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Developing a tool for assessing park-and-ride facilities in a sustainable mobility perspective

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ABSTRACT

This article presents results from context-related empirical case-studies of the traffic-reducing effects of 12 existing Norwegian park-and-ride facilities (P&R), in a sustainable mobility perspective. It further presents results from studies of planning processes related to construction or expansion of P&Rs. Main findings are that introduction or expansion of P&R normally cannot be expected to contribute to traffic reductions, if understood in a strategic, long-term and system-wide perspective. Further, that Norwegian planning processes are weak with respect to evidence-based ex-ante assessments of the traffic-reducing effects of P&R. The results and experiences from these studies were used in developing an easy-to-use tool for ex-ante assessments of traffic-reducing effects of P&R, taking properties of the facilities and the context of their location into consideration. The tool also includes suggestions of alternative measures to introducing or expanding P&Rs. As cities and urban regions in many countries struggle to curb traffic-growth and achieve more sustainable mobility patterns, we believe the empirical results, as well as the suggested assessment tool, will be useful also beyond the Norwegian context.

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1. Introduction

Environmental concerns and road congestion make planners and politicians look for measures that can reduce total vehicle kilometres travelled (vkt) by private car in urban regions (European Commission, 2011; European Environment Agency, 2018; Owens & Cowell, 2002; UN Habitat, 2013). The Norwegian government has stated that increasing transport demand caused by the rapid population growth in Norwegian urban regions should not cause growth in person transport (vkt), and this is often termed the *zero-growth objective* (Ministry of Local Government and Modernisation, 2012; Ministry of Transport and Communications, 2013; 2017; see also Tønnesen, Krogstad, & Christiansen, 2019). This is also a prioritised objective in many regional and municipal plans. Achieving this goal in the rapidly growing Norwegian cities requires that higher shares of passenger transport need to be done by public transport, bicycle and foot, and lower shares by private cars.

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Park & ride (P&R) is parking offered in connection to public transport, allowing for users to drive their private car to a parking facility, park the car and ride with public transport for part of the journey (Parkhurst & Meek, 2014). This has been suggested as an efficient measure in achieving the zero-growth objective in Norwegian urban regions (Bane Nor, 2017). Previous studies have, however, questioned whether P&R contributes to reduce traffic volumes in urban regions, and some have found that it rather can result in increased traffic (Meek, Ison, & Enoch, 2011; Mingardo, 2013; Parkhurst, 1995, 2000; Parkhurst & Meek, 2014; Zijlstra, Vanoutrive, & Verhetsel, 2015). Results can be affected by characteristics of the studied P&Rs and their contexts, as well as the mechanisms and time-horizons included in the studies (Mingardo, 2013; Parkhurst & Meek, 2014).

In Norway, there has been little critical discussion concerning P&R and its effect on traffic volumes. Contrary to many other measures aimed at reducing car traffic, P&R are not considered restrictive, and therefore meet little public opposition. This is also part of the explanation why bus-based P&R is popular among UK local authorities (Meek, Ison, & Enoch, 2010). Various Norwegian authorities have developed strategies for how they can provide more P&R (Akershus County, 2014; Bane Nor, 2017; Hordaland County, 2015; Ruter, 2010). It seems from these documents that the traffic-reducing effects of P&R have not been questioned or assessed, and they provide no descriptions of ways of assessing demand and effects.

Parkhurst and Meek (2014) describe how differences in perspectives tend to reflect professional orientation: a transport planner will emphasise the direct effects of P&R on traffic and congestion, an economic development professional will focus on benefits for car-users and commercial activities, and a transport operator will consider effects on operating conditions and patronage. They also describe how professionals focusing on reducing climate change emissions can be expected to take a more strategic perspective, and including system-wide and long-term implications. Focusing on curbing or reducing car-usage (vkt) in the urban region, this article takes the latter perspective. It sees planning and analyses of P&R in light of the complex short- and long-term interactions between development of land-use, transport systems, travel behaviour and traffic-volumes.

The article presents findings from a study of three planning processes, focusing on the motivation for constructing or expanding P&Rs, and what analyses were executed. The main questions are: *How are traffic-reducing effects of P&Rs assessed in current Norwegian planning practice, and how can these assessments improve?* It further discusses a number of mechanisms working in the short-term as well as the long-term perspective, that can be activated by introduction or expansion of P&R and affect traffic volumes in urban regions. It presents results from empirical investigations of how these mechanisms work and affect traffic in 12 cases, that are existing Norwegian P&Rs differing with respect to properties and contexts. Discussions are supported by results from a survey among users of 23 P&Rs, including the 12 case-sites. The aim is to answer the following question: *How do properties of P&Rs, and the context they are located in, affect the traffic-reducing effects (vkt) of P&R?* Finally, the experiences from conducting these analyses, as well as the results, have been used for developing *easy-to-use guidelines for ex-ante assessments concerning if and how expanding an existing or implementing a new P&R can be expected to affect traffic volumes*. The aim has been to provide a tool for more knowledge-based assessments, plans and decisions concerning construction and expansion of P&R.

It can be argued that a more grounded understanding of mechanisms activated when a measure such as P&R is implemented, context-related empirical knowledge on the traffic-reducing effects, as well as good tools for ex-ante assessments, would improve the chances that measures implemented contribute to achieving the desired effects and objectives (Krizek, Forsyth, & Slotterback, 2009; Næss, Hansson, Richardson, & Tennøy, 2013; Tennøy, Hansson, Lissandrello, & Næss, 2016). The aim of this article is to contribute to this.

2. Theoretical framework: how P&R can affect traffic volumes

Construction or expansion of a P&R may affect traffic volumes through several and different causal mechanisms. Which mechanisms are activated, and whether they result in increased or reduced traffic, depend on properties of the P&R itself and the context it is located in[1]. Due to the aim and focus of this article (described in Section 1), we sought to define key mechanisms through which introduction or expansion of P&Rs affect traffic volumes *i)* by directly affecting people's travel behaviour, and *ii)* by affecting land-use development and transport systems in ways indirectly affecting people's travel behaviour. In doing so, we combined causal and structural analyses to understand 'what it is about' introduction or expansion of P&Rs that directly and indirectly can affect travel behaviour and traffic volumes (Bhaskar, 2008, 1989; Danermark, Ekström, Jakobsen, & Karlsson, 2002; Sayer, 1992), with our existing knowledge (as land use- and transport planners and researchers) concerning interrelations between land use, transport systems and travel behaviour, and literature studies.

We searched for literature directly related to P&R in Google Scholar, ISI Web of Knowledge and Science Direct. We used the search words 'Park and Ride' and 'Park & Ride', combined with search words 'traffic reduction', 'traffic increase', 'traffic growth' and 'sustainable mobility'. We limited the search to works published since 2000. This resulted in a diverse list of scientific articles and book chapters. From this list, we selected articles theoretically defining and empirically investigating mechanisms through which P&R might affect travel behaviour and traffic volumes, taking a comprehensive and critical perspective. In this process, we excluded, for instance, articles based purely on modelling exercises, articles studying location of P&Rs with respect to catchment areas for specific PT-services, and articles focusing on various stakeholders' perceptions of P&R.

We found few empirical articles addressing effects of P&R on total traffic volumes, and even fewer taking into account the more system-wide and long-term indirect mechanisms. We browsed through about 20 articles that were somewhat relevant in defining the direct and indirect effects of P&R on traffic volumes, and selected some key articles that we use as references here.

The key articles present thorough discussions of previous research and discussions, and they are all widely referred. The articles were useful in our selection of which mechanisms to investigate, and to address in the tool we aimed at developing. The articles by Parkhurst (1995[2]; 2000) draw up the critical theoretical discussions concerning effects of bus-based P&R on traffic volumes, based on his own and others' empirical research. Meek et al. (2011) present and critically discuss results from a number of UK empirical studies, and contribute with their own empirical research on bus-based P&R in

the UK. They contribute to the theoretical understanding of the phenomenon by drawing up a useful description of different concepts of bus-based P&R. Mingardo (2013) introduces three useful categories of P&Rs that further advances the theoretical understandings of effects of P&R, and presents findings from empirical investigations of rail-based P&R in the Netherlands. Parkhurst and Meek (2014) provide a synthesis of works by a number of leading authors, and a review of the empirical evidence from the UK and the Netherlands concerning effects of P&R on travel behaviour and road traffic. They also draw up the discussion concerning the effectiveness of P&R as a policy measure for more sustainable mobility, as we also aim at contributing to through our article. The selected key mechanisms are discussed below.

One mechanism is that introduction or expansion of a P&R allows shifts from using car all the way to a destination, to using public transit on parts of the journey. This contributes to reduced traffic volumes (vkt), and the effects are stronger if the P&R intercepts the journey by car relatively close to the starting point and far from the final destination (Meek et al., 2011; Mingardo, 2013; Parkhurst, 2000; Parkhurst & Meek, 2014). The traffic-reducing effects of a system of P&Rs are reduced if users do not use their closest P&R, but instead drive longer to another P&R (Parkhurst, 2000). They can do so as an adjustment to public transport fare zones and road tolls, as well as to differences in occupancy rates at P&Rs and in public transport service qualities.

Introduction or expansion of a P&R may also cause people who previously used to walk, bike or use public transport to the station to start driving their car to the P&R instead (Mingardo, 2013). Some of those who earlier used to bicycle or use public transport all the way from home to work or other destinations, may start driving to a P&R and use a faster or more comfortable public transport mode from there. Both mechanisms contribute to increased traffic volumes.

P&R may occupy land in town centres and close to public transport nodes, that could alternatively have been used for urban development and activities, through densification and transformation (Hanssen, 2015; Parkhurst & Meek, 2014). These areas will normally have the best accessibility by other modes than car, and local trips to and from for instance work-places located here would be less car-based than to similar activities located elsewhere in the area (Næss, Strand, Wolday, & Stefansdottir, 2019). This can be understood as P&R causing displacement of activities to more car-dependent locations, contributing to increased traffic. Transformation of areas close to town centres and stations with more housing and work-places could also generate more passengers with easy access to the public transit service by foot and bicycle (Duncan, 2010).

Taking regional and long-term dynamics into account, P&R combined with rapid public transport increase accessibility to the outer parts of cities and urban regions, that can trigger car-based urban sprawl, and by that increased traffic (Næss et al., 2019; Parkhurst, 2000; Parkhurst & Meek, 2014; Tennøy, Tønnesen, & Og Gundersen, 2019; Wägener & Fürst, 2004). This mechanism is normally stronger in cities with a high pressure on the housing market and high residential prices in central areas.

In congested transport systems, there will often be a potential for road traffic, that is released if congestion is reduced, for instance, if road capacity is expanded (Cervero, 2003; Downs, 1962, 2004; Goodwin, 1996; Litman, 2019; Mogridge, 1997; Noland & Lem, 2002). Likewise, traffic reduced by introducing or expanding P&Rs can be replaced by

induced traffic. Easier access facilitated by P&R can also result in the generation of additional trips (Parkhurst, 1995).

There are also other mechanisms that could be activated, that are not considered here. For instance, could P&R facilities increase car accessibility to the area where the P&R is located, and hence stimulate the use of private car to this destination if general parking accessibility is low, and if the P&R is not strictly regulated and monitored. This would be most relevant if the P&R is located in a town centre or another area attracting many people.

The combined effects of the mechanisms activated when a P&R is introduced or expanded might be either increased or reduced traffic in the urban region (vkt). Results depend on properties of the P&R and the context it is located in: The location of the P&R relative to residential areas and to the main city centre, the quality of the public transport service (travel time, capacity), fare structure, congestion level, potential for urban sprawl, etc. When considering if a new or expanded P&R will contribute to increased or reduced traffic, all these mechanisms should be taken into consideration.

3. Research design and methodology

The research questions, together with the multi-causal nature of the problem, and our focus on investigating several mechanisms involved, called for in-depth case studies and a mixed-methods approach (Bergene, 2007; Yin, 2003).

3.1 Current planning and assessment methods

We investigated three recently concluded planning processes, to understand and describe current practices and methods for assessing effects of P&R on traffic volumes, and the need for improvements. The cases were Vestby (railroad connection) and Botilrud (bus connection), where the existing capacity was expanded, and Brubakken (bus connection) that was a new facility. Main methods were document studies (planning documents) and interviews with 13 planners involved in policy-making or the concrete planning processes. We asked which objectives had been defined for expanding or constructing the P&R, if reducing traffic volumes were among the objectives, which alternatives had been considered, and which analyses had been executed (see interview guide in appendix A).

3.2 Traffic-reducing effects of P&R

Twelve existing P&Rs were selected as cases for investigating how properties of the P&Rs, and the context in which they are located, affect their traffic-reducing effects. Results from the investigations of individual P&Rs were used as input in cross-case discussions concerning what kinds of P&Rs, and in which contexts, can be expected to contribute to reduced traffic in urban regions. The 12 cases represent different kinds of P&Rs and contexts. Two are located in the Kristiansand-region (90 000 inhabitants), two in the Trondheim-region (190 000 inhabitants), one in the Bergen-region (280 000 inhabitants) and seven in the Oslo-region (1 000 000 inhabitants). Six of the 12 P&Rs are served by bus, five by railroad and one by ferry. All are served by regular public transport services. The P&Rs were selected to also represent different types of P&R, and locations in

different distances from the main destination in the region. Mingardo (2013) distinguishes between remote P&Rs located close to where commuters live (that should be preferred if the goal is to reduce overall car use), peripheral P&Rs located closer to the city centre, and local P&Rs located along main transport corridors. Two of the case-sites can be classified as remote P&Rs, one as peripheral P&R and five as local P&R according to Mingardo's (2013) definitions. Five P&Rs do not fit well in any of the definitions, as we understand it. These are P&Rs located in town-centres served by railway or ferry. We refer to them as 'Town centre' when classifying P&Rs in Tables 1 and 2.

A combination of quantitative and qualitative data and methods were applied. One was to register license plate number of cars parked at the P&Rs, retrieve home-addresses of the owners from public registers, and use GIS to analyse distances between users' homes and the P&R both 'as the crow flies' (air distance) and as distance along the road. Because it is often argued that people use the car because they transport children to kindergarten or school, we registered whether there was a child's seat in the cars. We also registered the number of parking spaces for cars and bikes, occupancy, and how early the sites were filled up.

At 23 P&Rs, including the 12 case-sites, we conducted surveys among the users (Christiansen & Hanssen, 2014). The questions concerned, among other things, trip-purpose, final destination, alternative travel modes to the P&R, why they chose P&R instead of driving all the way to the destination, how they would travel if the P&R did not exist or if they had to pay a parking fee, as well as age, gender, and number of children in the household. Respondents were recruited as they arrived at bus stops and train stations where the P&Rs are located. The recruiters provided information about the study and asked if they were willing to participate. Those who agreed were asked for their email address. The net-based survey was sent immediately, and could be answered during the journey or later.

The licence plate registrations and the surveys were conducted once at each location. This was done in the morning rush-hours on weekdays (except Fridays) between 7.00 and 10.00. The data collection was done in the period September 2013 to June 2014, meaning that it varies at which time of the year the data were collected at different sites. This could to some extent influence the responses to the survey, and for instance on the number of bicycles registered at the P&Rs.

Data from the registrations and the survey were used to calculate the extra vehicle kilometres travelled by the current users if the P&Rs were removed, as a way of estimating traffic-reducing effects of the P&Rs. The calculations were done in two different ways. One was to use survey-answers concerning final destinations to calculate average distance travelled by public transport from the various P&Rs to the users[3] destination, double the distance, and consider this as the average traffic volume saved per (used) parking space per workday. The second was to also use answers from the survey concerning how they would have travelled if the P&R they used did not exist, and then calculate the difference between traffic generated in the two situations. This allowed for including more alternative responses to introducing or removing a P&R, and for doing more realistic calculations.

For the 12 case-sites, we also collected data concerning the context of the P&Rs. Discussions with local planners were important as sources of knowledge, and for critical scrutinizing of our understandings of the situation. We collected data concerning the locations of all P&Rs in the relevant regions, as well as data on fare-zones and road-tolling zones. These data were used together with data on home-addresses of the users of

Table 1. Key figures for six P&Rs – five at rail stations, one at ferry terminal (Kleppestø).

Location	Rosenholm	Slependen	Ski	Asker	Hommelvik	Kleppestø
Located in region	Oslo	Oslo	Oslo	Oslo	Trondheim	Bergen
Type of P&R	Peripheral	Remote	Town Centre	Town Centre	Town Centre	Town Centre
Spaces for cars	156	81	541	726	30	465
Site occupancy	98%	100%	99%	99%	98%	69%
Spaces for bicycles	24	64	733	546	-	-
Bicycle spaces used	2	9	130	88	24	-
Average distance between P&R and destination (km)	12.5	15.9	27.6	24	27.5	13.7
Average distance between home and P&R along road (km)	6.7	6.7	10.3	9.4	5.7	6.7
Share of journey done by PT	65%	70%	73%	72%	83%	67&
Share < 1 km from home to P&R	0%	6%	2%	1%	3%	1%
Share 1–3 km	21%	54%	45%	16%	28%	25%
Share 3–10 km	61%	24%	19%	53%	33%	56%
Share > 10 km	18%	17%	34%	30%	15%	19%
Share who says bus to P&R was an alternative	10%	24%	53%	24 %	30 %	83%
Share who alternatively would walk, bicycle or use bus to access the station	21%	29%	33%	23%	26%	31%
Share who would have driven to another P&R	27%	26%	28%	17%	13%	-
Share who alternatively would use car to the destination	31%	21%	39%	24%	11%	25%
Calculated vkm saved per user, using data from survey	5.8	5.6	17.8	9.3	7.0	-
Influence of fare zones or toll	Yes	No	No	Yes	No	No
Relation to local centre	Outside	Outside	In centre	In centre	In centre	In centre
Traffic-inducing displacement of activities?	No	No	Yes	Yes	Yes	Yes
Encouraging urban sprawl?	No	No	Yes	Yes	Some	Some
Reason to expect induced traffic?	Yes	Yes	Yes	Yes	No	Yes

Table 2. Key figures for six P&Rs, all served by bus (Melhus is also served by train).

Location	Ringerike sykehus	Botilrud	Heiatoppen	Melhus	Tangvall	Vennesla
Located in region	Oslo	Oslo	Oslo	Trondheim	Kristians.	Kristians.
Type of P&R	Local	Local	Local	Town Centre	Local	Remote
Spaces for cars	68	61	81	170	172	24
Site occupancy	100%	98%	54%	96%	24%	71%
Spaces for bicycles	0	0	6	34	42	12
Bicycle spaces used	0	0	0	9	13	0
Average distance between P&R and destination (km)	53.8	49.8	27.5	17.4	14.9	15.0
Average distance between home and P&R along road (km)	5.6	7.5	9.4	6.2	13	4.6
Share of journey done by PT	91%	87%	75%	74%	53%	77%
Share < 1 km from home to P&R	3%	0%	1%	3%	3%	0%
Share 1–3 km	4%	2%	23%	28%	13%	57%
Share 3–10 km	66 %	58 %	39 %	50 %	47 %	36%
Share > 10 km	28%	40%	37%	19%	37%	7%
Share who says bus to P&R was an alternative	33%	39%	50%	41%	67%	25%
Share who alternatively would walk, bicycle or use bus to access the station	17%	8%	40%	22%	0%	0%
Share who would have driven to another P&R	39%	79%	33%	17%	0%	60%
Share who alternatively would use car to the destination	17%	0%	5%	26%	33%	25%
Calculated vkm saved per user, using data from survey	17.1	− 0.4	− 2.7	7.0	10.0	9.2
Influence of fare zones or toll	No	No	No	No	No	No
Relation to local centre	Outside	Outside	Outside	In centre	Outside	Outside
Traffic-inducing displacement of activities?	No	No	No	Yes	No	No
Encouraging urban sprawl?	Yes	Yes	Yes	Yes	Yes	Yes
Reason to expect induced traffic?	Yes	Yes	Yes	No	No	No

the various P&Rs, and answers to the survey, to analyse if they use their closest P&R. We studied plans, maps and aerial photos to evaluate whether the P&R occupied space in centres or public transport nodes with a strong potential for the development of housing, work-places and other activities, and where the P&R hence were understood as causing traffic-inducing displacement of activities. We studied regional plans and municipal master plans to judge whether the P&Rs were located in areas and regions with high potential for urban sprawl, contributing to increased traffic. We also collected data from road-authorities concerning congestion-levels in the cities, to discuss if traffic 'taken out' of the system because of the P&R would likely be replaced by induced traffic. For each of the 12 P&Rs, we discussed what could be alternatives to expanding the site if it was fully occupied.

The results and understandings from analysing 12 individual P&Rs were used as inputs for cross-case discussions, with the aim to figure out what characterizes P&Rs contributing to reduced total traffic volumes in an urban region. This was analysed in a more short-term and static perspective, assuming that home- and work-addresses of users were stable, as well as in a regional and long-term perspective, including land-use dynamics.

3.3 Developing a tool for assessing effects of P&R on traffic volumes

Findings, experiences and insights from the studies of planning processes and assessment methods, as well as from our assessment of effects of 12 P&Rs on the overall traffic volumes, were used to develop guidelines for assessing if new or expanded P&Rs could be expected to contribute to reduced traffic volumes in an urban region. This also included which alternative measures can be implemented instead of P&R in different contexts. The guidelines are meant to be used by planners and policy-makers, and the aim is to describe easy-to-use methods for assessments, using easily accessible input data.

4. Planning processes, analyses and assessment methods for P&R

Through our investigations, we found that the initiative for constructing or expanding a P&R can come from commuters, organisations, public transport operators, municipalities, regional authorities or political decision-makers. The expressed motivation is often an observed demand for new spaces, as demand exceeds existing capacity. This was also the key argument in the three cases we studied (in the case where a new P&R was constructed, this was a response to perceived lack of capacity of an existing P&R). When asked, interviewees explained that the underlying objective obviously is to reduce traffic, by enabling commuters to park their car at the P&R and travel by public transport to the final destination. It varies who are responsible for planning, financing and implementing P&Rs. In our three cases, it was the Norwegian Public Roads Administration. In other cases, it could be railway authorities, public transport operators (bus, railway) or regional authorities. Whether municipal authorities and political decision-makers are involved, depend on zoning regulations.

Several interviewees said there is a need for more systematic and strategic planning and analyses of P&R in a regional perspective. They told that new P&Rs often had been located where land was available near the existing public transit service, without much consideration. This was also the case in our three cases. Effects on traffic volumes had not been analysed, and alternative measures (parking fees, improved bus access to the

station/bus-stop, or the like) had not been considered. In one case, there had been some discussion on alternative locations. Concerning dimensioning of P&Rs, 'the more the better' had been the criteria in the cases. The interviewees could not identify sources for knowledge they used or could use in assessment and planning of P&R. We concluded that there was a need for developing an easy-to-use tool for ex-ante assessments of traffic-reducing effects of P&Rs (new and expansions).

5. How properties and context of P&R affect their traffic-reducing effects

5.1 Key figure for individual cases

Each P&R was analysed separately (see Hanssen, Tennøy, Christiansen, & Og Øksenholt, 2015). Key findings have been summarised in Tables 1 and 2, together with information on key properties of each P&R. The findings are used as input to the cross case-discussions below.

5.2 Analyses across cases

Current users of the p&rs

Direct traffic-reducing effects of the 12 P&Rs were analysed by calculating the extra traffic generated if the sites were removed. These calculations assumed that current users would do the same journey as before (that there would be no change in home-addresses, work-place location or other things affecting the origin-destination matrix), and that they would find other ways of travelling. These effects were calculated in two different ways (see Section 3.2 for description of methods).

First, assuming that the only alternative to driving to the P&R and travel by public transport from there is to drive all the way to the final destination, we used survey-answers concerning final destinations of the P&R-users to calculate average distance travelled by public transport from each P&R. By doubling the figures (to include return trips), we found that traffic saved varied between 25 km (Rosenholm) and 107.6 km (Ringerike) perused parking space per day (see Figure 1). Understood and calculated this way, all P&Rs save traffic and the P&Rs located furthest from the users' final destinations save most traffic (vkt).

Second, we also used answers from the survey concerning how P&R-users would have travelled if the P&R they used did not exist (see aggregated answers in Figure 4), and calculated the difference between traffic generated in the situations with the P&R (the car-trips to and from the P&R) and without the P&R. This allowed for including more alternative responses to removal of the P&R: Finding alternative parking options close to the station or bus stop, using other modes of transport than the car to and from the station or bus stop, drive to another P&R, or drive all the way to the destination. Calculated this way, the effects of removing P&Rs vary from a 5.4 km increase per parking space per day (Heiatoppen) to a 35.6 km reduction (Ski). Results are listed in Tables 1 and 2, and illustrated in Figure 1.

There are significant differences in results between the two ways of calculating traffic-reducing effects. This underlines the importance of understanding that many P&R-users do have other options than driving all the way if the P&R they use does not exist. The

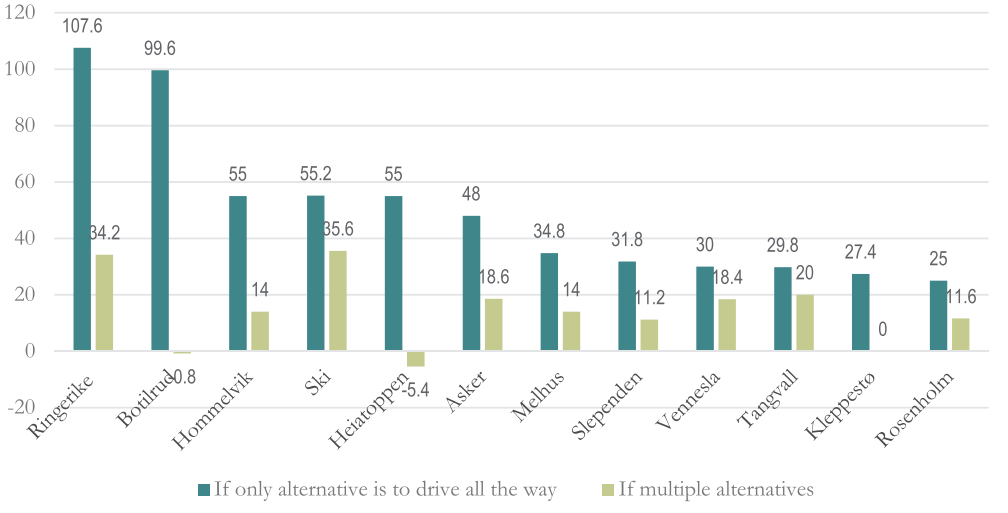

Figure 1. Calculated effects of removing P&Rs, vehicle kilometres travelled per parking space per day.

ranking between P&Rs with respect to traffic-reducing effects also differs when calculated in two different ways. The main explanation for this is the large variation in how many answered that they would drive to the next P&R and travel by public transport from there. This varies from 0% at Tangvall to 79% at Botilrud (see Tables 1 and 2), and is obviously related to whether there exists an alternative P&R to drive to. For Botilrud and Heiatoppen, results show reduced traffic if the P&R was removed. At Botilrud, the explanation is related to none answering that they would drive all the way to the destination, while 79% would drive to the next P&R and 8% would use other modes to the bus-stop. At Heiatoppen, only 5% answered they would drive all the way, 33% would use another P&R and 40% would use other modes than car to the bus-stop.

The results of these calculations show effects if *individual* P&Rs did not exist, and not the effects of removing the whole *system* of P&Rs. If we instead had asked (in the survey) what the P&R-users would have done if there were no P&Rs along their route to the destination, the second way of calculating would probably have resulted in higher figures for traffic saved by the P&Rs. Our understanding is anyhow that all 12 P&Rs contribute to reduced traffic volumes, if assuming that nothing changes, except from the existence/non-existence of the P&Rs. Further, that the P&Rs located the furthest from the final destinations of their users contribute the most to reducing traffic.

Shifting mode of transport between home and the station or bus-stop

Introduction or expansion of P&R can lead to people shifting from other modes to car on the trips to and from the station or bus-stop, as described in Section 2. Likewise, removing a P&R could make people shift from car to other modes between home and P&R, as the survey referred above to confirm. The shares of the total travel distance done by public transport in our cases vary between 53% (Tangvall) and 91% (Ringerike), and the average distances between home and the P&R vary from 4,6 km (Vennesla) to 13 km (Tangvall), see Tables 1 and 2. This means that shifts to other modes than car for the

transport to the stations in several cases have the potential to reduce total traffic volumes significantly.

We analysed the 12 P&Rs to gain a better understanding of the options the P&R-users have. Between 0% and 40% of the users of different P&Rs answered that they would have travelled by other modes than car to the station or bus stop, and by public transport from there, if the P&R they used was not an option. Between 1% and 6% of the users of the 12 P&Rs lived within walking distance from the P&R they used (1 km measured along the road). Hence, it would not affect traffic volumes much if those living in walking-distance started to walk instead of driving to the station. The number of P&R-users living within 3 km from the P&R they use vary between 2% and 60%, and for half of the P&Rs more than 30% live within 3 km from the P&R. Hence, for some of the P&Rs, bicycle could be a relevant mode between home and station for a high share of the users. P&Rs served by railway have higher shares of users living within 3 km than bus-based P&Rs. In the surveys, between 10% (Rosenholm) and 83% (Kleppestø) of the P&R-users answered that they could have used a local bus to the P&R. Analyses of whether P&R-users drove to their closest P&R (see below) revealed that users living in the same local neighbourhood drove their separate cars to the same P&R (for instance Botilrud), and that many users of some P&Rs drove along the same route as the bus serving the P&R (for instance Kleppestø). Hence, there seems to be a potential for car-sharing and for travelling by bus to the stop or station instead of driving their own car and park at the P&R.

The findings show that a significant share of the P&R-users do have alternatives to using P&R, other than driving all the way to the final destination. This is relevant in discussions concerning alternatives to constructing or expanding P&R.

Users do not always use their closest P&R

The traffic-reducing effects of P&Rs are stronger the longer the parts of the total journeys are done by public transport instead of by car. It was hence interesting to investigate if users drove to their closest P&R, and if not, what were the explanations for this. We analysed this using information on home-addresses of each P&R-user, the location of all P&Rs in the transport corridors, fare-zones and road tolls, as well as differences in occupancy rates and the quality of the public transport servicing the different P&Rs. We found that users do not always use the P&R closest to their home address. When analysing Rosenholm, located outside the road toll zone and inside the local fare zone for Oslo, we found that many users of this P&R had passed several other P&R-opportunities before parking at Rosenholm, see Figure 2. Also, when analysing Asker, we found that many users passed several P&Rs served by bus on their way to Asker P&R, which is served by train.

In the survey among users of 23 P&Rs, including the 12 case-sites, 28% of the respondents answered that they had driven past at least one P&R before parking at the P&R they used. Making users stop at their closest P&R could contribute to reduce traffic volumes.

Traffic inducing displacement of activities

We analysed if the 12 P&Rs investigated could be understood as displacing activities by occupying land with high potential for other uses, based on qualitative analyses of maps and aerial photos, and interviews with local planners. Five of the P&Rs were assessed as

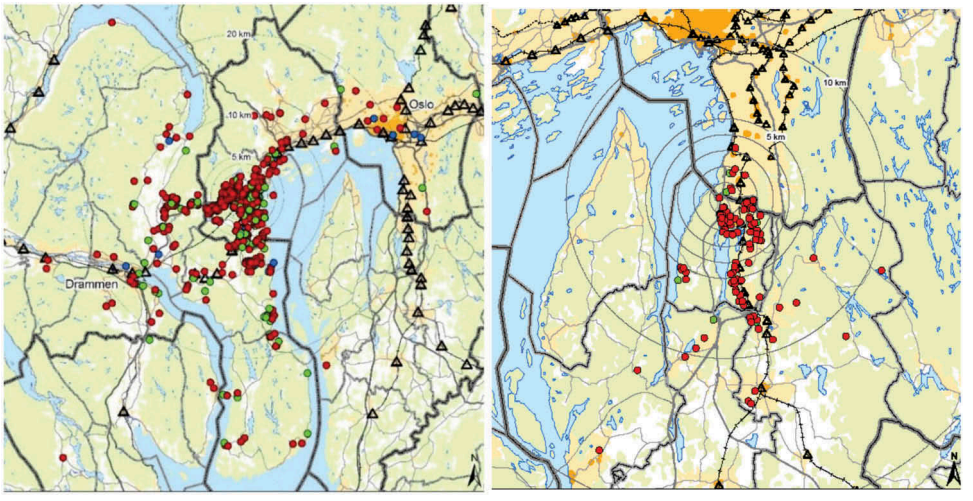

Figure 2. The residential locations for users of Asker P&R (left) and Rosenholm P&R (right). The circles indicate distance from the station in one kilometre intervals. Coloured dots indicate home addresses of car owners using the P&R, and green dots indicate cars with children's seat installed.

displacing activities to more car-dependent locations, contributing to increased traffic. These were all P&Rs serving railway or ferry, located in town centres with the best accessibility in the area by other modes than car. For instance, in the centre of Ski, most of the 541 parking spaces at the existing P&Rs need to be removed, put underground or in multi-storey garages if the planned densification and transformation of the town centre shall be realised (Ski Municipality, 2016). There are plans for constructions with room for 1500 flats and 3500 work-places in this town-centre, located only 10 min from Oslo by frequent trains when an ongoing upgrading of the railway system is completed (Rambøll, 2016; Sweco, 2017). In Melhus, a new P&R along the road and served by bus was built after our study was concluded. The aim was to relieve the town centre, where the railway station and bus-terminal are located, from traffic and parking, to stimulate densification and transformation with flats, work-places and retail. In the town centre in Asker, with 726 parking spaces defined as P&R, the parking and the related traffic are understood as a hindrance for desired development. We have not attempted to quantify the traffic effects of displacements of activities.

Traffic inducing land-use sprawl

When analysed in a regional perspective, and including long-term land-use dynamics, our assessment is that almost all investigated P&Rs contribute to urban sprawl that causes traffic growth. Without these P&Rs, fewer people could choose to live in the car-dependent outer parts of the urban regions. The P&Rs facilitate long commutes between fringe-located housing areas and the central parts of the city. This is beneficial in several ways, but do contributes to increase transport demand and traffic volumes (vkt). The potential for urban sprawl and region enlargement is higher in larger cities, in regions with strong population growth, with high housing prices in central parts of the city, and where the main centre offers many attractive and specialised jobs. This means that P&Rs

located in the Oslo and Bergen regions can be expected to contribute more strongly to urban sprawl than in the other regions.

Potential for removed traffic being replaced by induced traffic

We analysed the congestion levels in the four relevant cities, to assess whether one could expect that traffic taken out of the system by P&Rs would be replaced by induced traffic, and hence counteracting the traffic-reducing effects of P&Rs. We found that this was the case in Oslo and Bergen.

In the survey, we asked the users why they did not drive their own car all the way to the destination. The most frequent reason (63%) was congestion, see Figure 3. Hence, if congestion was reduced for instance because the P&R capacity way expanded, one could expect that some of the current P&R-users would start driving all the way to their destination. Other frequent reasons were expensive parking at the work-place, and that it is faster to use public transport. More detailed analyses of the survey data showed that the importance of the factors varies with the regions in which the P&Rs are located. More P&R-users living in Oslo, but also in Bergen, agreed that congestion was a reason why they did not drive all the way by car, as compared to P&R-users in the other regions.

6. Discussion

6.1 P&R cannot be understood as a sustainable mobility measure

Our analyses illustrate that analysing traffic-reducing effects of P&R is complex, that results depend on which mechanisms are included, as also found in the previous research (Parkhurst & Meek, 2014). When analysing each individual P&R in a short term and rather static perspective, assuming that the same users will do the same journey with or without the P&Rs, but changing mode of transport, all P&Rs investigated were found to save traffic. We found, however, significantly lower traffic-reductions when basing the calculations on survey-answers concerning how people would travel if the P&R they used did not exist, than when assuming that the only alternative to using a P&R is to drive all the way to the

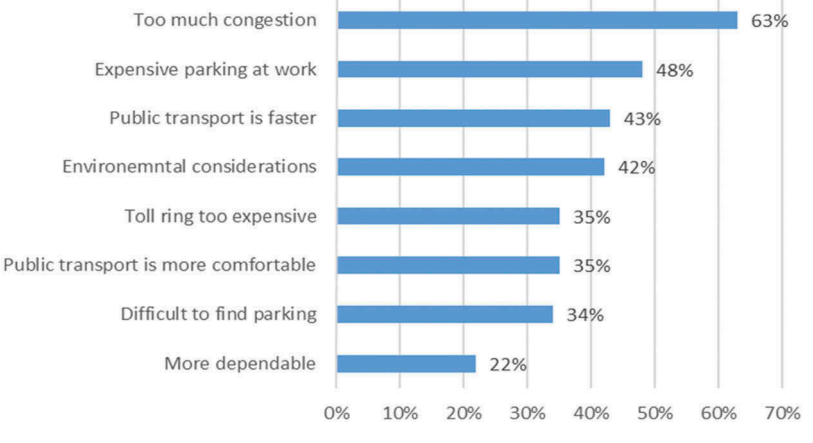

Figure 3. Reasons for not driving all the way to the destination. Multiple answers are possible. Percentages. N = 690.

final destination. This underlines that the latter assumption is an over-simplification that can result in strong over-estimation of traffic-reducing effects of introducing or expanding P&Rs. Understood this way, most P&Rs will contribute to reduced traffic, and the further from the final destination they are located, the more traffic is saved.

When understood in a more strategic and system-wide perspective, including long-term land-use dynamics, most P&Rs were understood as facilitating traffic-inducing land-use sprawl and contributing to traffic-growth. It is well documented that housing, work-places, retail and other activities generate more traffic the further from the main centre of an urban region they are located (Ewing & Cervero, 2010; Næss, 2012; Næss et al., 2019; Wägener & Fürst, 2004). It is also well documented that improved accessibility, for instance, caused by road capacity expansions in congested transport systems, makes fringe-areas more attractive for the development of housing, work-places and other activities (Cervero, 2003; Downs, 2004; Tennøy et al., 2019). As with road capacity expansions, P&Rs facilitate a car-based land-use development, as the transport to and from the home is done by car. This results in a car-dependent and traffic-generating land-use pattern, where many local trips are done by car and where many have long commutes to central parts of the city.

We also found that about half the P&Rs in our study are examples of a problematic situation that causes debate in the Norwegian context. These are P&Rs mainly serving railway, located in town-centres in municipalities located outside larger cities. The debate concerns whether the P&Rs should be removed or significantly reduced in size, to give room for the development of housing, work-places, retail and urban life. For instance, according to the regional plan for Oslo and the surrounding county Akershus, most of the strong growth in housing and work-places in Akershus is to be realised as dense, urban development close to existing town centres with railway stations (Akershus County and Oslo Municipality, 2015). An important concern in the discussions is reduced accessibility by public transport to work-places in the main city for people living in car-based areas, if P&R is reduced or removed. Another is the potential traffic growth if existing P&Rs are removed, and P&R-users start driving all the way to their final destinations. There is, however, little doubt that freeing up the space currently occupied by P&R is necessary if the desired development is to be realised. Similar discussions are going on in other Norwegian urban regions.

In a sustainable mobility perspective, demand for new and expanded P&Rs is a symptom of a car-dependent and traffic-inducing land-use development (see also Parkhurst & Meek, 2014). Meeting the demand by increasing the P&R capacity will reinforce rather than help solving the problem. It does neither contribute to more sustainable mobility patterns (Banister, 2008), nor to achieving the Norwegian zero-growth objective. A relevant question is hence what the alternatives to expanding or constructing P&Rs are.

6.2 Alternatives to constructing or expanding p&rs

Throughout the investigations of the 12 P&Rs in our study, we asked what would be the alternatives to expand them, if the demand should occur. As discussed above, we found that a relatively low share of the P&R-users lived in walking distance to the

station they used, while a higher share of the users lives in bicycle-distance. Relatively high shares of the users could have travelled by public transport to the station or all the way from home to their destination. The demand for increased P&R-capacity could be reduced if some of these P&R-users used these options instead of driving to the P&R. Improving conditions for walking and bicycling would be one way of encouraging this shift, as would improve bus-services to the station or bus-stop, or the direct bus-services to the final destinations. As many P&R-users already have these options, and still drive to the P&R, introducing or increasing parking-fees at P&Rs with capacity problems have been suggested as ways of reducing the demand.

In the survey among users of 23 P&Rs, we asked both how they would have travelled if P&R was not offered at the station or bus-stop they use, and if a low parking fee (25 NOK[4] per day) was introduced, see results in Figure 4. Only 15% answered that they would travel like they used to, and paid the parking fee, as we understand as an indication that some respondents answered tactically. Still, 25% answered that they would walk, bicycle or use local public transport to the station if a parking fee was introduced. 13% would look for other (free) parking near the station, and 25% would drive to another P&R[5]. Twenty-three percent answered they would drive all the way to their final destinations. This means that introducing a parking fee in many situations would reduce the demand for P&R and the need to expand the capacity. The answers are quite similar when respondents were asked what they would do if P&R was not offered at the station they used. It is, however, not clear from our survey how this would affect the net traffic effects (as discussed in Section 5.2).

In areas with low density and long distances from homes to the local public transport feeding the P&R, parking could be offered along the local bus route. This would reduce the distance travelled by car, and remove the demand for P&R in town-centres where P&R is a hindrance for desired development and qualities. Our analyses showed that many users of the same P&R live in the same local neighbourhood, and suitable incentives could make car-pooling an option for some in this situation. In some

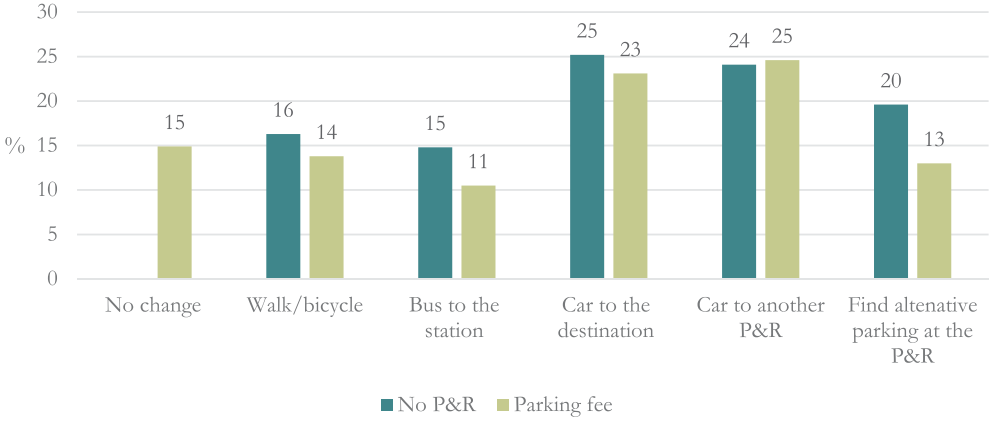

Figure 4. How respondents answered they would react if the P&R they use did not exist, or if a parking fee was introduced at the P&R. Percentages. N = 455.

situations, P&R serving railway could be replaced by new or expanded P&Rs served by bus services, to free up land for desired town-centre development.

7. A tool for assessing if proposed p&rs will contribute to reduced traffic

The experiences from assessing traffic-reducing effects of 12 P&Rs were used in developing a tool for ex-ante assessments of proposed new P&Rs or expansion of existing ones. Assumed users are planners and policy-makers. Therefore, the tool should be easy-to-use, and make use of data and information that are relatively easily accessible to them. The guidelines include a table with key-questions that should be answered with a yes or a no, suggestions for analyses to be done to answering the questions, how necessary data can be collected, as well as a list of measures that could be considered as alternatives to introducing or expanding a P&R. The key questions are listed in Table 3, together with suggestions for further actions depending on the answers.

Suggested analyses that could be executed to answer the questions, and methods and data sources that would be useful[6]:

- Distance from P&R to main destination – potential for traffic saved: GIS analyses, Google maps or the like, information from local planners
- Location of homes of users: Registration of car license plates, retrieving home addresses of car owners (open data) and doing GIS analyses, information from local planners
- Alternatives to driving to the station and park at the P&R: Information about public transport services, and accessibility by foot or bicycle from GIS analyses, information from operators and local planners
- Whether the P&R can cause traffic-inducing displacement of activities: Maps, aerial photos, master plans, information from local planners
- The potential for urban sprawl and regional enlargement: Master plans, regional plans, information from local planners
- The potential for induced traffic: Information on road capacity, congestions and delays on main roads, and potential for induced traffic from traffic authorities and local planners

If the answer to all questions in the table are no, the proposed P&R will probably contribute to reduced overall traffic volumes (vkt). If the answers to one or more of the questions are yes, other alternatives should be considered. What alternatives are appropriate will vary with the context. Funding will be an issue, and a relevant question could be whether money spent on constructing and running the P&R could be used for other measures contributing to achieving defined goals and objectives. The following measures should be considered as alternatives to introducing or expanding a P&R:

- Improving conditions for walking or bicycling to the station
- Improving feeder bus service from residential areas to the station or bus-stop and/or introducing smaller P&Rs at stops served by the feeder service
- Improving regional bus services direct to the main final destinations/main city centre

Table 3. Questions used for evaluating whether a P&R project may reduce traffic volumes.

Question	If Yes	If No
Does the location contribute to long car journeys compared to the length travelled by public transport?	Does not result in significant reduction. Consider alternatives	Allow, if no other significant and unwanted effects
Are many of the users of P&R living close to the station/bus-stop? Do many of the users have a good public feeder service to the station/bus-stop allowing them to leave the car at home?	Results in no or limited effect. Consider other alternatives	Allow, if no other significant and unwanted effects
Do users have another public transport service (within walking or bicycling distance from home) to the final destination?	Could increase traffic volumes. Consider alternatives	Allow, if no other significant and unwanted effects
Are there other and better uses of the site occupied by P&R? Does the parking and traffic hinder other development?	Can displace activities or developments. Consider alternatives	Allow, if no other significant and unwanted effects
Do properties of the P&R or the system of P&Rs cause people to travel longer by car than necessary to reach this P&R?	Contributes to increased traffic to and from the station. Consider alternatives	Allow, if no other significant and unwanted effects
Will this P&R stimulate urban sprawl or regional enlargement?	Could contribute to increased (induced) traffic. Consider other approaches for good access to the station or bus stop	Allow, if no other significant and unwanted effects
Will the traffic relief caused by the actual P&R be replaced by induced traffic?	Does not reduce traffic volumes. Consider other approaches for good access to the station or bus stop.	Allow, if no other significant and unwanted effects

- Introducing or increasing parking fees at the P&R
- Adjusting fare zones for public transport, and/or parking fees at P&Rs, to influence users to choose their closest P&R
- Introducing incentives for carpooling to the P&R, as well as from the P&R to the final destination[7]
- Relocating the P&R, if occupying space with better alternative uses
- Replacing space-consuming P&R with multi-story or underground facilities, freeing up space for desired development
- Reducing the number of parking spaces at the P&R
- Increasing parking capacity at other sites

8. Concluding remarks

We found that P&Rs are constructed and expanded as part of a strategy to stop traffic growth in Norwegian urban regions, and that the effects of P&R on the overall traffic volumes are not assessed as part of the planning processes. Our empirical investigations, together with previous studies, show that P&R in many contexts cannot be understood as a measure contributing to more sustainable mobility patterns or to achieving the Norwegian zero-growth objective. Even though analyses of individual P&Rs in a short-term and static perspective showed that P&Rs save traffic, the results are the opposite when also taking system-wide and long-term mechanisms causing urban sprawl and induced traffic into account. This is in accordance with the findings of Parkhurst and Meek (2014). P&R can also be a hindrance for a traffic-reducing densification and transformation, by occupying land close to railway stations and in local town-centres. We developed an easy-to-use tool for ex-ante assessments of the effects of P&R on overall traffic volumes, including suggestions for alternatives to constructing or expanding P&Rs. The aim is to help improving ex-ante assessments, and by that contributing to hinder that P&Rs are built to reduce overall traffic in contexts where the long-term and system-wide effects rather will be increased car-dependency and traffic growth. As P&R is a popular measure in many countries and cities, we believe our findings and guidelines also can be useful outside Norway.

Notes

1. The research design is inspired by understandings embedded in the meta-theory of critical realism (Bhaskar, 2008, 1989; Danermark et al., 2002; Sayer, 1992).
2. We understand Parkhurst (1995) as the starting point of this discussion, and therefore include it, despite that it is published before 2000.
3. We removed cases with a travel distance of 60 km or more assuming there may be errors in registration or that somebody else than the owner uses the car. The car may also be rented or leased.
4. NOK 25 was a typical price for parking *30 min* in the centre of a large Norwegian city.
5. They did probably assume parking would be free at other stations.
6. Surveys were not included in the list of useful methods and data sources, for three reasons. One is that we do not see this as 'data and information that are relatively easily accessible to planners and policy-makers', as we have defined as a criterion for the methods we suggest. Conducting a survey that can provide relevant and useful answers is resource-demanding, and quite a big step from current practice, where hardly no analyses are

conducted at all. The second reason is that in cases where a new P&R-facility is planned, a survey would need to cover quite large and undefined areas (as it is difficult to know who will use the future P&R) and reach users at their home address. The third reason is that we understand that some respondents have answered tactically to hypothetical questions in our survey, which was not related to any concrete changes in P&R. We believe there would be more tactical answers in a survey concerning concrete changes. Hence, our understanding is that the results of the survey might not be a good basis for making decisions.

7. Introducing incentives for carpooling from P&R to the final destination could potentially instead contribute to increased road traffic, if it results in car-drivers riding with each other to the final destination instead of all going by bus or train. This could, for instance, be in order to split driving costs (petrol, road tolls, etc.) or to be allowed driving in dedicated public transport lanes (if regulations allow for private cars with one or more passengers). To our understanding this is not very relevant in the Norwegian context, and we have hence not included it in the suggestions.

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Appendix A: Interview guide planning processes

For three case interviewees were asked the following questions:

- Who initiated the process and how was it followed up?
- What objectives were defined for introducing or expanding the P&R? Was reduced car traffic (vkt) and GHG emissions among the objectives?
- Were other alternatives than introducing or expanding the P&R considered (relocation, parking fee, improved access to the P&R by other modes than car, etc.) considered in the planning process?
- What assessments were done with respect to effects on traffic volumes and GHG-emissions? On what knowledge were such analyses based?
- Were the analyses and plans transparent, in that they clearly described possible effects of the P&R project on traffic and GHG-emissions?