchments (Google Earth Pro, 2015).

The scope of the research is not, however, restricted to locations within the six catchments. In looking at publicly-accessible car-parking garages, for instance, the entire neighbourhood of Stadscentrum (containing the Beurs catchment) and area within the Alexander catchment were examined as these are some of the few locations where publicly-accessible off-street parking exists.

RQ1: What are the policies governing the availability and pricing of car parking and providing incentives for travellers to use alternative travel modes?

This question asks for an analysis of the municipal and provincial transport strategies, and how they view car parking. Key to this is how the municipality manages demand for car parking spaces. This research question looked at:

- The municipality's policy on transport and mobility – this also includes the 'city region' (Stadsregio) which is comprised of a number of adjoining municipalities in the vicinity of the Rijn river.
- The province's (Zuid Holland) policy on transport and mobility – the province does have an influence on municipal priorities.
- The approach of all levels of government on carbon emissions from transport – determining whether or not the demand-led approach is considered in the policy documents.
- Private off-street parking regulations – minimum parking requirements for building developers
- Public off-street parking fees and capacity – parking garages for short term visitors, both publicly run and privately run. This will also look at how certain durations of parking are encouraged or not.

- Parking permits and parking fees (for on-street parking) – these were given special focus as these are shown to be of significance in influencing willingness to drive

This research question was mainly quantitative with some qualitative analysis of the policy documents the municipality maintains on transport and land use in the city. The municipal and provincial policy rationale and assumptions were examined here. In this question, no primary data was collected except the count of spaces in one parking garage in Alexander. It emerged, in this case, that there was a privately-run public off-street parking garage visible on Google Street View and on the municipality car parking guide, but for which no website could be found.

Data used

Secondary data sources included:

- The municipality's latest transport policy: Traffic and Transport Vision and Policy, 2003-2017 (2003).
- The province's mobility document: Spatial Program (Programma Ruimte)
- Research documents on emissions output of vehicles (e.g. 'Mobility Balance 2012' from the national government).
- Minimum parking standards guide (Parkerennormen 2010).
- Parking pressure data (per block; sourced from the Traffic and Transport department across a wide date range).
- Private (publicly accessible) parking garage fees (e.g. data sourced from QPark).
- Municipality information on car parking (fees, public municipal off-street parking garages and residents parking garages).
- The BAG index (*Basis Administratie Gebouwen* – Building Administration clearinghouse) on floor surface area per building.
- Private parking garage fees (e.g. data sourced from QPark, Alpcoa)

This data was initially divided between qualitative analysis (discussion about government documents) and quantitative analysis (an examination of fees, parking pressure, parking minimums etc.)

Sampling procedure and analysis

As the majority of this research question necessitated collection of secondary data, desk research was undertaken. The six catchment zones were described in terms of on-street parking tariffs, parking permit fees, minimum parking requirements (for private off-street parking), and parking pressure. However, for questions about public off-street parking, a wider scope was adopted to take into account spatial concentration; this meant not only looking at the six catchment areas but specifically in the neighbourhoods of Stadscentrum and Alexander, where such facilities actually exist.

A correlation analysis using the statistics program SPSS was done to measure the change in one variable against the other (for instance, distance from the city centre and parking garage hourly fee). For this, a *Spearman's Rank Correlation* was chosen as this used the data as a ranking (rather than for the specific value of the data point), works monotonic variable relationships (the variables change together but not necessarily at the same rate) and provided greater validity for smaller data clusters as was present with this data.

The Spearman's Rank Correlation only worked with a sample of public off-street parking garages in Stadscentrum, not those of Alexander. The data from Alexander was non-monotonic and thus unable to undertake a correlation analysis. By contrast, that of Alexander was able to go a step further and be used in a *Linear Regression Analysis* – fitting the assumptions of normally distributed residuals (variation unable to be explained by the model), no significant outliers (data points which are far removed from the pattern of the rest) and homoscedasticity (the variances along the line of best fit is consistent). A regression equation was ascertained. This led to conclusions as to how the municipality might be pricing its public off-street parking, compared with that of the market price, and thus how the municipality frames its parking policy for short-term public parking.

Research Question 2: How is car parking proportioned at different distances from Metro stations and Rotterdam's urban centre?

This question calls for data on the quantities of car parking in Rotterdam and that these quantities be logically categorised. This data is intended to furnish the reader with an image of how parking in Rotterdam is distributed, and what types of parking exist after having already explored the strategies, policies and pricing approach of the municipality. This research question acts to inform the reader of how the third research question (recommendations, following a discussion) relates to the first one (on policy).

Embedded within this research question were four main criteria for categorisation:

- The distribution and density of car parking facilities in relation to distance from the city (Stadscentrum) –the effect of distance on car parking distribution.
- Distance from a high-quality public transport mode (Rotterdam's Metro stations, in this case) – Whether proximity influences arrangement of car-parking facilities.
- The distribution of mode share and population density across the city with respect to car parking composition – how population density relates to car parking density.

- Parking pressure – the quantity of on-street parking spaces occupied out of the total available spaces per street. This sub-question looks at the distribution of car parking pressure.

Parking pressure as an element of parking composition was also considered. This effectively shows the demand for parking in a particular location. However, the distance factor and the proximity to a high quality transport mode were considered the most important aspects. These were indicated consistently in literature, and past empirical studies on travel behaviour, to be deciding factors of mode share. They are also relatively easy to measure, in terms of existing and primary data gathering. It was on this basis that the sampling procedure was established. Factors such as the design of urban spaces were taken into consideration, but since it would have been very hard to measure them, considering little consensus on a suitable metric for such measurement, they were not included in the analysis. Finally, there was no strong literature found on specific demographic influences on car ownership. This leaves out a potential explanatory variable to the pattern of car ownership visible in Rotterdam, and makes explanations of car ownership difficult or overly-general.

Data used

For this research question, data was comprised of both primary and secondary sources, and was quantitative in nature.

Primary data was gathered as (tallying) counts of on-street parking, private off-street parking, residential addresses and non-residential addresses. Parking garages were in a separate count – a distinction that the municipality itself applies. Primary data gathering was conducted as the municipality's existing data did not provide conclusive information on per-street-segments of on-street parking nor on private off-street parking. It too had some methodological problems (for example, some records were from 1996 and thus too old to still be valid). The decision to use density of car parking spaces as a metric is similar to what other authors have done, e.g., Manville et al. (2013), and is by far the clearest indicator.

The relevant primary data included:

- The on-street parking ratio (number of parking spaces per road segment divided by no. of addresses on road segment): the **OSPR**
- The off-street parking ratio (number of private off-street parking spaces per road segment divided by no. of addresses on road segment): the **OFSPR**

A typical calculation of OSPR involved an initial count of, say, a street with 35 on-street car parking spaces between intersections of that street (thus, per segment). This number was then divided by the counts of addresses *on the same road segment* with a distinction made between residential and non-residential addresses (say, 20 residential addresses and 7 non-residential addresses). These two address types were then added together and the 35 addresses were divided by it to reach the ratio. In this case, it would be calculated as 35/(20+7) = 1.3. The on-street parking ratio, in this instance, would be 1.3 with there being 30% more on-street parking spaces than residences. The exact same procedure is done for the OFSPR, but with the count of off-street parking spaces.

The Neighbourhood Profile database was based on three primary scales as well as the city-wide scale. These scales were (1) the block level (a few streets), (2) the suburb level (*buurten*) and (3) the district level (*wijken*). There was also data sourced from the Central Bureau of Statistics (CBS); specifically, data on the quantity of owned vehicles per postcode was of use. Other data from the CBS was aggregate and at too big a scale from which to derive any useful conclusions (only at the city-wide scale).

The relevant secondary data included:

- Parking pressure data (per block; sourced from the Traffic and Transport department across a wide date range).
- Residences per hectare (Neighbourhood Profile)
- Modal split car use (Neighbourhood Profile)
- Open space parking places per resident (Neighbourhood Profile)
- The municipality's 'Municipal Basis Administration' (Gemeentelijke Basisadministratie) – calculating average household population size

The Neighbourhood Profile dataset was held in both Excel spreadsheet form and Shapefile Form (a dataset that the GIS program ArcMap uses) as was the Traffic and Transport department data. This was helpful for graphing and calculations, as well as visual representation.

Sampling procedure and analysis

The 500-metre radius is a conservative estimate of walking distance and it is likely that many more residents at further distances will gladly walk to the public transport node. The municipalities 'Gebiedsprofiel' (Neighbourhood Profiler) sets 800 metres as its definition of an appropriate distance from a Metro station. Work by Curtis and Scheurer (2010) highlighted this as a common estimate for walking distance (approximately 10 minutes walking time). Yet such a measurement is far from perfect, and for the purposes of this thesis did not work. On its own, the measurement of walking time is problematic as it fails to account for individual walking speeds, crossing speeds (at traffic lights, whose green light cycles may be contingent on traffic flow at a given time) and walking distances within buildings. Further to this, the distance from the street to the front door of an address would fail to be taken into account. It is for these reasons that a simpler and more conservative measure (allowing for the possibility of greater walking tolerance) was been applied: the radial 500-metre buffer. Most Metro stations did not have designated bicycle parking though 500 metres is a reasonable cycling distance regardless.

In order to measure the effect of distance, it was necessary to compare distance among all six of the catchment zones. This involved grouping the six zones into three zones of two: inner city zones (Beurs and Agniesebuurt), middle suburb zones (Voorschoterlaan and Oud Crooswijk) and outer suburb zones (Alexander and Terbregge). Next, the task was to measure whether proximity to a Metro station matters or not for parking composition. This involved a comparison between Beurs and Agniesebuurt; between Voorschoterlaan and Oud Crooswijk; and between Alexander and Terbregge. Within the set distance zones, the independent variable was the presence of a Metro station.

A *Mann-Whitney U test* was used here to assess whether the difference in distributions were significant. This statistical test was appropriate as it is intended for datasets where the variance is not homogenous (this means that not all variables that were tested had the same variance). It also uses ordinal data (data which is ranked, but for where specific values do not count themselves) which suits the purpose of articulating the distribution curve of the OSPR and OFSPR. For analysis over all six catchments (grouped in three groups of two; by distance grade from Stadscentrum), the *Kruskal Walis test* was used. This was helpful for the same reasons the Mann-Whitney U test was but with multiple groups for comparison (three in this case). It is also known as the “one-way ANOVA on ranks” (Laerd, 2013).

In tallying the quantities of addresses, driveways and the quantity of parking bays, counts were made where it was certain that one of the aforementioned existed. For instance, addresses were counted by the amount of doorbells or the amount of letter boxes on a building. For on-street parking, specific parking positions (see figure 4) were counted as were curb-side parking spaces where it was legal and not obstructive to park. Parking spaces which were not specifically designated but where it was technically legal to park *and* had cars parked there were also counted. Consequently, parking on the sidewalk itself, often prevalent in the Netherlands, was not counted, nor was parking outside designated parking spaces (see figure 22). It is technically illegal to park for any time longer than a few minutes (for the loading and unloading of goods, as an example). Including this in the analysis would not be helpful in forming an explicit parking policy as it is not relevant to the distribution of designated parking spaces. For off-street parking, a driveway and a garage at the back were assumed to hold (depending on the driveway length) two vehicles for the garage and driveway respectively (see figure 20).

Figure 20: Two types of private off-street parking are shown here; private driveway and private garage parking (Google Street View, 2014).

Figure 21: A count of 8 on-street parking spots (Google Street View, 2014).

Figure 22: An illegal parker (Google Street View, 2014).

These methods ensured that the findings derived from the primary data had integrity and that each zone had its own dataset. The assumptions in these methods are that the prevailing physical conditions have the greatest influence on mode share (this is the majority view in the literature) but smaller nuances in the data due to social factors may not be accounted for.

Limitations and Challenges

Primary data gathering

A limitation to the primary data-gathering approach was the ability to access data on the amount of internal car parking spots in large buildings or the contract of car space distribution per building as agreed by the municipality when the buildings were built. There were many such buildings like this, especially in the inner city where building size (as represented by the Floor Space Index – the building's total floor surface area) is large. This was resolved by estimating the amount of car parking from what was visible from outside (either in a site visit, using Google Maps or using Google Earth Pro - where 3D buildings are visible). This creates a problem with accuracy for parking data of the street on which these buildings are placed, but is largely unavoidable. If large buildings such as these were to be ignored, then data from the inner-city regions may likely be rendered unusable due to these buildings' concentration in the inner city. The private parking amenities of such buildings could not be so readily ignored.

To overcome this, visual inspection of car parks (where legally possible) was undertaken. This was successful for half of the large buildings, but not successful for large buildings where the car parking was located directly underneath the structure itself. Attempts to contact the administrators of such buildings, both in person and through email, were not successful—much of this information was 'commercial in confidence' and thus not for disclosure.

As a result, a different method was applied: information from the BAG (Basis Registration Addresses and Buildings database) concerning the total floor space (surface area) of each building was used and then matched against the current minimum parking requirements guide. This is a good estimate of the amount of parking spaces on offer as few developers tend to build more than what is required given the high costs this imposes. However, these minimum parking requirements are not legally binding, and in some cases they can be negated and have less than the minimum (or more than the maximum) depending on negotiations between the developer and the municipality. This was undertaken for large commercial buildings where visual inspection failed and where it could not be assumed that any given address within the building had a specific floor-share (many owners lease out a specific amount of floor space for companies at those company's requests).

For residential buildings, it was simpler. Again, exact floor spaces were hard to estimate but given that many of these apartments were large and upmarket, and given that between 85-100m2 of living space equates to one car space according to the minimum parking requirements, it was a reasonable assumption to count one car space per address. Most of the apartments scoped out in the Beurs catchment zone were upmarket and many appeared to have deep driveways implying access to a high-capacity car park below. This assumption also makes sense on economic grounds; if a developer were to build an underground carpark within an apartment complex, they would likely want to maximise their returns and make it spacious so as to justify their investment costs.

Time constraints

It would have been of value to include some in-depth interviews with the private owners of public off-street parking (such as the company QPark, which has multiple parking facilities dotted around Rotterdam), the municipality officers responsible for managing the municipality's facilities and those responsible for formulating transport policy. Unfortunately, due to time-constraints this was not possible. Only some email exchanges were possible and this did not yield substantive qualitative results.

Having face-to-face interviews would have given an insight into the reasoning and rationale behind policy decisions, strategic visions and the fee structure. It would have helped answer the 'why' questions on the secondary data obtained – revealing reasons behind inconsistencies that would otherwise not be identified (such as relationship between parking fees and urban density); it would look at political questions unanswered in official documents. The discussion and recommendation sections would then likely be more substantive.

Comparing different data sets

When trying to match data from the Neighbourhood Profile to the primary data (for example, comparing parking pressure to the ratio of on-street parking), the issue of scale emerged. As a result of some missing block and street level data from the municipality's datasets (all of the Neighbourhood Profile datasets and Traffic and Transport datasets were impacted), the only possible thing to do was to use the suburb scale (*buurten*) instead. These were not perfect comparisons, but were as consistent as possible with what available data existed. An attempt was made to ensure that, in the case of the 500 metre radius buffer, no more than three different suburbs (*buurten*) would be 'captured' within the radius. For the parking pressure data, street-level data would have been very helpful but only block-level data (consisting of a few streets and street blocks) was useable. This was overcome by applying the block-level data to the streets they covered; while not precise, it was as close an approximation as possible.

There was also limitation in terms of quality of some secondary data, especially from the Traffic & Transport department. Their records of parking pressure were often too old (dating as far back as 2006) and their methodology very limited. Parking pressure was defined by as a percentage of how much of the available street parking capacity was being used. This metric only examined those cars that had successfully parked, meaning that an occupancy rate of 90% (90% of available car parking spaces in use) would be considered 'high parking pressure'. This is limited as the rate of turnover is ignored (a high turnover rate would likely mean many on-street car parking spaces become available at any given point in time) (Arnott & Rowse, 2009) of parking pressure as they are directly caused by a serious constraint in parking supply.

The methodology employed by the Gemeente when measuring parking pressure was also problematic with respect to the way the data was obtained. Records of parking occupancy were separated into night time (6pm-6am) and daytime (6am-6pm). A person was hired to drive down every street in Rotterdam (similar to the Google Street View method) and record the occupancy rate and capacity during the two times during weekdays. This overly broad sampling approach fails to capture the true variation within 'night time' and within 'day time' periods. The literature (see, Millard-Ball et al., 2014 as an example) indicates that parking congestion varies per hour, mirroring peak hour traffic congestion. The best interpretation, therefore, must be about a general difference in night-time and daytime parking but nothing more. As an example, a high occupancy score at night-time would likely suggest that these vehicles belong to owners who live on the street without off-street parking.

Results

RQ1: What are the policies governing the availability and pricing of car parking and providing incentives for travellers to use alternative travel modes?

This research question examines regulations and policy interventions for car parking and transport infrastructure in Rotterdam, and their potential consequences to shape travel behaviour. The underpinning logic of the municipal and provincial policy is also given consideration.

Municipality policy

Parking policy in Rotterdam is flexible for both building ordinances with their minimum parking requirements and with the wider transport focus of the municipality. The municipality has, in effect, a transport 'vision' as its strategy for mobility but this is contingent on government finances and the wishes of the community. There are three main documents related to the mobility vision:

- The mobility vision itself: The Regional Traffic and Transport Plan 2003-2020 (*Regionale Verkeers en Vervoersplan: Beleidvisie*). This is the municipality's policy vision: a long term document on the direction of transport policy for the municipality.
- The supplementary notes and explanations of the aforementioned vision (*Toelichting op het RVVP*). This gives the reasoning and evidence for the direction in policy.
- The Regional Implementation Agenda 2011-2015 (*Regionale Uitvoeringsagenda Verkeer en Vervoer*) – part of the city region (*Stadsregio*) governing body plan which overlooks the municipality of Rotterdam as well as adjoining municipalities concentrated around the Rijn river.

The Regional Traffic and Transport Plan (2003) sets out an agenda to ensure that residents of Rotterdam can "travel within reasonable time to their chosen destination" (p. 4). The documents aims for better use of existing infrastructure, intensification (increasing population density) and better traffic flows. The document seeks to incentivise travel where it is most efficient by, for example, encouraging off-peak travel and discouraging superfluous trips whenever possible. In general there is an emphasis on making cycling and public transport more efficient than driving in terms of travel times, though the document is not clear on how this is to be achieved.

For car parking, the plan acknowledges the need to give the choice of driving to commuters (in the sense of ensuring commuters have a breadth of choice in modes) but that there is a limit to driving insofar that it impacts on the environment, 'liveability' and traffic congestion. To this, the municipality proposes that 'full and consistent information' be given to drivers as to the positives and negatives of driving, through both information and pricing. The municipality's intention is to discourage driving to the inner city areas of Rotterdam and would rather have those who intend to drive park at the Park and Ride (P+R) locations dotted around the city. The municipality realises that it has very little control over private off-street parking directly but also does not reference its own minimum parking requirements. It seeks to guide, not actually enforce things or provide structural interventions.

The Regional Implementation Agenda of 2011 is more up-to-date but has similar intentions to that of the Regional Traffic and Transport Plan of 2003. However, its explicit focus is to expand roads and not public transport, which is expected to be improved in terms of 'quality, not quantity' (there will be no expansion of the network, but rather improvements on the existing network). For motorists, a new approach to taxation has been proposed whereby car use is taxed heavily but ownership of a car isn't. P+R is also set to be expanded to encourage greater use of public transport. The Regional office sees a need to integrate the price of public transport with that of car parking, in tandem with P+R growth.

The general theme in these documents is that it's up to commuters to decide for themselves which mode they take and that they will only be reminded of the implications of their choice. Further, the municipality is keen to see greater utilisation of existing infrastructure.

Minimum parking requirements – municipality regulation

The minimum parking requirements for Rotterdam are designated according to different zones and for different land uses. The municipality distinguishes residential land use from 'non-residential' land use (as has this thesis), with an extensive list of the latter. Residential areas fall into one of four sectors (1, 2, 3 or 4) while non-residential zones fall under three sectors (A, B and C). The catchment zones of Beurs and Agniesebuurt fall into sector 1; Voorschoterlaan and Oud Crooswijk fall into sector 2, while sector 4 is host to both the Alexander and Terbregge catchments (see figure 23 below).

These sectors are depicted in a map in the appendix.

	Required parking space(s) per address			
Usable surface area (m2)	**Sector 1:**	**Sector 2:**	**Sector 3:**	**Sector 4:**
< 40	0.1	0.1	0.1	0.1
40 – 65	0.6	0.6	0.6	0.6
65 – 85	0.6	0.8	1	1.4
85 – 120	1	1	1.2	1.6
120 +	1.2	1.2	1.4	1.8

Figure 23: Minimum parking requirements for residential dwellings within the municipality of Rotterdam (Gemeente Rotterdam, 2010).

These are graphed in figure 24:

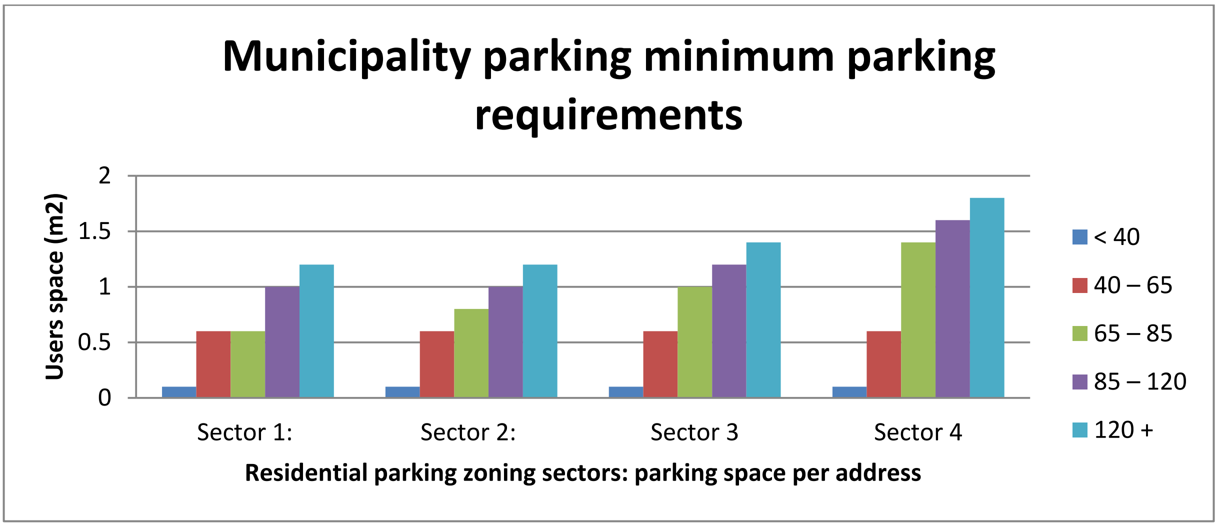


Figure 24: Graph of minimum parking requirements.

As can be seen, the dwellings with the larger surface area for living (*gebruikersruimte*) demands increasing amounts of private off-street car parking the further out from Stadscentrum one travels. Very small apartments with under 40 m2 of living space have the same required rates of car parking in every location in Rotterdam. See the appendix for an extensive list of non-residential land-use parking requirements.

It is worth noting that these regulations concerning car parking and apartment (surface area) size are not fixed and can be adjusted in negotiation between developer and municipality. They were established in 2010 and have changed with different approaches to planning.

Presently the focus appears to be moving more on-street car parking to private off-street parking (as shown in figure 25). A sample of one residential street (with approximately 40 parking spaces) from each catchment zone was examined and actual residential addresses' private off-street car parking spaces were tallied. This was contrasted with a calculation of the private off-street parking spaces as it would have been under the current minimum parking regulations.

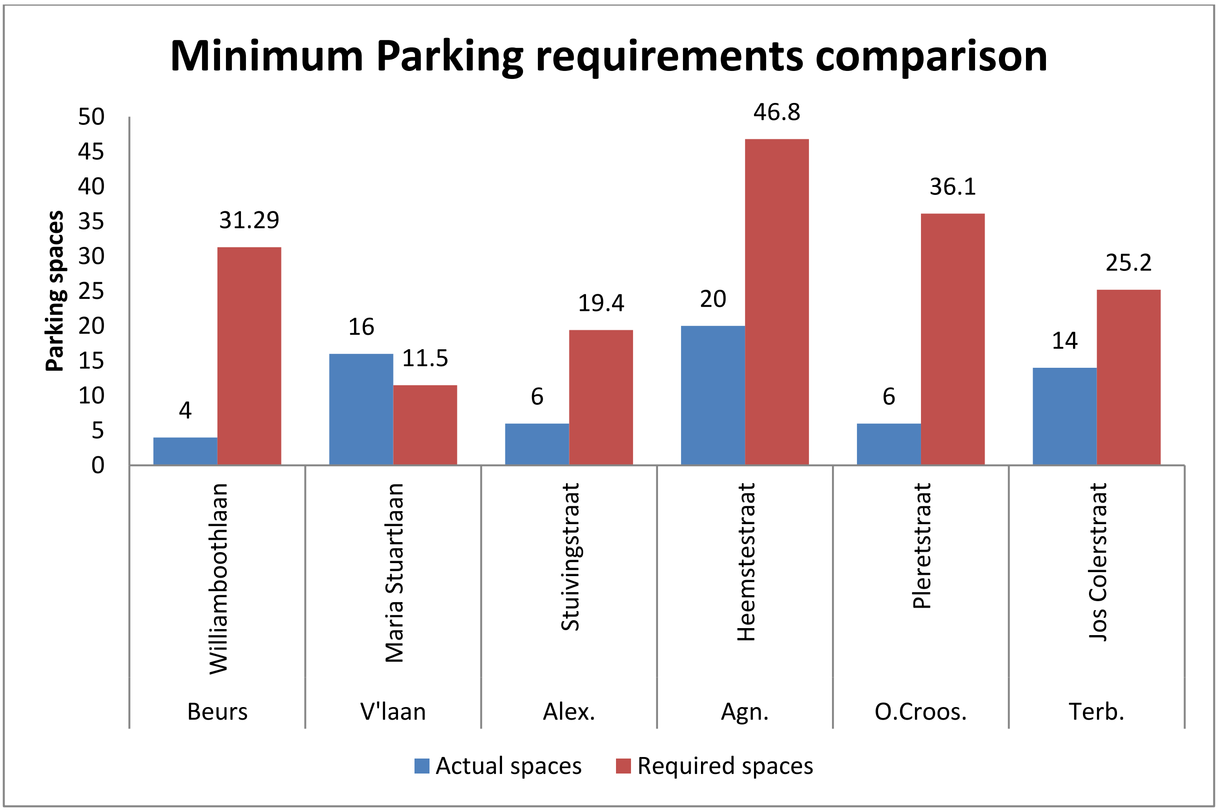


Figure 25: The comparison between what actually exists in the form of private off-street parking and what is currently legislated shows vast differences.

In every catchment zone except Voorschoterlaan, the required spaces dwarfed the actual amount of off-street parking spaces. This is suggestive of historically lower minimum parking regulations. Out of this sample, no pattern of actual space provision is observable.

Provincial policy

The province of South Holland focuses mainly on larger-scale transport projects and makes no explicit statement on car parking infrastructure or policy. The scope of the province's agenda was found in their

2014 document ‘Vision: Space and Mobility’. This vision document calls for a four-pronged approach to mobility in the province:

- better use and revaluation of existing infrastructure
- Increasing the agglomeration structure of major urban regions
- Improving spatial quality and quality of life
- Facilitating the transition to efficient water and energy coordination

The first two points have implications for land use and transport. Key points to come out of the Vision document were:

- An increasing focus on more intensive use of existing infrastructure (as mentioned in the outset);
- Concentration of growth around existing public transport infrastructure;
- Increased focus on mixed use intensification in general (less exclusively commercial or residential zones, as examples);
- Reprogramming of office spaces to residential and mixed uses;
- Rotterdam Central Station precinct and the Alexander precinct (one of the catchment zones in this thesis) designated as spaces for urban consolidation and greater densities. Both sit on major rail junctions;
- Increased focus on ‘bottom up’ strategies. The province will defer decision making to the community and business instead of implementing their own decisions; there is to be a focus on smaller projects to be done in partnership with private developers;
- Acknowledgement from the municipality that low income residents will increase proportionally in the future and that more low-income housing is needed. The province argues that this is largely the role of housing companies and municipalities.
- Provincial plans for a number of roughly equal road and rail projects in the pipeline.

In general, the province appears to be handling the ‘big infrastructure’ items while setting a general direction for land use in its cities. Conversely, the municipality of Rotterdam formulates parking policy and has its own transport agenda as well.

On-street parking fee distribution

The municipality has three rates of parking fees for the city, responding to different levels of demand at different locations. Generally, those locations closer to the city centre have the highest fee grade. The fee grades are:

- €3.33 per hour
- €2.50 per hour
- €1.67 per hour

These were further divided up into four six-hour timeslots:

- 6am-12pm
- 12pm-6pm
- 6pm-12am
- 12am-6am

Figure 26 shows the catchment zones that enforce paid parking.

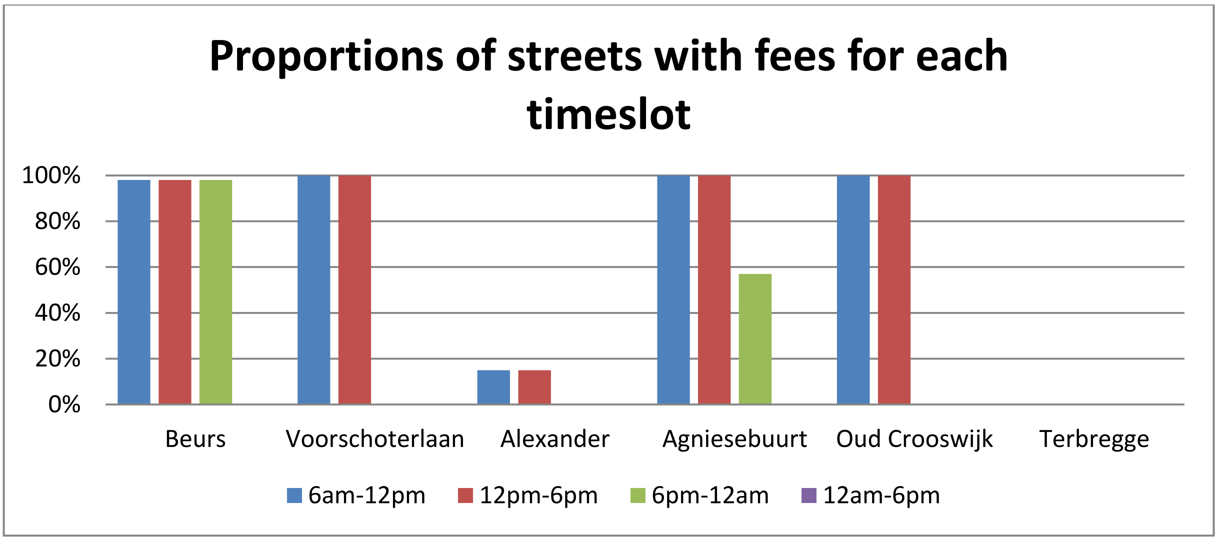


Figure 26: This shows the proportions of all sampled streets (per catchment) that have fees at certain hours.

No catchment area charged fees for on-street parking in 12am-6am slot. For each of the catchment zones, except for Agniesebuurt and Beurs, the slot of 6pm-12am was also set at zero fees. For each recorded street which had fees, the two daylight parking slots, from 6am through to 6pm, always had fees, indicating an emphasis on daytime parking.

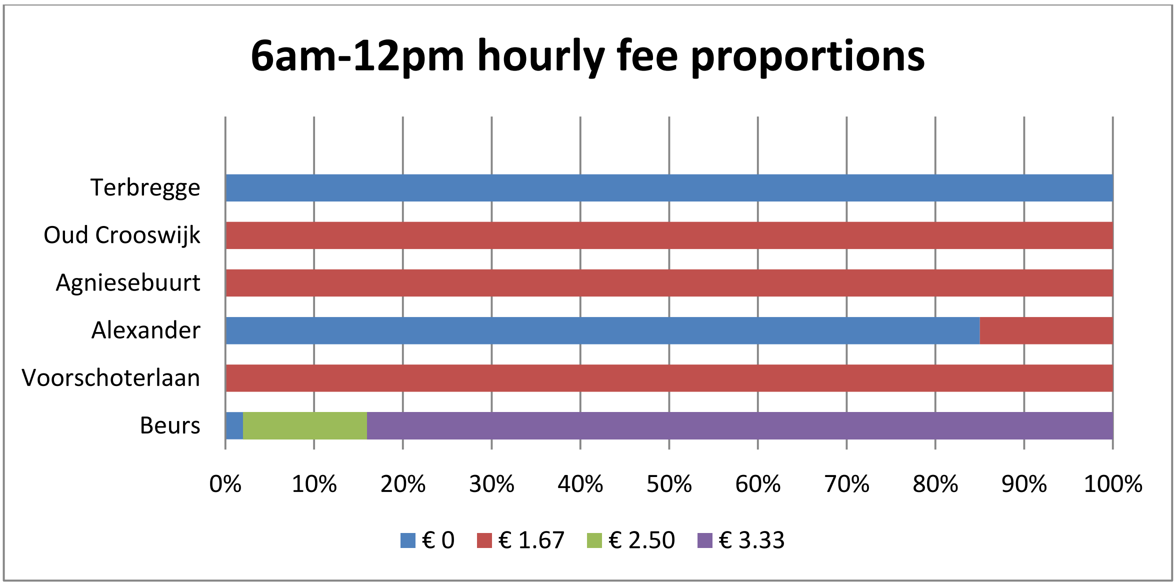


Figure 27: The distribution of parking fees across the six catchments.

As shown in figure 27, there is blanket fee coverage for Voorschoterlaan, Agniesebuurt and Oud Crooswijk, while Terbregge charges no fees. Beurs has the variability of charged fees and most of that catchment's streets have the highest fees in the city.

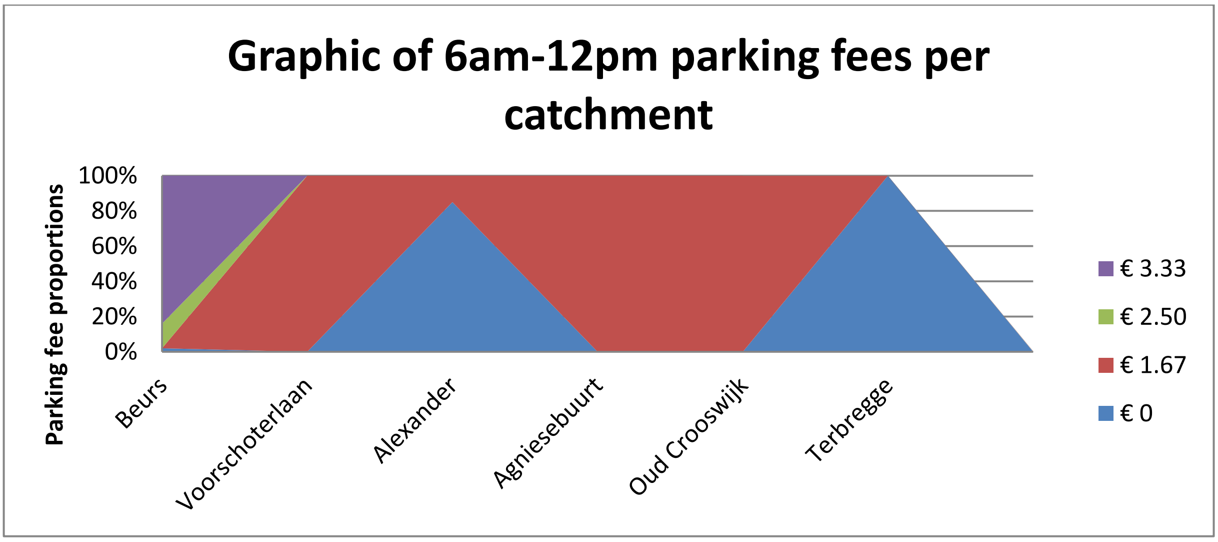


Figure 28: An alternative interpretation of the fee distributions. The two '€0 fee mountains' are the two outer most catchments.

Figure 28 gives an alternative visual representation of how the different parking fees are proportioned in each zone. The two outer-most catchments of Alexander and Terbregge are shown here to have a large majority of their on-street car parking free of fees (due to their low parking pressure).

Parking pressure and fees

Figure 29 shows the change in the monthly permit fees from 2011 to 2015 for on-street parking permits.

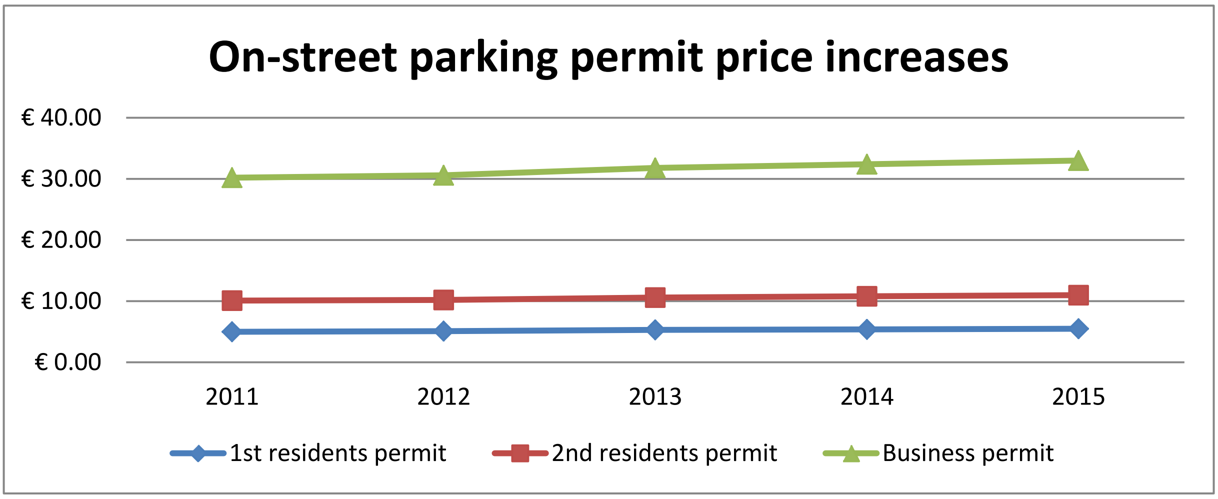


Figure 29: On-street parking permit fee increases over the last five years.

As is shown in figure 29, the rate of increase in fees since 2011 is higher for the business permit compared with the residents' permit. It is also cheaper to have a second residents' permit than to have a business permit.

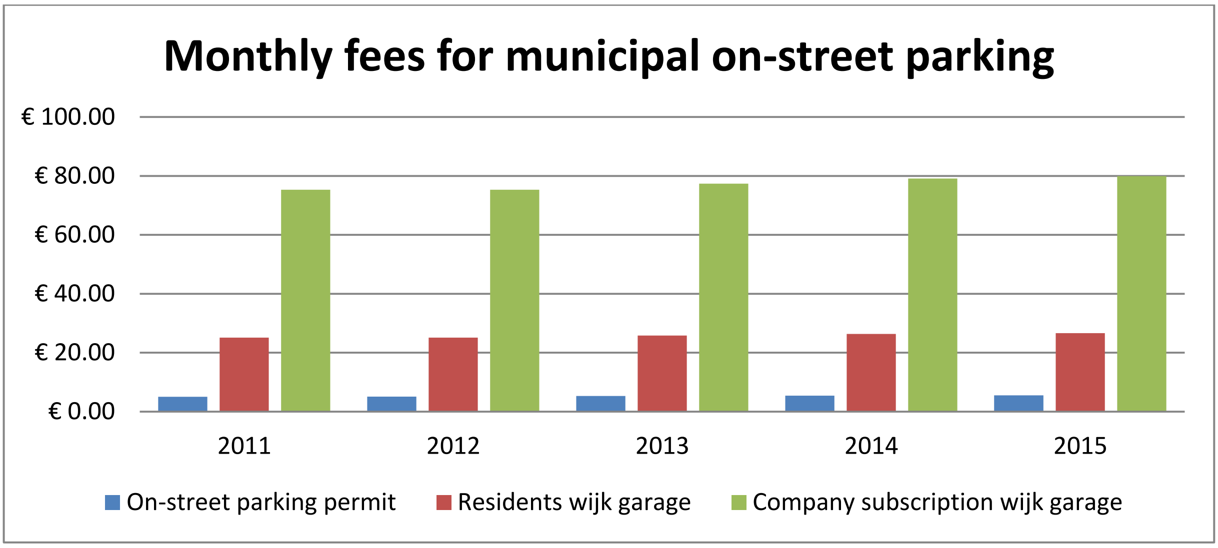


Figure 30: For residents, there are different options of municipality-subsidised parking.

For the residents' parking garage (run by the municipality) prices are higher and especially so for companies who wish to use the spaces. According to the municipality, these parking garages offer priority to adjoining residences, then to other residences and finally to businesses.

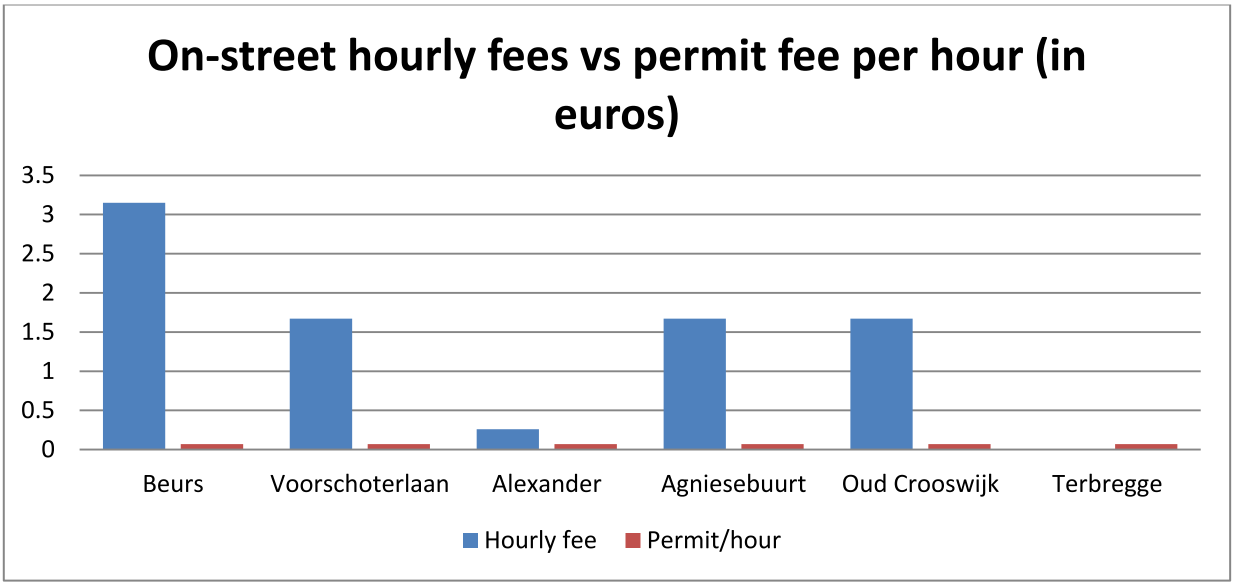


Figure 31: This graph shows the relative costs per hour of on-street parking against what each hour actually costs with the permit.

Figure 31 depicts the average hourly fee: on-street parking spots with fees multiplied by the applicable fee, summed across the catchment zone, and then divided by the total amount of on-street parking spaces in the catchment. As can be seen, parking permits offer an enormous subsidy, with permit holders paying 7 euro cents across the whole city per hour (there is no differentiation for different neighbourhoods for the permit fee) per hour compared with the €3.33 for on-street parking in the Beurs catchment. Residents who lack private off-street parking in Terbregge need not pay for a permit as there is no fee for on-street parking in that catchment.

Parking fees are said to respond to demand, as measured by parking pressure, for each area. As shown below in figure 32 and 33, day parking pressure does not vary significantly but hourly parking fees do across both Metro catchments and non-Metro catchments. This could be because the three-graded pricing mechanism is keeping the parking pressure consistent.

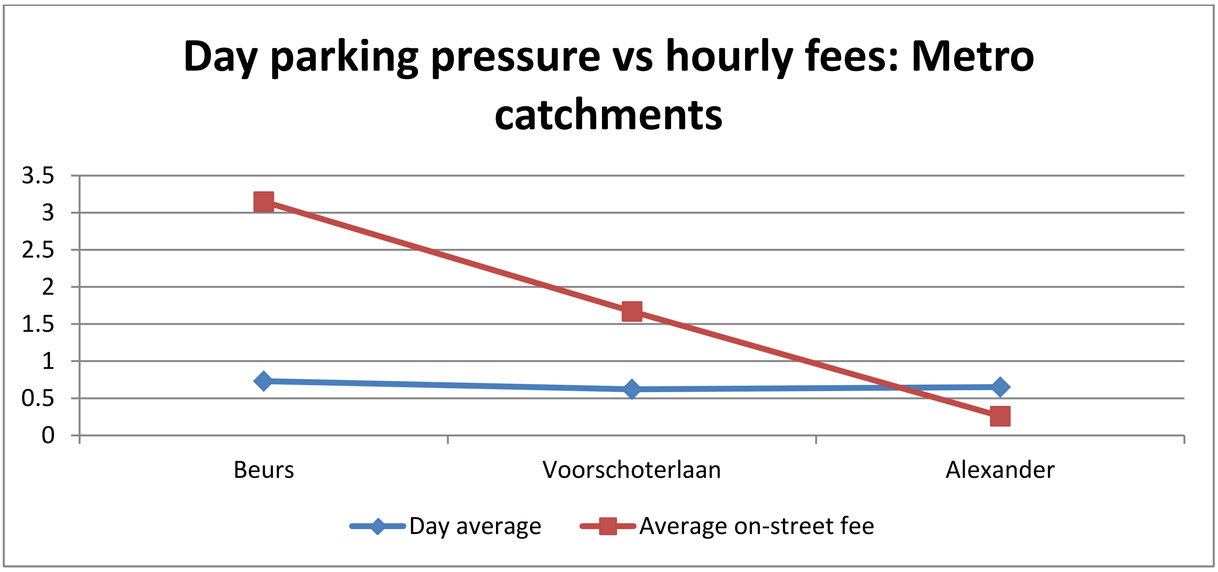


Figure 32: Parking fees decline while parking pressure sees no significant change.

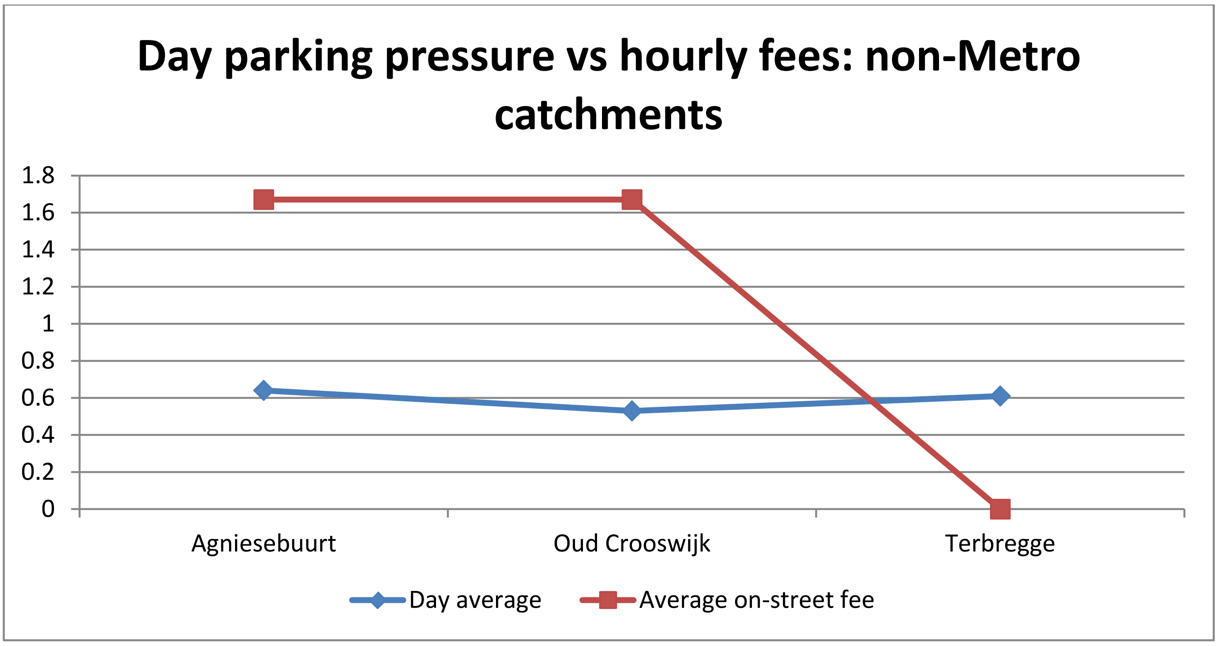


Figure 33: While the average on-street parking fee drops to zero in Terbregge from €1.67 in Agniesebuurt and Oud Crooswijk, the average parking pressure doesn't shift much.

Agniesebuurt and Oud Crooswijk remain in the same sector of on-street parking fees.

Figure 34 shows a consistent relationship between night time on-street car parking pressure and the proportion of private off-street car parking. In catchments where there are higher rates of off-street parking, the parking pressure is not as high. This is consistent throughout all the catchments.

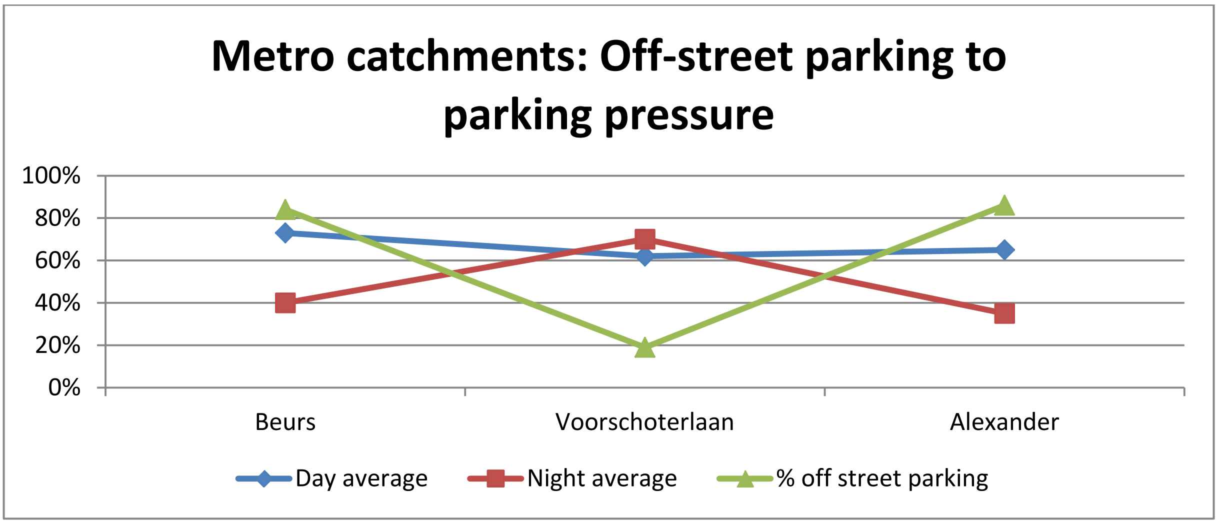


Figure 34: Night parking pressure averages correspond negatively with that of the percentage of off-street parking (out of all parking) in the catchment.

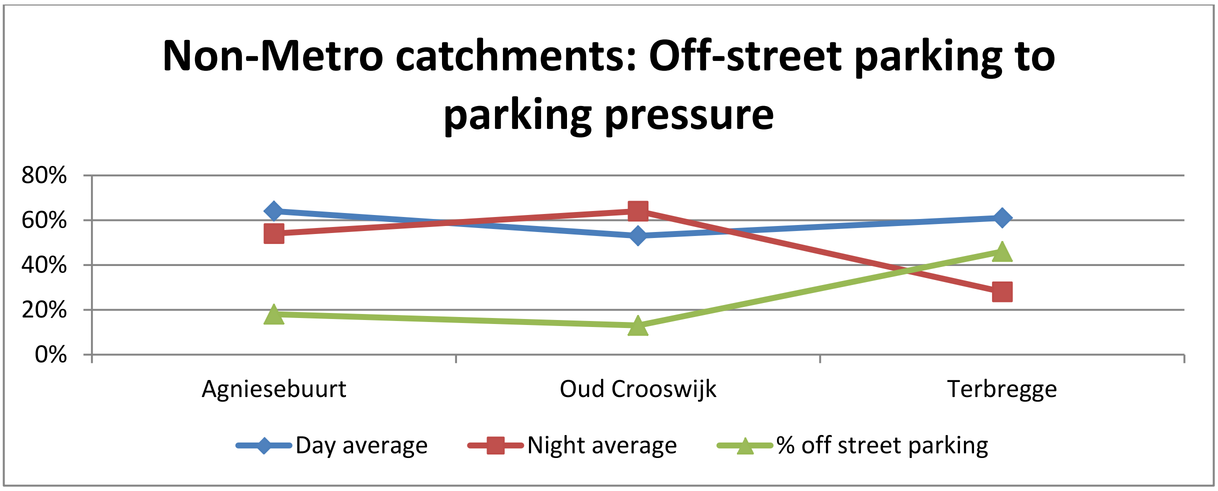


Figure 35: Again, there is a negative correspondence between the percentage of private off-street parking and the night parking pressure average.

In effect, this is what the municipality sees. There does not appear to be any relationship between off-street parking or night time parking pressure and distance from Stadscentrum or proximity to a Metro station. However, a very marginal trend is visible, showing a declining day average of parking pressure over distance in general.

Parking garage location, capacity and fees

Parking garages were investigated across the city and many were outside the six catchment zones. These were the *public* (private and publicly-run) *off-street parking facilities.* The analysis and results here illustrate the relationship between the fees of these facilities and distance to local desirable points (Beursplein, Stadscentrum, in this instance), and any relationship that exists between each facility's capacity (in parking spaces) and the fees.

In looking at the relationship between kilometres from Beursplein and fees of public off-street parking garages, a clear pattern was identified: greater walking distance is related to cheaper hourly fees.

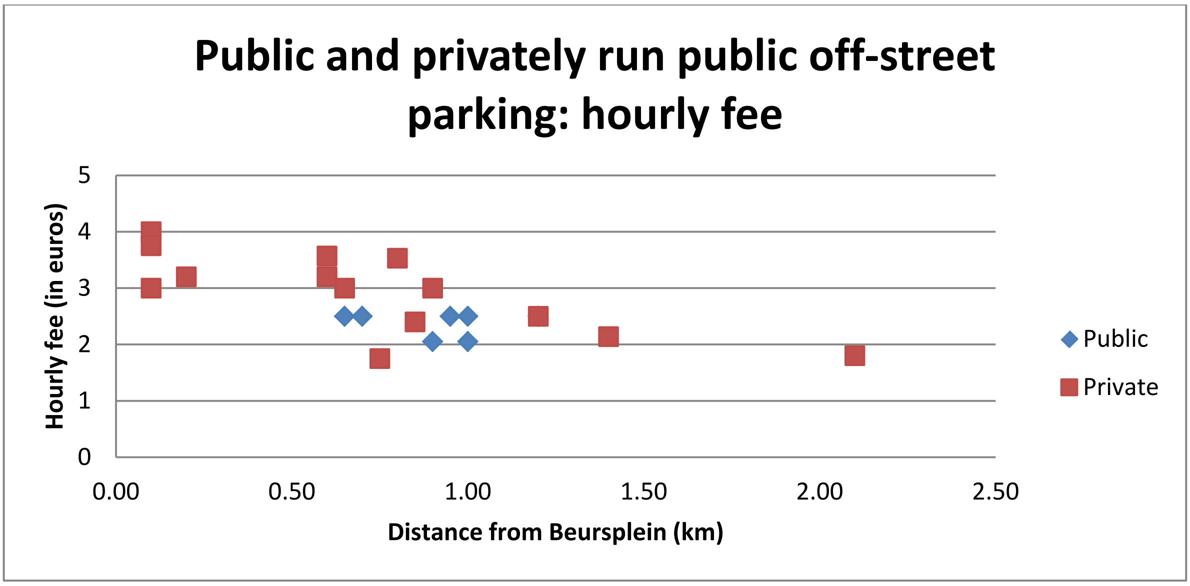


Figure 36: Five hour fee comparison with respect to distance from Beursplein.

Figure 36 compares hourly fees between public and privately run public off-street parking by distance. 'Publicly run' refers to parking lots or garages which are run by the municipality; 'privately run' refers to private businesses such as Q-park, which owns a number of off-street parking facilities in Rotterdam.

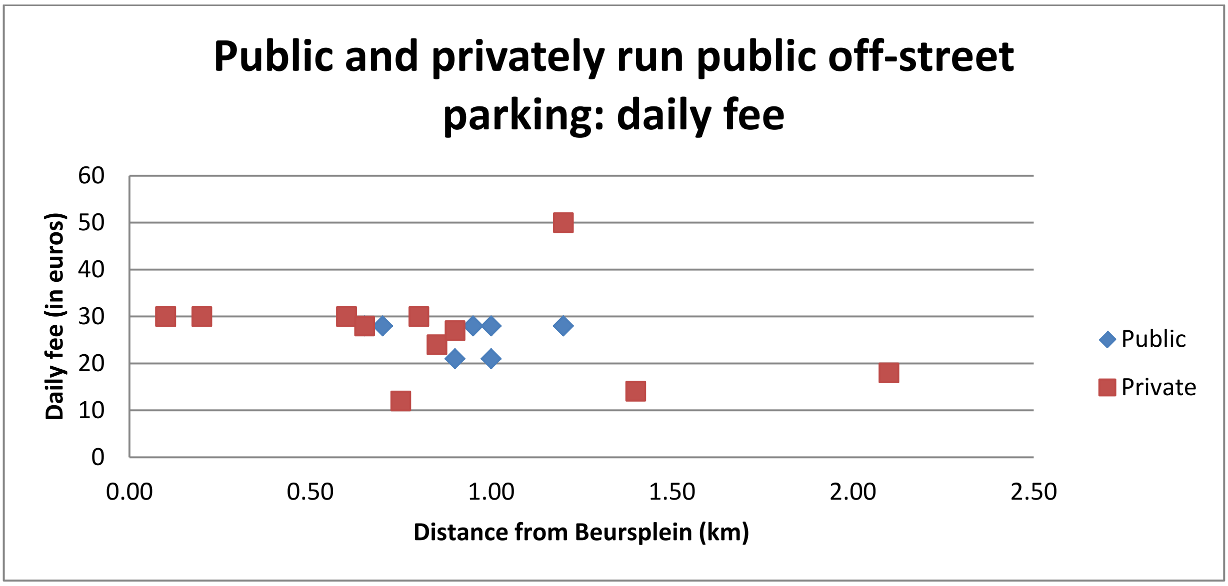


Figure 37: Day parking fee comparison with respect to distance from Beursplein.

As can be seen, the public parking hourly fees are roughly aligned with those of the private fees – assuming fees are a function of distance from the main commercial activities at Beursplein.

Those results are similar when looking at pricing per day which sits at just under €30 as an average for Stadscentrum. Here too, there is little deviation from the approximate market price.

For Alexander, the picture is slightly different. The central locations of the area were not clear (it could be the station or a particular office building, or one of the two large shopping malls), but the Alexandrium shopping mall was chosen.

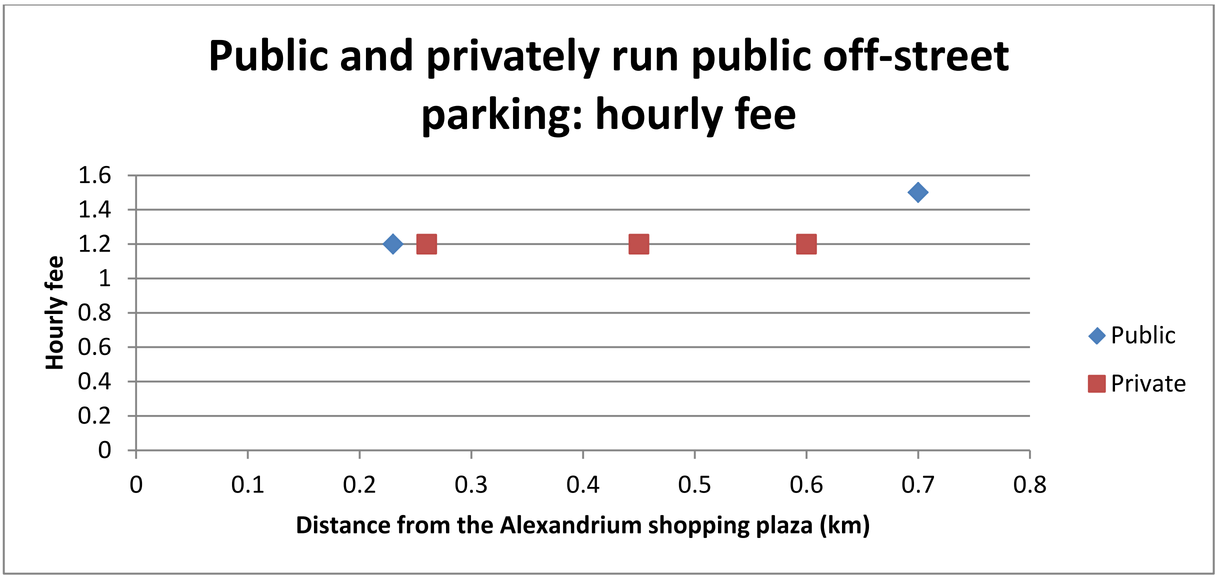


Figure 38: Hourly fee comparison with respect to distance from the Alexandrium shopping plaza.

As can be seen, there is no discernible pattern for those wishing to reach the Alexandrium. This indeed suggests motorists may have a number of key destinations in mind when visiting the area.

A regression analysis was performed to derive a model for the distance-fee relationship for Stadscentrum. Hourly fees were used.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.710[a]	.505	.480	.45160	1.504

a. Predictors: (Constant), Distance

b. Dependent Variable: Hourlyfee

Figure 39: Correlational analysis between fees and distance from Beursplein.

As can be seen, there is a moderate correlation between distance and fees.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.157	1	4.157	20.385	.000[b]
	Residual	4.079	20	.204		
	Total	8.236	21			

a. Dependent Variable: Hourlyfee

b. Predictors: (Constant), Distance

Figure 40: Residual data from regression analysis.

There is a large amount of residual data (data unexplained) in the model; however, the regression component remains statistically significant: the variable of distance is a reasonable predictor of fees. (Though there are other variables in the picture).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.499	.197		17.791	.000
	Distance	-.949	.210	-.710	-4.515	.000

a. Dependent Variable: Hourlyfee

Figure 41: Coefficients for regression analysis equation.

In this respect, an equation might be written as Price (€) = 3.499 – 0.95X + e (where X is distance from Beursplein in this case).

A correlation (see figure 42) between capacity of parking garage capacity and fees was performed to see if there was any relationship. From the rank-order correlation procedure used, it is clear it is clear that there is a negligible correlation between capacity (of parking garage) and distance, in kilometres, from Beursplein. In general there was no distinguishable pattern between capacity and fees. No relationship was found to exist.

Correlations

			Hourlyfee	Dailyfee	Capacity
Spearman's rho	Hourlyfee	Correlation Coefficient	1.000	.833**	.338
		Sig. (2-tailed)	.	.000	.124
		N	22	22	22
	Dailyfee	Correlation Coefficient	.833**	1.000	.478*
		Sig. (2-tailed)	.000	.	.024
		N	22	22	22
	Capacity	Correlation Coefficient	.338	.478*	1.000
		Sig. (2-tailed)	.124	.024	.
		N	22	22	22

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 42: Three variable correlation analysis between Capacity, Daily Fees and Hourly fees.

From this, it is clear that there is a negligible (but statistically significant at the 0.05 level) positive relationship between parking capacity and fees. Parking capacity is not an indicator of fee pricing.

Stadscentrum (encompassing the Beurs catchment) is shown in figure 43:

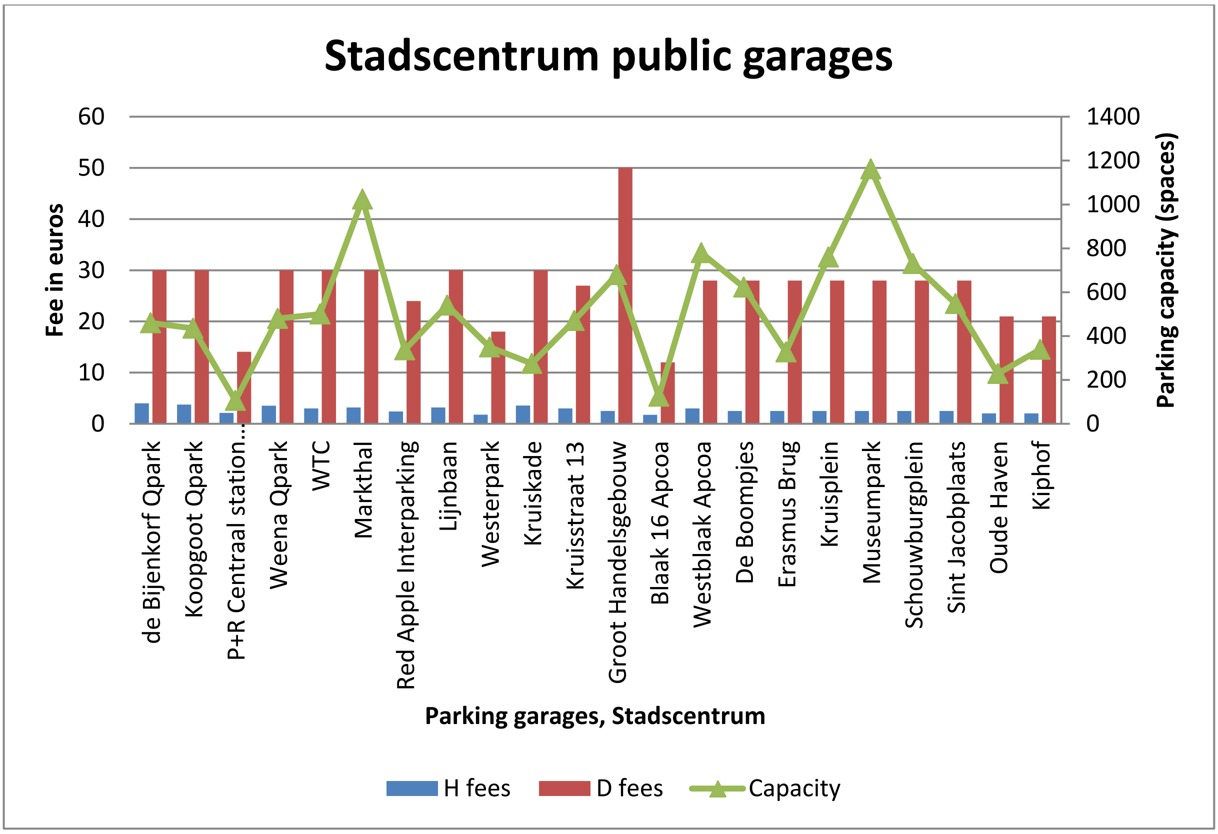


Figure 43: Parking fees against capacity - here there is no relationship.

For Alexander, the garages had a similar fee and capacity structure with no discernible relationship between the two.

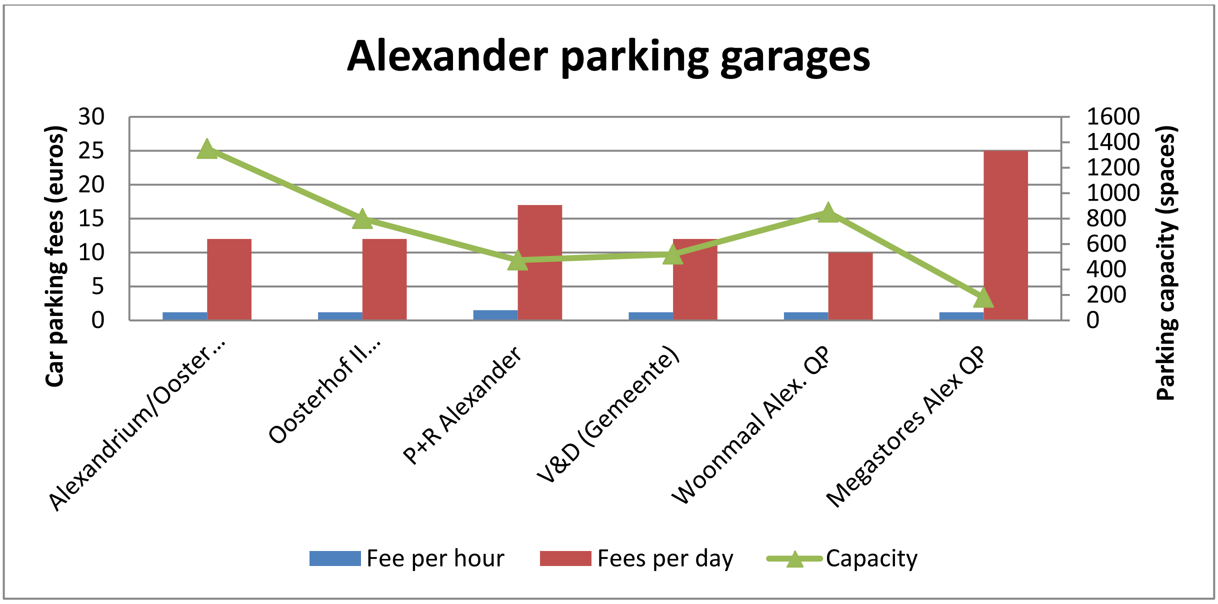


Figure 44: Parking fees to capacity - no relationship.

Fees and duration

Many public parking garages offer a discount for short-term parkers, for instance, for those who stay more than four hours or for those who stay for a day ('short-term' parkers, usually visitors, who tend not to stay for more than a day and often for only an hour or so). The difference in *fees per hour* for a four-hour parking session compared to that of a one-hour session may be reflected in the form of a discount for the user, to encourage a specific time frame of use. In graph 45 (below), what the customer pays in real life is denoted 'Actual 5 hourly fee' and marked by a red square; the blue triangles denote 'raw 5 hourly fees' which means how much it would cost without any discounts or extra fees from the specific duration of the stay.

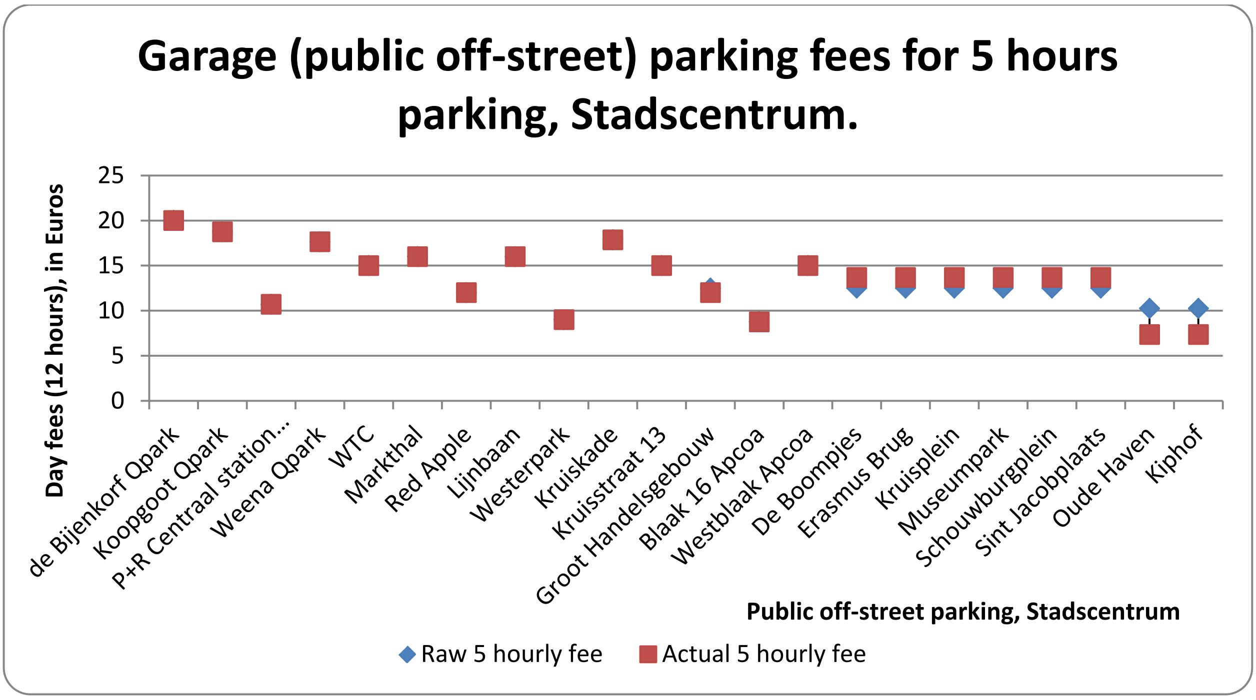


Figure 45: Actual day parking fees against the raw parking fees.

The municipality-run parking garages for short-term parking seemed to slightly discourage longer term use (up to 5 hours) in the centre, while its two B garages (those on the outskirts of Stadscentrum, but still in the inner city, from where one might need to walk) encouraged longer use.

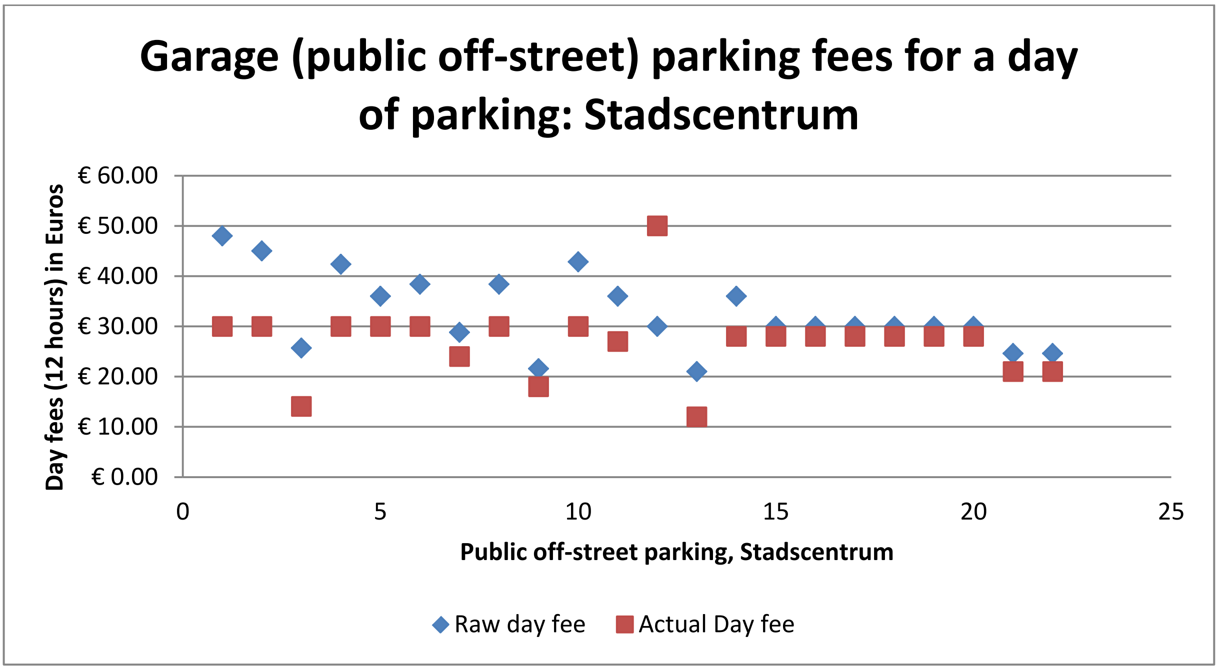


Figure 46: Actual day parking fees against the per day 'raw' hourly fees. Most carparks offer a discount for day parking.

For daily (daylight hours) fees (raw 12 x hourly fee) vs day ticket fees, there is a clear discount to be had for staying longer for those who would leave their car parked for 12 hours or more by buying a day ticket. Comparing daily fees and day ticket fees, those who left their car parked for 12 hours or more can enjoy a discount by buying a day ticket.

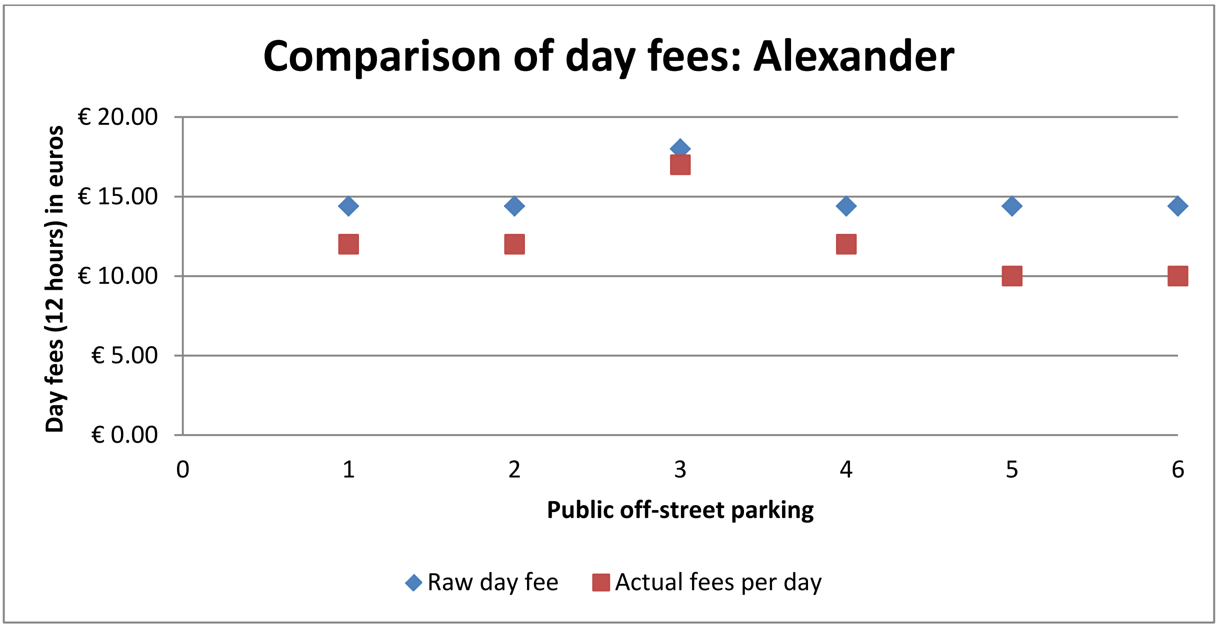


Figure 47: Day fees against 'raw' per hourly fees for Alexander. Here, again, the day fee rate has a discount.

A similar result is found for Alexander, where the only publicly-run public off-street parking is the P+R spaces, intended for commuters (case 3).

RQ2: How is car parking proportioned at different distances from Metro Stations and Rotterdam's urban centre?

This research question examines the distribution of the various types of car parking as it currently stands. Specifically, this question addresses potential differences in the composition of car parking with respect to distance from the centre of Rotterdam (the neighbourhood 'Stadscentrum') and proximity to a Metro station. This research question acts as a comparison to the management of parking by the municipality and the municipal and provincial transport strategies.

Parking proportions

Data derived from the catchments suggests that distance is indeed a factor in the overall quantity of car parking but that this relationship is not linear. Both Beurs and Alexander stand out as having large proportions of car parking, both on-street and off-street, but otherwise with a decline in total parking quantities with increasing distance from Stadscentrum. In effect, figure 48 describes the overall density of car parking for each of the catchments.

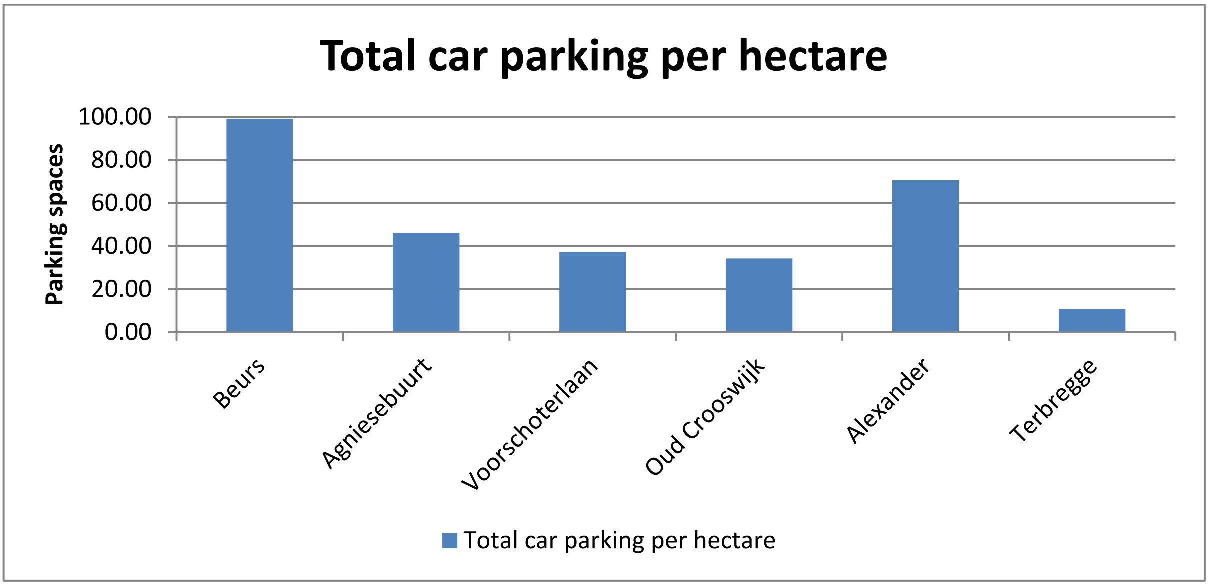


Figure 48: Total car parking density per catchment.

This is broken down further to the three main categories of car parking: on-street parking, private off-street parking and garage parking. Alexander and Beurs stand out as having more garage parking spaces (public off-street parking) than any other type.

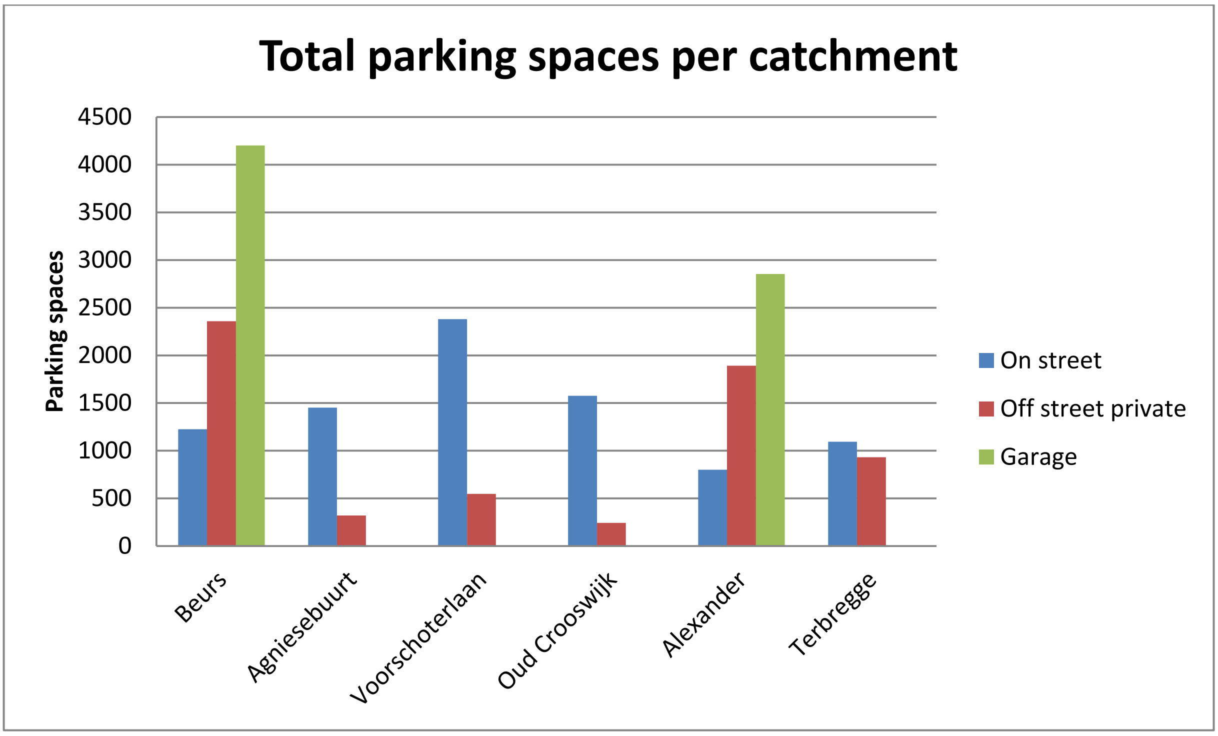


Figure 49: Basic composition of car parking per catchment.

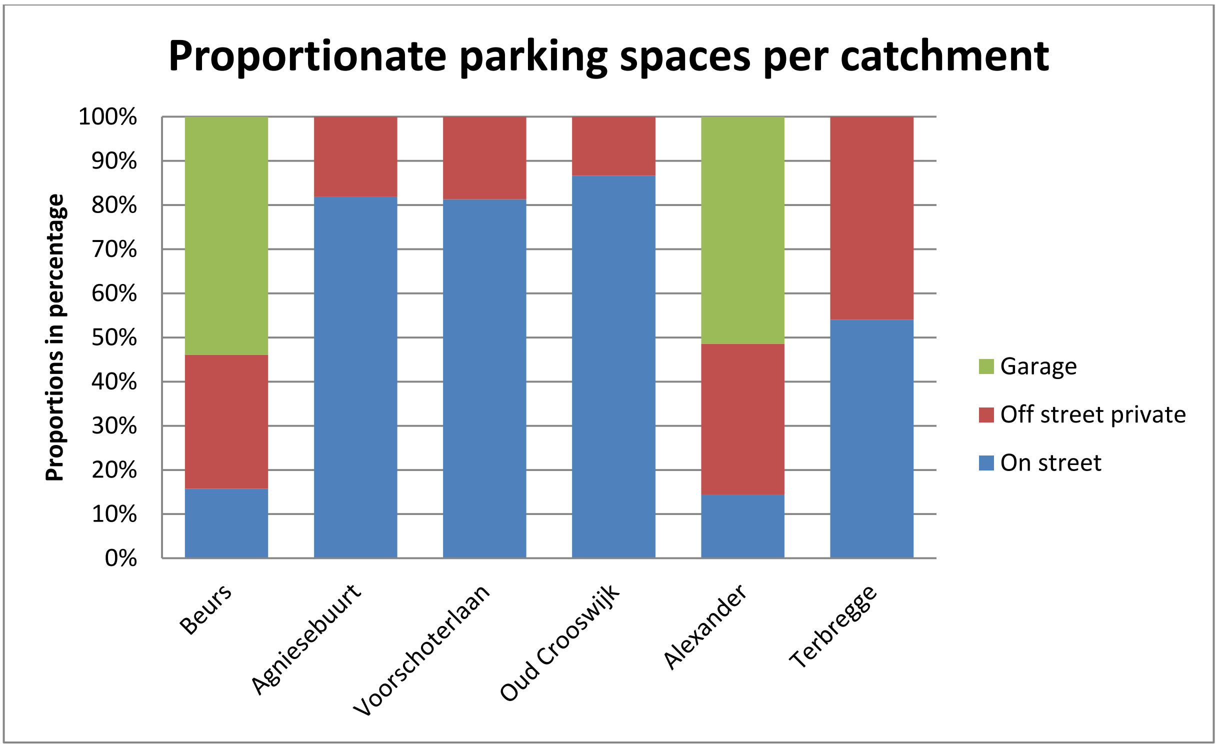


Figure 50: Proportional composition of car parking per catchment.

This is further confirmed in figure 50 showing proportional distribution of parking spaces. There is no clear overall pattern, though both Beurs and Alexander have most of their parking capacity in *private off-street parking* or *public off-street parkin*g (private or municipal parking garages and terrains). These two catchment zones are almost identical in terms of their parking proportions while also both being major public transport junctions.

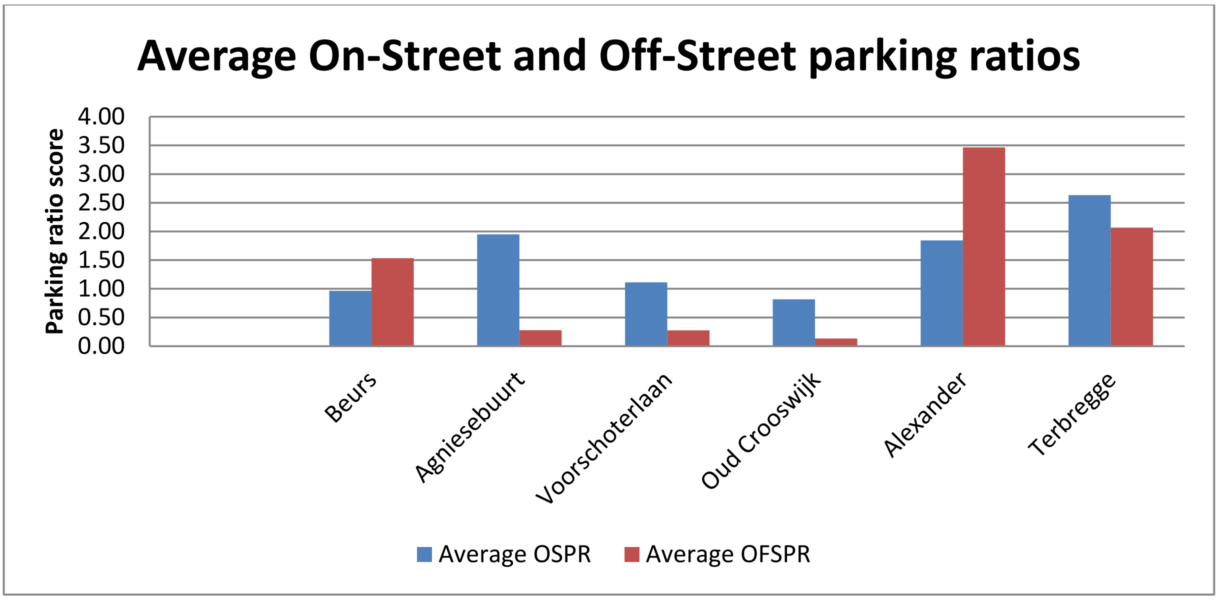


Figure 51: OSPR and OFSPR per catchment

The OSPR and OFSR (On-street Parking Ratio and Off-Street Parking ratio respectively) are calculated by dividing the amount of on-street parking and private off-street parking in a street by the quantity of addresses in the same street segment. This is depicted in figure 51 which shows that Beurs and Alexander have a large quantity of streets where the ratio off-street private car parking to addresses is high. This suggests sufficient demand to build dwellings with off-street parking. In contrast, very few addresses in the zones of Agniesebuurt, Voorschoterlaan and Oud Crooswijk have private off-street parking, and in all three, most addresses are resourced by on-street parking. In these areas, the private off-street parking ratio is at its lowest. A summary table showing these values and their standard deviations are shown below in figure 52:

Catchment	Average OSPR	S. deviation OSPR	Average OFSPR	S. deviation OFSPR
Beurs	0.96	1.10	1.54	3.41
Voorschoterlaan	1.11	0.97	0.28	0.43
Alexander	1.85	2.35	3.46	6.57
Agniesebuurt	1.95	4.12	0.28	0.49
Oud Crooswijk	0.82	0.42	0.13	0.30
Terbregge	2.63	5.39	2.07	6.53

Figure 52: Table of OSPR and OFSPR values and standard deviations (spread).

Table 52 adds insight into the diversity of the present built environment. The standard deviation represents the spread of the on-street parking and off-street parking ratios. Here it is shown that some catchments do not vary much – Oud Crooswijk and Voorschoterlaan have low standard deviation scores for both OSPR and OFSPR. This may suggest that housing stock and street layouts here are fairly homogenous (each street is similar to the next). Agniesebuurt also has a low OFSPR standard deviation but a high OSPR standard deviation; here, housing stock is likely to be homogenous but street layout and the distribution of on-street parking is not. Terbregge is at the other end of the spectrum with the highest OSPR deviation and the second highest OFSPR standard deviation. Alexander has also high standard deviations for both ratios while Beurs only has a high deviation for the OFSPR.

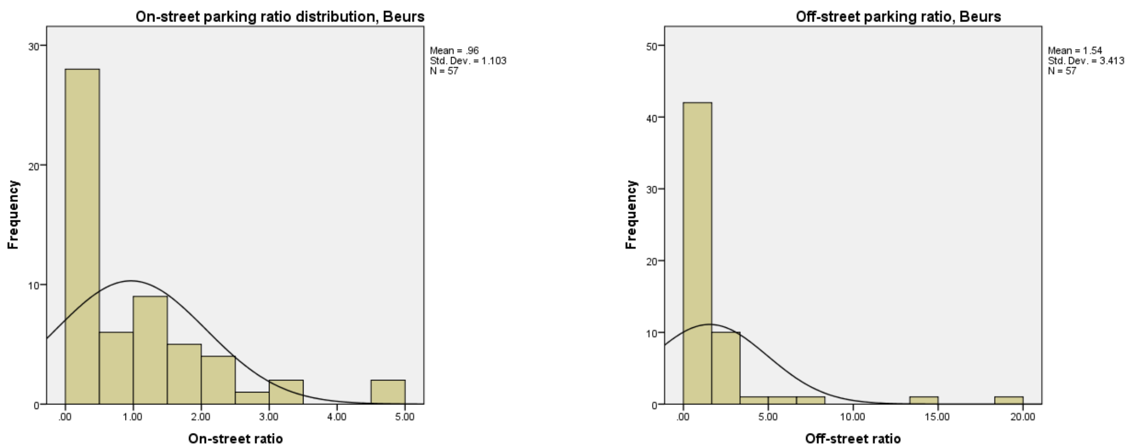


Figure 53: OSPR and OFSPR for catchment Beurs.

The two distribution graphs in figure 53 show OSPR and OFSPR, respectively, for the Beurs catchment. There is less variation in off-street parking ratios than in the on-street, reflecting different street sizes against consistent resident density. For maps of the other catchments, see the appendix.

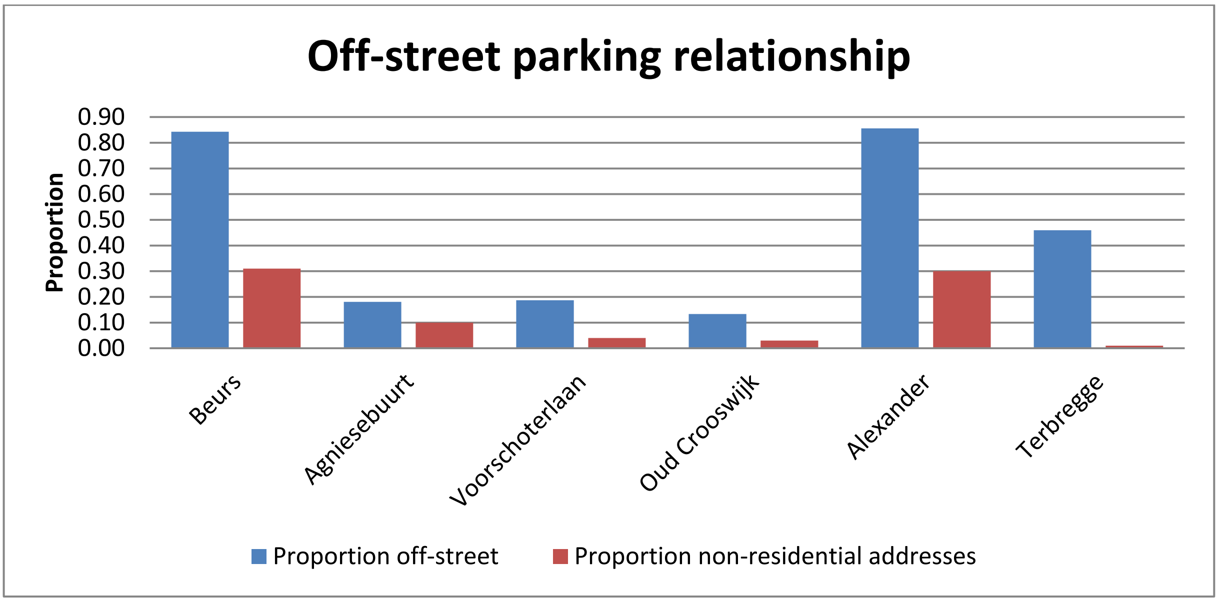


Figure 54: Off-street parking to non-residential addresses. Here a relationship is seen.

As shown in figure 54, there does appear to be a relationship between, on the one hand, the proportion of non-residential zones and, on the other hand, *private off-street parking* and *non-residential land uses (e.g. warehouses or cemeteries)*. For each non-residential address proportion there is a very similar off-street parking proportion.

Parking and land use

This section looks at rates of parking to households, population and mode share; it examines the effective density of car parking for each catchment.

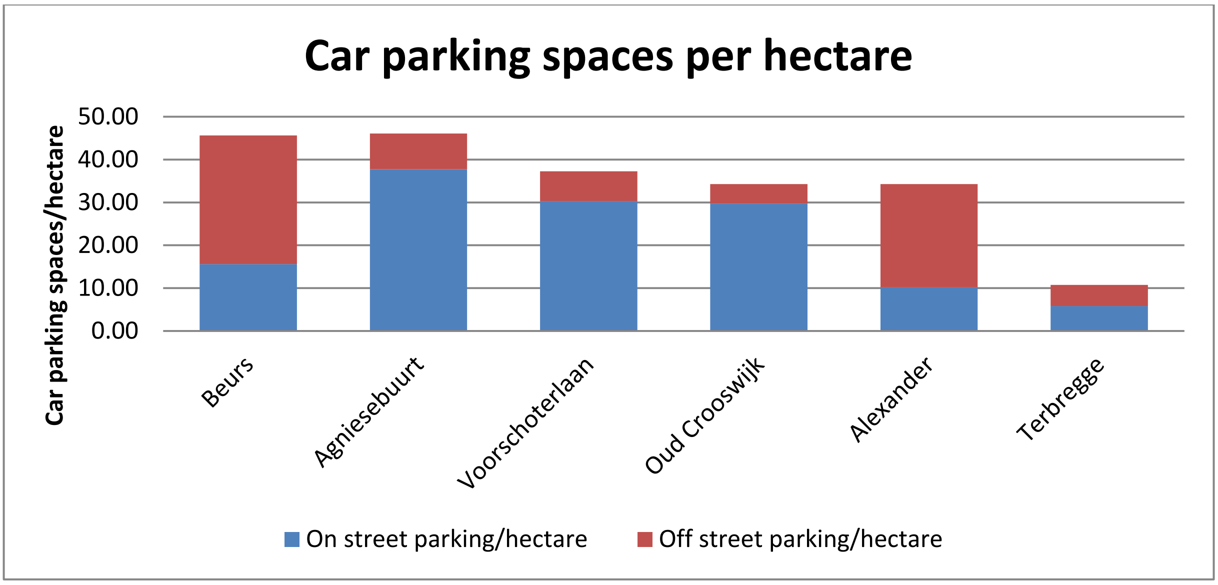


Figure 55: Spatial configurations of on-street and off-street parking.

Figure 55 shows the spatial density of car parking in the six catchment zones. Note that 'off street parking' refers to private off street parking such as carports and also public off-street parking such as multi-story garages adjoining shopping plazas.

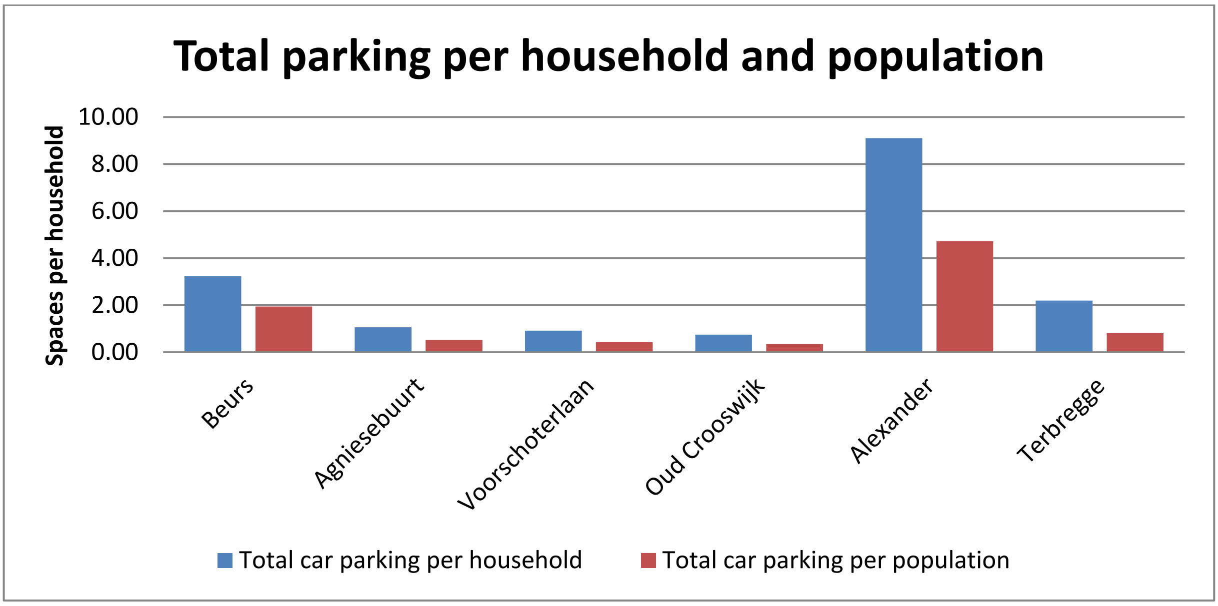


Figure 56: The amount of car parking spaces per household across the six catchments.

As figure 56 shows, Alexander stands out as having the greatest proportion of overall car parking capacity. This is could be due to the large shopping centre and office towers that fall within the catchment zone. Large gaps between car parking per household and car parking per population suggests a larger household size. It needs to be noted that this does not necessarily mean more people drive, as many large households may be comprised of children who are not yet at driving age or who cannot afford a car.

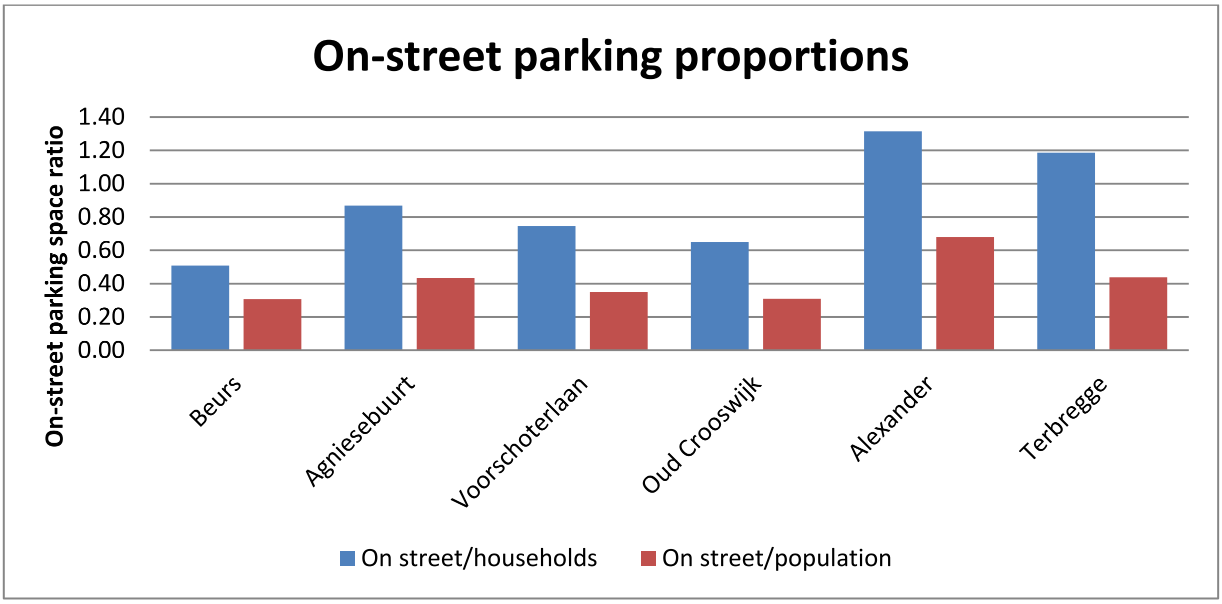


Figure 57: the amount of on-street car parking spaces per head of population across the six catchments

Beurs has the least on-street parking per household or population. There is a general trend of increasing on-street car parking with greater distances from Stadscentrum.

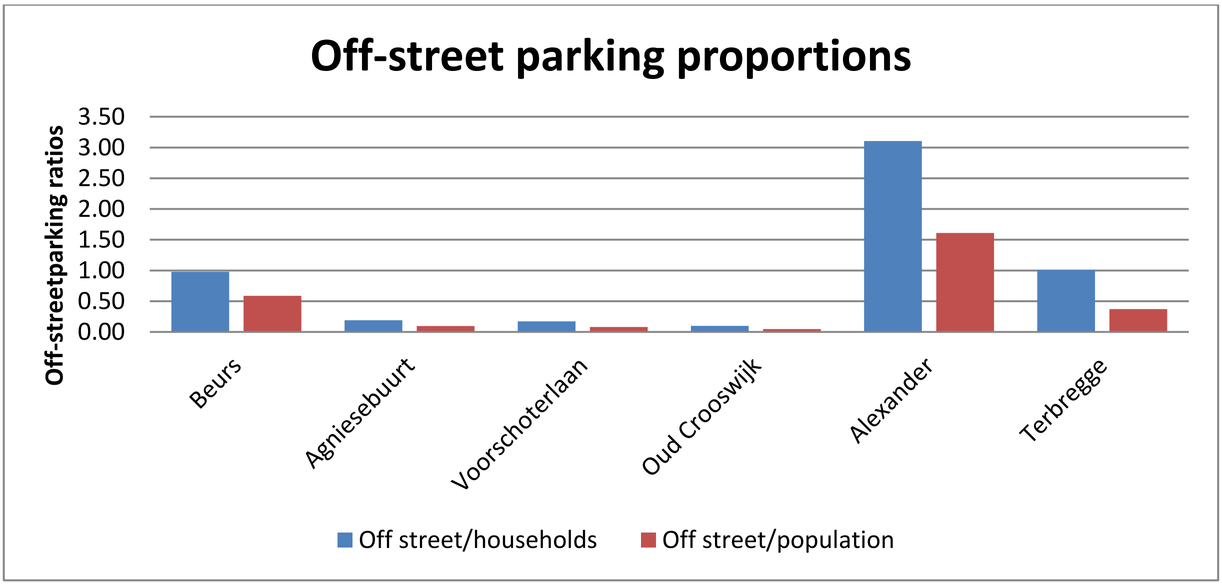


Figure 58: the amount of off-street car parking spaces per head of pouplation across the six catchments.

A markedly different picture is painted for private off-street parking to households/population ratios. The large spike for Alexander may be due to the large quantities of car parking around the non-residential land-use zones and the shopping centre in that catchment.

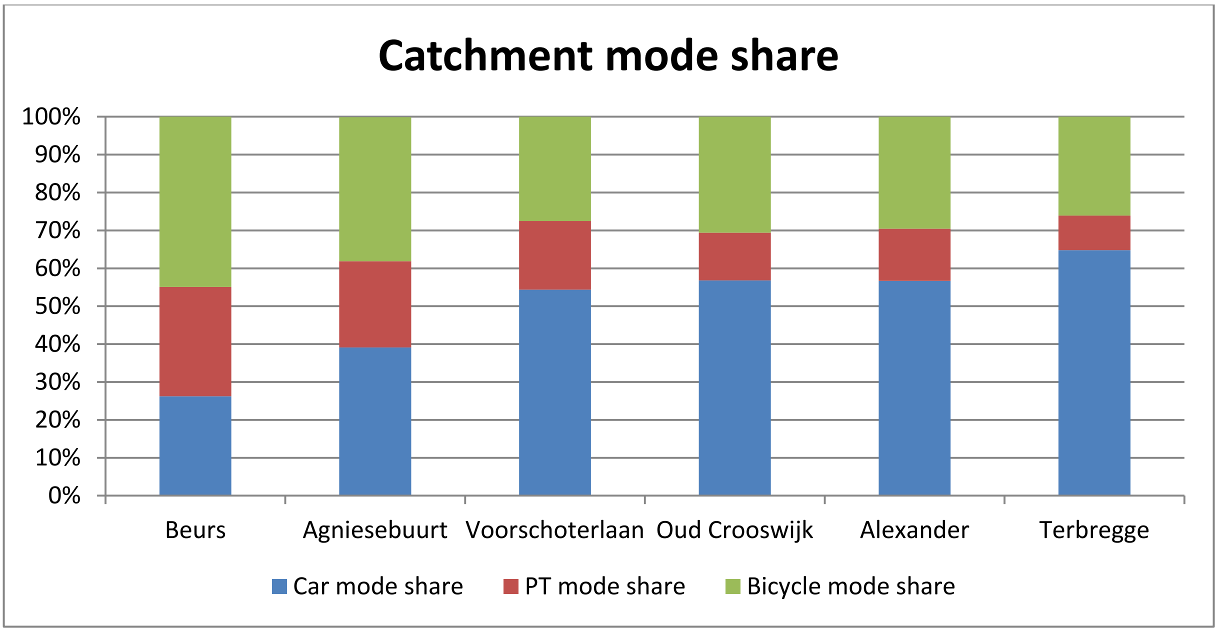


Figure 59: Mode share across the six catchments

Figure 59 above and correlation output shown in figure 60 compares mode share across each of the catchment zones. A correlation was done of automobile mode share against total car parking

Correlations

			Mshare	Tpdensity
Spearman's rho	Mshare	Correlation Coefficient	1.000	-.829*
		Sig. (2-tailed)	.	.042
		N	6	6
	Tpdensity	Correlation Coefficient	-.829*	1.000
		Sig. (2-tailed)	.042	.
		N	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 60: Correlation between total parking density and mode share (across the catchments).

density.

The result, shown above, demonstrates a negative, statistically significant correlation between total car parking density (rank-ordered by catchment) and automobile use. In other words, in catchments with a high rate of automobile use, the density of car parking was significantly lower. This suggests that the presence of large parking facilities may be overlooked by residents in areas like Beurs, or that such areas have large amounts of visitors driving and needing a place to park.

Figure 61 (below) depicts the proportion of off-street parking and car mode share on the same graph. As can be seen, there is no distinct pattern prevalent though Beurs has a high quantity of off-street parking with respect to residents' mode share patterns of lower car use.

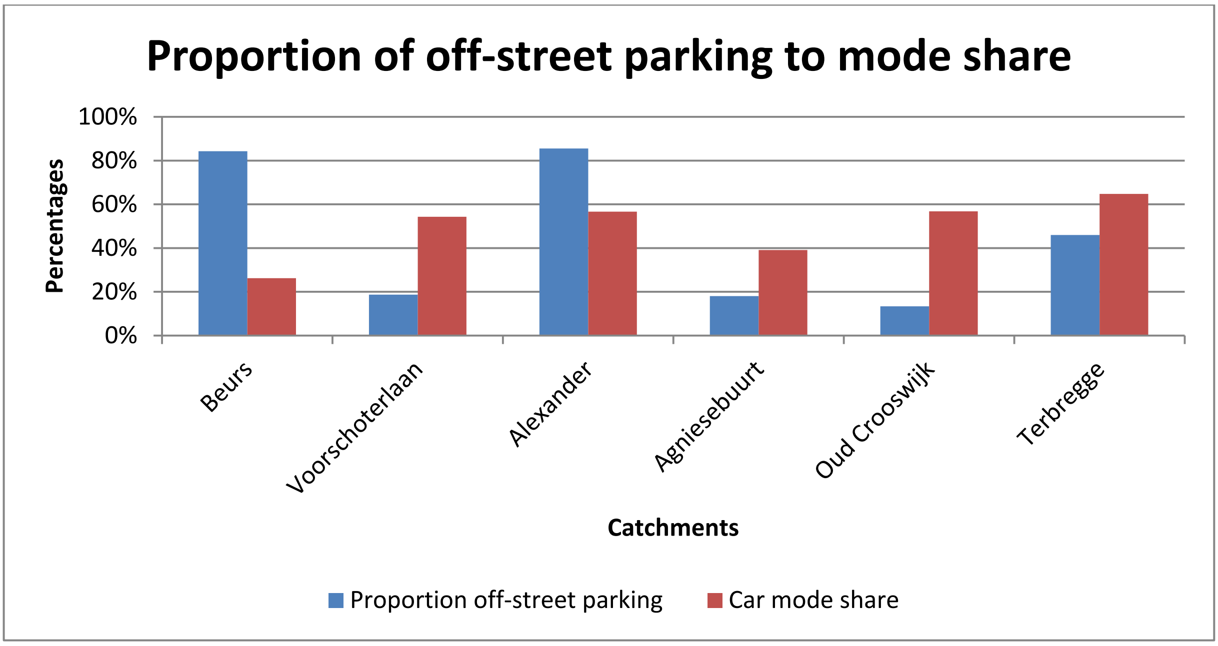


Figure 61: The proportion of private off-street parking to mode share. Here, no clear pattern is visible.

Metro catchments and non-Metro catchments

A relevant sub-question to the second research question concerns differences in off-street and on-street parking with respect to proximity to a Metro station (the Beurs, Voorschoterlaan and Alexander catchments) compared to those without (Agniesebuurt, Oud Crooswijk and Terbregge). This was done by comparing the Metro group and the non-Metro group (independent samples significance test), comparing within groups of the same distance from Stadscentrum (Beurs/Agniesebuurt, Voorschoterlaan/Oud Crooswijk and Alexander/Terbregge) and comparing those groups – measuring distance, rather than accessibility, to the Metro.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Onstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.696	Retain the null hypothesis.
2	The distribution of Offstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.050	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 62: Mann-Whitney U test results for total on and off street parking across the six catchments.

A Mann-Whitney test was undertaken once it was established that homogeneity of variance in the sampling could not be upheld. This test was based on the rank-ordering of the numbers, not the specific values themselves. There was no statistical significance (p values = 0.696) found for catchment zones around a Metro station compared with those not near a Metro station. However, for off-street parking (the bottom row) the significance level was borderline (p= 0.050).

When this was broken down to three *distance* groups of two (Beurs/Agniesebuurt, Voorschoterlaan/Oud Crooswijk/ and Alexander/Terbregge), all on-street parking were found to have statistically insignificant differences across all three of the distance groupings (with P-values equal to and greater than 0.265). However, for off-street parking, only the outer suburban group (Alexander/Terbregge) had an statistically insignificant difference with the middle (Voorschoterlaan/Oud Crooswijk) and inner (Beurs/Agniesebuurt) groups recording statistically significant differences (P=0.004 and 0.047 for the middle and inner groups respectively) between the zone with the Metro station and the zone without.

Summaries of further results can be found in the appendix.

Spatial concentration of parking pressure

Parking pressure in this instance refers to the amount of cars occupying the available capacity per street. The municipality's data in this respect was not available for many streets so an aggregate was derived by looking at 'blocks' (groupings of streets). Suburb averages are graphed in figure 63:

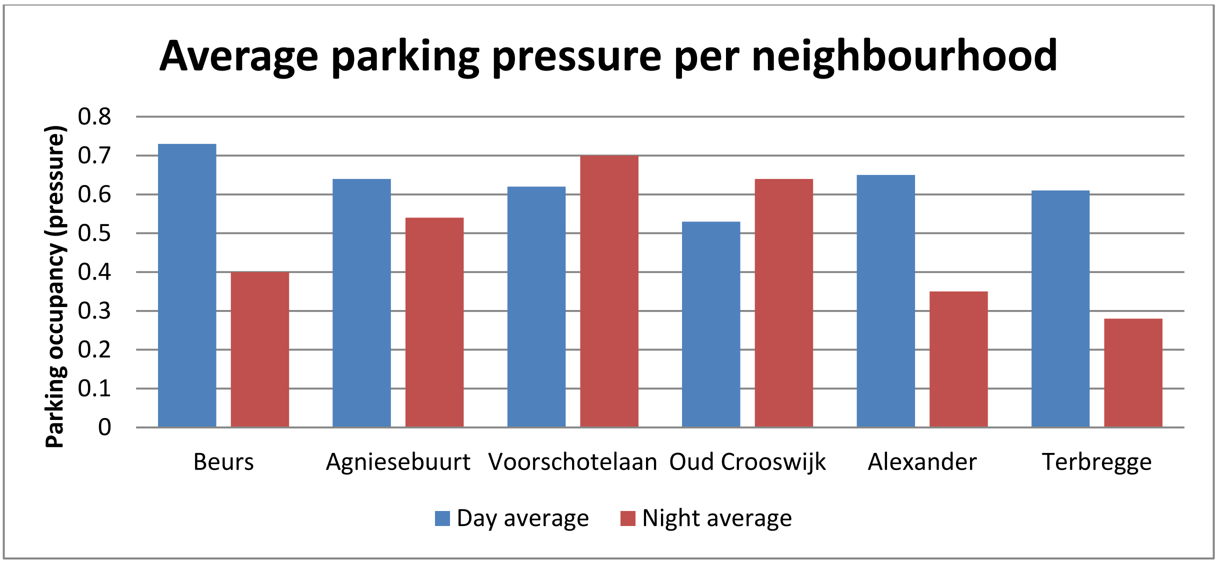


Figure 63: Average parking pressure for night-time and day-time across the six catchments.

The neighbourhoods of Voorschotelaan and Oud Crooswijk have the greatest parking pressure at night hours (6pm to 6am) and this could be due to having a large proportion of residential areas with low rates of off-street parking. In all other catchments, the day parking pressure was higher than the night parking pressure.

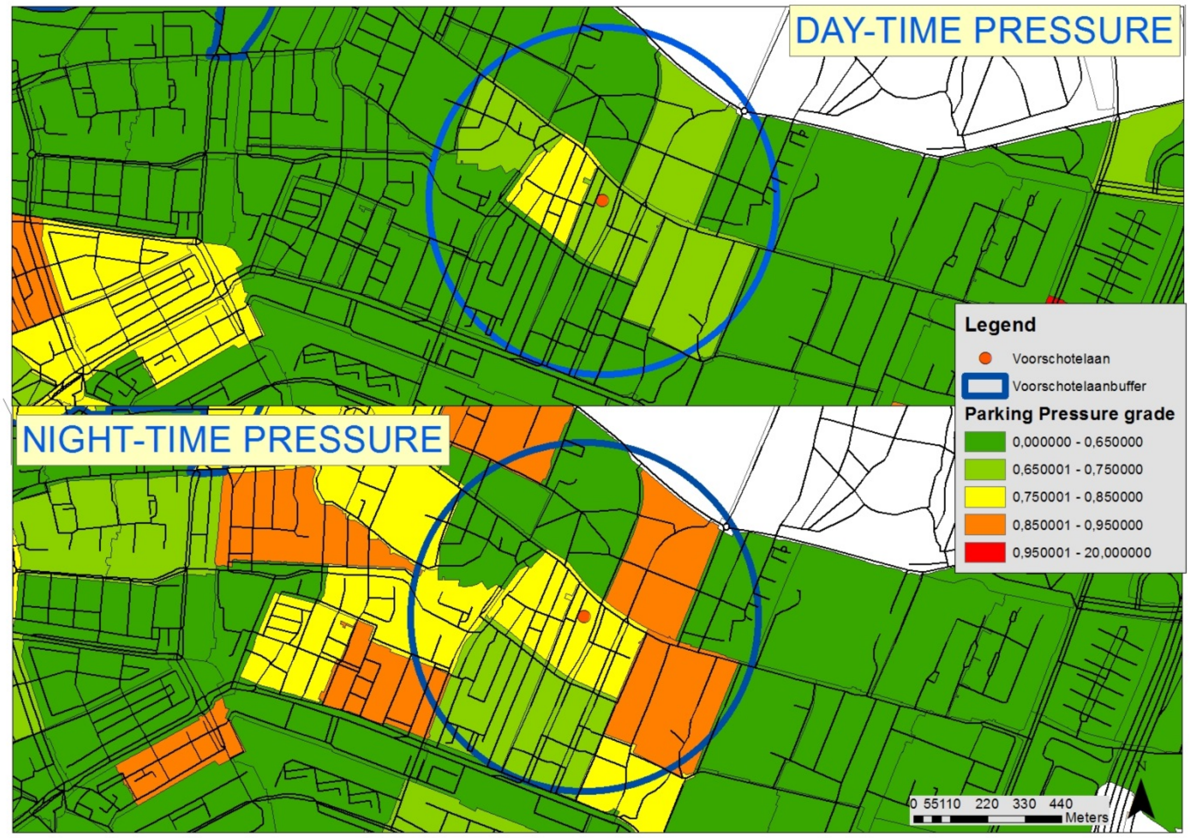


Figure 64: Parking pressure of the Voorschoterlaan catchment mapped at block level (data derived from G. Rotterdam, 2015).

This is the catchment of Voorschoterlaan (other examples are found in the appendix). The bottom map shows the night time on-street parking, which is under greater pressure. Parking pressure is not evenly distributed throughout Rotterdam.

Analysis

The results section is intended to paint a picture of the composition of car parking in Rotterdam and the approach of the municipality. The key points can be summarised as follows:

Research Question 1: Policy and pricing

- Municipal transport policy is focused on better use of existing public transport infrastructure, urban intensification and a few very specific projects for roads and some rail transport more generally.
- Minimum parking requirements (for private off-street parking) are considered a separate legislative requirement to transport policy and as such do not reference it (and vice-versa).
- The City Regional Plan emphasises an expanded (supply-led) road system but not the same for public transport; public transport will instead be 'consolidated' (to be made better use of) and enhanced, not expanded.
- The vast majority of current minimum parking requirements, if applied, would provide more private off-street parking spaces than exist now.
- Most catchments with high rates of private off-street parking also have low rates of night-time parking pressure, and vice-versa.
- On-street parking fees increase with closer proximity to the city centre (Stadscentrum), though the pattern is not entirely radial.
- Historical fee increases for parking permits have targeted commercial users, not residents. These permits have a flat rate across the entire city.

Research Question 2: Current state

- High urban density (residents/hectare) shows little relation to car parking densities in total, though catchments with large proportions of commercial zoning (e.g. Alexander) tend to also have high rates of off-street parking.
- There is no significant difference in either on- or off-street parking proportions with respect to proximity to a Metro station or distance from Stadscentrum.
- For two clusters of catchments (Beurs/Agniesebuurt and Voorschoterlaan/Oud Crooswijk), there was a statistically significant difference at the 0.05 level within each cluster's off-street parking ratios.

- No relationship was found between car parking garage capacity and fees.

These are all points of interest for further analysis.

Transport policy

The municipality's transport policy is characterised by a supply-led approach to road expansion alongside regulations concerning the quantity of private-off-street parking in newly-constructed dwellings (Gemeente, 2003; Gemeente, 2010) – the minimum parking requirements. There is also a renewed focus on Transit Oriented Developments (TODs) at certain nodes in the city, such as at Alexander.

The current transport strategy, released in 2003 with a vision until 2020, is likely not so relevant today, especially in light of sudden external factors like the Global Financial Crisis of 2008-2010 which have since changed the way planning is undertaken in the Netherlands (Gerrits et al., 2012). Since the crisis, institutions responsible for land use plans in the Netherlands have been trying to promote development and increase 'flexibility' with less regulation for new developments. This loosening of land use planning legislation has seen the government's role go from a proactive one to a passive one. Consequently, there is no explicit agenda that neither the municipality nor the province seeks to implement.

The subsequent direction posited by the Regional Implementation Agenda is of consolidation, rather than expansion, of public transport infrastructure but at the same time keeping options open on road expansion (Regional Implementation Agenda, 2011). At this rate, it would seem as though Rotterdam would not be offering a significant departure from its current trajectory of supply-led transport planning. There is no reference made to decreasing the mode share of cars, and instead it is suggested that P+R is the best way to attract greater patronage to public transport. This, it argues, is a compromise between encouraging public transport use and ensuring 'choice' and flexibility. No reference is made to the environmental impacts of their policies.

There is no mention of changing the minimum parking requirements in any strategy document from the municipality, from the Regional City body (Stadsregio) or from the province. As the results suggest, if today's minimum parking standards for residences were to be applied to existing housing stock, there would be a substantial increase in private off-street car parking and this would thus have an effect on mode share (Zhan, 2013). Much of Rotterdam's existing housing stock was built cheaply and to maximise space; this resulted in little to no private off-street parking for cars. The municipality's current focus, it would seem, is to push the responsibility of car parking provision to the developer, and have them enforced through the minimum parking requirements. This push would indeed free up road space for through-traffic, but as work by Zhan (2013a, 2013b) and Weinberger (2012) show, the certainty factor of having guaranteed private off-street car parking may contribute to greater car use and an increased net automobile mode share.

On-street parking fees

The distributions of on-street parking fees (displayed in the results section) confirm that the cost of on-street parking generally declines with distance from Stadscentrum. The Beurs catchment has the highest average fees while Terbregge visitors pay nothing for on-street car parking.

In the Alexander catchment, only 15% of the surveyed streets have fees for on-street car parking, which is notable given how the catchment itself is quite dense and is a major transport interchange with a P+R centre. Much of this is likely due to there being many roads without any on-street car-parking (e.g. Schorpioenstraat) and of the roads that do, many are in the low-density residential side streets where visitors are unlikely to park anyway and where most residents have parking permits. Alexander also has many public off-street parking garages which would likely divert drivers who would otherwise create capacity issues such as spillover and cruising. These public off-street parking garages help shift the burden away from street-capacity, thereby negating the need to raise on-street parking fees, in spite of the fact that few residents have their own private off-street parking.

There is extensive literature to show that usage fees are a moderator of demand for car parking (see for instance Shoup, 1999) and the policies of the municipality suggest this is also the case for Rotterdam. The graph of daily average parking fees to daily on-street parking pressure (per catchment; figure 32 & 33) shows that while the fees decrease the further one is away from Stadscentrum, the parking pressure remains relatively constant. This suggests that the fees are not proportionate and do not reflect the demand for on-street car parking in these catchments. As the parking pressure sits at around 60-70%, it is unlikely that further fee increases would be necessary to ensure a sufficient supply of car parking.

Residential parking permits also play a role. These are of a fixed rate (€5.50 per month or €66.00 per year) and do not vary with respect to location in Rotterdam. For residents, the prices have changed little over the last five years while commercial users have paid more over time; this signifies that the municipality is giving residents priority access to on-street parking. This subsidisation of residential parking is inconsistent with the night-time parking pressure rates (these are important as it is at night when most commuting automobile users need a place to park), which show that some catchments (such as Voorschoterlaan) have high parking pressure at night, while others don’t (Alexander, for instance). This is most likely due to there being a relatively high amount of private off-street parking facilities which helps shoulder some of the night-time parking burden from residents. For non-residents (those without a parking permit), parking at night-time is largely free across the entire city.

The municipality only releases parking permits to residents who do not have access to private off-street parking and as such the catchments with higher rates of private off-street parking probably need less in the way of pricing mechanisms to control parking pressure. However, the prices remain fixed, in spite of both parking pressure and off-street parking rates per catchment. This may present problems for catchments where night-time parking pressure is high and where houses have little private off-street parking. Permit grants are only limited by the amount of dwellings without private off-street parking and such households can request a second permit if need be (for an extra fee).

Figures 34 & 35 show the proportions of private off-street parking in terms of both night-time and day-time parking pressure. Here, it is clear that day parking pressure has no relationship to private off-street parking. But with night-time parking pressure, a relationship is visible. Where there is a high proportion of private off-street parking, there is a lower parking pressure rate for the night-time. This is likely due to 9-to-5 office commuters returning home and needing a place to store their vehicles overnight. Those catchments with higher rates of private off-street parking were able to reduce parking pressure from drivers that would otherwise find themselves competing for spaces on the street. The private off-street parking helps avoid spill-over and cruising.

If on-street parking were to be truly left to the market to set price and allocation of parking spaces, then we might expect fees to be fairly elastic; in other words, a rise in the hourly fee would result in a marked decline in demand and subsequent parking pressure. There is some evidence for this. Work by Kobus (2015) shows that on a per-hour basis, the price elasticity of on-street car parking is -5.5[2] in the Netherlands. This means that an increase in on-street parking prices would result in a sharp downward shift in demand for parking. His work also shows that drivers who wish to park for short periods of time are not fussed about paying premium fees but those who park for longer are. This has implications for the abandonment of parking permits and increases in parking fees: many drivers indeed will likely cease parking on the street and either switch to another mode, cut down on the amount of journeys or seek cheaper locations in which to park.

For commercial addresses (shops and offices), the need for on-street parking is likely to be overstated in Rotterdam. Work by Mingardo (2009) points to the fact that patronage of shops and businesses is not usually done with an automobile, with only 36% of customers driving in 2010. Moreover, higher fees for on-street parking had little to no effect on the patronage of shops; shoppers valued ambience and quality as being the primary reasons for choosing a particular business (Mingardo, 2009). Some studies show that higher parking fees near commercial zones results in an increase in turnover and, therefore, heightened patronage (Mingardo & Meerkerk, 2012). Observations of the Alexander catchment show that this is the case there; not every parking space is occupied, despite low fees. Nevertheless, no data exists to support the conclusion that business at the mall would decline from less car parking; indeed it appears there is low parking pressure in and around the Alexandrium shopping mall. This is an area for further investigation.

[2] Elasticity is a measure of how responsive one variable is to another in economics. In this case, the author measured how demand (from motorists) would respond to an increase on-street parking prices. The value of -5.5 indicates that on-street parking is highly elastic. There is a sharp decline in demand for parking with an increase in on-street parking fees.

Finally it must be noted that the methodology employed by the municipality in gathering parking pressure is not particularly credible. They take a 'snapshot' of parking pressure on one evening and one time in the day is a limited method to obtain data on parking pressure. It fails to capture the hourly variation that is critical to calculating parking pressure over time and overlooks the role of seasons in parking behaviour. Furthermore, much of the municipality's data is old, with the data on Terbregge from 1996 (a point in time when much of Terbregge was not even built yet). In this sense, interpreting the data on parking pressure must be done with caution.

Public off-street parking: fees, capacity and access

The results on publicly-accessible off-street parking (both private and municipal-run) are not very conclusive. The most obvious fact derived from the analysis was that garage fees (in Stadscentrum) tend to decline the further the garages are located from the centre (taken as Beursplein). This confirms the work of Arnotte and Rowse (2009), who show that parking spaces are typically priced on minimising walking distance (a higher price is paid for less walking distance). Some parking spaces charged up to €2 more per hour for the advantage of being on the doorstep of Beursplein. This gives an idea of the market 'price' of ten minutes of walking time.

Comparing publicly run and privately run garages, no differences in pricing were discernible for hourly or daily fee rates. The spread of daily fees of publicly-run garages (of which there are only six in Stadscentrum) appeared to mirror those of the privately-run garages better than they do mirror those of respective hourly fees, but the differences here are likely marginal. This shows one of two possible things: (1) that the publicly-run garage fees are set at the market price for public off-street parking spaces at that particular location (in terms of distance from Beursplein), or (2) the fees of the publicly-run public off-street parking garages are set reasonably low so as to force their private competitors' fees down. If all garages were suffering from a lack of patronage, it may suggest that their fees are too high to elicit sufficient demand for spaces.

In terms of fees and encouraging certain durations of parking, it is clear that the vast majority of the privately-run public off-street parking garages do not offer a discount or penalise users who stay for 1 hour versus those who stay for 5 hours. For the municipality-run ones, this is different. Those garages classed as 'A' types (close to Beursplein) encourage shorter stays and so a slightly higher fee per hour rate is charged past three hours. For those in type 'B' it is the opposite, with a cheaper per-hour rate for longer stays.

However, in terms of offering a discounted rate for a full day's parking (calculated as 12 hours), all the parking spaces in both Alexander and Stadscentrum (bar one) were consistent: it is cheaper on a per-hour basis to use the parking space for a day than to use it for, say, two hours. This shows that the certainty of having a paying customer throughout the day is important to the operators of these carparks. This is logical; operators whose parking spaces are underutilised would not be generating sufficient revenue. For consumers, having discounted day parking may encourage would-be drivers to drive into Stadscentrum and Alexander – which in turn may push up automobile mode share. Such drivers are likely not thinking about per hourly costs of car parking in this way.

Parking proportions

The results from the total car parking per hectare chart are surprising. It shows that car parking generally declines with increasing distance from Stadscentrum. This is likely related to the density of addresses; when there is greater density of addresses, there is also a greater density of car parking – a fact also observed by Manville et al. (2013). As a result, the catchment of Terbregge which lacks public transport connectivity is also a catchment which does not have extensive parking infrastructure.

Of the total parking per hectare, it is clear that the Alexander and Beurs catchments have the majority of their car parking in ‘garages’ (public off-street parking) with only a small proportion of on-street parking spaces. This is in contrast to Agniesebuurt, Voorschoterlaan and Oud Crooswijk where the vast majority of total car parking capacity is on the street. This presents a different dynamic to that of Alexander and Beurs. Residents in the latter catchments do not need to consciously think about where they are to park, an advantage which may lead them to drive more frequently. Those in Agniesebuurt, Voorschoterlaan and Oud Crooswijk would be inconvenienced in their search for car parking at peak times, by comparison.

With respect to the On-Street Parking Ratio (OSPR) and the Off-Street Parking Ratio (OFSPR) it is clear that Alexander has the highest OFSPR, followed closely by Terbregge and Beurs. These areas have large proportions of car parking, to the point where each address has up to four or five car parking spaces at its disposal. This may sound like an oversupply but such a conclusion must be stated with caution; some non-residential land uses (such as office blocks or warehousing, as is prevalent in Alexander) necessitate large off-street parking lots for their employees or contractors. Further evidence of this is found in the standard distribution of the ratio scores: Alexander has a large standard distribution which indicates that the range of scores varies considerably per street. This suggests vastly different demands of the different land uses, as mentioned earlier.

The charts of parking per household and population (figures 56 & 57) indicates that Alexander, and to a lesser extent Beurs, have more parking than is usually required for the residents. This is likely parking for visitors, such as what exists at the shopping mall in Alexander. Terbregge has one parking space per head of population (including those who cannot drive such as children) and as a result is likely to meet demand for households who only need one car. By contrast, Beurs has twice the amount of car parking per head of population, with Alexander having almost five times the amount of car parking per head of population. In this instance, it is clear that most of the car parking in Alexander is for visitors. So too, therefore, must most of the localised traffic congestion be brought about by visiting automobiles. Outside of commercial business hours (after 18:00 for the Alexandrium shopping mall, except on Friday nights where shopping hours are extended to 21:00), the existing large car capacity is likely underutilised and empty. This was also confirmed during the primary data-gathering day of Alexander; at 11:00am on a Thursday, most of the underground car parking spaces were unoccupied.

The correlation between automobile mode share and total car parking density gives a surprising result. Those areas with the highest density of car parking also had the highest rate of non-automobile mode share (i.e. public transport, cycling and walking). The negative correlation of -0.83 (statistically significant) and shows that the amount of car parking in total declines with increasing rates of car use by residents. What should be noted is that these figures refer to residents' preferences of mode use. Consequently, conclusions about car parking overlook for whom the parking is designated. Much of the parking in Beurs and Alexander is intended for visitors, not residents. This means that car use for non-residents is encouraged but remains discouraged for residents; those residents lacking in their own private off-street parking would instead need to hire a space by a private operator (this is likely to be expensive) or compete with non-residents for on-street parking spaces (albeit with a permit). This is consistent with the proximity a catchment like Beurs has to high quality public transport nodes; residents within the Beurs catchment are much less likely to need to drive given this provision of public transport. It is likely that some residents have car parking facilities that they don't really need.

Proximity to a Metro station

The results clearly indicate that there is no difference in the OSPR and OFSPR across all six catchments in terms of whether or not a Metro station is nearby. In fact, even within each cluster of the Metro/non-Metro group (e.g. Beurs/Agniesebuurt), only OFSPR for Alexander/Terbregge and Voorschoterlaan/Oud Crooswijk showed a significant difference. Both Voorschoterlaan and Alexander have a higher OFSPR than their non-Metro versions (Oud Crooswijk and Terbregge). It is not clear why this is the case though it is likely other factors such as higher average income may explain this difference; those neighbourhoods with higher incomes likely have residents who can afford bigger properties with private off-street parking. Nevertheless, it shows an inconsistency. These addresses, which are already in close proximity to a high quality public transport mode (the Metro), also have the luxury of having more off-street car parking even though they would logically need less. By virtue of the presence of the Metro stations, an argument about public transport not really working for residents and thus needing private off-street parking seems to reinforce the need to supply car parking facilities, even in locations where the quality of alternatives is high.

Discussion

What sorts of strategies, with respect to parking, can be used to generate further mode shifts to public transport? How to effect this mode shift is the intent of this thesis and a key question to consider in terms of parking management, and asks decision-makers to conceive of car parking facilities, not as an appendage of a building code or design of a street but rather as a significant part of the integration between land use and transport. As has been shown, car parking strongly influences mode share and travel behaviour. Yet it remains largely overlooked in Rotterdam.

How parking is framed by the municipality

When considering the way the municipality of Rotterdam frames minimum parking requirements, it is clear that the adopted philosophy is not only supply-led in nature, but also one lacking in policy ambition. In terms of Barter's (2014) terminology, it is a case of treating car parking as on-site infrastructure – something naturally needing to be provided. Conversely, the municipality's rationale with respect to transport, land-use and associated environmental impacts is one of flexibility and choice – opting for suggestive action and ensuring that any future program or project is in line with what is economically competitive; other bases for government programs or projects (such as environmental emission reduction) become of relatively little importance. This has been further compounded by cuts to funding for relevant projects.

For transport and land use strategies, the focus has gone from being visionary to being unambitious, except for 'economically important' projects. This 'hands off' approach means that coping with future challenges is left in the hands of individuals (Gerrits et al., 2012). The municipality uses the rhetoric of 'giving choices' (to commuters) as a way to put a positive spin on their lack of engagement with the issues and their continuation of policies that uphold the status quo. Leadership is now delegated to the citizens themselves.

This is disappointing. In the first instance, it may be obvious that 'choice' exists when it comes to mode share, but when one speaks of choice, rational decision-making is still often used. In this case, if the alternative to driving is substandard (as it so often is) then the commuter will opt to drive. By saying it comes down to 'choice', the municipality and province are conceding that they do not believe in one choice being objectively better than another and in doing so, ignoring the ramifications of the most popular choice for the commuter; this is often car use which has a negative environmental impact.

Inherent in this is a contradiction – the municipality claims it wants to be environmentally conscious yet delegates responsibility down to individual commuters. In terms of car parking, it goes to the opposite extreme by legislating how much car parking each dwelling is supposed to have, thereby promoting the role of the car further. This amounts to a legislated, supply-led provision of car parking and a demand-led provision of public transport and is one of the reasons why this thesis advocates for a demand-led provision of car parking where public transport is already in good supply.

The basis for minimum parking requirements

For Rotterdam residents, minimum parking requirements for residential dwellings are based on the notion of ‘useable floor space’ whereby the greater the floor-space, the larger the demands for car parking (regardless of the use of the space). There is likely a tenuous connection between floor space, the quantity of bedrooms and therefore potential drivers, but this ignores factors such as the size of homes, the size of households (which has been dwindling in recent years) and age groups. For non-residential buildings, there is an extensive list of off-street parking requirements with some ranging from 15 parking spaces per 100m of users space for cemeteries compared with 1 space per 2 rooms for hotels (Gemeente Rotterdam, 2010). The bases on which the minimum parking requirements are formed seem completely ad hoc and are not explained in any of the planning or strategy documents, a fact Shoup (1999) also noted in his study of parking requirements in California.

There is also another assumption of minimum parking requirements: that more car space is needed the further one is from the city (Stadscentrum). This upholds the idea that families would not want to live in the centre or that car use is ubiquitous in the outer suburbs (this seems to be the case) and by consequence, more car parking is needed to meet the need to store so many vehicles. Such statements seek to reinforce the need to have a car and to use it. This assumption in particular implies that public transport in the outer suburbs of Rotterdam is not to be improved and therefore residents should still utilise their cars to get around. This is problematic as it sidelines the responsibility of the province and municipality to provide public transport in the first case and normalises car dependence.

No silver bullet: Removal of minimum parking requirements and parking permits

There may be unexpected side-effects of removing minimum parking requirements. There does not appear to be any literature exploring the possible negative scenarios of the removal of minimum parking requirements, probably as few case studies actually exist. Nevertheless, it is a form of deregulation and may be exposed to ‘market distortions’.

An example of this might be an alliance between developers, or a monopoly of one, to provide parking at a certain location and charge higher than market fees. Competition in the market would hinge on there being a cost-effective and time-efficient way to construct a rival garage, within acceptable walking distance of the desired location, and to bid prices down thereafter – but this may be unrealistic given the large investment costs entailed. From the sample of twenty-two public off-street parking garages in Stadscentrum, there were only eight operators (including the municipality). From this, Qpark had the highest density of car parking spaces around Beursplein. If demand for parking in Stadscentrum was higher than it was presently, and potentially customers of the car parking garages were adverse to walking greater distances (and thus happy to pay premium for minimal walking distance), then it is likely Qpark could push their prices up even higher and dominate the market.

A lack of minimum parking requirements and parking permits will likely encounter political opposition too. A survey of Dutch motorists found that 86% of those surveyed would be against having to pay for parking on a per-hourly basis (Trends in Parkeren, 2014). Many motorists may feel such fee hikes are unreasonable, especially seeing as they obtain no great benefit personally and may just see it as an unnecessary increase in cost (Mingardo, 2009). There is no greater guarantee of a well-located parking spot nor is there necessarily going to be a substitute for driving developed within reasonable time after the fee increase, they might argue, and so a parking fee increase is manifestly unfair. A counter argument against this might like to highlight the 'hidden costs' of driving – such as damage done to the environment and localised air pollution – or to indicate exactly where the extra money in the municipality might go to in that area. If there is a clear explanation as to why the costs need to go up and *where* the money generated from this will be spent, then some commuters may eventually warm to the idea.

Another problem might be a conflict between the need for a car for work and the inability to pay for both the car and the separate car parking fee. There is already evidence that removing minimum parking requirements actually lowers the cost of housing, even by as much as 10% (Jia & Wachs, 1999 and McDonnell et al., 2010a), but this may not be factored into decisions about where to live by the commuter themselves. Further, the transition from the current minimum parking requirements approach to that of no minimum parking requirements may not elicit a strong enough response from the developers in order for the price of accommodation to drop. For developers this transition would signify a reduction in their costs but they may opt not to pass this saving on to their customers, the residents.

Finally there is the question of equity. If parking permits and minimum parking requirements are rolled back, there is a risk that lower-income residents will be 'priced out' of the neighbourhood by motorists with greater means and willingness to pay for the available on-street parking spaces. While it is true that by virtue of owning a car, the costs of living are much higher to begin with, additional fees from a lack of subsidies for parking facilities are likely to place further stress on low-income motorists. In turn, this may further entrench poverty, especially as some places of lower-income work are often located in areas (such as Rotterdam's harbour) where no good public transport exists. By contrast, residents with higher incomes tend to be less elastic to price increases (Hess, 2001) and subsequently may not alter their behaviour even after on-street parking fee hikes. This would severely limit the effectiveness of a minimum parking requirement and parking permit rollback.

A different set of minimum parking requirements?

Ultimately, if the municipality is to have a role in setting minimum parking requirements, then perhaps it should be designating specific amounts for specific demographics and in specific locations where public transport expansion is clearly non-viable. It is quite possible that there will not be enough incentives within the market to generate a rational and sustainable car parking capacity for an urban city. Thus, a government might rightly consider the basis for deciding how many car parking units a particular building should have based on a number of criteria. Such criteria would differ per land use scenario as well. Venues that attract temporary sudden influxes of people, such as sports stadiums, may benefit from a good public transport link and little parking considering the volume of people; some have suggested sports clubs might offer public transport tickets as part of their admission price to further encourage people to use public transport. For residential developments, the following criteria might help in forming a basis for how many car parking spaces are required:

- *The amount of people with a valid driving license per address*: This is a true reflection of who could potentially drive, and therefore the first step to gauging an indicator of demand. If a household contained three residents all of whom had licenses, then it may be appropriate for some provision of private off-street car parking. Residents may decide for themselves if a particular address is appropriate for them, given the parking availability allocated to that address.
- *Proximity to a high quality public transport mode*: This mirrors what has already been covered in this thesis. In terms of mode choice, both carrot (provision of a Metro station) and stick (cessation of private off-street parking requirements or subsidies) approaches are important for getting people to change their travel behaviour (Beiraro & Sarsfield Cabral, 2007).
- *Income of residents:* This could assist in determining if a family needs a car space (e.g. to get to work in a difficult-to-access location), but can’t afford one. If it were left to the market, an extra fee for the car parking may not be able to be paid by low-income residents, or the apartment/house + car parking bundle may be unaffordable.
- *Type of vehicle:* A specific type of vehicle such as a tradesman’s van that necessitates a private off-street parking spot could also be considered. In Rotterdam, some residents work in the shipping harbour where there is scant public transport. It is, in this case, perhaps unreasonable to build public transport infrastructure to the harbour.
- *Users of the vehicle:* Car-sharing is a growing urban phenomena and this presents new opportunities for the utilisation of car parking facilities. Whether or not a resident is subscribed to a car-sharing system is relevant to whether or not they need a designated private off-street car park. This already exists in Delft, where developers (in conversation with incoming residents) can choose to opt out of private off-street parking on the proviso that they also do not demand an on-street car parking permit (Nationaal Parkeercongres, 2010).

- *Emissions of the vehicle:* Another potential area to look at is the emissions output of the vehicle registered to the address in question. This frames the problem as one of 'what sorts of vehicles we should accept', rather than a question about congestion but here again, parking policy can be of assistance.

These are some factors that give a better indication as to whether or not a private off-street car parking space is required, rather than the simplistic 'users' floor space' currently employed.

An example is shown in figure 65. This is a house just near to Voorschoterlaan Metro station, in the heart of that eponymous catchment. As can be seen, the house is large at 197m^2 as its useable surface area, but it is also next to the Metro station. If this house were to be constructed at a time of no minimum parking requirements – hosting a young professional couple without children, for example – then the site developer would not likely automatically place private off-street car parking on site but rather have it as an additional fee for the couple to consider.

A developer is likely to respond to a historical willingness to pay and so we would expect to see dwellings aimed at middle to upper class residents include some quantity of private off-street parking as an option. These are the sorts of residents who may indeed opt for their own private off-street car parking space. In the case of the developer over-supplying this form of car parking, we would expect to see the car parking spaces sold to external parties. In this way, developers will be able to correct for over and under supply of private off-street car parking and the right balance can be struck.

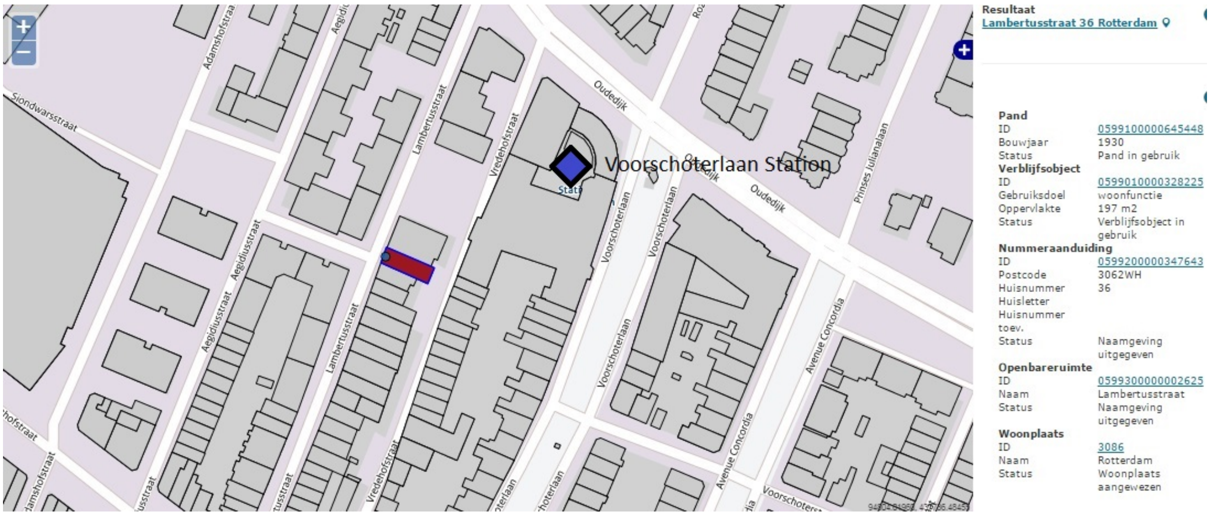


Figure 65: Hypothetical minimum parking requirement for this address, based on its immediate proximity to the Voorschoterlaan Metro station.

Changes to on-street parking use

While the removal of minimum parking requirements in buildings would likely help reduce the amount of private off-street parking, forcing residents to reconsider whether they need to use a car, this may have the unintended effect on on-street parking pressure and thus parking spillover and cruising. Under these circumstances, residents who would be parking their vehicles in their own private garages, off the street, would instead park them on the street and request a parking permit. This would be perfectly legitimate as all residents can request an on-street parking permit if they do not have access to private off-street parking on their property (Gemeente Rotterdam, 2015). This places the burden of car parking provision onto the street and, once more, demands subsidies of the municipality in the form of parking permits. It also disadvantages those who already have parking permits and makes no distinction on the basis of need or geographic location within Rotterdam.

From this it is clear that if minimum parking requirements are to be removed, then so too must on-street parking permits in their current form. Otherwise, the demand for car parking would simply shift to the on-street parking permits. At current prices, an on-street parking permit, no matter its location, would actually work out to be cheaper in terms of upfront costs (€5.50 for an on-street monthly permit compared to €26.55 for the shared-resident private parking garage). With greater on-street parking pressure brought about by less private off-street parking, the magnitude of spillover and cruising would likely increase in streets with newly-constructed dwellings.

In order for a situation of no on-street parking permits (or private off-street parking) to work, it is likely that the pricing of the on-street parking would have to be flexible to account for constant variation in parking demand. Currently, the municipality imposes only three different parking prices, gradations of which are too imprecise to capture the subtle differences in parking demand. A possible solution to this is to have multiple parking tariff zones such as that found in Amsterdam. Amsterdam has seven parking zones with different sub-zones for particular points in time or days where such fees apply (Gemeente Amsterdam, 2015). This is perhaps a good starting point for Rotterdam to plan from.

The aim of pricing car parking to maximise turnover may work in favour of fair distribution of the existing on-street parking resource but may also create localised congestion and an increase in emissions. Under circumstances when there are no parking permits, competition for available parking spaces would likely intensify and could result in more cruising as drivers search more intensively for scarce car parking spaces. The rate of turnover would also be higher – this would see many cars using the one space over a period of time (to keep costs down). This may, in turn, increase emissions output ‘per parking space’ as those who still wish to drive, despite the disincentive, try and minimise their parking costs. This may happen, in particular, at the start of a transition away from parking permits and minimum parking requirements; indeed it is this furtive hunting for car parking that may ultimately turn some people away from driving.

Park and Ride (P+R) – a compromise

The municipality of Rotterdam, supported by the province, believe that Park and Ride (P+R) facilities are a good measure to attract public transport commuters. The use of P+Rs to facilitate the use of public transport fits well with the aim of the municipality to 'inform' residents of the advantages and disadvantages of driving (parking costs, however, are not explicitly mentioned), rather than set in place policy barriers to car use (Regional Traffic and Transport Plan, 2003). P+R is offered as a compromise, but based on the precept that commuters still wish to use their vehicles.

Nonetheless, the effectiveness of P+R in Rotterdam has been called into question from analysis done by Mingardo (2013). The analysis involved surveying commuters on their travel preferences, and found three significant issues of note: (1) P+R induces commuters, who would otherwise walk or cycle to the station, to drive; (2) some residents simply use the parking spaces for their own uses, without using the public transport facility on site; and (3), P+R has the effect of increasing vehicle kilometres travelled – the car journey makes up the larger chunk of the overall journey pattern. A further reason of concern was that higher parking fees, which deter commuters using P+R for general parking, may lead commuters to simply deciding instead to drive all the way into work (especially if their work offers them designated off-street parking). P+R can also be seen as promoting land use patterns which favour cars – it enforces the need to drive as far as a certain point (the P+R location itself).

The P+R facilities around Rotterdam do have fees for general (non-public-transport related) parking which are set higher than the area average. This will likely discourage drivers who would otherwise use the facilities simply for parking. However, the other issues raised by Mingardo (2013) still stand. If P+R facilities are intended to attract commuters and visitors from locations where public transport is exiguous, a longer-term strategy may be to shape land-use patterns that are more conducive to public transport networks (Cevero, 2002). This perhaps should be part of a long-term goal of the province. If, on the other hand, the intention is to attract people to ailing public transport services where patronage is falling or at least not increasing, then the answer may lie in actually improving services or, as is already the case, focus on development intensification around certain railway stations. The P+R facilities are making the statement that, in order to use public transport, you must – in the first place – own a car and drive it to the public transport facility. This does not signify a significant mode share shift.

Mode share – the case of push and pull

The motivation to drive instead of catch a train, tram or bus suggests that public transport is not working for whom it is intended. This can be due to the routing of the service (e.g. the outer suburban bus services that take an indirect route because of the urban design of those neighbourhoods) or the preferences of the individual (see, for instance, de Witte et al., 2013). Nevertheless, the survey evidence from the municipality found that the top two reasons for not using public transport more often were costs (41% of responses) and changeover times, at 30% of responses (de Graaf, 2014). In other words, it is financially unviable for many and it takes too long (or feels like it does). For owners of a car, using public transport might feel more expensive than it actually is because of the bundled costs of parking. However, this is because the costs of car parking are not visible and are subsidised; proportionally, driving (including car parking) seems cheaper and provides certainty to the commuter. This will hopefully change once a demand-led approach to car parking is adopted. This is, in effect, the ‘push’ away from cars; in turn, a ‘pull’ towards public transport is needed.

If a shift in mode share to public transport accompanies increases in parking fees then it is likely that public transport operators will be able to put their increased revenue back into public transport services. In order for this to occur, public transport must be able to act as a viable substitute for the car – not as it currently now is (Alpkokin, 2012). This would involve a focus on the SNAMUTS approach of public transport, overlayed with attention to neighbourhoods that especially need public transport for equity reasons (where there are low-income people who need good quality public transport to access their work). Under these circumstances, public transport would be of such good quality (the ‘pull’ factor) that a mode shift transition could be effected and maintained (indicated by nominated mode choice and vehicle kilometres travelled).

Perhaps decision-makers can begin by scrutinising popular driving destinations. A paper by Walviuz et al. (2014), ‘Parking and Mobility Management’, introduces an interesting metric for measuring how popular a destination is by car: the car ratio. This metric looks at the amount of cars used per 100 employees at a specific destination and then gives it a score. The amount of people per car is important; if out of ten employees, three travel by car alone, four more in the one car and the remaining three by bicycle, then the car ratio would be 40% as four cars are involved. If destinations were to be assessed by the car ratio, a better picture of mobility needs in Rotterdam may emerge. An analysis of this level, however, may extend beyond the boundaries of the municipality of Rotterdam and could best be examined at a provincial level, or even national level, as was done in the past with the ABC locations index. With 73% of interviewed residents using a car to travel outside the municipal boundaries (de Graaf, 2014), it makes sense to examine this systematically and at an appropriate scale.

Conclusion and Recommendations

The policies of the municipality of Rotterdam and those of the province of South Holland are similar when it comes to transport and land use. Both emphasise consolidation of public transport networks, the expansion of some road projects and intensifying mixed-use development. None of them consider the merits of a shift in parking policy, however.

Parking in Rotterdam is found to be generally under-priced. This is especially the case for on-street parking with respect to parking permits and parking at night-time. During night-time, it is found that parking pressure is usually at its highest but on-street parking fees are at their lowest or simply do not exist. Catchments with large rates of private off-street parking had less intense night-time parking pressure. For public off-street parking (garages and parking lots), there was no observable difference between public and private facilities in terms of price, nor was there a difference in price in terms of capacity (how many parking spaces existed). Rather, these forms of off-street parking were priced with respect to distance from a popular destination – in this study of the neighbourhood Stadscentrum, the central location was Beursplein (the centre of the city of Rotterdam).

In terms of minimum parking requirements for new dwellings, the size of the apartment matters, with larger dwellings (or dwellings on a larger site) having more parking spaces required under the existing legislation. The legislation is not, however, fixed and is open to negotiation between developer and municipality. In general, the current minimum parking standards (established in 2010) exceed what exists currently in the present housing stock in many of the catchments in this research.

The municipality should consider abolishing these minimum parking requirements. By abandoning these minimum parking requirements one should expect to see a fall in quantities of private off-street car parking being built. There is evidence of this occurring in American cities already (Barter, 2014). Barter (2014, 2012) cites some Japanese case studies of cities, including Tokyo, where all drivers need to possess a ‘proof of parking’ card to demonstrate their ability to store their vehicles. Without this card, the vehicle is not registered.

If both minimum parking requirements and parking permits are to be scrapped then it is likely that fewer people will drive (Shoup, 2015). It would be difficult to find parking spaces due to the high pressure and those who choose private off-street parking would likely pay a large fee (one that was previously bundled with the costs of housing). Both of these are large deterrents which may effect a more permanent shift away from the automobile in the form of declining rates of automobile use. Those who grasp the true costs of parking may decide to abandon car ownership altogether.

In the current study, Rotterdam was found to have an uneven distribution of car parking capacity across six chosen sample ‘catchments’ in its metropolitan area. For both on-street and off-street parking, there was no pattern of distribution with respect to distance. Interestingly, Alexander and Beurs – two areas with good public transport connections – also held the most car parking spaces. For catchments with a Metro station compared to those without, there was no difference for on-street parking but differences were observed for all off-street catchments except those in the inner city (Beurs/Agniesebuurt) for off-street parking. Those catchments with the Metro stations had more private off-street parking than those without. Catchments with many non-residential land uses tended to host far greater amounts of private off-street parking too; again, Beurs and Alexander had the most, and indeed most of their parking was comprised of off-street varieties.

This thesis contends that, in light of the municipality's policy, the range of policy tools at their disposal and the reality of parking composition in the city of Rotterdam, significant changes are in order to tip the balance of mode share away from the automobile and reverse the growth in automobile use and ownership that has marked the last few decades in the Netherlands and Rotterdam in particular. It is hoped that with a shift away from supply-led solutions of providing roads to overcome the problems of traffic congestion, traffic congestion will lessen and public transport will regain greater mode share in Rotterdam. This will, in turn, realise a reduction in greenhouse gas emissions.

Recommendations:

This thesis attempts to inform decision-makers on a way forward to tackling traffic congestion and ensuring car parking policy is consistent.

Short term:

1. *Price on-street parking based on parking pressure more precisely*.

   There are currently three set price standards and these do not truly reflect the total amount of variation that exists (see, for instance, work done in San Francisco on this by Pierce & Shoup, 2013). Prices should be able to vary per hour, per day and per street depending on the parking pressure observed. Those streets with high rates of parking pressure would have higher fees. Other determinants of fee rates could relate to public transport facilities present nearby, the income of the owner of the vehicle (a fee based on ability to pay) or even the emissions of the vehicle itself. Under these circumstances, we may expect that the catchment of Stadscentrum will have substantially higher fees than that of Oud Crooswijk as the latter lacks both public transport and high rates of parking pressure (see figure 35).

2. *Price on-street parking throughout the 24-hour day*.

   As shown in the results section, night-time parking pressure is generally higher but most neighbourhoods in Rotterdam have no fees for on-street parking from 6pm to 12am and none exist between 12am and 6am (see figure 26 in the results section). This needs to be made consistent with the introduction of a fee in these timeframes to match the parking pressure in question. Catchments such as Agniesebuurt and Voorschoterlaan would be eligible for night time parking, as examples.

3. *Increase density around railway stations*.

This is already stated as an intention of both province and municipality, and would be especially useful in Alexander, replacing the overabundant car parking that exists around that interchange. In general, replacing car parking with spaces for living will accord with the standards of Transit Oriented Development and will likely induce a mode shift away from the car (Cevero, 2002).

4. *Restrict on-street parking permits to one per household, except under special circumstances*.

   The liberal use of parking permits means that households can get more than one parking permit. The second parking permit costs twice as much as the former and further parking permits also cost double. There should thus be an active restriction on how many parking permits one can own at any given time or, alternatively, they should be priced higher for each consecutive permit. At each subsequent permit request, the price can perhaps double. Special circumstances could be granted for those adversely affected by the increased costs.

Medium term:

1. *Establish regular monitoring of P+R vehicles*.

   This follows on from Mingardo's work (2013) and confirms that an optimum use of P+R has yet to be achieved in Rotterdam and the province more generally. Recently, fees have been introduced to P+R spaces, for both public transport users and general parkers alike (the latter having an extra surcharge). This is probably a good move, but so far little analysis exists on its long-term impact on mode share and driver behaviour. An analysis needs to be done on the impact the fees have and whether or not P+R are helpful at assisting a significant mode share shift to public transport.

2. *Set in place a land-use planning tool which makes explicit statements about the provision of public transport facilities with respect to new developments.*

   As revealed in the theoretical framework, much of Rotterdam's congestion is caused by vehicles from outside the municipality. Further, much of the way Rotterdam's housing stock has developed in the past has overlooked the role of public transport focusing exclusively on car parking (this too has not been organised – see figure 25). A new strategy needs to be developed at the provincial level at ensuring that there is a set guaranteed level of public transport provision accompanying new residential developments. At the street scale, urban designers should let a pre-decided range of OSPRs and OFSPRs inform their designs, based on the possible list of influencing factors mentioned in the discussion section.

3. *Commence a rollback of minimum parking requirements for commercial buildings*.

   Already the municipality is targeting non-residential users for on-street parking fee increases (see figure 29) and this takes the next logical step – private off-street parking. This also allows for the possibility of utilising underused commercial parking for residential uses (see point 4, long-term recommendations), an effective shift in the sharing of the car parking space burden.

4. *Lower minimum parking requirements for residential buildings*.

   A warning from Bos et al. (2014) suggests that developers may challenge municipalities over historical parking shortages in specific areas. Developers may demand that the municipality contribute to parking facilities where there has always been a shortage in parking. Having a gradual shift towards demand-led parking, as advocated throughout this thesis, is more appropriate to induce this shift and will likely cause less angst among the relevant stakeholders. There must also be a legal framework to absolve the municipality of responsibility for future private off-street parking shortages.

Long term:

1. *Eliminate all minimum parking requirements from the building code.*

   This would be the final step to realising a demand-led parking policy. It would finally accord with the ideas propositioned by Barter (2014). In having the developer decide how many parking spaces are needed, all factors considered, over-supply of parking will ultimately be avoided. It would contribute to the 'push' factor towards public transport. It would also have the effect of freeing up space that would otherwise be spent on car parking for residential uses. In turn, this can potentially drive down costs of construction, the benefits of which may be passed onto the residents themselves. There may be exceptions in some areas such as Terbregge, where it may not be possible to instate high quality public transport without radically changing its composition but where some houses already have high rates of private off-street car parking.

2. *Reduce the amount of allocated on-street parking permits so that they are intended only for those with a designated need for a vehicle (e.g. labourers).*

   This follows on from short-term recommendation no. 4. As shown earlier in figures 30 & 31, car parking is indeed subsidised for residents and this is likely to be very expensive for the municipality. The parking permits also fail to discriminate users on the basis of need (e.g. labourers with a van or residents who expressly need to use a car), making the only distinction between commercial and residential applicants of the permit. Parking permits should exist but their applicability would be assessed on merit and thus will not be open to everyone. A pricing mechanism sensitive to hourly parking pressure, proximity to public transport facilities and extant off-street parking is a better approach.

3. *Increase bus service frequency and ensure it times well with trains (as recommended by SNAMUTS).*

   This is to ensure the 'pull' factor of public transport is able to meet any incoming demand for it. It is also about ensuring that other modes of transport such as buses and trams are of comparable quality to that of the Metros and that they all link up in a high-frequency network, as per quality goals stipulated by SNAMUTS. In this case, all Metro stations would have 'turn up and go' frequencies (which make timetables redundant) at off-peak times as well as on-peak; buses and trams would have similar frequencies and be able to connect with all other public transport lines with minimal wait times. Intercity trains should also be of improved frequency – a significant impediment to greater patronage on those services (see theoretical framework section '*Rotterdam resident views*').

4. *Facilitate car-sharing and parking space programs so that those with surplus parking can benefit those with a need for extra capacity*.

   This follows on medium term recommendation no. 4 and is also a theme of Smart Options for Parking and Parking and Spatial Organisation (Parkeren and Ruimtelijke Ordening, 2014). Both reports argue that the municipality can act as a mediator between different land stakeholders in terms of parking. As the municipality has an overview of all the parking facilities in a certain area, this makes sense (provided that the municipality isn't actually supplying the infrastructure). This is manifestly the future of municipal governance as highlighted by Gerrits et al. (2012). The municipality will likely become less of an active supplier of parking infrastructure but rather a manager and mediator of those who do choose to supply it. For the catchments of Alexander and Beurs are such schemes are particularly helpful as they both have high rates of private off-street parking associated with office-buildings which are closed on the weekends and outside working hours.

These recommendations are intended to increase the mode share of public transport but would also likely increase the mode share of cyclists and pedestrians. In any event, it will most certainly make automobile use unattractive as a means to get around by reflecting the true costs of parking. For drivers too, pricing parking as suggested in this thesis will likely mean more efficient use of available parking spaces, especially for on-street parking where the current arrangements encourage parking for a longer duration at the expense of other drivers.

Rotterdam can and should change its parking policy for the betterment of its long-term future.

Glossary

Frequency: The amount of public transport units provided on a particular line or station per hour. E.g the Metro station Voorschoterlaan has a frequency of 12 trains per hour or every 5 minutes approximately.

Mode share: the percentage of total travellers using a specific vehicle of transport (mode) or the number of trips (or kilometres) undertaken in a specific mode against the total number of trips. E.g.34% of commuters travelling between home and the workplace use a private vehicle

On-street parking: parking that is located on or adjoining a road with no physical barrier to access

Off-street parking: parking that is located on private property or is otherwise inaccessible for general road users

Private off-street parking: parking that is owned and maintained exclusively by the resident or landlord and is for their use only. This can be a carport or a single-car garage with a driveway or a large office block with underground employee parking. This form of parking guarantees a parking space and often increases housing value.

Public municipal off-street parking: parking, typically a garage with a hourly fee, that is readily accessible to any driver (customer) who wishes to use the facility; for primarily *short-term parking* such as during shopping. This facility was built, is operated and maintained by the municipality (Gemeente Rotterdam) who set their own fees

Public privately-run off-street parking: parking, typically a garage with an hourly fee, that is readily accessible to any driver (customer) who wishes to use the facility; for primarily short-term parking such as during shopping. This facility is built, operated and run by a private company (such as QPark) and charges fees according to the market price of parking in such a location, with such facilities etc.

Public transport loadings: This is the quantity of people (commuters) using a particular public transport service or node (bus stop or Metro station as examples).

Residents parking garage: These are parking garages that are (usually, but not always) run by the municipality to cater for car-parking demands of residents in population-dense locations (e.g. Stadscentrum). Here, access is restricted exclusively to those residents who have a permit but specific parking spaces are not designated per access-holder.

Bibliography

Kruskal-Wallis H test using SPSS statistics. (2014). *Lund Research Limited*.

Basis Administratie Gebouwen. (2015). *Kadaster Online*.

Alpkokin, P. (2012). Historical and critical review of spatial and transport planning in the Netherlands. *Land Use Policy, 29*(3), 536-547. doi: http://dx.doi.org/10.1016/j.landusepol.2011.09.007

Anderson, S. P., & de Palma, A. (2004). The economics of pricing parking. *Journal of Urban Economics, 55*(1), 1-20. doi: http://dx.doi.org/10.1016/j.jue.2003.06.004

Arnott, R., De Palma, A., & Lindsey, R. (1991). A temporal and spatial equilibrium analysis of commuter parking. *Journal of public economics, 45*(3), 301-335.

Arnott, R., Inci, E., & Rowse, J. (2015). Downtown curbside parking capacity. *Journal of Urban Economics, 86*(0), 83-97. doi: http://dx.doi.org/10.1016/j.jue.2014.12.005

Arnott, R., & Rowse, J. (2009). Downtown parking in auto city. *Regional Science and Urban Economics, 39*(1), 1-14. doi: http://dx.doi.org/10.1016/j.regsciurbeco.2008.08.001

Auchincloss, A. H., Weinberger, R., Aytur, S., Namba, A., & Ricchezza, A. (2014). Public Parking Fees and Fines: A Survey of U.S. Cities. *Public Works Management & Policy*. doi: 10.1177/1087724x13514380

Banister, D. (2011). The trilogy of distance, speed and time. *Journal of Transport Geography, 19*(4), 950-959. doi: http://dx.doi.org/10.1016/j.jtrangeo.2010.12.004

Barr, L. (2000). Testing for the Significance of Induced Highway Travel Demand in Metropolitan Areas. *Transportation Research Record: Journal of the Transportation Research Board, 1706*(-1), 1-8. doi: 10.3141/1706-01

Barter, P. A. (2013). ADAPTIVE PARKING: A FLEXIBLE FRAMEWORK FOR PARKING REFORM.

Barter, P. A. (2014). A parking policy typology for clearer thinking on parking reform. *International Journal of Urban Sciences*, 1-21. doi: 10.1080/12265934.2014.927740

Beirão, G., & Sarsfield Cabral, J. A. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy, 14*(6), 478-489. doi: http://dx.doi.org/10.1016/j.tranpol.2007.04.009

Bertolini, L., le Clercq, F., & Kapoen, L. (2005). Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. *Transport Policy, 12*(3), 207-220.

Bogaerts, A., Dieleman, F., Dijst, M., & Geertman, S. (2007). Economic deconcentration in a rational planning system: The Dutch case *Employment Deconcentration in European Metropolitan Areas* (pp. 29-52): Springer.

Bos, E., Savooyen, E. v., Martens, S. M., & Graumans, E. (2014). Parkeren en Ruimtelijke Ordening: een wereld te winnen. *Kennisplatform CROW*(Beleidssteun).

Cao, J. (2014). Residential self-selection in the relationships between the built environment and travel behavior: Introduction to the special issue. *2014, 7*(3), 3. doi: 10.5198/jtlu.v7i3.726

Cervero, R. (2002). Built environments and mode choice: toward a normative framework. *Transportation Research Part D: Transport and Environment, 7*(4), 265-284. doi: http://dx.doi.org/10.1016/S1361-9209(01)00024-4

Cervero, R. (2002). Induced Travel Demand: Research Design, Empirical Evidence, and Normative Policies. *Journal of Planning Literature, 17*(1), 3-20. doi: 10.1177/088122017001001

Cervero, R., & Radisch, C. (1996). Travel choices in pedestrian versus automobile oriented neighborhoods. *Transport Policy, 3*(3), 127-141. doi: http://dx.doi.org/10.1016/0967-070X(96)00016-9

Chatman, D. G. (2014). Estimating the effect of land use and transportation planning on travel patterns: Three problems in controlling for residential self-selection. *2014, 7*(3), 10. doi: 10.5198/jtlu.v7i3.729

Cuenot, F., Fulton, L., & Staub, J. (2012). The prospect for modal shifts in passenger transport worldwide and impacts on energy use and CO2. *Energy Policy, 41*(0), 98-106. doi: http://dx.doi.org/10.1016/j.enpol.2010.07.017

Curtis, C., & Scheurer, J. (2010). Planning for sustainable accessibility: Developing tools to aid discussion and decision-making. *Progress in Planning, 74*(2), 53-106. doi: http://dx.doi.org/10.1016/j.progress.2010.05.001

Curtis, C., Scheurer, J., & Burke, M. I. (2010). *The Dead End of Demand Modelling: Supplying a futures-based public transport plan.* Paper presented at the 24th Association of European Schools of Planning (AESOP) Annual Conference.

Cutter, W. B., & Franco, S. F. (2012). Do parking requirements significantly increase the area dedicated to parking? A test of the effect of parking requirements values in Los Angeles County. *Transportation Research Part A: Policy and Practice, 46*(6), 901-925. doi: http://dx.doi.org/10.1016/j.tra.2012.02.012

de Graaf, A. (2014). Rotterdammers over het verkeer. *Onderzoek Business Intelligence unit, 4089a*.

De Graaf, A. (2014). Verplaatsingen in Rotterdam, stadsregio Rotterdam en Nederland. *Onderzoek Business Intelligence unit*.

De Vos, J. (2015). The influence of land use and mobility policy on travel behavior: A comparative case study of Flanders and the Netherlands. *2015*. doi: 10.5198/jtlu.v0i0.709

De Witte, A., Hollevoet, J., Dobruszkes, F., Hubert, M., & Macharis, C. (2013). Linking modal choice to motility: A comprehensive review. *Transportation Research Part A: Policy and Practice, 49*(0), 329-341. doi: http://dx.doi.org/10.1016/j.tra.2013.01.009

Deetman, S., Hof, A. F., Pfluger, B., van Vuuren, D. P., Girod, B., & van Ruijven, B. J. (2013). Deep greenhouse gas emission reductions in Europe: Exploring different options. *Energy Policy, 55*(0), 152-164. doi: http://dx.doi.org/10.1016/j.enpol.2012.11.047

Den Boer, E., van Essen, H., Brouwer, F., Pastori, E., & Moizo, A. (2011). Potential of modal shift to rail transport-Study on the projected effects on GHG emissions and transport volumes.

den Exter, R., Lenhart, J., & Kern, K. (2014). Governing climate change in Dutch cities: anchoring local climate strategies in organisation, policy and practical implementation. *Local Environment*, 1-19. doi: 10.1080/13549839.2014.892919

Dodson, J. (2010). In the Wrong Place at the Wrong Time? Assessing some Planning, Transport and Housing Market Limits to Urban Consolidation Policies. *Urban Policy and Research, 28*(4), 487-504. doi: 10.1080/08111146.2010.517158

Feng, J., Dijst, M., Prillwitz, J., & Wissink, B. (2013). Travel Time and Distance in International Perspective: A Comparison between Nanjing (China) and the Randstad (The Netherlands). *Urban Studies, 50*(14), 2993-3010. doi: 10.1177/0042098013482504

Frumkin, H. (2002). Urban sprawl and public health. *Public health reports, 117*(3), 201.

Gardner, B., & Abraham, C. (2008). Psychological correlates of car use: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*(4), 300-311. doi: http://dx.doi.org/10.1016/j.trf.2008.01.004

Gerrits, L., Rauws, W., & de Roo, G. (2012). Dutch spatial planning policies in transition. *Planning Theory & Practice, 13*(2), 336-341. doi: 10.1080/14649357.2012.669992

Gil, J., & Read, S. (2013). PATTERNS OF SUSTAINABLE MOBILITY AND THE STRUCTURE OF MODALITY IN THE RANDSTAD CITY-REGION.

Graham-Rowe, E., Skippon, S., Gardner, B., & Abraham, C. (2011). Can we reduce car use and, if so, how? A review of available evidence. *Transportation Research Part A: Policy and Practice, 45*(5), 401-418. doi: http://dx.doi.org/10.1016/j.tra.2011.02.001

Grimsrud, M., & El-Geneidy, A. (2014). Transit to eternal youth: lifecycle and generational trends in Greater Montreal public transport mode share. *Transportation, 41*(1), 1-19. doi: 10.1007/s11116-013-9454-9

Guo, Z. (2013). Does residential parking supply affect household car ownership? The case of New York City. *Journal of Transport Geography, 26*(0), 18-28. doi: http://dx.doi.org/10.1016/j.jtrangeo.2012.08.006

Guo, Z. (2013). Residential Street Parking and Car Ownership. *Journal of the American Planning Association, 79*(1), 32-48. doi: 10.1080/01944363.2013.790100

Guo, Z., & Xu, P. (2013). Duet of the Commons: The Impact of Street Cleaning on Car Usage in the New York City Area. *Journal of Planning Education and Research, 33*(1), 34-48. doi: 10.1177/0739456x12459360

H., v. d. L. (2014). The latent demand in road traffic *KiM Netherlands Institute for Transport Policy Analysis, English version*.

Hess, D. B. (2001). Effect of free parking on commuter mode choice: Evidence from travel diary data. *Transportation Research Record: Journal of the Transportation Research Board, 1753*(1), 35-42.

Hutton, B. (2013). *Planning sustainable transport*: Routledge.

Jakobsson, C., Fujii, S., & Gärling, T. (2000). Determinants of private car users' acceptance of road pricing. *Transport Policy, 7*(2), 153-158. doi: http://dx.doi.org/10.1016/S0967-070X(00)00005-6

Jia, W., & Wachs, M. (1999). Parking Requirements and Housing Affordability: Case Study of San Francisco. *Transportation Research Record: Journal of the Transportation Research Board, 1685*, 156-160. doi: doi:10.3141/1685-20

König, A., & Axhausen, K. W. (2002). *The reliability of the Transportation System and its influence on the Choice Behaviour.* Paper presented at the Swiss Transport Research Conference (STRC), Monte Verità/Ascona.
Kopnina, H., & Williams, M. (2012). Car attitudes in children from different socio-economic backgrounds in the Netherlands. *Transport Policy, 24*(0), 118-125. doi: http://dx.doi.org/10.1016/j.tranpol.2012.07.010
Liddle, B. (2013). Urban density and climate change: a STIRPAT analysis using city-level data. *Journal of Transport Geography, 28*(0), 22-29. doi: http://dx.doi.org/10.1016/j.jtrangeo.2012.10.010
Litman, T. (2006). *Parking management: strategies, evaluation and planning*: Victoria Transport Policy Inst.
Litman, T. (2014). The Mobility-Productivity Paradox: Exploring the Negative Relationships Between Mobility and Economic Productivity.
Madireddy, M., De Coensel, B., Can, A., Degraeuwe, B., Beusen, B., De Vlieger, I., & Botteldooren, D. (2011). Assessment of the impact of speed limit reduction and traffic signal coordination on vehicle emissions using an integrated approach. *Transportation Research Part D: Transport and Environment, 16*(7), 504-508.
Maibach, E., Steg, L., & Anable, J. (2009). Promoting physical activity and reducing climate change: Opportunities to replace short car trips with active transportation. *Preventive Medicine, 49*(4), 326-327. doi: http://dx.doi.org/10.1016/j.ypmed.2009.06.028
Manville, M., Beata, A., & Shoup, D. (2013). Turning housing into driving: Parking requirements and density in Los Angeles and New York. *Housing Policy Debate, 23*(2), 350-375.
Mashhoodi, B., & Berghauser Pont, M. (2011). *Studying land-use distribution and mixed-use patterns in relation to density, accessibility and urban form.* Paper presented at the ISUF 2011: 18th International seminar on urban form: Urban Morphology and the Post-Carbon City, Montreal, Canada, 26-29 August 2011.
MBW, K. (2015). Economic Studies on Public Facility use. *Tinbergen Institute Research*.
McCarthy, J. (1998). Reconstruction, regeneration and re-imaging: The case of Rotterdam. *Cities, 15*(5), 337-344. doi: http://dx.doi.org/10.1016/S0264-2751(98)00029-8
McDonnell, S., Madar, J., & Been, V. (2010). Minimum parking requirements and housing affordability in New York City. *Housing Policy Debate, 21*(1), 45-68. doi: 10.1080/10511482.2011.534386
McDonnell, S., Madar, J., & Been, V. (2010). *Minimum parking requirements, transit proximity and development in New York City.* Paper presented at the Proceedings 89th annual meeting of the Transportation Research Board.
Millard-Ball, A., Weinberger, R. R., & Hampshire, R. C. (2014). Is the curb 80% full or 20% empty? Assessing the impacts of San Francisco's parking pricing experiment. *Transportation Research Part A: Policy and Practice, 63*(0), 76-92. doi: http://dx.doi.org/10.1016/j.tra.2014.02.016
Mingardo, G. (2013). Transport and environmental effects of rail-based Park and Ride: evidence from the Netherlands. *Journal of Transport Geography, 30*(0), 7-16. doi: http://dx.doi.org/10.1016/j.jtrangeo.2013.02.004
Mingardo, G. (2013). Vervoer naar retail. *Kennisplatform CROW*(Beleidssteun).
Mingardo, G., & van Meerkerk, J. (2012). Is parking supply related to turnover of shopping areas? The case of the Netherlands. *Journal of Retailing and Consumer Services, 19*(2), 195-201. doi: http://dx.doi.org/10.1016/j.jretconser.2011.12.001
Mingardo, G., van Wee, B., & Rye, T. (2015). Urban parking policy in Europe: A conceptualization of past and possible future trends. *Transportation Research Part A: Policy and Practice, 74*, 268-281.
Mobiliteitsbeleid, K. I. v. (2011). Naar duurzaam wegverkeer in 2050. *KiM Netherlands Institute for Transport Policy Analysis*.
Mobiliteitsbeleid, K. I. v. (2012). Mobiliteitsbalans 2012. *Ministerie Infrastructuur en Millieu*.
Næss, P. (2009). Residential Self-Selection and Appropriate Control Variables in Land Use: Travel Studies. *Transport Reviews, 29*(3), 293-324. doi: 10.1080/01441640802710812
Naess, P. (2014). Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. *2014, 7*(3), 23. doi: 10.5198/jtlu.v7i3.491
Noland, R., & Hanson, C. (2013). How Does Induced Travel Affect Sustainable Transportation Policy? In J. Renne & B. Fields (Eds.), *Transport Beyond Oil* (pp. 70-85): Island Press/Center for Resource Economics.
Paans, J. (2012). Bijlage Bouwverordening Rotterdam 2010. *Raad van Gemeente Rotterdam*.
Passier, G., Driever, J., van Baalen, J., Foster, D., Kadijk, G., Verbeek, R., & en Waterstaat, O. M. v. V. (2008). Technologisch CO2-reductie potentieel voor transport in 2040. *TNO rapport MON-RPT-033-DTS-2008-02880. Delft*.
Pierce, G., & Shoup, D. (2013). Getting the prices right: an evaluation of pricing parking by demand in San Francisco. *Journal of the American Planning Association, 79*(1), 67-81.

Rabl, A., & de Nazelle, A. (2012). Benefits of shift from car to active transport. *Transport Policy, 19*(1), 121-131. doi: http://dx.doi.org/10.1016/j.tranpol.2011.09.008
Razin, E., Dijst, M. J., & Vazquez, C. I. (2007). *Employment deconcentration in European metropolitan areas: market forces versus planning regulations* (Vol. 91): Springer.
Reckien, D., Flacke, J., Dawson, R. J., Heidrich, O., Olazabal, M., Foley, A., . . . Pietrapertosa, F. (2014). Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Climatic Change, 122*(1-2), 331-340. doi: 10.1007/s10584-013-0989-8
Rietveld, P., & Daniel, V. (2004). Determinants of bicycle use: do municipal policies matter? *Transportation Research Part A: Policy and Practice, 38*(7), 531-550. doi: http://dx.doi.org/10.1016/j.tra.2004.05.003
Rotterdam, G. (2015). Parkeren in Rotterdam.
Rotterdam, S. (2003). Regionaal Verkeer en vervoerplan 2003-2020: beleidsvisie. *5e Nota*.
Rotterdam, S. (2003). Regionaals Verkeer en Vervoer Plan 2003-2020 toelichting. (5e Nota).
Rotterdam, S. (2011). Regionale Uitvoerings Agenda verkeer en vervoer 2011-2015

Sallis, J. F., Frank, L. D., Saelens, B. E., & Kraft, M. K. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. *Transportation Research Part A: Policy and Practice, 38*(4), 249-268. doi: http://dx.doi.org/10.1016/j.tra.2003.11.003
Schade, J., & Baum, M. (2007). Reactance or acceptance? Reactions towards the introduction of road pricing. *Transportation Research Part A: Policy and Practice, 41*(1), 41-48.
Scheiner, J. (2014). Residential self-selection in travel behavior: Towards an integration into mobility biographies. *2014, 7*(3), 14. doi: 10.5198/jtlu.v7i3.439
Schwanen, T., Dijst, M., & Dieleman, F. M. (2004). Policies for Urban Form and their Impact on Travel: The Netherlands Experience. *Urban Studies, 41*(3), 579-603. doi: 10.1080/0042098042000178690
Shoup, D. C. (1995). An opportunity to reduce minimum parking requirements. *Journal of the American Planning Association, 61*(1), 14-28.
Shoup, D. C. (1999). The trouble with minimum parking requirements. *Transportation Research Part A: Policy and Practice, 33*(7), 549-574.
Shoup, D. C., & Association, A. P. (2005). *The high cost of free parking* (Vol. 206): Planners Press Chicago.
SNAMUTS. (2015). SPATIAL NETWORK ANALYSIS FOR MULTI-MODAL URBAN TRANSPORT SYSTEMS.
Su, Q., & Zhou, L. (2012). Parking management, financial subsidies to alternatives to drive alone and commute mode choices in Seattle. *Regional Science and Urban Economics, 42*(1–2), 88-97. doi: http://dx.doi.org/10.1016/j.regsciurbeco.2011.07.002
Sweet, M. (2014). Traffic congestion's economic impacts: evidence from US metropolitan regions. *Urban Studies, 51*(10), 2088-2110.
Tarievenoverzicht. (2015). Tarivenoverzicht parkeren op straat 2015. *Gemeente Rotterdam Publicatie, 2015*.
Tasseron, G., Martens, C., & van der Heijden, R. (2014). De mogelijke impact van in-car informatie op stedelijk parkeergedrag.
Teodorović, D., & Lučić, P. (2006). Intelligent parking systems. *European Journal of Operational Research, 175*(3), 1666-1681. doi: http://dx.doi.org/10.1016/j.ejor.2005.02.033
Vale, D. S. (2013). Does commuting time tolerance impede sustainable urban mobility? Analysing the impacts on commuting behaviour as a result of workplace relocation to a mixed-use centre in Lisbon. *Journal of Transport Geography, 32*(0), 38-48. doi: http://dx.doi.org/10.1016/j.jtrangeo.2013.08.003
van Bemmel-Misrachi, R. (2014). Gemeente Rotterdam Internship - Accessibility and Mobility Indicators. *LUP Internship reports*(Own work).
Van de Coevering, P. (2008). *The future of residential parking in the Netherlands: The impact of increasing car ownership on the character of residential areas.* Paper presented at the EUROPEAN TRANSPORT CONFERENCE 2008; PROCEEDINGS.
van der Loop, H. (2014). De latente vraag in het wegverkeer. *KiM Netherlands Institute for Transport Policy Analysis*.
van Ommeren, J., Wentink, D., & Dekkers, J. (2011). The real price of parking policy. *Journal of Urban Economics, 70*(1), 25-31. doi: http://dx.doi.org/10.1016/j.jue.2011.02.001
van Ommeren, J. N., Wentink, D., & Rietveld, P. (2012). Empirical evidence on cruising for parking. *Transportation Research Part A: Policy and Practice, 46*(1), 123-130.
van Tilburg, W. (2014). Trends in Parkeren. *Kennisplatform CROW*(Verandingen in mobiliteit
).
Vigar, G. (2013). *The politics of mobility: Transport planning, the environment and public policy*: Routledge.

Walker, J. (2012). *Human Transit: How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives*: Island Press.
Walviuz, M., Hilckmann, B., & Bekhuis, F. (2014). Parkeren en Mobiliteitsmanagement: benut de kansen. *Kennisplatform CROW*.
Weinberger, R. (2012). Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive. *Transport Policy, 20*(0), 93-102. doi: http://dx.doi.org/10.1016/j.tranpol.2011.08.002
Willson, R. W. (1995). Suburban Parking Requirements: A Tacit Policy for Automobile Use and Sprawl. *Journal of the American Planning Association, 61*(1), 29-42. doi: 10.1080/01944369508975617

Appendix

Table of contents:

A) Full literature list of psychological and structural interventions in mode share

The work by Graham-Rowe et al. (2011) in scrutinising available literature on reducing car gives an overview, alongside a meta-analysis, of various studies into how car use can be reduced. An outline is given below:

Author & date	Methodological quality	Effectiveness of intervention	Intervention strategy
Jakobson et al. (2002)	High	Effective at reducing distance travelled for all 3 intervention arms but only effective for 2 intervention arms in regards to trip frequency reductions	Structural & psychological (economic disincentives & introduction of plan to reduce car use)
Foxx and Schaeffer (1981)	High	Not effective once the incentives had been removed	Structural (weekly lottery prizes & grand draws for participants whom had achieved set mileage reductions)
Tertoolen et al. (1998)	High	Not effective once within subjects characteristics were controlled	Psychological (information, feedback & commitment)
Foxx and Hake (1977)	High	Effective at reducing vehicle miles travelled	Structural (cash incentives for participants to achieved set mileage reductions)
Cervero (2002)	High	Not effective at reducing vehicle miles travelled daily but somewhat successful at reducing daily travel time in minutes	Structural (city CarShare scheme)
Mullins and Mullins (1995)	High	Effective at reducing	Structural (transferred worksites

		average commute distance (miles) travelled per work branch	closer to home or traded worksites)
Bamberg (2006)	High	Effective at reducing proportion of trip frequency taken by car	Structural (a free one day PT ticket & information for using the services for people who had just moved house)
Eriksson et al. (2008)	High	Specifically effective at reducing car as driver trips frequency or car as passenger trips frequency for those with strong car habit	Psychological (implementation intentions)
Fujii and Kitamura (2003)	High	Not effective	Structural (free bus ticket & information for using the services)
Garvill et al. (2003)	High	Effective at reducing frequency of car trips for those with strong car habit and to a lesser extent for those with weak car habit	Psychological (providing information to increase awareness of alternative modes for pre-planned trips)
Fujii and Taniguchi (2005)	High	Not effective at reducing total frequency of car trips regardless of trip length	Psychological (encouraged to make behavioural plans to modify car trip chains
Hodgson et al. (1998)	High	Not effective at reducing average numbers of trips per week in car	Psychological & structural (information provision plus bike & park-&-ride schemes, improved bus priority)
Anable et al. (2004) Gloucestershire – Personalised travel Planning	Medium	Successful at reducing car as driver mode share & to a lesser extent at reducing car as passenger mode share	Psychological (personalised Information provision, as well as materials & incentives)
Anable et al. (2004) Nottingham City Council– PTP	Medium	Successful at reducing% of miles driven by car also at reducing car driving trips & hours spent in car. (No results for control)	Psychological (personalised travel information)
Department for Transport (2007) Darlington- Sustainable travel town	Medium	Successful at reducing vehicle kilometre per private car/per day & trips in car as driver & passenger	Psychological (personalised travel advice, awareness raising, information & rewards)
Balepur et al. (1998)	Medium/low	Successful at reducing vehicle miles travelled but increased vehicle trips	Structural (Telecentre users)
Henderson and Mokhtarian (1996)	Medium/low	Successful at reducing vehicle miles travelled & trips taken in personal vehicle	Structural (Telecommuting)
Mokhtarian and Varma (1998)	Medium/low	Successful at reducing vehicle miles travelled & trips take per person per day	Structural (Telecommuting)
Shoup (1998)	Medium	Successful at reducing % of solo drivers, number of vehicle trips & vehicle miles travelled	Structural (cash alternative to parking subsidies)
Department for Transport (2005) Residential: Bracknell	Medium	Successful at reducing % of single car occupant mode choice. Car with or as passenger mode increased. (No results for control.)	Psychological (personalised travel advice, information & incentives)
Department for Transport	Medium	Successful at reducing	Psychological (personalised travel

(2005) Workplace: Bracknell		mode share from driving a car to work. (No results for control.)	advice, information & incentives)
Department for Transport (2007) Melbourne (Victoria, Australia) PTP	Medium	Successful at reducing drive alone mode choice	Psychological (Personalised & generic travel information)
Anable et al. (2004) Bristol City Council –Personalised travel Planning	Medium	Successful at reducing car as driver mode share & to a lesser extent at reducing car as passenger mode share	Psychological & structural (personalised information for those interested as well rewards & discounts. Public transport improvements in the area)
Department for Transport (2005) Workplace: Cambridge	Medium	Mixed results. Successful at reducing single occupancy car use mode choice at one of the two worksites	Psychological (offering new employees travel advice & guidance from travel planner)
Department for Transport (2005) Workplace: York	Medium	Successful at reducing mode share of car trips as driver & /or passenger mode. (No results given for control.)	Psychological & structural (personalised travel advice, information & incentives plus bus passes)
Department for Transport (2007) Worcester- Sustainable travel town	Medium	Successful at reducing frequency of car as driver mode. Somewhat successful at reducing car trips per person per year	Psychological & structural (information provision, awareness raising & rewards. Express bus services launched in the same area)
Miller and Everett (1982)	Medium	Mixed results across 15 worksites. Some decreased drive alone mode share & some increased it	Structural (parking price increased at the workplace)
Department for Transport (2007) Nottingham PTP pilot	Medium	Successful at reducing trips in car as driver mode choice & car as passenger mode choice	Psychological & structural (personalised information & incentives. Carried out in an area that was affected by a proposed bus service)
Department for Transport (2007) Peterborough- Sustainable travel town.	Medium	Successful at reducing trips in car as driver & trips in car as passenger (No raw data given for either group)	Psychological & Structural (Information provision, awareness raising, & rewards. Plus Major works undertaken on the town rail bridge)
Rose and Ampt (2001)	Low	Successful at reducing car-driver trips vehicle miles driven & total hours spent in car	Psychological (information provision & feedback)
Arentze and Borgers (2001)	Low	Successful at reducing total distance travelled in car & reducing car driver mode choice	Structural (new railway station)
Steininger et al. (1996)	Low	Successful only at reducing car mileage per person for car owning households	Structural (car-sharing organisation)
Kristensen and Marshall (1999) Parking Information System	Low	Successful at reducing vehicle kilometre per day & average trip length from gate at the outer perimeter of the city to parking locations	Structural (Telematics parking information system)
Ho and Stewart (1992)	Low	Successful at reducing vehicle miles travelled per week but not successful at reducing drive alone choice	Structural (reducing to a compressed 4 day work week)
Hamer et al. (1991)	Low	Successful at reducing car	Structural (working from home)

		distance travelled & trips taken	
Henry and Gordon (2003)	Low	Successful at reducing miles driven in car & somewhat successful at reducing trips taken in car	Structural (ozone alert day)
Mokhtarian (1988)	Low	Successful at reducing vehicle miles travelled per person to meeting but increased attendance therefore increased total miles driven amongst all those attending the meeting	Structural (two teleconferencing sites to replace one location for meeting)
Kristensen and Marshall (1999) Company Bike Scheme	Low	Successful at switching from car to company bike & reducing distance travelled	Structural (provision of company bikes)
Mehranian et al. (1987)	Low	A comparison of interventions. Suggest the elaborate intervention had an unwanted affect due to poor design	Structural (rideshare schemes & subsides)
Bamberg and Schmidt (2001)	Low	Successful at reducing car use from home to university in the mornings	Structural (introduction of a 'semester ticket' which subsidies public transport for students)
Giuliano and Hwanc (1993)	Low	Successful at reducing drive alone mode choice & increasing car-pool mode choice	Structural (a regulation that requires employers to implement a commuter trip reduction programme)
Johnstone et al. (1983)	Low	Successful at increasing car share to work, however there were some unwanted affects of the scheme	Structural (carless day scheme – private motorist select a day of the week when it was illegal to use their car)
Rose (2008)	Low	Successful at reducing car single car driver mode & increased car pool/sharing	Psychological (both generic & tailored information provision)
Zvonkovic (2001)	Low	Successful at reducing drive alone mode choice & increasing carpooling mode choice	Psychological (education & rewards plus free bus passes)
Rea and Ryan (2007)	Low	Successful at reducing drive alone mode choice & increasing car-pool mode choice	Structural (discounted transit passes & car-sharing privileges)
Anable et al. (2004) Buckinghamshire County Council – Car Sharing Scheme	Low	Successful at reducing car as driver mode share	Structural (carshare scheme)
Anable et al. (2004) Buckinghamshire County Council – Workplace travel plans	Low	Successful at reducing car as driver mode choice & a slight increase in car as passenger mode choice	Structural (discounts for staff on public transport)
Anable et al. (2004) Merseyside TravelWise: Workplace travel plans	Low	Successful at reducing single occupancy vehicle driving mode for St Helen's College study	Structural (improved car park restrictions & entry systems, free bus passes in exchange for car park pass, cycle facilities & transport advice)
Anable et al. (2004) York: Workplace travel plans	Low	Successful at reducing single occupancy & shared car mode choice for local government ombudsman employees	Unknown
Department for Transport	Low	Successful at reducing car	Psychological (personalised travel

(2007) Brisbane (Queensland) PTP		as driver mode choice	Information provision as well as rewards & gifts)
Steer Davies Gleeve (2004)	Low	Successful at reducing % of car use in 3 of the schools it was trialled in	Structural (provision of a yellow school bus)
Rye and McGuigan (2000)	Low	Successful at reducing the proportion of people driving to work alone	Structural & psychological (carpool matching, preferential parking for car-poolers, reductions in PT costs, & travel information)
Department for Planning and Infrastructure (2001) City of Perth	Low	Successful at reducing car as driver mode choice	Psychological (wide range of tailored information on alternative transport)
Shaheen et al. (2000)	Low	Successful at reducing commute personal vehicle mode choice & a increase in car-pool mode choice	Structural (car-sharing system)
Anable et al. (2004) Merseyside: School travel plans	Low	Successful at reducing total car use to school in most schools	Unclear (schools tailored their plans to their specific situation)
Department for Transport (2005) Knaresbourgh School Travel Plans	Low	Successful at reducing single occupancy car mode choice but results may be overstated	Psychological (tailored travel information plus journey plans, & incentives)
Department for Transport (2005) Winchester: Workplaces	Low	Successful at reducing single occupancy car use choice but results may be overstated	Psychological (tailored travel information & journey plans, incentives, e.g. free bus/train tickets & bike accessories)
Department for Transport (2005) Worcester: Workplaces	Low	Unsuccessful at reducing single occupancy car use & increasing car as passenger mode choice	Psychological (tailored travel advice, information & incentives)
Department for Transport (2005) West Sussex: Schools	Low	Wide variation in the effectiveness across schools but overall somewhat successful at decreasing single occupancy car mode choice	Unknown
Department for Transport (2005) Oldham: Workplaces	Low	Unsuccessful at reducing single occupancy car use choice	Psychological (tailored travel advice, information. Journey planning, incentives & discounts)
Department for Transport (2005) Durham: Workplaces	Low	Generally successful in reducing single occupancy car use & somewhat successful at reducing car with or as passenger mode choice	Psychological (tailored travel advice, information, incentives & discounts)
Anable et al. (2004) Birmingham City Council– Workplace travel plans	Low	Mixed results. Some workplaces reduce car as driver mode share & others increased it	Psychological & structural (tailored travel advice & information. Incentives such as discounts on PT, season tickets, equipment & resources)
Baudains et al. (2002)	Low	Successful at reducing single occupancy vehicle trips across the three interventions	Psychological & structural (various type of information, One groups had an environmental leadership & another a steering committee)
Cooper (2007)	Low	Successful at reducing single occupancy vehicle mode choice & increasing car-pool mode choice	Psychological (targeted messages & personalised information provision. Commitment)
Anable et al. (2004) Nottingham City Council- Workplace travel plans	Low	Successful at reducing solo car driving choice & at increasing car sharing	Structural (entered into a section agreement. Strategies unknown)

		mode choice at Nottingham City Hospital & the Government Office	
Anable et al. (2004) Cambridgeshire County Council- Workplace travel plans	Low	A range of results & success. For seven examples given it shows success at reducing car use for commuters	Unknown
Anable et al. (2004) City of York: Travel awareness marketing & campaigns	Low	Successful at vehicle reduction to & from city centre	Psychological (awareness raising)
Anable et al. (2004) Buckinghamshire County Council: School travel plans	Low	Successful at reducing car mode choice for journeys to school	Structural & psychological (incentive schemes, walking bus, permit schemes, education & awareness raising)
Anable et al. (2004) City of York: School travel plans	Low	Unsuccessful at reducing car use to school	Unknown
Olsson and Miller (1978)	Low	Somewhat successful at increasing carpool users	Structural (parking discounts & carpool formation)
Alcott and DedCindis (1991)	Low	Successful at reducing car alone mode choice & somewhat successful at increasing car-pool mode choice	Psychological (education & awareness raising)
Kristensen and Marshall (1999) Bus service improvements	Low	Successful at shifting from car to City bus	Structural (bus service improvements)
Weisbrod (1982)	Low	Successful at reducing proportion of trips coming into downtown crossing area	Structural (automobile-restricted zone)
Meland (1995)	Low	Not successful at reducing car-driver trips inbound through the toll ring	Structural (electronic toll ring)
Watson and Holland (1978)	Low	Successful at reducing car as driver & car as passenger trips & increasing carpool trips	Structural (area licence scheme – pay to drive into designated restricted zone during certain hours)
APEIS (2004)	Low	Successful at reducing trips by owner driven car	Psychological (education programmes plus travel diaries & feedback)
Department for Transport (2007) Brighton & Hove PTP scheme	Low	Successful at reducing car driver tips & car mode share choice	Psychological (personalised travel information & incentives)

B) Parking zone maps, the municipality of Rotterdam

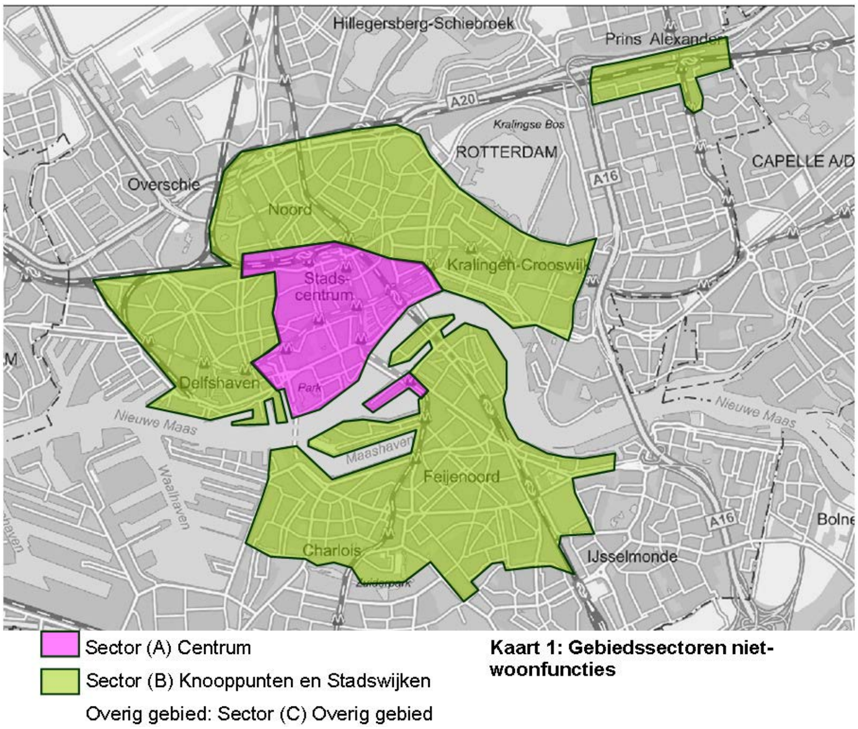


Figure 66: The two primary, non-residential, car parking zones in Rotterdam (G. Rotterdam, 2010). As can be seen, there are three zones: A (yellow zone), B (purple zone) and C (all other areas).

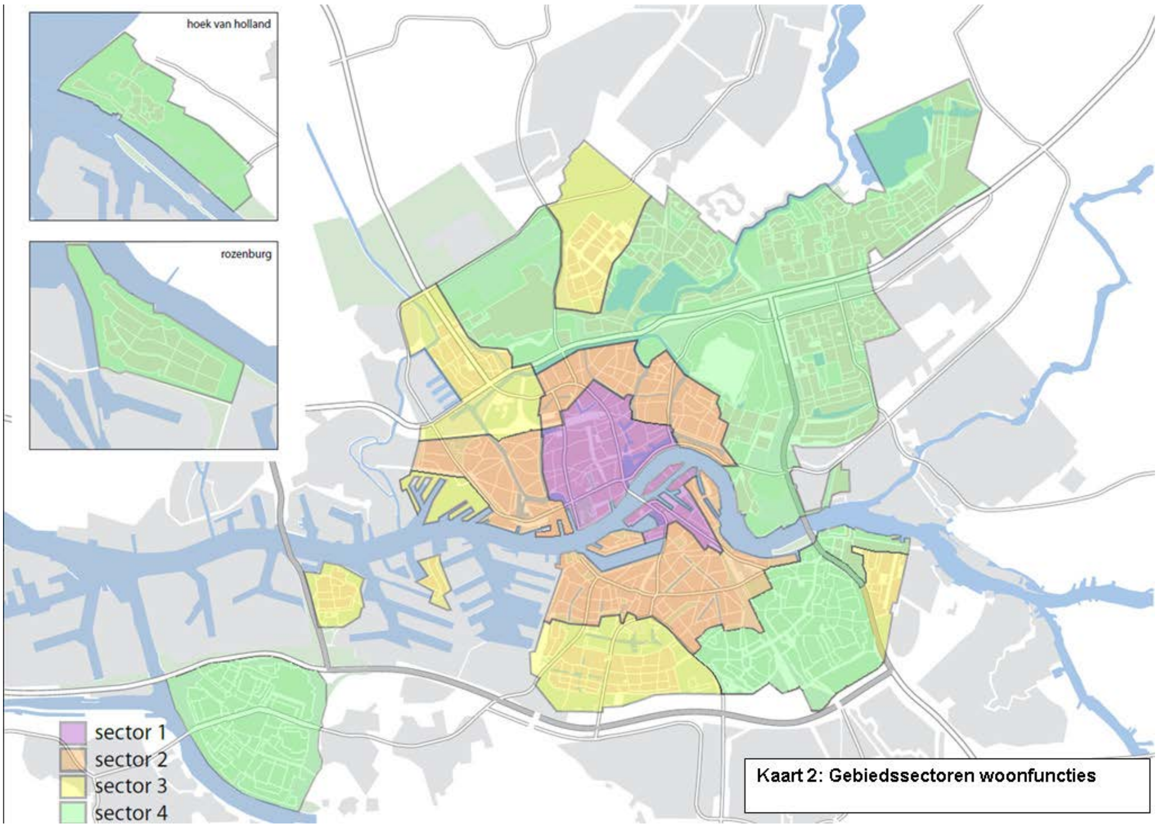
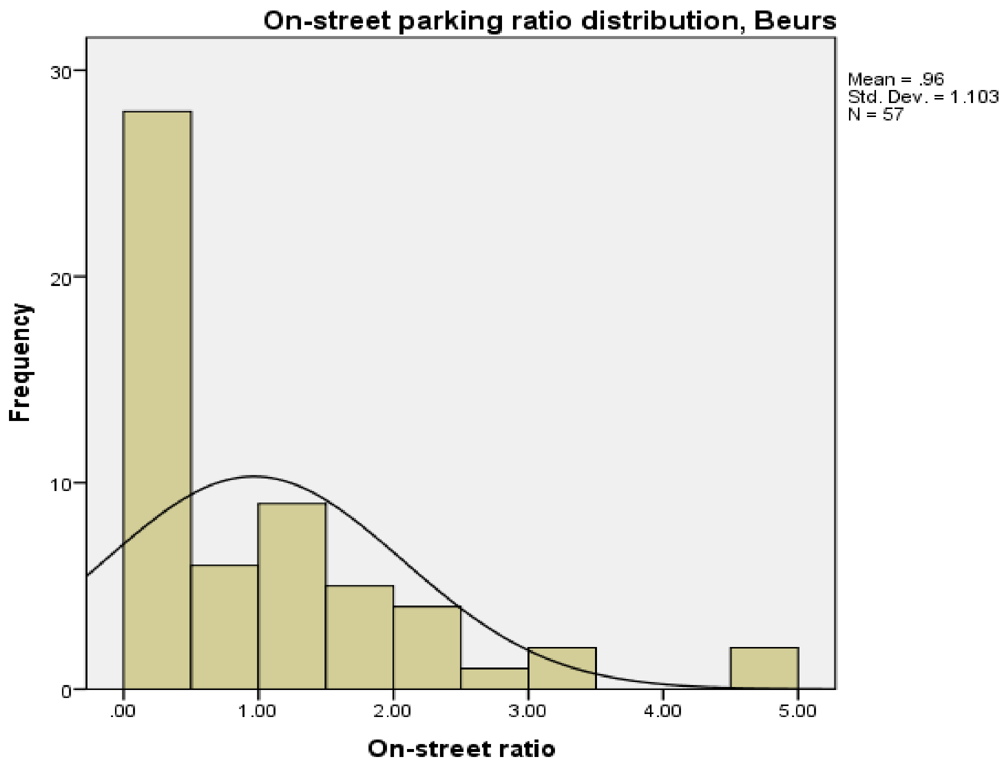
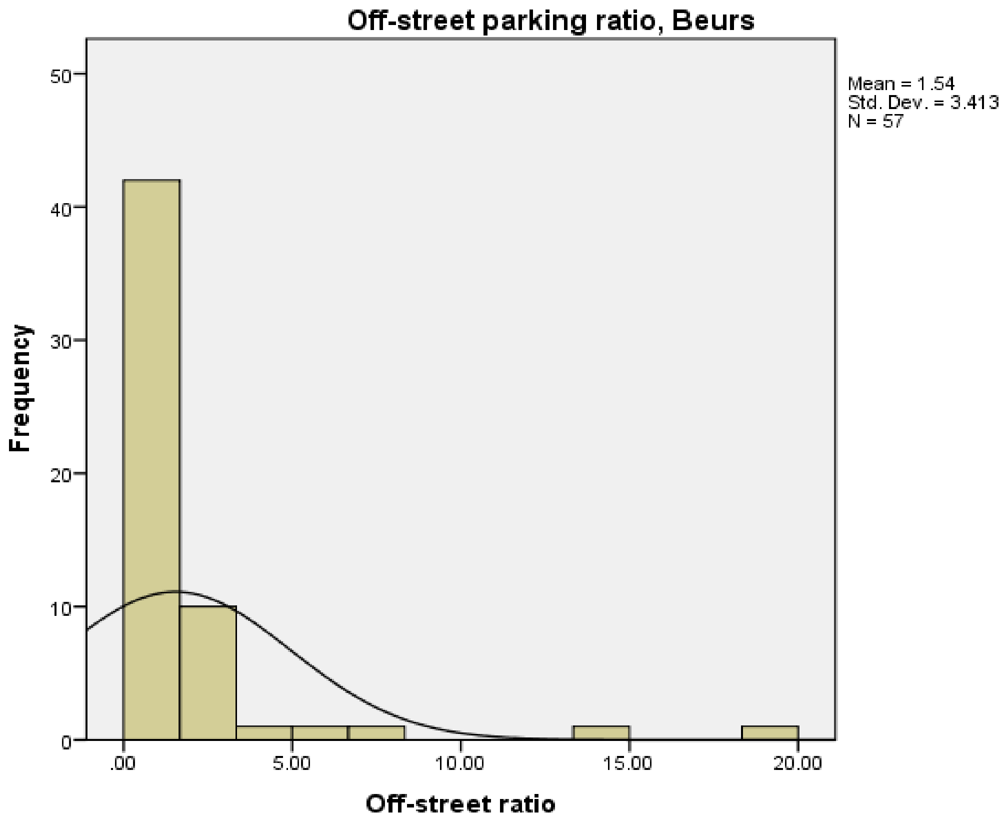


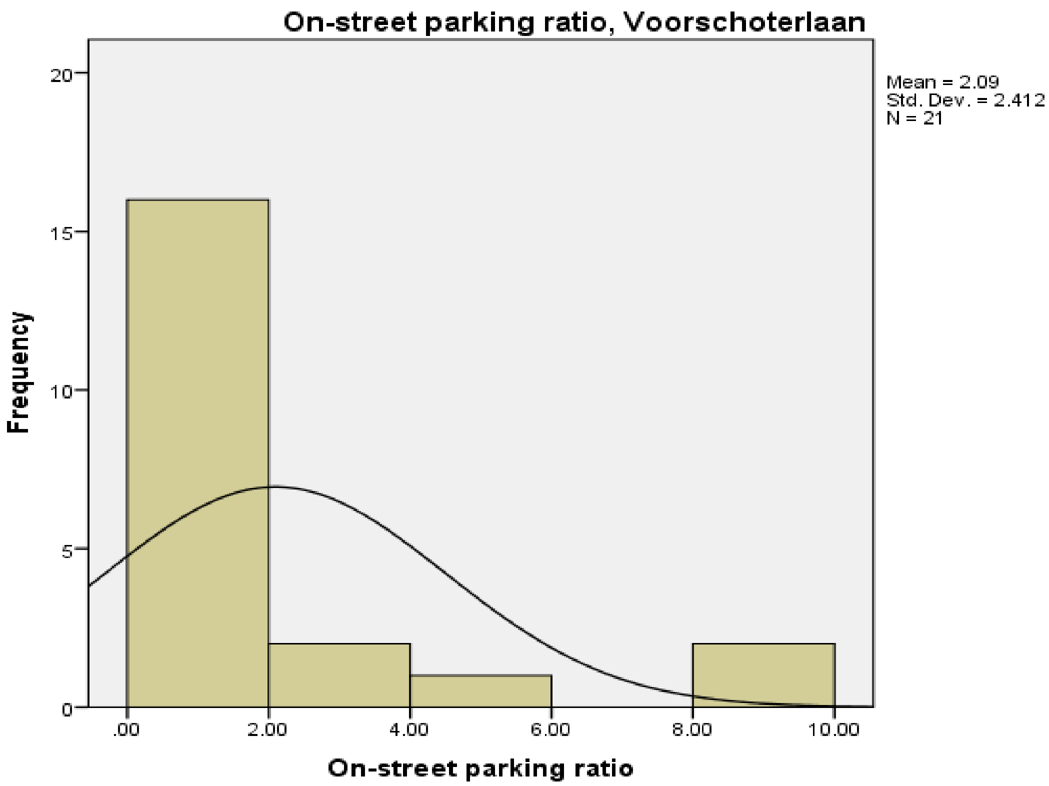
Figure 67: The four parking sectors which apply to residential buildings. Each has its own minimum parking requirements.

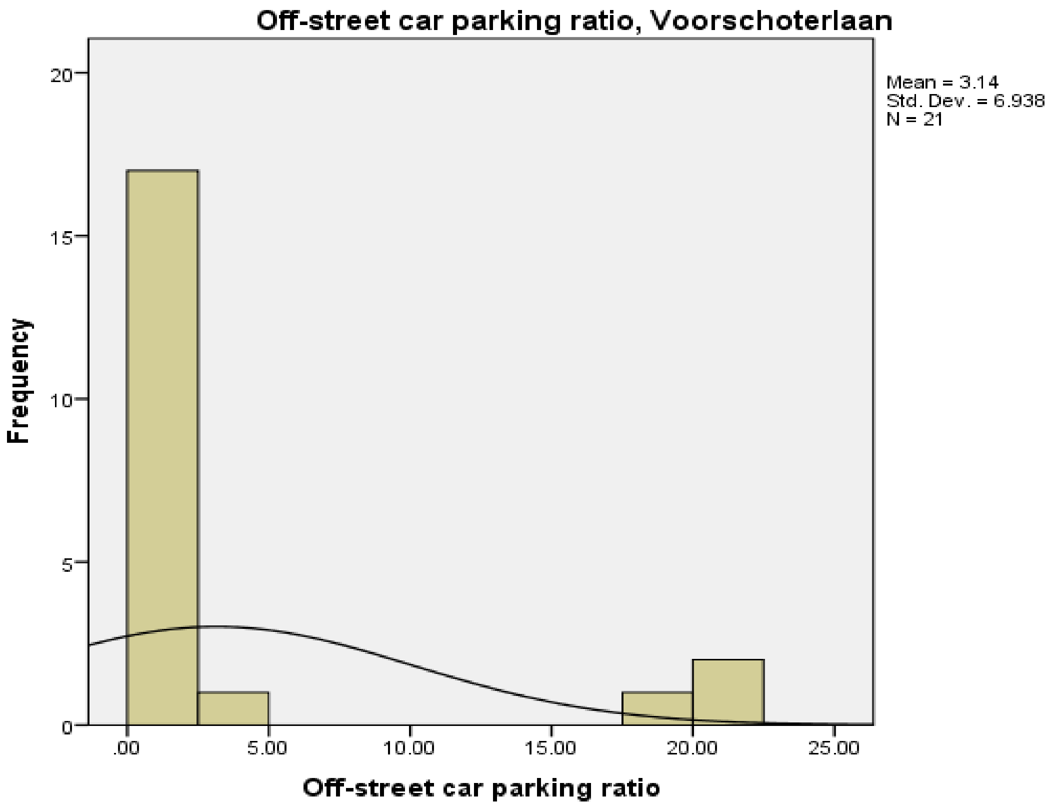
C) SPSS output charts of OSPR and OFSPR

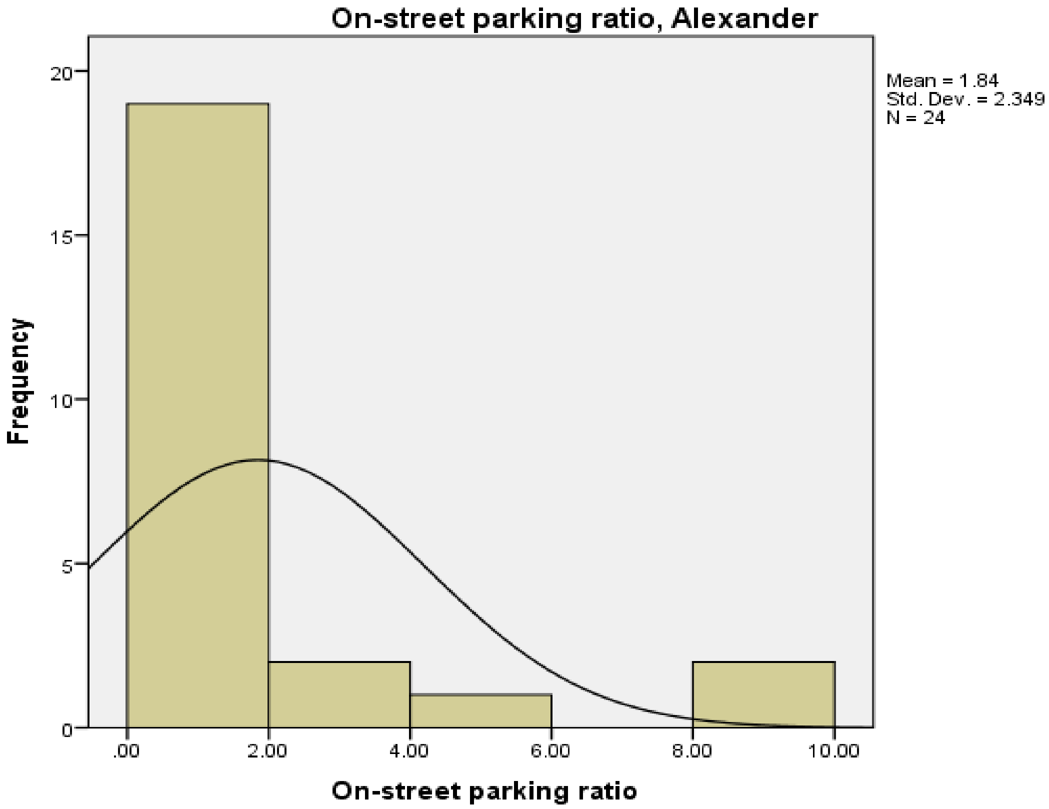
The distributions of the on-street and off-street car parking ratios (OSPR and OFSPR respectively) are as follows:



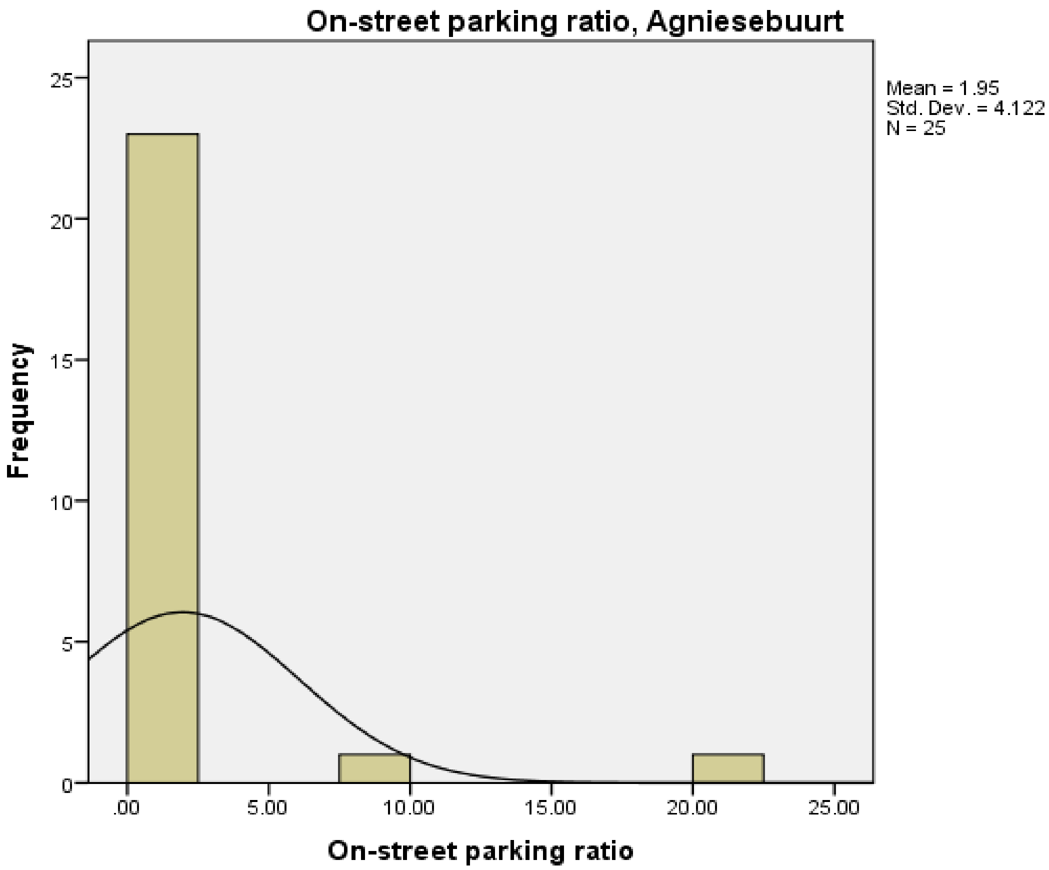



On-street parking ratio, Voorschoterlaan
Mean = 2.09
Std. Dev. = 2.412
N = 21
Frequency
On-street parking ratio
20
15
10
5
0
.00
2.00
4.00
6.00
8.00
10.00

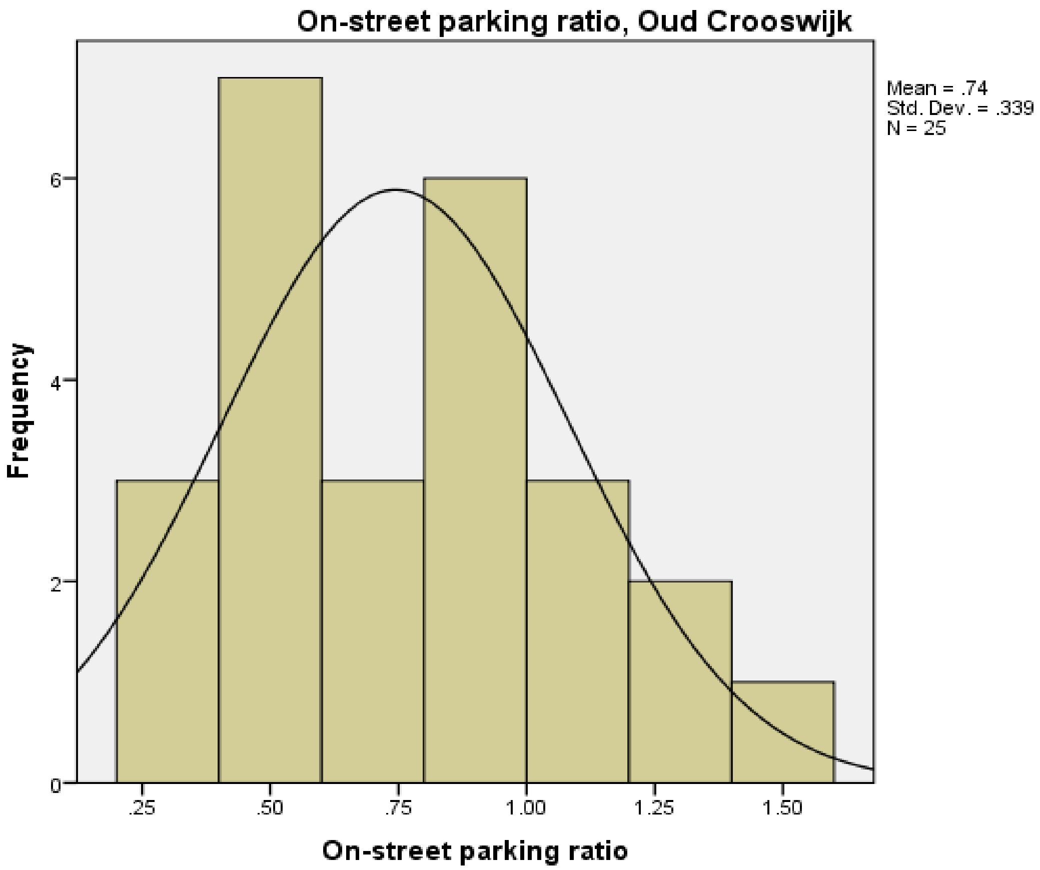

Off-street car parking ratio, Voorschoterlaan
Mean = 3.14
Std. Dev. = 6.938
N = 21
Frequency
Off-street car parking ratio
20
15
10
5
0
.00
5.00
10.00
15.00
20.00
25.00

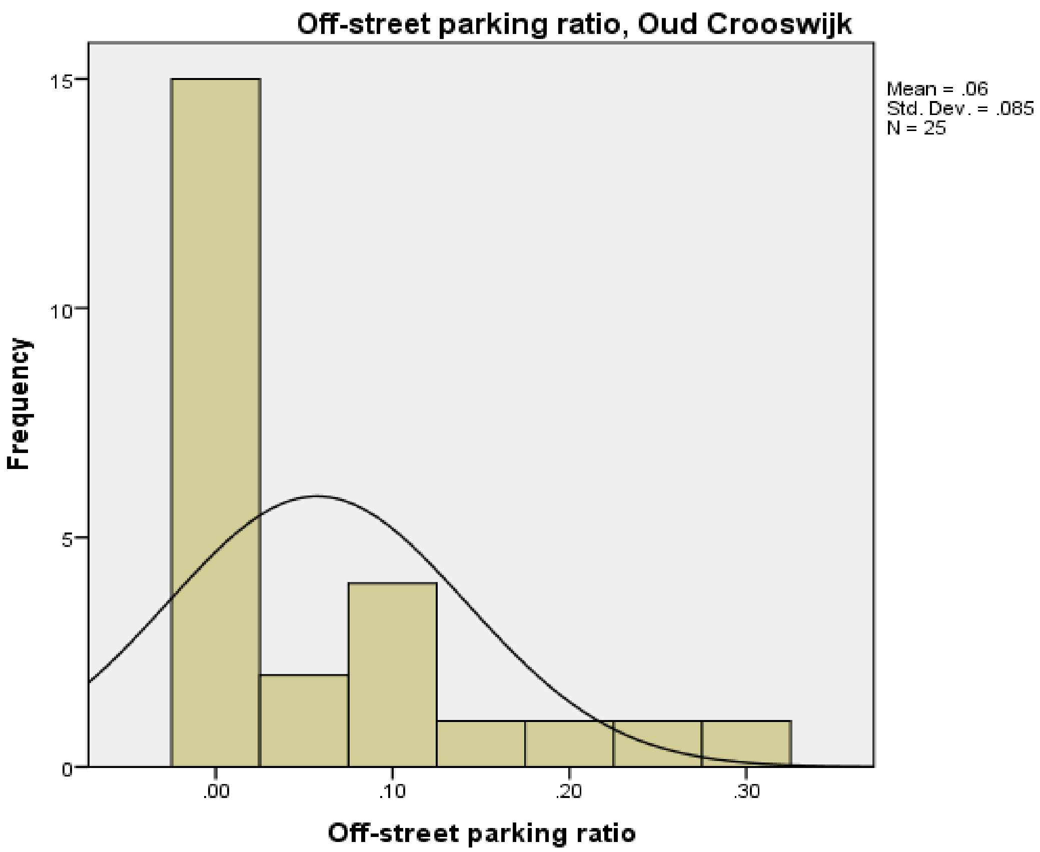

On-street parking ratio, Alexander
Mean = 1.84
Std. Dev. = 2.349
N = 24
Frequency
0
5
10
15
20
.00
2.00
4.00
6.00
8.00
10.00
On-street parking ratio

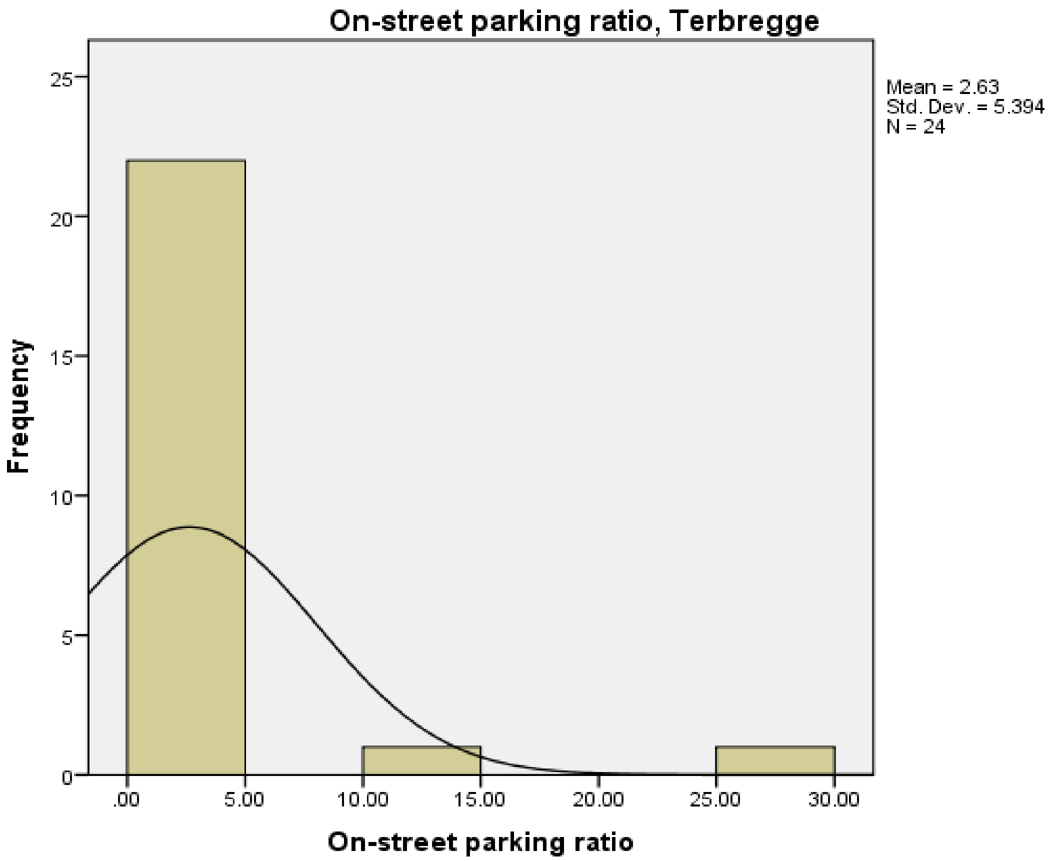

Off-street parking ratio, Alexander
Mean = 3.46
Std. Dev. = 6.568
N = 24
Frequency
0
5
10
15
20
.00
5.00
10.00
15.00
20.00
25.00
Off-street parking ratio

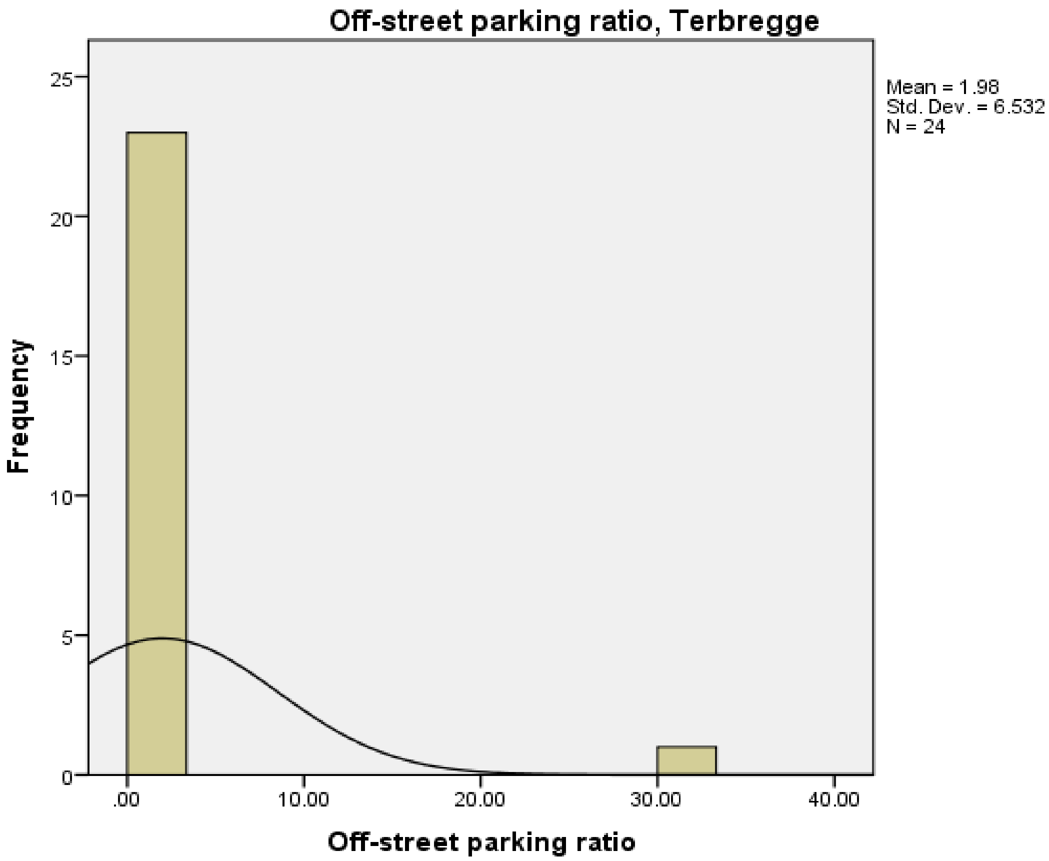

On-street parking ratio, Agniesebuurt
Mean = 1.95
Std. Dev. = 4.122
N = 25
Frequency
25
20
15
10
5
0
.00
5.00
10.00
15.00
20.00
25.00
On-street parking ratio


Off-street parking ratio, Agniesebuurt
Mean = .28
Std. Dev. = .49
N = 25
Frequency
20
15
10
5
0
.00
.50
1.00
1.50
2.00
2.50
Off-street parking ratio


On-street parking ratio, Oud Crooswijk
Mean = .74
Std. Dev. = .339
N = 25
Frequency
0
2
4
6
.25
.50
.75
1.00
1.25
1.50
On-street parking ratio

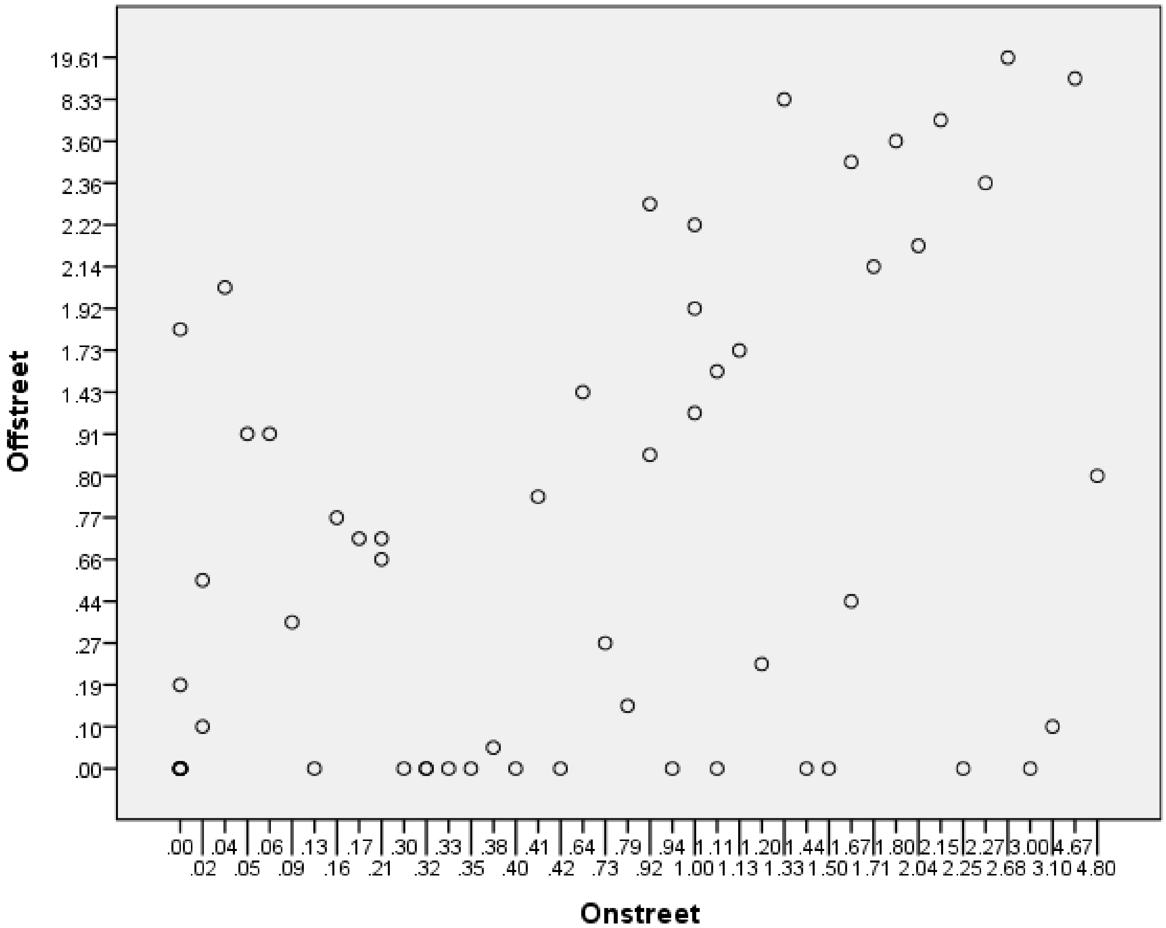

Off-street parking ratio, Oud Crooswijk
Mean = .06
Std. Dev. = .085
N = 25
Frequency
0
5
10
15
.00
.10
.20
.30
Off-street parking ratio





D) The relationship between OSPR and OFSPR

Beurs

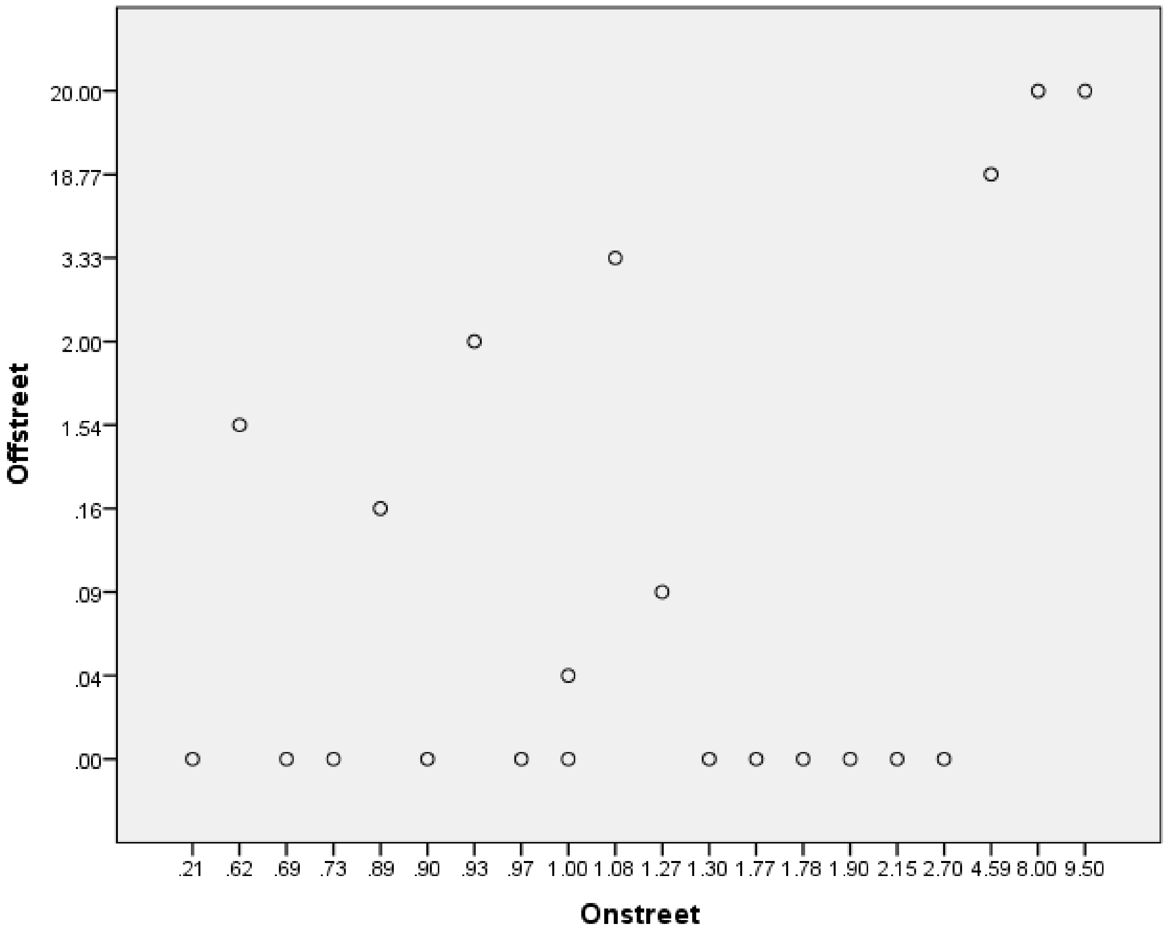


Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.406**
		Sig. (2-tailed)	.	.002
		N	57	57
	Offstreet	Correlation Coefficient	.406**	1.000
		Sig. (2-tailed)	.002	.
		N	57	57

**. Correlation is significant at the 0.01 level (2-tailed).

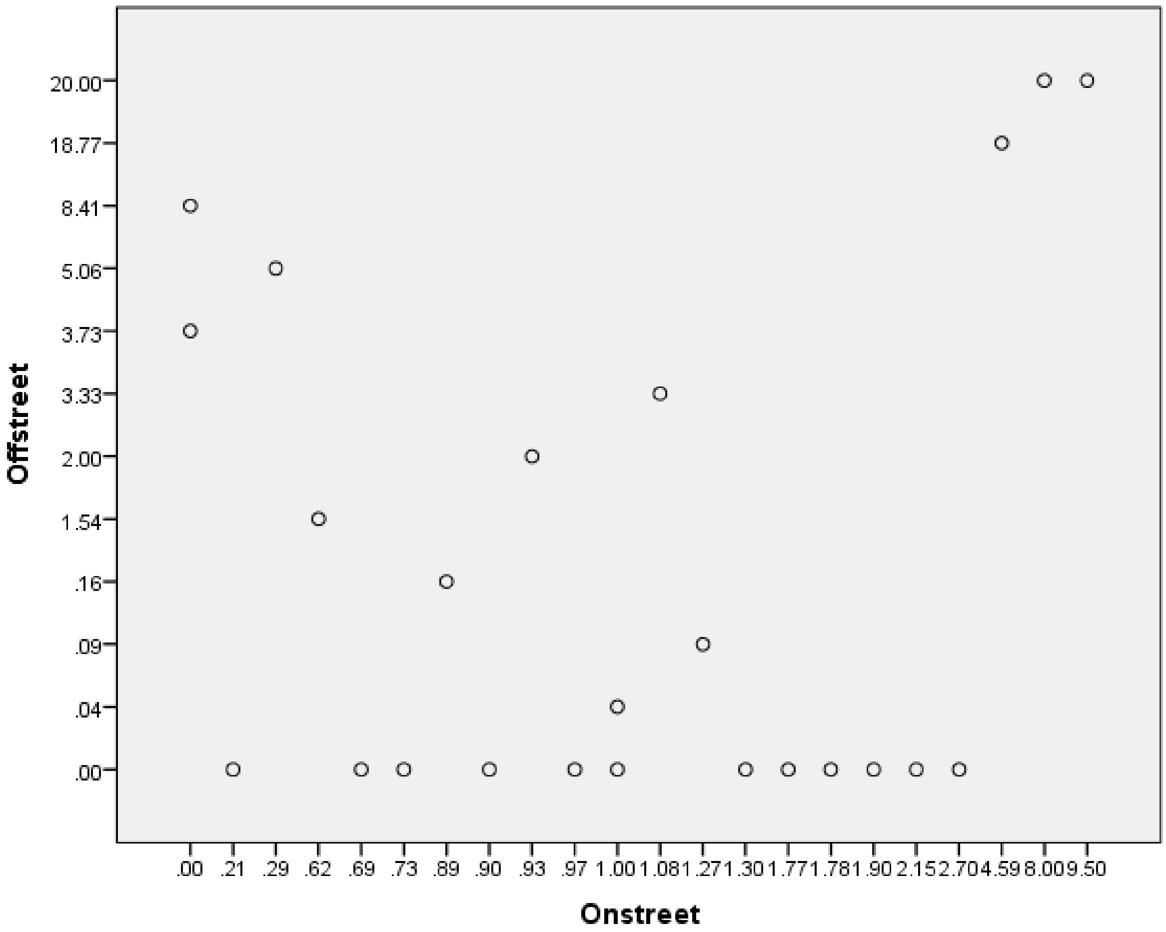
Voorschoterlaan



Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.267
		Sig. (2-tailed)	.	.242
		N	21	21
	Offstreet	Correlation Coefficient	.267	1.000
		Sig. (2-tailed)	.242	.
		N	21	21

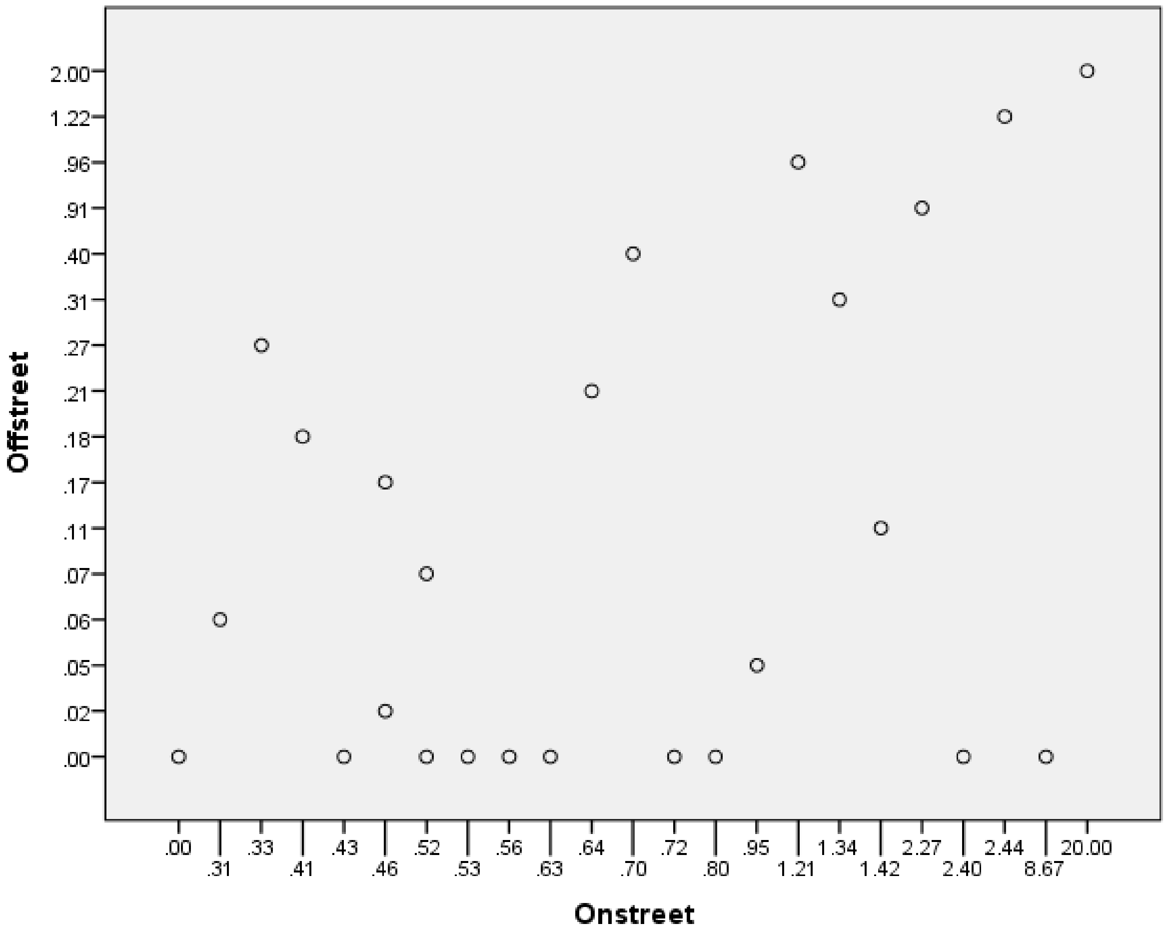
Alexander



Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.009
		Sig. (2-tailed)	.	.966
		N	24	24
	Offstreet	Correlation Coefficient	.009	1.000
		Sig. (2-tailed)	.966	.
		N	24	24

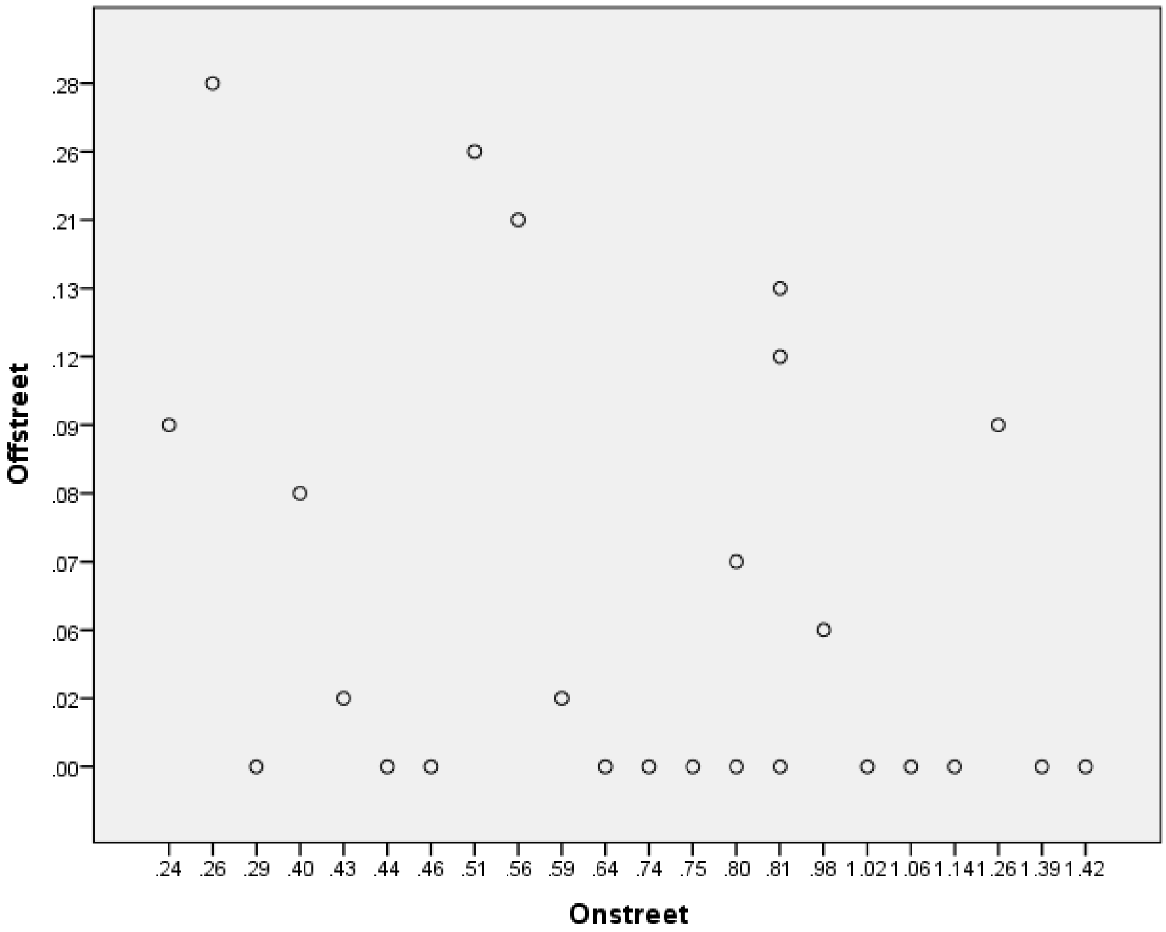
Agniesebuurt



Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.294
		Sig. (2-tailed)	.	.153
		N	25	25
	Offstreet	Correlation Coefficient	.294	1.000
		Sig. (2-tailed)	.153	.
		N	25	25

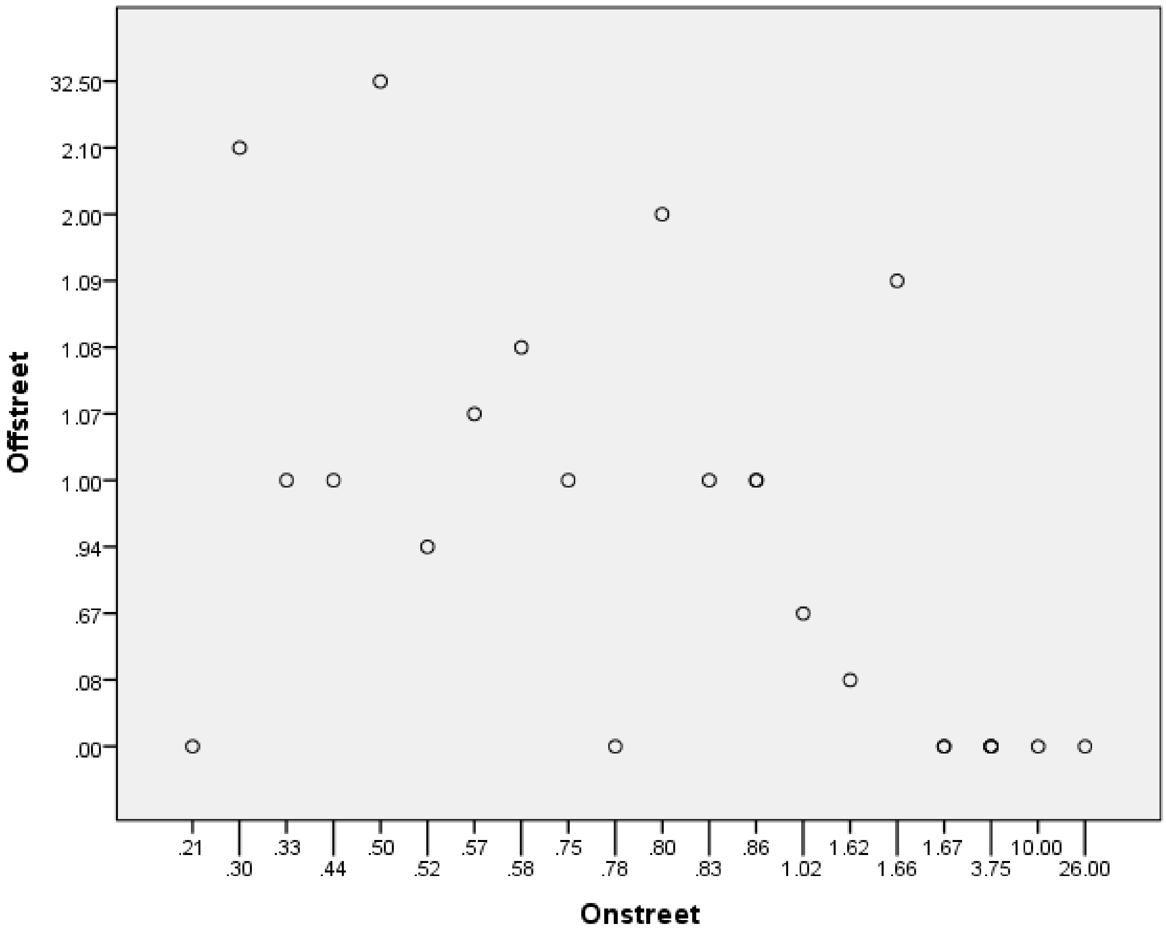
Oud Crooswijk



Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	-.306
		Sig. (2-tailed)	.	.137
		N	25	25
	Offstreet	Correlation Coefficient	-.306	1.000
		Sig. (2-tailed)	.137	.
		N	25	25

Terbregge



Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	-.588**
		Sig. (2-tailed)	.	.002
		N	24	24
	Offstreet	Correlation Coefficient	-.588**	1.000
		Sig. (2-tailed)	.002	.
		N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

E) Full statistical results from primary research

The statistical results of the primary data (parking distributions) are shown below:

Overall difference between Metro and non-Metro catchments for both on and off-street parking.

Overall significance

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Onstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.696	Retain the null hypothesis.
2	The distribution of Offstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.050	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Frequency data:

Distance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Inner	82	38.3	38.3	38.3
	Middle	84	39.3	39.3	77.6
	Outer	48	22.4	22.4	100.0
	Total	214	100.0	100.0	

Metro

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Metro	138	64.5	64.5	64.5
	Non Metro	76	35.5	35.5	100.0
	Total	214	100.0	100.0	

K test (Kruskal Walis Test) for non-parametric statistics

On-street car parking

Ranks

	Distance	N	Mean Rank
Onstreet	Inner	82	95.58
	Middle	84	108.82
	Outer	48	125.55
	Total	214	

Test Statistics[a,b]

	Onstreet
Chi-Square	7.159
df	2
Asymp. Sig.	.028

a. Kruskal Wallis Test

b. Grouping Variable: Distance

The Kruskal Walis test demonstrated that there was a statistically significant difference between the different catchment groupings with respect to on-street parking based on distance $\chi^2 = 7.159$, $p = 0.028$, with the mean rank scores of 95.58, 108.82 and 125.55 for ‘inner’, ‘middle’ and ‘outer’ catchments respectively.

Off-street car parking

Ranks

	Distance	N	Mean Rank
Offstreet	Inner	82	113.18
	Middle	84	97.73
	Outer	48	114.91
	Total	214	

Test Statistics[a,b]

	Offstreet
Chi-Square	3.625
df	2
Asymp. Sig.	.163

a. Kruskal Wallis Test

b. Grouping Variable: Distance

Here, the Kruskal Walis test offered no statistically significant difference between the different catchment groups based on off-street parking. This is likely due to different minimum parking standards over different periods in Rotterdam’s history.

Analysis of within distance groups (Metro vs non-Metro e.g. Beurs vs Agniesebuurt):

Inner group

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Onstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.265	Retain the null hypothesis.
2	The distribution of Offstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.047	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Middle group:

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Onstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.429	Retain the null hypothesis.
2	The distribution of Offstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.005	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Outer group:

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Onstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.571	Retain the null hypothesis.
2	The distribution of Offstreet is the same across categories of Metro.	Independent-Samples Mann-Whitney U Test	.974	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Correlation of within distance groups: on-street parking to off-street parking:

As stated in the methods, spearman's rho was selected as the best option for the correlation analysis. It works best with ordinal data and variables with differing variances.

Terbregge:

Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	-.588**
		Sig. (2-tailed)	.	.002
		N	24	24
	Offstreet	Correlation Coefficient	-.588**	1.000
		Sig. (2-tailed)	.002	.
		N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Oud Crooswijk

Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	-.306
		Sig. (2-tailed)	.	.137
		N	25	25
	Offstreet	Correlation Coefficient	-.306	1.000
		Sig. (2-tailed)	.137	.
		N	25	25

Agniesebuurt

Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.294
		Sig. (2-tailed)	.	.153
		N	25	25
	Offstreet	Correlation Coefficient	.294	1.000
		Sig. (2-tailed)	.153	.
		N	25	25

Alexander

Correlations

			Offstreet	Onstreet
Spearman's rho	Offstreet	Correlation Coefficient	1.000	.267
		Sig. (2-tailed)	.	.242
		N	21	21
	Onstreet	Correlation Coefficient	.267	1.000
		Sig. (2-tailed)	.242	.
		N	21	21

Lack of statistical significance adds credence to the claim that there is no logical ordering to the neighbourhoods and this correlation could have been brought about by chance. The neighbourhoods are reflective of historically different approaches to managing car parking.

Beurs

Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.158
		Sig. (2-tailed)	.	.242
		N	57	57
	Offstreet	Correlation Coefficient	.158	1.000
		Sig. (2-tailed)	.242	.
		N	57	57

Beurs

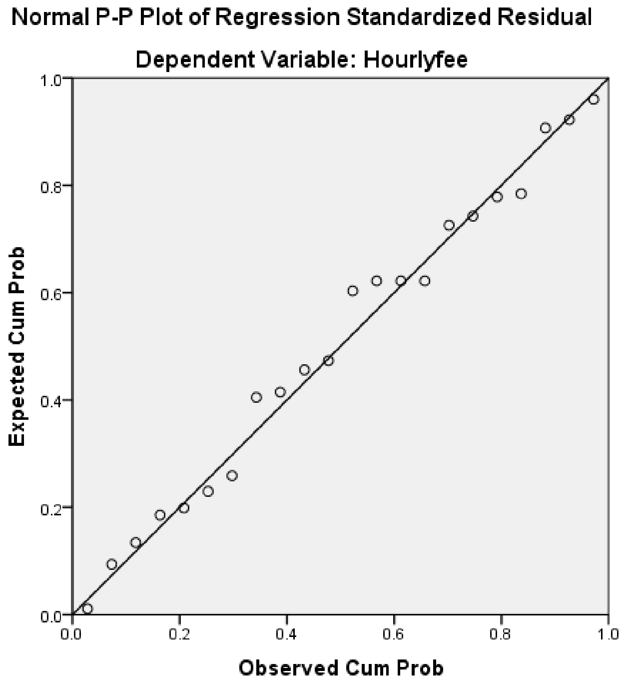
Correlations

			Onstreet	Offstreet
Spearman's rho	Onstreet	Correlation Coefficient	1.000	.406**
		Sig. (2-tailed)	.	.002
		N	57	57
	Offstreet	Correlation Coefficient	.406**	1.000
		Sig. (2-tailed)	.002	.
		N	57	57

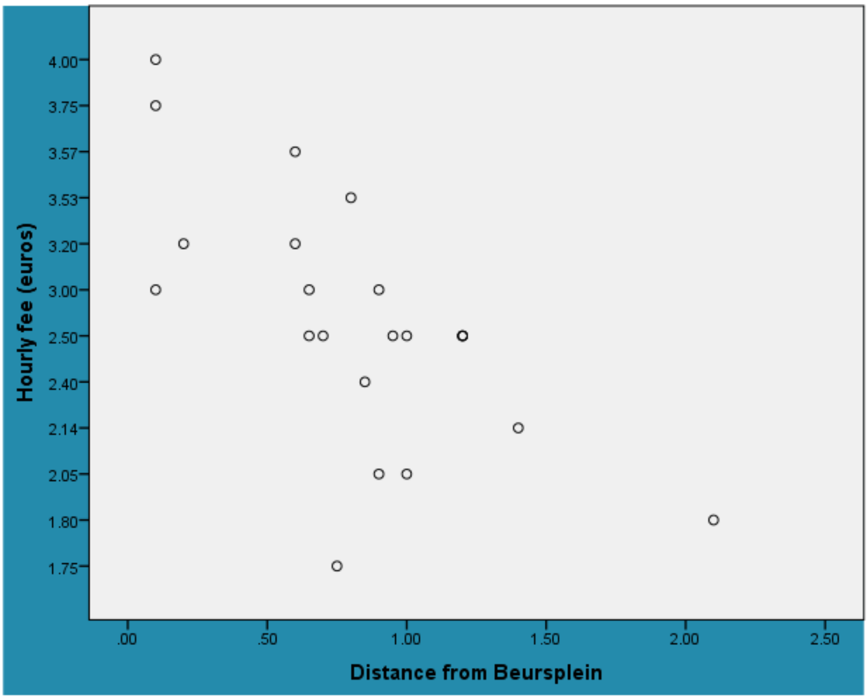
**. Correlation is significant at the 0.01 level (2-tailed).

Beurs is the only one where there is a significant but very weak correlation.

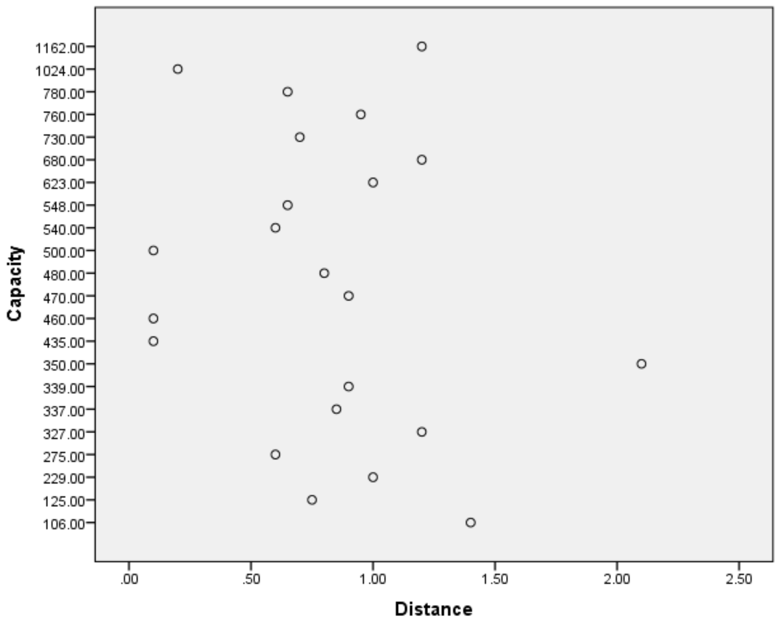
F) Additional information on regression analysis



This is a visualisation of the standardised residual of the regression analysis.

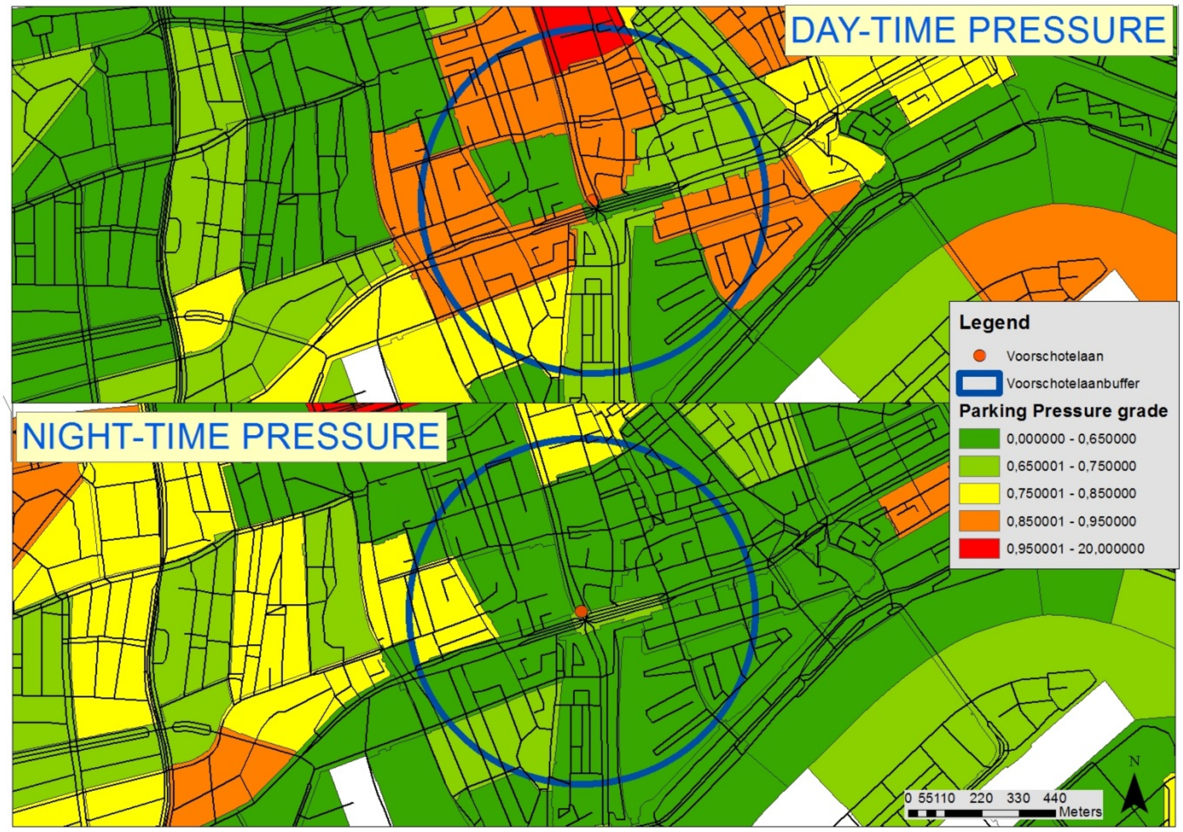


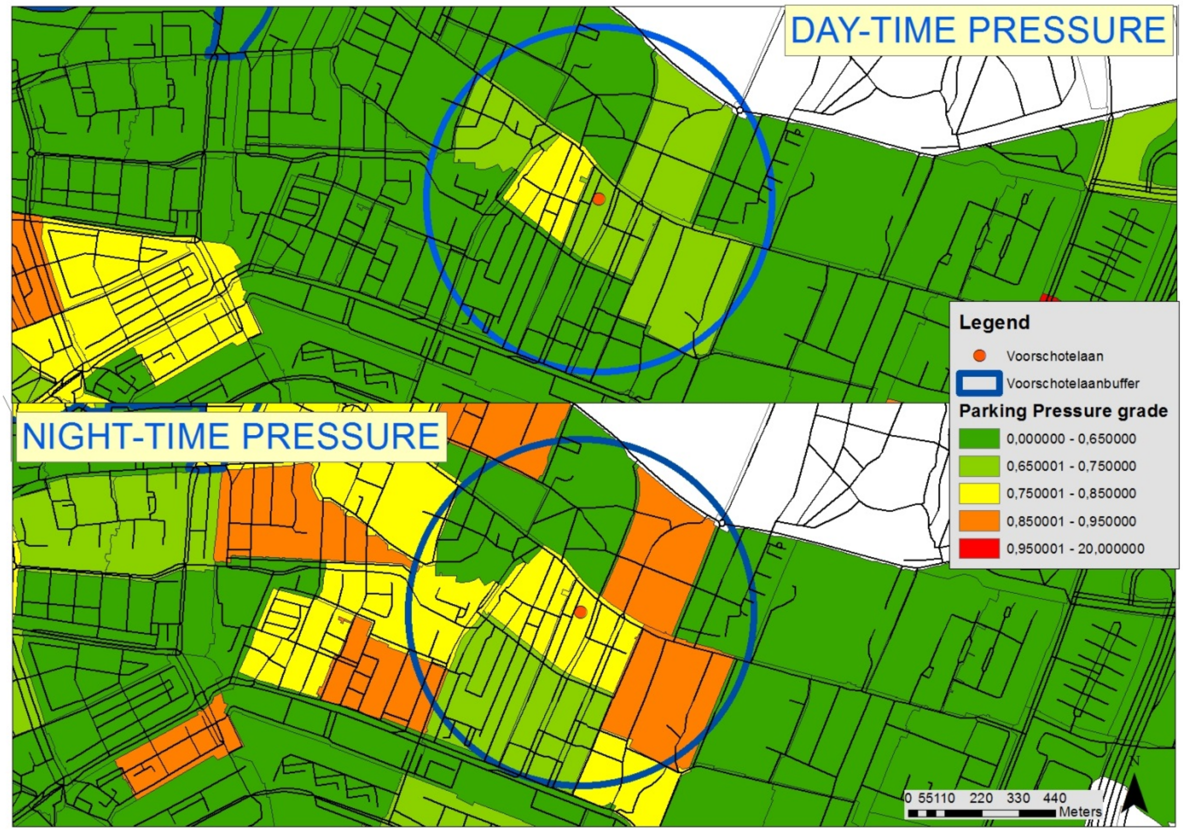
The above chart depicts the relationship between the two variables of ‘Distance from Beursplein’ and ‘Hourly fee’.

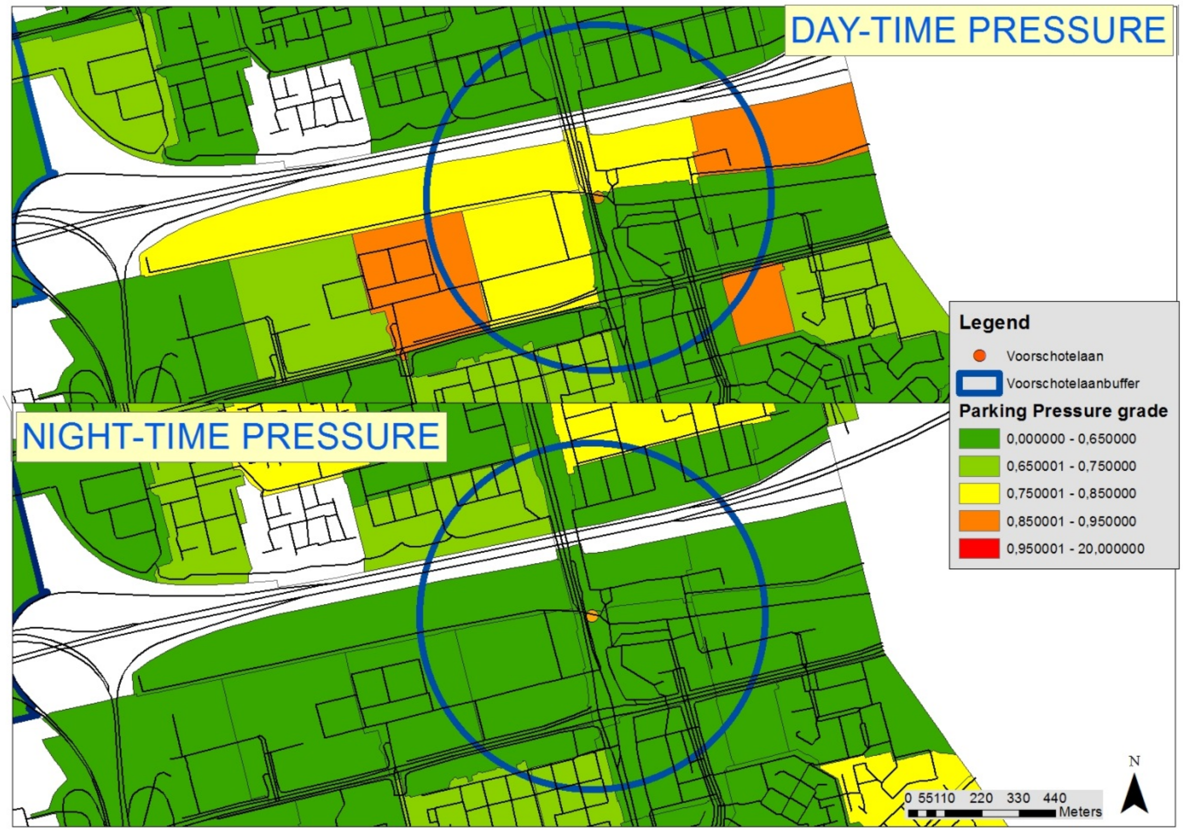


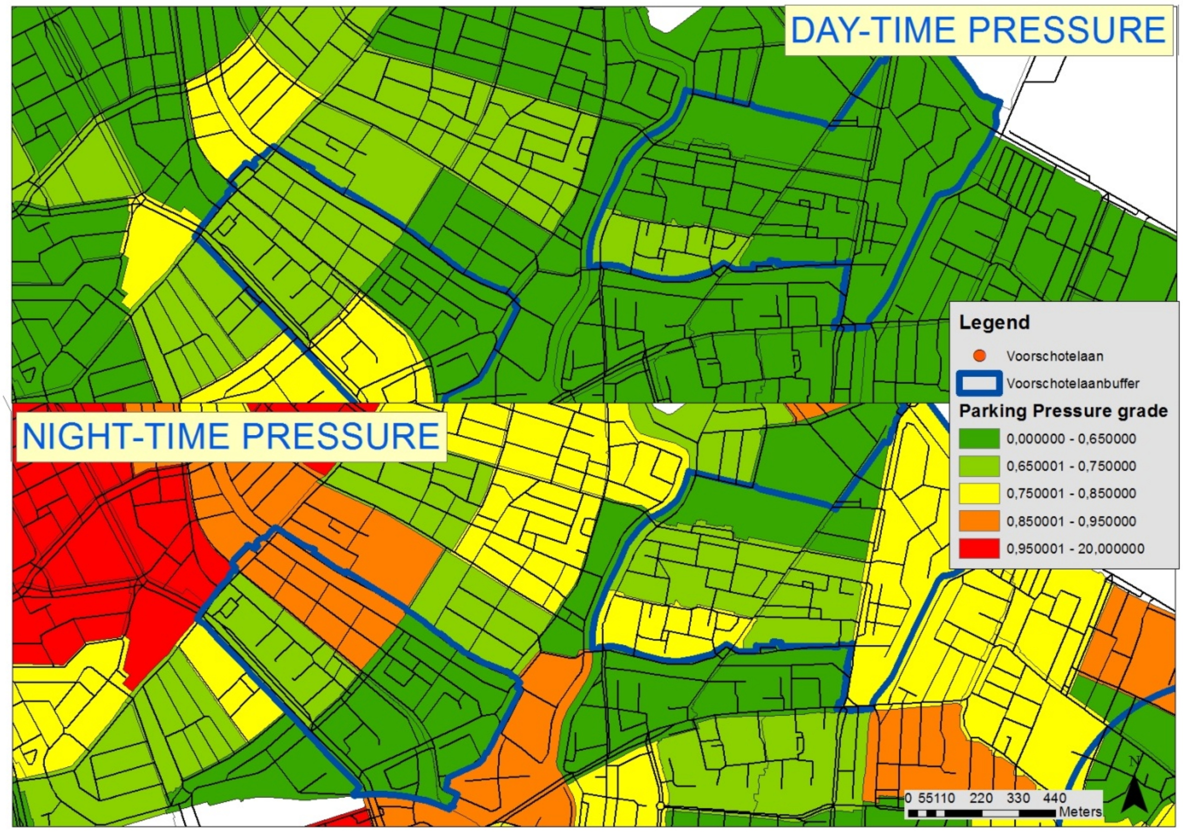
As can be seen above, there is no clear relationship between distance and capacity.

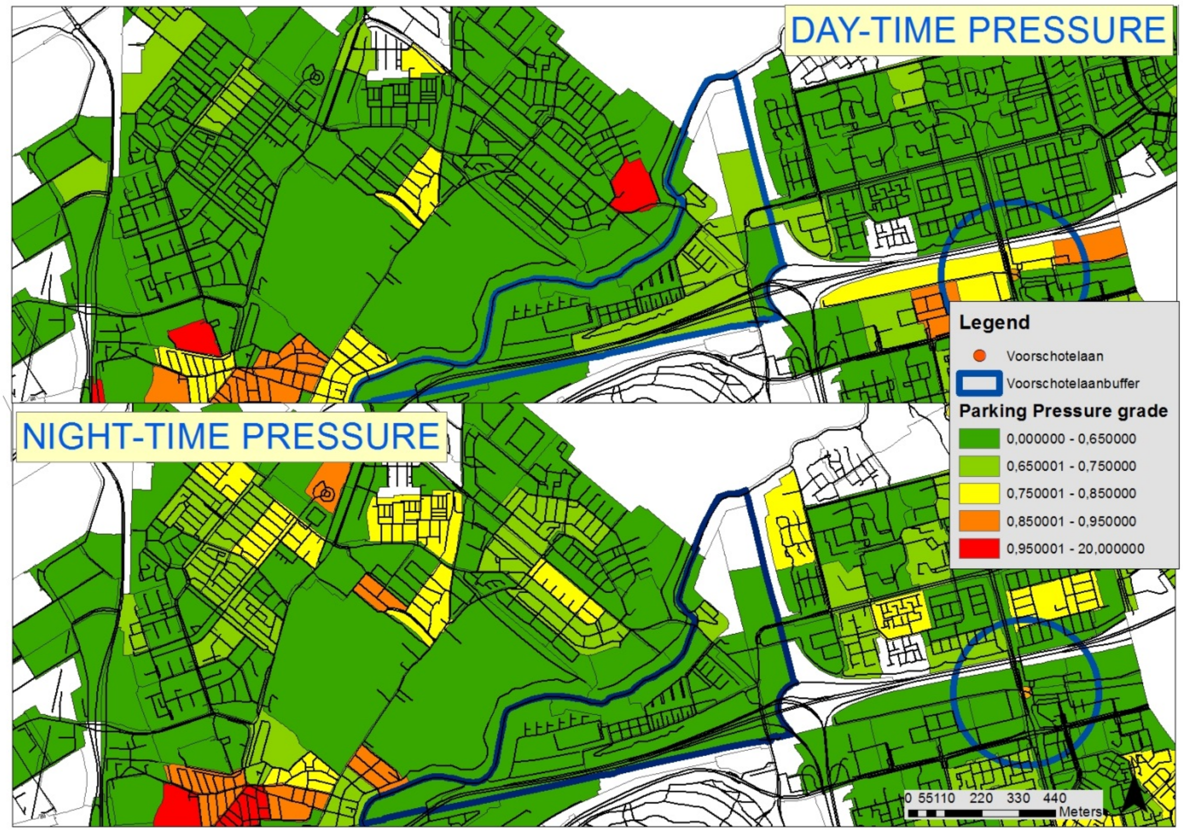
G) Parking pressure maps for each catchment




DAY-TIME PRESSURE
NIGHT-TIME PRESSURE
Legend
Voorschotelaan
Voorschotelaanbuffer
Parking Pressure grade
0,000000 - 0,650000
0,650001 - 0,750000
0,750001 - 0,850000
0,850001 - 0,950000
0,950001 - 20,000000
0 55110 220 330 440
Meters
N


DAY-TIME PRESSURE
NIGHT-TIME PRESSURE
Legend
Voorschotelaan
Voorschotelaanbuffer
Parking Pressure grade
0,000000 - 0,650000
0,650001 - 0,750000
0,750001 - 0,850000
0,850001 - 0,950000
0,950001 - 20,000000
0 55110 220 330 440
Meters
N





With the exception of Beurs and Alexander, every catchment has higher rates of night-time pressure than day time parking pressure. That said, the pressure is generally not too immense (at an average maximum of 80%) and likely does not merit the construction of more parking facilities.