The contribution of Park and Ride to a robust mobility system

M. Snelder 1
B. Egeter2
T. Hendriks3
L.H. Immers4

Abstract: P+R-plus is a new layer of P+R (Park and Ride) on top of existing P+R facilities at many public transport stops. Someone who parks his car at a P+R-plus location is guaranteed that he can reach all important locations within a metropolitan region with a maximum of one transfer and with metro quality (reliable and highly frequent). This implies that the traveller doesn’t have to be familiar with the public transport system. The main difference with many existing P+R-locations is that P+R-plus offers public transport connections in multiple directions whereas traditional P+R is in general focused on one destination area. In this paper a method is presented for designing P+R. This method is by means of example applied the metropolitan region Rotterdam-The Hague in the Netherlands.

Keywords: P+R-plus, Park and Ride, robust mobility system, design method

1. Introduction

Transport networks in many urbanized areas are vulnerable. Small disturbances can cause large delays for many travellers. In (Schrijver et al., 2008) and (Snelder et al., 2009), an architecture for designing robust road networks is presented. In this architecture robustness is defined as the extent to which a network is able to maintain the function for which it was originally designed. Vulnerability is the opposite of robustness. A network that is vulnerable is not robust, and vice versa. Of course, road networks are not the only networks that are vulnerable. Vulnerability also plays a role in public transport networks, the inland waterway network and other networks. Therefore, not only the road network should be made robust, but the mobility system as a whole should be made robust against different disturbances. In this paper, we describe how Park and Ride (P+R) can contribute to a robust mobility system.

The architecture for designing robust road networks contains several general design principles. One of the principles is that travellers should have choice options to travel from their origin to their destination. This can be alternative routes within the road network, but also alternative routes via other modes like public transport. Different modes of transport are considered to be complementary to each other. A good connection between the road network and public transport network is part of a robust mobility system. Urban areas often have parking problems and congestion problems. In these areas public transport has a high potential. The car performs well outside urban areas. Therefore, P+R is a way of combining the strengths of both modes. It improves the accessibility of urban areas and it offers choice options to the travellers.

Of course, P+R is not a new concept. This concept exists in many ways in different countries. However, there are some developments that require a different view on P+R. The growth of cities, results in the fact that existing P+R locations are often located in the congested area whereas the travellers prefer to transfer from their car to the public transport before they enter

1 TNO, Van Mourik Broekmanweg 6, P.O. Box 49, 2600 AA Delft, the Netherlands
2 Bart Egeter Advies, Maaskade 147d, 3071 NN Rotterdam, the Netherlands
3 ANWB, Wassenaarseweg 220, 2596 EC The Hague, the Netherlands
4 Catholic University of Leuven, CIB, Traffic & Infrastructure, Celestijnenlaan 300A B-3001 Belgium & TRAIL Research School, Kluyverweg 4, 2629 HT Delft, the Netherlands
the congestion. Furthermore, the trip patterns are becoming more and more diffuse, which makes the traditional concept of parking the car at the border of the city and using the public transport to travel to the city centre less adequate.

This paper aims to present a method for designing a robust mobility system by including a new type of P+R: P+R-plus. The method is illustrated by applying it to the metropolitan region Rotterdam-The Hague in the Netherlands.

This paper focuses on the structure related questions of a P+R design. Of course, the service concepts at the P+R locations, like the information provision, ease of payment, parking fares, safety and walking distances are critical success factors for P+R as well. Many studies have been done about this topic (e.g. AGV Movares, 2008; ANWB, 2000; ANWB, 2010). In this paper we assume that the P+R facilities that are included in our design offer high quality services and that the information provision about the P+R location, the connecting public transfer lines and roads is well organized.

Section 2 presents a method by which a P+R-plus layer can be designed. The method is applied to the region Rotterdam – The Hague in the Netherlands by means of example. This example is presented in section 3. Section 4 explains how the method can be applied to other regions and in section 5 some conclusions are presented.

2. Design method for P+R

In this section the design method is presented. This method is partly based upon the method that is presented in (Egeter et al., 2007) and (Snelder et al., 2009). We extended this method by including P+R in it. Each step of the method is briefly explained below.

Step 1: Functional analysis. A functional analysis is an analysis in which the performance of an existing network (or a planned future network) is evaluated.

Step 2: Design process. We propose to use the following six steps (a to f) for designing a transport network with P+R:

- Step 2a: determine the most important destinations.
- Step 2b: determine the quality standards of the public transport from the P+R-locations.
- Step 2c: determine the most important entrance roads to the metropolitan region for incoming traffic and determine the most important public transport possibilities for outgoing traffic.
- Step 2d: determine the P+R locations with the highest potential according to certain criteria and by making choices in several design dilemmas.
- Step 2e: determine the actions that need to be taken in order to improve the road network and public transport to meet the quality standards of step 2b.
- Step 2f: check whether or not all destinations of step 2a can be reached with the desired quality. For the other destinations additional solutions should be found.

These steps are carried out by a group of experts and stakeholders who have location specific knowledge, knowledge about the traffic and transport system and P+R, knowledge about traveller behaviour, knowledge about policy plans etc. This knowledge is brought in in workshop settings and later on worked out in more detail. Several sources are used to help the experts:

- Literature about P+R in different countries (source 1).
- An analysis of the P+R potential for different trip types/mobility patterns (source 2).
- A model analysis that shows the size of the potential P+R flow for the incoming roads to different types of destinations (source 3).

In the next section the method is applied to metropolitan region Rotterdam-The Hague in the Netherlands by means of example. The example is presented in such a way that the results of the main steps, functional analysis and design, become clear. All the sub steps and choices are
not presented one by one, because this would contain too much detail for this paper. Instead, the steps can be recognized throughout the text. They are marked in bold and between brackets in the next sections (e.g. step 2a).

3. Example Rotterdam-the Hague area

This example is made together with the Royal Dutch Touring Club ANWB in order to show how the method can be applied and in order to show how P+R can contribute to a robust mobility system. The P+R designs that are shown in this section have the status of example, which implies that they are not yet included in the planning process of governments.

3.1. Functional analysis existing P+R and the public transport and road connections

Before a new design is made, it is important to understand how the existing Park and Ride facilities work. Therefore, a functional analysis is carried out on a reference network (step 1). The reference network consists of the robust road network design for 2020 as presented in (Schrijver et al., 2008) and (Snelder et al., 2009), the existing public transport network combined with the measures that are included in the policy plans up to 2020 and the existing P+R locations.

In order to analyse how P+R functions in the region Rotterdam-The Hague, first some lessons can be learned from a comparison with P+R in other countries (source 1). The CROW made a comparison between P+R in different countries (CROW, 2005). Their main conclusions are that the British P+R system with high service standards and (dedicated) shuffle services between the parking locations and the city centres resembles the Dutch ‘transferium concept’. Local and regional governments take the initiative for constructing the P+R locations. The main success factors are the comfort of the high quality public transport (busses in most cases), the high frequency (minimum of 4 times per hour and preferably 6 or more times per hour), clear P+R locations located before the congestion and well visible from the road side and attractive parking fares. Furthermore, P+R is part of a large set of measures to make cities accessible and liveable, dedicated infrastructure for the public transport and priority at intersections. The parking fares are high in the city centre (preferably twice as high as the costs of parking at P+R locations and public transport to the city centre). P+R in Germany resembles the concept of P+R in the Netherlands. In large urban agglomerations P+R locations are situated at the ends of public transport lines. These locations are well accessible from the roads that go to the city centres. The concept is successful because of the congestion and parking problems and because of the good information provision. The French approach goes a step further. In France, P+R is part of an integral spatial and mobility policy. Germany and France offer usually tram, metro or regional bus connections as transport mode between the P+R locations and the destinations.

A more detailed functional analysis of the functioning of P+R in the Netherlands showed that in the area Rotterdam – The Hague, there are many small P+R locations at public transport stops (metro or tram) in residential areas. These P+R facilities enlarge the circle of influence of the public transport because besides walking and bicycling, car driving becomes an option to reach the public transport. These small P+R facilities function fine and should be extended. Besides the small P+R facilities, there are larger P+R facilities at the city borders near the motorways. These facilities offer car drivers with a destination in the city centre the possibility to travel the last mile by public transport. In this way, they avoid the problem of finding parking places and paying high parking fares. The most important shortcoming of these larger P+R facilities is that they are organized by public transport line which implies that only a limited number of destinations can be reached by public transport within an acceptable travel time. Furthermore, it requires a lot of knowledge of the travellers about the public transport lines. More general problems that are mentioned about P+R are image
problems, unfamiliarity with public transport and P+R and ambiguity about the location and costs of P+R.
Besides this qualitative analysis, also some quantitative figures are relevant for the functioning of P+R and the future potential for P+R. An analysis of the mobility patterns in the region Rotterdam-The Hague (source 2) showed that:

- In 2008, 5% of all trips were made with multiple modes and only 0.2% was made by car combined with public transport. For 83% of this 0.2%, the distance that was travelled by public transport was larger than the travelled distance by car (based on MON, 2008).
- The potential is larger: 36% of all the trip in the metropolitan region Rotterdam-The Hague are made on relations were P+R might be interesting. 8% of the trips go to the city centre (KIM, 2009). These are the trips with the highest potential because the parking problems are the largest and the quality of the public transport is the best in the city centre.
- The total number of trips, and therewith the number of potential P+R trips, grows in this area with 25% between 2000 en 2020 (KIM, 2009).
- Trips between two urban areas (the areas around the city centres) and between an urban area and a peripheral area will show a large growth (KIM, 2009). Therefore, for these relations P+R should be available as well.
- The number of trips to the city centre will not grow much (KIM, 2009).
- The share of the train for the outgoing traffic will increase with 4 percent points) and the number of car trips will increase towards 2020. These are developments that might increase the potential for P+R (KIM, 2009).

The above mentioned general figures for the potential of P+R are analysed in more depth for all the incoming roads by using model simulations (step 2d – source 3). The results are presented in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Total P+R</th>
</tr>
</thead>
<tbody>
<tr>
<td>N44 south Wassenaar</td>
<td>693</td>
</tr>
<tr>
<td>A4 south Prins Clausplein</td>
<td>1526</td>
</tr>
<tr>
<td>N211 north</td>
<td>78</td>
</tr>
<tr>
<td>A4 north kp Ypenburg</td>
<td>374</td>
</tr>
<tr>
<td>A12 west Prins Clausplein</td>
<td>1208</td>
</tr>
<tr>
<td>A12 west Zoetermeer</td>
<td>1086</td>
</tr>
<tr>
<td>A20 west Terbregseplein</td>
<td>1325</td>
</tr>
<tr>
<td>A13 south Kleinpolderplein</td>
<td>1435</td>
</tr>
<tr>
<td>A20 east kp Kethelpoort</td>
<td>1407</td>
</tr>
<tr>
<td>A15 east kp Benelux</td>
<td>676</td>
</tr>
<tr>
<td>A29 north kp Vaanplein</td>
<td>928</td>
</tr>
<tr>
<td>A15 west Kijfhoek</td>
<td>631</td>
</tr>
<tr>
<td>A16 north Kijfhoek</td>
<td>1315</td>
</tr>
</tbody>
</table>

Table 1 : Trips on incoming routes between 5.00 – 15.00 on a average work day in 2008

Table 1 should be interpreted as follows. For instance, the record N44 south Wassenaar shows that on an average workday, in the period 5.00 – 15.00 h, 3000 vehicles travel in the southern direction to a location in the direct surroundings of an intersection of two or more metro/train or intercity train lines (Category I), 1450 vehicles have a destination in the surrounding of an intersection of a metro/train line with a tram/bus line (Category 2), 2000 vehicles have a destination near a metro/train or very well accessible tram/high quality bus line (Category 3)
and 10300 vehicles have another destination. If we assume that respectively a maximum of 20%, 5%, 1% and 0% of all the vehicles with a category I, II, III and IV destination can or want to make use of P+R, the potential daily P+R flow is 693 vehicles. For the other incoming roads, the same analysis is carried out. Most of the road numbers can be found in Figure 1. The potential P+R flows for the different roads are used in the design phase to identify the best locations for P+R.

Based on the functional analysis the following design questions were raised:

**Main question:** how can we offer car drivers and car passengers, who come from a place outside the metropolitan region Rotterdam-The Hague to a destination inside the region, good P+R facilities by which they can reach all important destinations with high quality public transport? Figure 1 gives a spatial impression of this design question. In green the most important entrance roads are shown (**step 2c**). These are the roads that are included in the robust road network as presented in (Schrijver et al., 2008). The blue dots are the most important destinations (work locations, shop locations and/or leisure locations that attract relatively many people) in the area Rotterdam-The Hague (**step 2a**). The question is where P+R facilities should be located in such a way that the drivers that come from the green roads can reach all the destinations.

**Figure 1 : Main design question: P+R-plus for incoming traffic to the metropolitan region**

Based on the above mentioned main question, the following secondary questions need to be addressed in the design:

- How can the number of small existing P+R facilities at public transport stops be extended?
- How can the public transport and P+R for traffic between Rotterdam and The Hague be improved?
How can P+R for traffic that leaves the metropolitan Rotterdam - the Hague region be improved?

In the next sections the main and secondary design questions are addressed in more detail. Before that, some design dilemmas are discussed.

3.2. Design dilemmas

When a P+R design is made, several design dilemmas come to mind. The word dilemma implies that there is no general way of designing. Therefore, location specific choices need to be made. The four main dilemmas are:

- Many small or a few large P+R locations. A limited number of P+R locations is easy to understand for the car driver and they can be well connected to the incoming roads. However, this does require a lot from the public transport network: from every P+R location all the destinations should be accessible. For the region Rotterdam-The Hague, the most appropriate choice seems to make a few large P+R locations for incoming and outgoing traffic. The traffic within the metropolitan region can make use of more smaller P+R facilities.

- Existing or new public transport. If existing public transport is used, the existing possibilities are used in the best possible way, which is financially attractive. The advantage of dedicated public transport is that it can be tailored to the P+R travellers. However, this does require a large market. For the region Rotterdam-The Hague a choice is made to make as much as possible use of the existing public transport.

- Many or a few stops. A choice for P+R locations at lines with many stops has the advantage that it makes many destinations accessible, but it results in longer travel times. With only a few stops, destinations further away become accessible, but the destinations along the way are not. Therefore, the choice of stops should be made in such a way that the most important destinations can be reached. For the region Rotterdam-The Hague a choice is made for lines with different stop distances. This choice is made because of size of the area and the locations of the most important destinations within the area.

- Many or a few direct lines. When a choice is made for many direct lines, many destinations can be reached without a transfer. This does result in relatively low frequencies and a network of lines that might be confusing to the travellers and is likely to be sensitive for disturbances. For the region Rotterdam-The Hague a choice is made to make all important destinations accessible by allowing a maximum of one transfer (for the incoming traffic from outside the metropolitan region).

By making these choices (step 2d), the most important quality standards of the public transport from the P+R-locations are set (step 2b). An additional quality standard is that all the main destinations (blue dots in Figure 2) can be reached with metro quality (minimum of 6 trains per hour). Furthermore, P+R locations for incoming traffic should preferably be located at the border of the metropolitan region ‘before the congestion’ and directly connected to the main incoming roads.

3.3. Main design question: P+R-plus for incoming traffic to the metropolitan region

Based on the functional analysis and the design method as presented in section 2, a P+R-plus layer on top off the existing P+R facilities is designed. The results are presented in Figure 2 (step 2e). This design consists of the following main elements:

- A choice of several P+R-plus locations at the border of the metropolitan region directly linked to the main incoming routes (green roads in Figure 2).
- Several proposals for adjustments in the public transport network in such a way that all the main destinations (blue dots in Figure 2) can be reached with metro quality (minimum of 6 trains per hour) and with a maximum of 1 transfer. The largest component of the public transport network consists of the existing metro and railway network.

In Figure 2, Gouda-West, Alexander and Bleizo are included as potential P+R-plus location. However, it is not strictly necessary to include all three locations. Gouda-west has the highest potential since all the traffic that comes from the A12 motorway (this is the motorway to the east of Gouda) and goes to The Hague and Rotterdam has the possibility to make use of that location. Furthermore, Gouda-west is located further away from the city centres which gives the traffic a possibility to avoid more congestion. When Gouda-West is used, the locations Bleizo and Alexander become redundant for incoming traffic. However, Gouda-west does not have a train station yet and Alexander already has a train station with a well functioning P+R facility. Therefore, if a choice is made for Alexander for the traffic that goes to Rotterdam, Bleizo might be better option than Gouda for the traffic that goes to The Hague.

Figure 5 summarizes all the differences between the reference situation and the new design and is therewith an indication for the actions that should to be taken by different stakeholders when they would decide to realize the design (step 2e).

3.4. Secondary design questions
As explained in section 3.1, we defined three secondary design questions.
- How can the number of small existing P+R facilities at public transport stops be extended?
- How can the public transport and P+R for traffic between Rotterdam and The Hague be improved?
- How can P+R for traffic that leaves the metropolitan Rotterdam - The Hague region be improved?

Below these questions are addressed in more detail.

**Extending the number of small existing P+R facilities at public transport stops**
For the car travellers that would like to transfer to public transport at a location near their origin, the existing usually relatively small P+R-facilities in living areas are a good option. At metro and light rail stops this type of P+R is being used more and more often. This concept should be extended to a level at which in the future each stop has a P+R facility (may be very small). Since this is an elaboration of an existing concept, it is not further discussed in this paper.

**Improving the public transport and P+R for traffic between Rotterdam and The Hague**
The main design question addressed the traffic that comes in to the metropolitan region Rotterdam-The Hague. Besides this incoming traffic, there is also traffic between Rotterdam and The Hague. In order to improve the coherency between these two cities several P+R facilities are designed near the three main roads in the robust road network design between Rotterdam and The Hague: the A4, the A13 and the N471-N14.

Figure 3 shows these P+R locations and the directions of the public transport lines at those P+R locations.

**Figure 3 : P+R for traffic between Rotterdam and The Hague**

![Figure 3 : P+R for traffic between Rotterdam and The Hague](image)
Improving P+R for traffic that leaves the metropolitan Rotterdam - The Hague region

For the outgoing traffic it is also important to have good P+R facilities. Of course, this traffic can make use of P+R near their destination (e.g. Amsterdam or Utrecht). However, there are also advantages related to transferring at a location near the origin (in this case Rotterdam-The Hague). In the origin region people are usually more familiar with P+R locations. Furthermore, this enables people for instance to work or relax in the train.

There are two types of locations that are suitable for P+R for outgoing traffic. These are the large intercity stations in the cities and the locations at the border of the metropolitan region where intercity trains stop. For the region Rotterdam-The Hague this implies that the following locations are suitable:

- Large stations in the cities: because of the location within the city centres, an appropriate parking fare is required to make sure that the parking places are not occupied by people who do not make use of P+R.
- Alexander: this is an existing intercity station at the border of Rotterdam that functions well for traffic that has a destination to the east of Rotterdam.
- For traffic in the northern and southern direction there are not yet good P+R facilities available. The same is the case for traffic from The Hague in the east direction. In order to facilitate this traffic three new intercity stations are added to the design: Rijnland, Zoetermeer, and Barendrecht.

In Figure 4 the P+R locations for outgoing traffic are shown.

**Figure 4 : P+R for outgoing traffic**


3.5. Actions

This section summarizes the actions that are needed to realize the P+R design for incoming traffic, outgoing traffic and traffic within the metropolitan region Rotterdam – The Hague (step 2e).

The required actions differ in type and complexity:

- The proposed P+R-plus locations are usually situated near existing stations/stops. However, also a few complete new locations are proposed: Rijnland, Gouda-West, and Blankenburg.

- For some locations investments in the road infrastructure are needed to make the P+R locations better accessible. This is especially the case for Barendrecht and to a lesser extent also for Benelux.

- With respect to public transport, the main investment will be to realize a 10 minute service (or even a higher frequency) at the existing network with the existing lines.

- Finally, several infrastructure adjustments are proposed for the public transport network that vary from very small to substantially large adjustments.

Of course information provision with respect to the location of P+R facilities and their accessibility, the services at the P+R location and the public transport lines from the P+R location to the destinations are important as well. Improving the information provision already improves the P+R facilities even when no infrastructural adjustments are made.

Figure 5: Required changes to the P+R stations, public transport and roads.
4. **Applicability to other regions**

The approach is applied to the metropolitan region Rotterdam – The Hague in the Netherlands. The choices that are made in the design dilemmas are specific for this region because they are based on the characteristics of the region. However, the design principles for P+R-plus are generally applicable.

- A choice of several P+R-plus locations at the border of the region. These locations should be connected to the most important incoming routes.
- A choice for a clear public transport network with a limited number of lines and minimally a ten minute service. Finally, a maximum of one transfer from each P+R-plus location to each destination within the area is accepted.

The public transport system by which the required metro quality is realized depends on the size of the region, the urbanization level and the already available public transport. The type of public transport can vary from a metro (high capacity, 100% separate tracks), to light rail to dedicated buses.

The stopping distances of the system should be optimally tuned to the size of the region and the origin and destination locations.

5. **Conclusions**

This paper proposed a method by which different types of P+R can be designed in order to improve the robustness of the mobility system as a whole. The main contribution is the concept of P+R-plus for incoming traffic. P+R-plus is a new type of P+R on top of the existing P+R at stops and stations. P+R-plus is supposed to improve the reliability of travel times and the robustness of the mobility system, because:

- It offers additional choice options for the travellers to reach their destinations.
- The P+R-plus traveller is guaranteed to reach all the important destinations in a region from a P+R-plus location with a maximum of one transfer and with metro quality. This is likely to improve the reliability of travel times. Furthermore, it has the advantage that the traveller no longer needs to be a public transport expert before he or she can use the P+R-plus locations.

The quality of the new designs has not yet been evaluated with model runs. This is the next step that needs to be taken, when the stakeholders decide that they would like to take this concept one step further to implementation.

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