

# Reducing car use through parking policies: an evidence review

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## 1 Executive summary

### 1.1 Aims

The Scottish Government aims to reduce car kilometres by 20% by 2030 from a 2019 baseline. Parking policy has been acknowledged as having the potential to play an important role in supporting this reduction target. In response to this, ClimateXChange commissioned an evidence review of the impact of parking policies on car use. This report contains the results of that review.

This research has gathered evidence on the effectiveness of different parking management interventions in reducing car use. Its purpose is to inform the development of parking policies which support the joint commitment by Scottish Government and the Convention of Scottish Local Authorities (COSLA) to reduce car use by 20% by 2030.

### 1.2 Findings

The analysis of the literature led to the following key findings.

#### Impact on car use

Five parking intervention types were identified as having an impact on one or more of the following elements: car kilometre reduction, modal split and car ownership.

Intervention type	Impact		
	Car km	Modal split	Car ownership
1. Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Decrease	Positive	Decrease
2. Parking pricing, on- and off-street	Decrease	Positive	Decrease
3. Parking levies	Decrease	Positive	No evidence found

4. Park and ride <sup>1</sup>	Increase	Negative	No evidence found
5. Parking capacity reductions at city or neighbourhood level	Decrease	Positive	No evidence found

**Parking standards, off-site or non-adjacent provision of residential parking, and low-car and car-free housing** is linked to positive impacts on car kilometres travelled, car ownership and modal split. Parking availability and location can influence car use; car-free developments have been found to have car use levels at less than half of city-wide averages, while parking located at 50m or more from dwellings was associated with 25% fewer car trips.

**Parking pricing** can contribute to car kilometre reductions and modal shift, particularly when combined with capacity reduction measures. Car parking costs have also been found to significantly influence car ownership levels.

**Workplace parking levies (WPL)** were found to have a positive impact on mode share. Public transport improvements implemented in tandem with WPL schemes were identified as significant contributing factors in encouraging modal shift.

**Park and ride** was found to generally increase vehicle kilometres travelled (VKT) when located close to destinations. However, when located close to journey origins, it was associated with reductions in vehicle kilometres of the order of 1.5km per park and ride user.

There is evidence that **parking capacity reductions at city or neighbourhood level** have an impact on car kilometres travelled and modal split. In the context of workplaces, there is strong evidence that the provision of parking is linked to an increase in car mode share.

### **Equity and equality issues**

There is extremely limited evidence regarding whether the reductions in car km and changes in modal split achieved by parking interventions are shared across social groups.

Evidence is not available to draw conclusions on how different intervention types may align to inequality reduction goals focussing on island communities and remote rural and rural areas, as per the Scottish Government’s Urban Rural Classifications (Scottish Government, 2020).

### **Alignment to national policies and strategies**

Four of the five intervention types for which strong evidence was found are associated with positive impact on car kilometre reduction, modal shift or car ownership. The exception to this is park and ride. Therefore, these interventions broadly align to climate change

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<sup>1</sup> Six out of eight of the papers providing evidence of a link between park and ride and car use found that park and ride was associated with increases in VKT when the site is located close to the journey destination. One further paper found no impact on VKT. Only when park and ride sites were located closer to journey origins did the literature find evidence of reductions in VKT.

mitigation goals in the Scotland's National Transport Strategy (NTS2) and National Planning Framework 4 (NPF4).

Among the four, there are also broad alignments found between individual intervention types and some other aspects of the NTS2 and NPF4. These aspects include encouraging active travel, reducing levels of car dominance, reducing congestion and air pollution, and supporting sustainable investments.

There is a lack of evidence in the reviewed literature on the application of a place-based approach in parking interventions. However, some of the intervention types may be better positioned to support the use of a place-based approach, given their potential to help reduce the space dedicated to car parking in a particular locality.

### 1.3 Recommendations

In considering the merit of implementing the intervention types with the greatest impact on car use we recommend:

- Testing temporary changes to parking spaces in order to gather further data on the different measures
- Promoting parking management in the context of workplace travel plans
- Considering the significance of site in decisions around park and ride

# Contents

<b>1</b>	<b>Executive summary</b> .....	<b>1</b>
1.1	Aims.....	1
1.2	Findings .....	1
1.3	Recommendations .....	3
<b>2</b>	<b>Glossary and acronyms</b> .....	<b>5</b>
<b>3</b>	<b>Introduction</b> .....	<b>6</b>
<b>4</b>	<b>Aims and scope</b> .....	<b>6</b>
4.1	Aims.....	6
4.2	Scope.....	7
4.3	Methodology.....	7
<b>5</b>	<b>Policy context</b> .....	<b>9</b>
5.1	A route map to achieve a 20 per cent reduction in car kilometres by 2030.....	9
5.2	2020 National Transport Strategy.....	9
5.3	National Planning Framework 4 .....	11
5.4	Place-based approach.....	12
5.5	Summary .....	12
<b>6</b>	<b>Findings</b> .....	<b>13</b>
6.1	Impact on car use.....	13
6.2	Equitable reduction in car kilometres.....	23
6.3	Impactful interventions .....	24
<b>7</b>	<b>Conclusions and recommendations</b> .....	<b>31</b>
7.1	Conclusions .....	31
7.2	Recommendations .....	37
7.3	Research gaps .....	37
<b>8</b>	<b>References</b> .....	<b>39</b>
<b>9</b>	<b>Appendices</b> .....	<b>43</b>
9.1	Appendix A. Methodology .....	43
9.2	Appendix B. Summary of papers providing evidence of impact on car use.....	45
9.3	Appendix C. Bibliography .....	48

## 2 Glossary and acronyms

COSLA	Convention of Scottish Local Authorities
LDP	Local development plan
LTN	Low-traffic neighbourhood
Modal shift	A change from one form of transport to another
Modal split	The percentage of travellers using a particular form of transport
NPF4	National Planning Framework 4
NTS2	2020 National Transport Strategy
P&R	Park and ride
Parking search kilometres	The distance travelled whilst searching for a parking space
Price elasticity	A measure of the effect of a price change or change in quantity on the demand for a product or service
Regression analysis	A statistical method allowing the quantification of the relationship between one or more independent variables and a dependant variable. In contexts where multiple independent variables influence the outcome, regression analysis enables the extent of the impact of each independent variable on the dependant variable to be identified.
SFPark	San Francisco's system for managing the availability of on- and off-street parking
Theory of change	A theory of how and why an initiative works which can be empirically tested by measuring indicators for every expected step on the hypothesised causal pathway to impact.
Travel plan	A plan made with the aim of increasing the sustainability of transport use and reducing reliance on single occupancy car journeys
US	United States of America
USD	US Dollar
VKT	Vehicle kilometres travelled
VMT	Vehicle miles travelled
WPL	Workplace parking levy

## 3 Introduction

The Scottish Government aims to reduce car kilometres by 20% by 2030 from a 2019 baseline. Parking policy has been recognised as having the potential to play an important role in supporting this reduction target. In response to this, ClimateXChange commissioned an evidence review of the impact of parking policies on car use.

In addition to providing evidence on the impacts of different types of parking intervention on vehicle kilometres travelled (VKT), gathered evidence on factors influencing the implementation of parking measures was gathered to inform debates around the public and political acceptability of different intervention types.

## 4 Aims and scope

### 4.1 Aims

The main aim with this research is to gather evidence on the effectiveness of different parking management interventions in reducing car use. Its purpose is to inform the development of parking policies which support the joint commitment by Scottish Government and Convention of Scottish Local Authorities (COSLA) to reduce car use by 20% by 2030.

More specifically, the research set out to:

- review available international evidence on the impact of different parking policies on reducing car kilometres;
- identify success factors and describe successful policies and good practices in order to draw lessons in policy design and implementation applicable to Scotland; and
- identify unintended consequences of the reviewed policies, including for protected groups and local businesses, and barriers to intervention.

These objectives led to the formulation of the following research questions, which informed the nature and extent of our research:

1. What is the impact of the intervention with regard to its contribution to reducing car kilometres and how does the actual impact compare to any ex-ante (modelled) prediction?
2. To what extent do the interventions align with national and regional transport strategies and the National Planning Framework 4, and support a place-based approach?
3. What success factors can be identified related to the interventions?
4. What lessons can be drawn for Scotland across policy design and implementation?
5. What unintended consequences resulted from the interventions (e.g., with regard to protected groups and local businesses)? How do these consequences compare to the predictions made prior to the implementation of the interventions. If there was a difference, why did this occur?
6. (How) did the interventions contribute to an equitable reduction in car kilometres?

7. What barriers to interventions were identified (e.g., related to cost efficiency, sustainability, legislation, public acceptability)? Were any recommendations made and/or experience gained in how to overcome them?

## 4.2 Scope

The review targeted academic and grey literature produced within a 15-year period prior to the research, focusing on interventions in jurisdictions similar to Scotland. For this reason, smaller northwest European countries, particularly the Nordic countries, were of key interest. The Nordic countries are particularly of interest because of their generally low population densities, extensive rural areas and large numbers of small towns. In many of these areas, population decline is a significant concern. At the same time, they offer excellent transport and planning data. The analysis was to include both transport and planning policy and cover site-level and design-based interventions, including parking standards, as well as the location and layout within developments.

Prior to beginning the research, an initial list of parking intervention types was developed, to inform and guide the search for relevant literature. It included the following terms:

- Parking time limits, permits and pricing, both on- and off-street
- Parking pricing in relation to vehicle characteristics
- Parking pricing in relation to household or user characteristics
- Levies/taxes on off-street parking
- Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing
- Park and ride (P&R)
- Parking capacity reductions at city or neighbourhood level and use of resulting space
- Residential parking in historic areas that are pedestrianised
- Shared-use parking
- Effective and fair parking enforcement
- Parking for EVs
- Mobility hubs
- 20-minute neighbourhood and 15-minute cities
- Parking and road space transformation/reallocation.

## 4.3 Methodology

The main phases of the research were a systematic literature search, followed by a literature review and the analysis of collected data. A systematic literature search on Google Scholar resulted in over 4,700 results. The results were sifted by title and then by abstract to identify relevant papers for review.

Searches using the regular Google search engine were also conducted in Catalan, Dutch, English, German, Norwegian, Spanish and Swedish. This was done to identify papers, particularly in the grey literature, which may have been missed in the systematic search, in addition to non-English language papers which may not have appeared when searched for

in English. The languages used in the search reflected the linguistic abilities of the research team and considered the countries of interest established during the inception phase. In addition, contacts working in relevant academic fields were asked to recommend papers.

Ultimately, 139 papers were selected for a detailed review. A full explanation of the methodology is provided in Appendix A, while a full list of papers included in the review is provided in Appendix C.



## 5 Policy context

Research Question 2 considered the extent to which different intervention types align to transport strategies and the NPF4, and to what extent they support place-based approaches. This section provides a brief overview of relevant strategies, policies, and the place-based approach to provide context for the findings on this question.

### 5.1 A route map to achieve a 20 per cent reduction in car kilometres by 2030

The route map for a 20% reduction in car kilometres by 2030 (Transport Scotland, 2022) responds to the Scottish Government's Climate Change Plan commitment to reduce car kilometres by 20 percent by 2030, which in turn forms part of the country's statutory obligations for greenhouse gas emissions reductions by 2045. The route map, which was developed in partnership with COSLA, builds on the vision set out in NTS2 (Transport Scotland, 2020) and aims to help reduce overreliance on car use through four key behaviours: making use of sustainable online options to reduce the need to travel; choosing local destinations to reduce the distance travelled; switching to walking, wheeling, cycling or public transport where possible; and combining a trip or share a journey to reduce the number of individual car trips made.

In describing interventions to support modal shift, the route map highlights that the Scottish Government will provide support to local authorities to ensure that, in their approach to parking, local transport strategies show how parking measures will contribute to meeting emissions reductions targets while also considering their impact on different travellers, including pedestrians, cyclists, public transport users and disabled car users.

The route map also highlights the development of workplace parking levy (WPL) regulations and guidance and the discretionary powers resulting from the Transport (Scotland) Act 2019, which enable local authorities to incorporate WPLs in their local transport strategies to disincentivise private car use. Funds generated from WPL schemes will have to be directed towards initiatives to help the travelling public, including public and sustainable transport provision and infrastructure.

The route map outlines the role of parking in interventions that can help people live well locally. It notes that car dependency has led to environments where the movement and parking of cars are prioritised, and that this encourages car use and discourages the use of other modes. It calls for a reduction in car dominance in local places and emphasises the importance of being able to access opportunities, including those for active travel, locally.

### 5.2 2020 National Transport Strategy

NTS2 (Transport Scotland, 2020) is structured around four main priorities: reducing inequalities, taking climate action, helping deliver inclusive economic growth, and improving health and wellbeing. The strategy's Sustainable Travel Hierarchy provides an overarching framework for its policies and informs the Scottish Government's decision-making around

transport. The hierarchy prioritises walking and wheeling, followed by cycling. Public transport follows, then taxis and shared transport, while private car use is found at the bottom. The Sustainable Investment Hierarchy, meanwhile, prioritises reducing the need to travel unsustainably. Following this are maintaining and safely operating existing assets, and capitalising on existing capacity. Targeted infrastructure improvements should only be carried out once the other steps have been taken. The strategy refers to parking explicitly in reference to the above-mentioned Transport (Scotland) Act 2019, which will enable local authorities to introduce workplace parking levies with the aim of supporting efforts to reduce private car use.

Two of NTS2's four priorities align with the focuses of the specific research questions. The priority 'Taking climate action' identifies the outcomes of helping deliver net zero, adapting to the effects of climate change and promoting greener, cleaner choices, and is closely related to the core focus of this research; measures which contribute to reductions in car kilometres, as covered by Research Question 1<sup>2</sup>. A second priority, 'reducing inequalities', aims to support ease of use, affordability and fair access to transport, and therefore is closely related to Research Question 6<sup>3,4</sup>. The remaining priorities are 'helping to deliver inclusive economic growth' and 'improving health and wellbeing'.

No weighting is applied to any of NTS2's four priorities, giving them equal importance. The priorities are interdependent and cross cutting in nature; for example, improving health and wellbeing through promoting active travel contributes to taking climate action, while reducing inequalities is linked to achieving inclusive economic growth. Individual interventions may contribute to multiple priorities. For example, in addition to reductions in VKT, and therefore contributions to climate change goals, an intervention may have other positive outcomes, such as encouraging the use of active travel options, or contributing to congestion reductions in urban areas. These outcomes can in turn benefit people's health and wellbeing.

The strategy also underlines that transport-related efforts to transition towards a net zero economy should be carried out in accordance with the Scottish Government's Just Transition principles<sup>5</sup>.

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<sup>2</sup> Research Question 1 is: 'What is the impact of the intervention with regard to its contribution to reducing car kilometres and how does the actual impact compare to any ex-ante (modelled) prediction?'

<sup>3</sup> According to NTS2, the assessment of effects around equalities should consider poverty and in particular child poverty, gender inequalities, social isolation, transport needs of young and older people and disabled people. In addition, Scotland's regional differences and the differing needs of cities and towns should also be considered. In cities and towns, congestion and detrimental effects on air quality are important. In rural areas, more limited public transport options and longer commuting distances are important factors affecting people's choices and opportunities. Island communities can face particular challenges related to these factors and often greater levels of isolation.

<sup>4</sup> Research Question 6 is 'How did the interventions contribute to an equitable reduction in car kilometres?'

<sup>5</sup> The Just Transition to net zero includes the following principles: supporting environmentally and socially sustainable jobs; supporting low-carbon investment and infrastructure; develop and maintain social consensus through meaningful engagement with workers, communities, non-governmental organisations, businesses,

### 5.3 National Planning Framework 4

NPF4 (Scottish Government, 2023) is structured around three overarching goals – sustainable places, liveable places and productive places – and informed by six spatial principles: just transitions, conserving and recycling assets, local living, compact urban growth, rebalanced development and rural revitalisation. Organised under the framework's goals are 33 policies.

Policy 13 on sustainable transport aims to 'encourage, promote and facilitate developments that prioritise walking, wheeling, cycling and public transport for everyday travel and reduce the need to travel unsustainably' (Scottish Government, 2023, p.57). Its policy outcomes are:

- Investment in transport infrastructure that supports connectivity and reflects place-based approaches and local living.
- More, better, safer and more inclusive active and sustainable travel opportunities.
- Developments are in locations which support sustainable travel.

In reference to local development plans (LDPs), Policy 13 states that they should promote a place-based approach that considers how to reduce car dominance, including minimising the space dedicated to car parking. It highlights the importance of considering elements such as local living and 20-minute neighbourhoods, car ownership levels and accessibility for users of all abilities.

With specific regard to levels of car parking provision, paragraph e) states that 'proposals which are ambitious in terms of low/no car parking will be supported, particularly in urban locations that are well served by sustainable transport modes and where they do not create barriers to access by disabled people' (Scottish Government, 2023, p.58).

When considering the alignment of intervention types to NPF4, it should be noted that some of the research questions have a clear focus on key elements of the framework. Of its six overarching goals, 'Sustainable places' covers policies on climate change mitigation and adaptations, and sustainable transport. This goal is also linked to the spatial principle 'Just Transition', which is concerned with ensuring the transition to net zero is fair and inclusive. These elements are closely linked to Research Questions 1 and 6, respectively.

NPF4 highlights instances where certain policies are relevant to cross-cutting policy outcomes. In the case of Policy 13, links are drawn to outcomes falling under all three goals: sustainable places, liveable places and productive places. Policy 13 clearly contributes to a transition towards more sustainable, lower emissions travel including active travel and public transport, as aimed at under Sustainable Places. Under Liveable Places, it is indicated that Policy 13 is linked to achieving 'homes that meet our diverse needs'. Specifically, the

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industry bodies and any other relevant groups; making all possible efforts to create decent, fair and high-value work in a way that does not negatively affect the current workforce and overall economy; and contributing to resource-efficient and sustainable economic approaches which help address inequalities and poverty (Transport Scotland, 2020).

policy makes clear that the views of disabled people must be sought when seeking to reduce reliance on the car, including when this is done by managing parking provision. Finally, under productive places, Policy 13 is linked to 'rural revitalisation' in that it ensures, through the assessment of transport impacts of developments, that an area's needs and characteristics are considered, while the policy also contributes to 'lifelong health and wellbeing' by encouraging active travel.

20 minute neighbourhoods, in addition to being referred to in Policy 13, are the specific focus of NPF4's Policy 15, which states that 'development proposals will include, where relevant, 20 minute neighbourhoods' (Scottish Government, 2023, p.61).

NPF4 encourages LDPs to promote a place-based approach. It states that LDPs should promote a place-based approach that considers how to reduce car dominance, including minimising the space dedicated to car parking. It highlights the importance of considering elements such as local living and 20-minute neighbourhoods, car ownership levels and accessibility for users of all abilities.

## 5.4 Place-based approach

Place-based approaches involve understanding the issues, interconnections and relationships in a place and coordinating action and investment to improve the quality of life for that community. Importantly, place-based approaches are not about understanding an issue or policy context in a particular geographical area. Rather, they aim to understand the place and then plan policy responses that are coordinated with co-benefits across a range of outcomes. They are collaborative processes that take a long-term approach. Place-based working requires the formation of partnerships across the public, private and third sectors and with communities directly (ourplace.scot, 2023).

## 5.5 Summary

Overall, the Scottish policy context for transport is one in which there is a place for using parking as a means of reducing demand for travel by car and for planning parking into new developments. In this way, the dominance of parked vehicles may be reduced, potentially enabling road space reallocation to support and encourage active travel and public transport.

## 6 Findings

In this section of the report, we summarise the evidence that responds to each of our research questions but, rather than responding question by question, we have grouped them into three overarching categories, reflecting both the availability of evidence for all research questions, and the fact that certain research questions are closely related. In addition, we disaggregate the results by intervention type to present the evidence of the effectiveness of each intervention, but also the barriers to their implementation and lessons that the literature provides about how to implement these measures.

### 6.1 Impact on car use

In this section we consider the quantity and quality of the evidence on impact of different parking-related interventions on reducing car kilometres. It is important to note that, as well as papers reporting changes in car km, we reviewed an equal number of reporting changes in modal split (i.e. the proportions of trips by different modes). These were included because a change in modal split is also likely to lead to a change in car km, although to what degree is unknown due to a lack of data on trip distances. There are also papers that report an association between parking and car ownership. This is significant as if people are less likely to own a car, they are much less likely to generate km travelled by car. It should be noted, however, that people who do not own a car may be more reliant on lift-giving by others and that this may lead to additional car trips being undertaken by lift providers.

In the following sub-sections, the findings from some papers that are classified as being of high-quality, relevant to each topic, are described in more detail. These papers have been selected because of the robustness of their methodology (for example, they may include a control group or use statistical methods<sup>6</sup> to control/explain the impact of other variables that influence car travel, such as socio-economic factors); and because they show strong evidence that the parking interventions that they study have an association with reduced car use or ownership. A full explanation of how strength of evidence and robustness of methodology was assessed is provided in Appendix A, while tables containing headline figures on strength of evidence and robustness of methodology are found in Appendix B.

#### 6.1.1. Car kilometres

This section reviews the evidence that parking interventions have an impact on car kilometres travelled.

A total of 37 of the reviewed papers were found to provide evidence of parking interventions having an impact on car kilometres travelled. Most show a moderate or high impact, though in seven cases little impact was observed from the parking intervention. With regard to which of the intervention types identified in Section 4.2 were included in

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<sup>6</sup> Regression analysis is a statistical method allowing the quantification of the relationship between one or more independent variables and a dependant variable. In contexts where multiple independent variables influence the outcome, regression analysis enables the extent of the impact of each independent variable on the dependant variable to be identified.

these papers, parking pricing featured most highly (11 papers), followed by park and ride (eight), parking levies (four), parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing (three), parking capacity reductions (two) and effective and fair enforcement (one)<sup>7</sup>. The number of papers scored at each level for robustness of methodology and strength of evidence is shown in Appendix B.

Some seven papers cited evidence of increased (six papers) or no change (one) in car kilometres as a result of parking policy and all were on P&R. All of the papers on other intervention types found that parking policy reduced vehicle km.

Average changes in car kilometres were found to be difficult to compare, as many studies report results in different ways. For example, city centre traffic levels, city traffic levels, traffic levels on main roads, nationwide VKT, nationwide VKT from commute traffic and search traffic in different areas are all used as measures. The comparability of the data does not affect the strength of evidence observed in individual studies, but it does mean that the number of studies showing exactly the same type of impact on car km is very limited.

The evidence is clear that parking pricing reduces car km, but the studies that quantified the reduction gave a wide range to the associated reductions, between 0.3% and 16%. This wide range is due to the impact being highly sensitive to the proportion of drivers who are affected by the charges or (for example, those who have a space provided by their employer are not affected by on-street charges); and because a few studies also reported on the impact of pricing measures implemented alongside overall parking capacity reductions (e.g. Pfaffenbichler and Schopf, 2011).

Modelled results from parking pricing in two studies indicate a 0.3 to 3% reduction in VKT at entire city level or nationwide level from a fee of, typically, €1 to €3 a day<sup>8</sup>. (Palmer and Ferris, 2010; Ecorys, 2022). A similar level of reduction is also reported in empirical studies such as Ostermeijer *et al.* (2022). On the other hand, two modelling studies considered the impact of much higher prices, those that the market would charge for providing off-street parking. Here, the reduction in car km was much larger, at 6% (Netherlands, nationwide, commute traffic only) and 16% respectively (all travel, nationwide, Switzerland) (CE Delft, 2018; Swiss Federal Office for Spatial Planning, 2021).

Real time parking occupancy monitoring and demand-responsive pricing at a city-centre scale can reduce parking search km travelled in the affected area by 20% or more. Thorwaldson *et al.* (2021) report the results of an experimental project in downtown San Francisco (SFPark), whereby off-street and on-street parking occupancy was measured (via sensors) and monitored, and prices adjusted by +/- USD 0.50 depending on occupancy, all in real time. In this way, less busy parking spaces became more attractive, while price increases in the busiest locations reduced demand and hence also search traffic kilometres

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<sup>7</sup> Note that the total for the number of interventions may differ from the total for the number of papers since some papers included references to multiple intervention types.

<sup>8</sup> At the time of writing this is equivalent to between £0.86 and £2.58.

travelled; and search traffic was directed to off-street car parks. This was communicated to drivers online and via an app (Zimmerman, Klein and Schroeder, 2014)

Empirical studies of parking pricing and capacity reduction on-street in Paris (early 2000s) and of low-traffic neighbourhoods (LTNs) in London in 2010s show VKT area-wide (all in Paris; just residents for LTNs) reduced by 6.4% to 16% (Pfaffenbichler and Schopf, 2011; Kodransky and Hermann, 2011) In Paris, the policy in this period both reduced the number of on-street parking spaces available from 172,800 in 2003 to 158,700 in 2007; and, in addition, made more of these spaces subject to a charge, so that whilst in 2003, of the total on-street parking available, 49,600 spaces had no charge or other restriction, this number had been reduced to only 2,700 by 2007. The change in parking price over this time is not reported (Pfaffenbichler and Schopf, 2011).

On the price elasticity, papers dealing with this topic were mostly in agreement that short term parking price elasticity is around  $-0.3$ , meaning that a 10% rise in price will lead to a 3% fall in demand, although one paper found elasticities greater than 1, indicating that demand falls more in percentage terms than the percentage rise in price (Milosavljević and Simićević, 2016). If anything, modelled impacts tend to be smaller than empirically observed ones – this is a finding from Milosavljević, and Simićević's work, but also from comparing other papers reviewed for this study.

#### **The impact of parking pricing on vehicle kilometres travelled in Amsterdam**

In 2018, the City of Amsterdam committed to a mobility plan which aimed to prioritise active transport, while reducing car use. As part of this plan, in April 2019, the city raised the prices of hourly paid on-street parking. The average hourly price increased by 66% (or €1.67), from €2.55 to €4.22 per hour, while in the city centre prices went up from €5.00 to €7.50 per hour. Over the same period, the City of Amsterdam removed 1,141 on-street parking spaces (0.6% of the total), turning them into public spaces such as playgrounds, park benches and bicycle parking.

The effect of these interventions was that traffic volumes fell citywide by 2 to 3%, with the decline in traffic larger during the evening peak period (between 4pm and 8pm). Vehicle kilometres travelled are estimated to have reduced by 109,000km a day<sup>9</sup>. Overall, on-street parking demand fell by about 17%, with demand for on- and off-street parking combined declining by about 14%. Moreover, off-street parking demand did not increase to offset the drop in on-street parking demand.

The effect of the reduction in on-street parking on car travel is believed to be very limited, since the price increase led to a bigger fall in demand (1.8% of total spaces) than the number of spaces which were removed. The effect of the sudden shock of increased parking charges was more dramatic.

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<sup>9</sup> The figures for the total reduction in car kilometres travelled and percentage reduction in traffic volume were generated by multiplying the average car journey length by the number of car journeys avoided following the interventions. As such, the estimated reduction in traffic volumes is a proxy for the percentage reduction in car kilometres travelled.

Success factors associated with the interventions include the share of motorists who have to pay for on-street parking (as the initiative is aimed at on-street parkers only), the availability of alternative transport methods (with good public and active transport provision increasing the likelihood people will reduce their car use), and the difference in price of on-street and off-street parking (if off-street parking becomes cheaper than on-street parking, motorists may simply move to alternative parking methods rather than reducing car use).

A higher on-street parking price may generate societal benefits by reducing cruising, congestion, pollution and accidents, while freeing up parking areas for other uses. Increasing parking prices also generates revenues which can finance public goods. The overall effect is estimated to improve societal welfare in economic terms, especially that of residents.

Source: Ostermeijer *et al.*, 2022

Park and ride was found to generally increase VKT when the P&R sites are located close to destinations, for example on the edge of a city. Hanssen *et al.* (2016) conducted a systematic analysis of evaluations of P&R sites and found that P&R is associated with reduced VKT where it is located close to traveller origins, while the opposite is true where it is located close to destinations. Similar findings came from an analysis of data for over 180 P&R sites presented by Zijlstra *et al.* (2015). These latter authors reported that, within their sample, P&R sites close to home origins intercept 21 cars (whose destination is a major city centre) per 100 parking spaces, while private car kms reduce (by 1 to 4 km per user, with an average of 1.5km) and public transport increases. P&R on urban fringes close to a final destination city centre intercept about 47 cars per 100 parking spaces provided, and car travel increases by 1 to 4 km per user. The reason for the higher number of cars intercepted at the destination P&R is because the site is closer to the destination, but the reason for the increase in car km is because a quite high proportion of these car trips would have used public transport for the whole trip in the absence of the P&R site.

The following is a summary of key findings from this section:

- Parking pricing of the order of €1 to €3 per day can reduce car km by between 0.3% and 3% at entire city or nationwide scale, while other studies identified reductions of between 6% and 16%. The reduction level is highly sensitive to the proportion of drivers who are affected by the charge and whether it is implemented alongside overall parking capacity reductions.
- Real time parking occupancy monitoring and demand-responsive pricing at a city-centre scale can reduce parking search kilometres travelled in the affected area by 20% or more.
- Park and ride was found to generally increase VKT when located close to destinations. However, when located close to journey origins, it was associated with reductions in vehicle kilometres.



### 6.1.2. Modal split

This section reviews the evidence that parking interventions have an impact on mode choice for trips. This is different from vehicle km in that the evidence here does not include measurement of the change in distance travelled as a result of the parking intervention.

Forty-seven papers were found to contain evidence of parking interventions' impact on modal split. Of these, 17 covered parking standards, off-site or non-adjacent provision of residential parking, or low-car and car-free housing, while 14 included parking time limits, permits and pricing and on- and off-street, and 10 included parking levies. Other interventions for which an impact on modal split was found were P&R (six papers), parking capacity reductions at city or neighbourhood level (three), parking and road space transformation/reallocation (two), parking pricing in relation to household or user characteristics (one) and shared use parking (one)<sup>10</sup>. For a breakdown of the number of papers ratings at different levels for robustness of methodology and strength of evidence, see Appendix B.

There is strong evidence based on papers with robust methodology that modal split is influenced by parking pricing and parking availability. These factors can reduce car modal split by 25-50% compared to a baseline where there is ample free parking. There is also strong evidence that travel plans have a greater impact on modal split when they include some form of parking management.

National travel survey data from Norway (Christiansen, Engebretsen and Hanssen, 2015; Christiansen, Hanssen, and Skollerud, 2015) shows that when employers provide parking, car mode share is at 58%, while when parking is not provided, it sits at 20% (Christiansen, Engebretsen and Hanssen, 2015). Since this work draws on a national survey, it provides some of the most robust evidence found on modal split; the studies have a large sample size due to being based on a large-scale household travel survey. Furthermore, since the survey also enquires about the location and cost of respondents' parking place at work and at home, it is possible to draw inferences at the level of different cities about the relationship between parking availability (and whether it is charged for) and travel behaviour, and also car ownership (see Section 6.1.3)<sup>11</sup>. In the Geneva region, a significant difference was also observed between car use by workers whose employer provides parking (39% mode share) and those that do not (24%) (Swiss Federal Office for Spatial Planning, 2021).

There is also evidence that the availability of parking spaces at a city scale influences mode split. McCahill *et al.* (2016) found that an increase in supply of between 0.1 and 0.4 parking spaces per person across US cities was associated with a 30% increase in car mode share.

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<sup>10</sup> Note that the total for the number of interventions may differ from the total for the number of papers since some papers included references to multiple intervention types.

<sup>11</sup> There is, however, no information on the level of charge that people surveyed pay. It should also be noted that the studies do not consider a planned intervention but rather the impact of parking conditions experienced in different parts of the city or country (e.g. distance of parking spaces from home).

Cars were also found to have a lower modal share in car-free and low-car residential areas. Car-free developments in Germany and the Netherlands were found to have car use levels at less than half the city average in their respective settlements (Foletta and Field, 2011; Melia, 2014), while in Norway, a study of four major cities found that people whose residential parking spot is 50m or more from their house make 25% fewer car trips than those whose parking spot is immediately outside their home (Christiansen, Hanssen and Skollerud, 2015).

### **Parking prices and limits in a low-carbon community**

Hammarby Sjöstad is a modern, environmentally sustainable, mixed-use district in Stockholm, located 3km from the city centre. The district is structured around a 37-metre boulevard and transport corridor, with tram lines, platforms, single car lanes, bicycle lanes, parking spaces and a public walkway. Greenspaces, plazas and walkways have also been prioritised in its development. Accessibility to services (including for disabled people) has been important throughout the development, as has access to amenities, with no resident more than 1km from a grocery store.

Parking in the district is priced and limited, with approximately 0.15 on-street parking spaces per household, and 0.55 spaces in public or private garages per household, while car ownership is low, with 210 cars per 1,000 residents (compared to 370 per 1,000 in the rest of Stockholm). These figures have contributed to cars having a low modal share; only 21% of journeys are made by car, with 52% by public transport and 27% by non-motorised modes. Furthermore, overall transport related emissions are estimated to be half of those generated by the average Stockholm resident and less than a third of the level of an average resident of Sweden.

Improved public transport provision and active travel infrastructure has also contributed to these outcomes and includes increased bus services, cycle and walking routes, a ferry service and an extension of the tram line (which serves one third of all trips made by residents). Public transport ticket integration has also helped to encourage its use, with bike and car-sharing schemes also present. Congestion pricing in the city centre, just outside of Hammarby Sjöstad, also helps to limit car use.

Lessons from this development include the importance of having a holistic approach to planning, integrated with infrastructure and through cooperation of all stakeholders. Availability of high-quality public transport is also key. Information and incentives to influence behaviour change are necessary, with evaluation and monitoring also important to continue the sustainability of projects.

Source: Foletta and Field, 2011

Cairns *et al.* (2010) reviewed in detail the content and impact of travel plans at 21 large workplaces (13 of them private sector) in Britain in the early 2000s. The difference in impact of the travel plan depending on whether or not some form of parking management in place was stark. At organisations with parking management in place, the travel plans achieved an

average reduction in drive-alone commuting of 24%, whilst those without parking management achieved an average reduction of 10%, from a much higher original level of staff driving alone. As the authors state “organisations that had addressed parking in some way had achieved more than double the reduction in car use of those that had not, and had car driver levels which were, on average, 25% lower” (Cairns *et al.*, 2010, p481). Some of the success factors underpinning the measures in the travel plan are discussed in Section 6.2.

Only two of the organisations without parking management achieved reductions of more than 10% in drive-alone commuting. Perhaps unsurprisingly, the organisations which did introduce parking management were those where there were many more staff than parking spaces available: parking management is a driver of travel plan success, but parking management becomes necessary where there is a shortage of parking. The paper did not control for other variables, such as public transport accessibility, which could also affect the impact of the travel plans.

Workplace parking levies (WPL) were also found to have an impact on mode share. In Nottingham the introduction of the WPL led to 8.6% of car commuters switching to other modes (Dale, *et al.*, 2019). According to Richardson (no date), the car mode share for trips to Perth (Australia) city centre dropped from 50% in the mid-90s to 35% in 2010, in part due to the introduction of a levy on off-street parking in the city which led to an increase in price and reduction in supply, but also due to improved public transport and new high density inner-urban residential development within walking distance of the city centre.

#### **Nottingham’s workplace parking levy**

In 2012, Nottingham became the first UK city to implement a WPL (Dale *et al.*, 2019). This affected car parking used by major employers within the city boundary, while health facilities, emergency services, workplaces with under 10 staff and places occupied by customers, delivery vehicles and blue badge holders are exempt (Dale *et al.*, 2014a). The scheme aimed to reduce congestion and fund public transport improvements to incentivise their use. In the UK, any revenue raised by such schemes must be used to fund transport improvements (Dale *et al.*, 2014a). The charge in 2014 in Nottingham was £334 per workplace parking place per year but was planned to rise with inflation (Dale *et al.*, 2014a).

The WPL has contributed to a modal shift away from the car in Nottingham. The total number of people travelling by car fell by 6.6% between 2010 and 2017, with public transport numbers rising by 9.6% over that period (Dale *et al.*, 2019). Over 22% of commuters surveyed stated that they switched to using the bus, tram, train or bike from car for their commutes since 2010, with 13.4% of commuters who use those modes stating that the change was due, at least in part, to the WPL (Dale *et al.*, 2019). However, the shift was smaller than initially estimated in the intervention’s theory of change. Dale *et al.* (2017) concluded that this was due to the existence of suppressed demand for commuting by car prior to the introduction of the WPL. Following the introduction of the levy and implementation of related public transport improvements, reduced congestion

levels encouraged some motorists to commute by car when they may previously have avoided it.

Public and business views were recognised as potential barriers to implementing workplace parking levies, alongside political risk for decision makers (Dale, 2017). Consequently, Nottingham City Council undertook extensive public consultation on the proposals (Dale, 2017). The outcomes of this consultation included the need for ongoing business support (e.g. parking management advice and travel planning support) to offset the WPL costs to employers (Dale *et al.*, 2019). These services are now funded by the WPL (Dale *et al.*, 2019).

The levy, which is ongoing, generated over £44 million in revenue in the first five years of its operation, from a £4 million outlay (Dale *et al.*, 2019). These revenues have been invested in expanding the city's tram network, redeveloping the main railway station and investing in local bus services, thereby contributing to a significant increase in public transport capacity (Dale *et al.*, 2019).

Sources: Dale, 2014a; Dale, 2017; Dale *et al.*, 2019

The following is a summary of key findings from this section:

- There is strong evidence that modal split is influenced by parking pricing and parking availability. These factors can reduce car modal split by 25-50% compared to a baseline where there is ample free parking.
- There is also strong evidence that travel plans have a greater impact on modal split when they include some form of parking management.

### 6.1.3. Car ownership

There is strong evidence of the effect of parking price, location and availability on car ownership. A total of 17 of the reviewed papers provided evidence on the impact of parking interventions on car ownership, with 13 of these including findings on parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing; and seven providing findings on parking time limits, permits and on- and off-street pricing<sup>12</sup>.

Comparing suburbs of the four largest cities in the Netherlands with their city centres, **car parking costs** (including search time, related to availability) **accounted for 30% of the variation in car ownership** (Ostermeijer *et al.*, 2019). **An increase in on-street residential permit prices in the centre of Amsterdam from the current €500 to €3,600<sup>13</sup> a year would cut car ownership by 24%**, based on a regression analysis of existing car ownership levels in different districts of the city, which finds that a €100 increase in annual parking permit costs is currently associated with a 1.7% decline in car ownership. Based on this observed

<sup>12</sup> Note that the total for the number of interventions differs from the total for the number of papers since some papers included references to multiple intervention types.

<sup>13</sup> At the time of writing, €500 is equivalent to £427 and €3,600 is equivalent to £3,074.

relationship between permit price and car ownership, the authors use modelling to predict the impact of a much larger, hypothetical price increase.

Also in central Amsterdam, the price of a resident's permit rose from about €180 in 2001 to €530 in 2018, and available spaces per permit fell by 20%. Car ownership fell by 16% in Amsterdam during this period but rose by 17% across the Netherlands as a whole inline with general economic growth (Strategy Development Partners and Martens, 2019). Therefore, it is reasonable to assume that residents' permit prices and availability may have played a role in influencing car ownership in Amsterdam. However, the study did not control for other variables such as changes in socio-economic factors including, for example, an increase in single-person households in the city.

Analysis of Norwegian travel survey data for its four largest cities found that only 19% of households with a parking space on their own property did not own a car. By comparison, among households who only have on-street parking, 53% did not own a car. This effect is independent of other socio-economic factors. For example, regression analysis of the associated data found that having reserved car parking had twice the impact on the probability of owning a car compared to the effect of being a family with small children (Christiansen, Hanssen, and Skollerud, 2015).

Even greater differences in ownership were found in the case of the Freiburg Vauban car-reduced development, which has **one third of the average level of car ownership** of the Federal German State in which it is located (Kirschner and Lanzendorf, 2020). This is without, however, controlling for other factors, such as demographics and public transport accessibility.

#### **The relationship between car use and ownership and parking – data from the Norwegian National Travel Survey**

Two Norwegian papers highlight the effect that parking at home or at workplaces can have on mode choice. The Norwegian national travel survey has a sample size of 60,000 individuals per year and this enables reliable analysis at the level of the medium-sized Norwegian city (50,000 population) as well as for larger cities such as Oslo. It asks questions about:

- Whether people have a parking space provided at home.
- Distance from home to the parking space.
- Provision of parking at work, whether it is charged, how it is charged (monthly, daily, ... etc), the level charge and whether it is easy to find a space.
- Socio-economic variables and car ownership.

Each trip origin and destination in the survey are also geo-coded so it is possible to derive their accessibility by bike and public transport, and their land-use density.

The authors constructed a range of regression models to control for the effect of socio-economic characteristics and public and cycling transport accessibility when considering the effects of parking. The regression models consistently showed that, even when controlling for these factors, parking pricing, availability and distance from the origin and

destination had a very significant effect on car use and ownership. For example, those who have to walk 50m or more to their parking space from their home make 50% more walking trips, 25% fewer car trips and 30% more public transport trips than those who do not. In the larger cities, around 11% of employees have to pay for their workplace parking and the majority pay around 20 NOK a day (£1.50) (2014). Only 42% of staff at such workplaces travel by car, compared to 60% of those who have free parking.

Based on their analysis, the authors identified that the following parking policies will be effective in reducing car km:

- Reducing parking capacity and increasing parking charges at work. They point out that the majority of Norwegian employees currently have free and easy-to-find parking at work, so that even a small change in this could make a big difference.
- Increasing the distance between home and residential parking space. They point to a City of Stavanger regulation that states in new builds, the distance from home to the parking space should be as far as from the home to the nearest public transport stop.
- Increasing urban densities, as they point out that the effectiveness of measures to reduce parking availability and increase its price are greatest in the densest areas.
- Combining parking restrictions and pricing with high quality public transport.

Sources: Christiansen, Engebretsen and Hanssen, 2015; Christiansen, Hanssen, and Skollerud, 2015

Not all the reviewed literature found a strong relationship between parking availability and car ownership. A study in London (Leibling, 2014) found very little relationship between lower parking availability (both on- and off-street) and car ownership, but also states that the methodology used to draw this conclusion was not particularly robust and that the case for or against a relationship between the two remains to be proven. Leibling makes considerable reference to outer London and its lower density, lower public transport accessibility and higher car dependence than inner and central London. Outer London is not dissimilar in this way to other UK cities outside London, whilst inner and central London are very different.

The following is a summary of key findings from this section:

- car parking costs have been found to account for up to 30% of the variation in car ownership; and
- access to on-site, as opposed to on-street, parking has been linked in some studies to significantly higher levels of car ownership.

#### **6.1.4. The influence of parking compared to other factors that affect car use and ownership**

There is obviously a relationship between parking availability, cost and accessibility by other modes: locations that tend to have limited and/or priced parking are often located in places that have high public transport, walking and cycling accessibility. Therefore, these factors must be controlled for to isolate the effect of priced or restrictive parking since it is to be

expected that locations with very good accessibility by other modes would have a higher share by these modes even with unlimited parking. Controlling for other influences on mode choice and/or car ownership was, however, done in four of the reviewed papers (Ostermeijer *et al.*, 2019; Thorwaldson *et al.*, 2021; Christiansen, Engebretsen and Hanssen, 2015; Christiansen, Hanssen, and Skollerud, 2015). That said, these papers still found a statistically significant impact from pricing or restricting parking.

## 6.2 Equitable reduction in car kilometres

In this section, we consider the quantity and quality of the evidence on the extent to which different intervention types contribute to increasing equality and achieving an equitable reduction in car kilometres.

There is extremely limited evidence in the reviewed literature regarding whether the reductions in car kilometres and changes in modal split achieved by parking interventions are shared across social groups. In total only five papers discussed the issue. One, Gonzalez *et al.*, 2022 (on parking regulations in Madrid) found evidence that change in travel mode in response to parking charging was greater amongst drivers on lower incomes, whilst wealthier drivers simply paid the charge and maintained their existing travel habits.

Other papers discussed other equity issues of parking:

- Impact on the use of streetspace, especially for older people and families with small children (Kirschner, 2021).
- Inequitable distribution of streetspace – for example, in Berlin, 10 times as much public space is devoted to parking as to children’s playgrounds (Agora Verkehrswende, 2018).
- The cost of parking in residential developments bundled with the cost of housing, so that car-free households (which tend to be poorer) also pay parking costs (Marsden, 2014).

A report by Parking Brussels (2020), devotes an entire chapter to the issue of parking management and equity. It starts from the assumption of Gonzalez *et al.* (2022) but then presents ways in which equity in parking could be enhanced and finds evidence of places that have done so, stating:

“Measures in favour of disadvantaged populations can be taken to address the limitations and challenges they face in terms of mobility and parking.

- To address the fact that the affordability of housing for low-income households can be made more difficult by minimum requirements for residential parking, housing and parking can be disconnected from each other (unbundling), resulting in more affordable homes without a parking space.
- Social rates can be applied for parking, based on the users’ income. The examples mentioned in this context concern parking tickets for residents (we do not have any cases of socially priced short-term parking).

- In Parking Benefit Districts in the United States, parking revenues are used to support public services and urban planning, creating a redistributive effect. That offers the opportunity to tackle two problems at the same time: the pressure on parking availability and the need for financial resources for the community.
- Because a P&R enables people living on the outskirts of the city to reach the city centre (and so their work) more easily while space for cars in the city centre remains limited (or at least more expensive), such a facility can play a part in redistributive territorial justice.
- The characteristics of neighbourhoods with social housing (particularly the highly urban appearance of large complexes) require modifications to deal with problems such as, for example, the under-occupancy of underground parking garages” (Parking Brussels, 2020, p24).

In addition, parking cashout at work (paying all employees a monthly payment equivalent to the cost of providing parking at the workplace, rather than providing parking automatically) is more equitable than providing parking free to all employees (but not providing anything for those who choose not to drive to work) and has been found to lead to significant reductions in VMT (Thorwaldson *et al*, 2021).

Overall, there is a lack of research on parking in relation to issues of equity and equality. We can conclude that there is limited evidence (two papers) that parking pricing will affect lower income drivers more than higher income drivers, though other papers did discuss equity issues related to parking more broadly, as explained above.

### 6.3 Impactful interventions

Here we present a list of interventions showing the relationship between each intervention and the research questions, including their impact on travel and car ownership, but also lessons for and barriers to implementation. These interventions have been selected on the basis of the number of papers that show evidence that they influence car kilometres, modal split and/or car ownership. They are listed in table 1, which summarises the impact they were found to have on car ownership, km’s and modal split.

Table 1. Summary of intervention types and their impact

Intervention type	Impact		
	Car km	Modal split	Car ownership
1. Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Decrease	Positive	Decrease
2. Parking pricing, on- and off-street	Decrease	Positive	Decrease
3. Parking levies	Decrease	Positive	No evidence found
4. Park and ride <sup>i</sup>	Increase	Negative	No evidence found
5. Parking capacity reductions at city or neighbourhood level	Decrease	Positive	No evidence found



i Six out of eight of the papers providing evidence of a link between P&R and car use found that P&R was associated with increases in VKT when the site is located close to the journey destination. One further paper found no impact on VKT. Only when P&R sites were located closer to journey origins did the literature confirm evidence of reductions in VKT.

The majority of papers considered evidence that parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing have an association with reduced car use or ownership, so this intervention is dealt with first.

### **6.3.1. Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing**

There was strong evidence of the impact of these interventions on both car use (modal split) and car ownership. As noted earlier, these factors can reduce car modal split by 25-50% compared to a baseline where there is ample free parking; and the probability of owning a car also reduced by a similar order of magnitude for residents of car-reduced developments, or for those whose car parking space is on-street or 50m or more from their home, compared to those who have a car parking space directly at home. The most comprehensive study we reviewed on this topic was Foletta and Field (2011), which looks in detail at eight car-reduced or car-free developments in the UK (Greenwich Millennium Village), Netherlands, Germany and Sweden, providing typically 0.5 parking spaces per residential unit (on a range of zero to 1.1), almost always provided in separate parking structures at a distance of 100m to 400m from dwellings. A few developments ban vehicle access completely, whereas others have some roadways where access is allowed for loading and unloading, and a separate network of fully accessible pedestrian and cycle paths. Where residents are disabled, parking spaces may be reserved for them, but these spaces may still not be directly outside their home.

Studies of the Norwegian context (Christiansen, Engebretsen and Hanssen, 2015; Christiansen, Hanssen, and Skollerud, 2015) do not look at specific developments, but the parking conditions they report—where parking is not adjacent to dwellings—are delivered through the design of developments (particularly of housing cooperatives, which are widespread in Norway, Sweden and Denmark) in a similar way to those reported by Foletta and Field (2011; vehicle access to dwellings is permitted, but not parking directly outside. Parking standards in Scandinavian new-build dwellings are of the order of 1 to 1.5 spaces per unit, but the studies also include data from people who live in older dwellings (for example, flats built before 1945) with no or more limited off-street parking. Data pertaining to these older developments can still be considered relevant, as they are similar in parking provision terms to newer developments with little or no off-street parking.

With regard to destinations, Cairns *et al* (2010) in their study of UK travel plans note that the most effective workplace travel plans were those at employers that had parking management in place; but these were also those that had limited amounts of off-street parking available—32 spaces per 100 FTE staff compared to around 80 spaces at the employers without parking management.

Based on their review of eight sites around Europe, Foletta and Field (2011) came up with a number of key factors that can help the success of car-reduced development. These points were echoed in the other literature reviewed:

- Developments should be close to town and city centres, and well-connected to them by high quality public transport.
- Within the developments, there should be safe, direct, accessible and comfortable cycling, wheeling and walking routes, and green space. If these are shared with vehicles, they should be heavily traffic-calmed and clearly marked as streets with pedestrian/bike priority.
- The developments should be more accessible on foot, by bike and by public transport than by private vehicle.
- Parking should be provided away from dwellings, and sold or rented separately from dwellings. Residents should not be eligible for on-street parking permits in the surrounding areas.
- Car-sharing and in some cases cargo-bike sharing should be available.
- Certain developments had binding or non-binding agreements for residents to sign, committing them to either not owning a car at all, or to parking it off street away from their dwelling.

The principle unintended consequence of parking standards that limit the amount of parking in new developments is overspill parking. It is to be expected that if a development with limited parking is located in an area with unrestricted on-street parking, or where residents can get a permit for on-street parking, then car use and ownership will be higher than where there is no available on-street parking around the development and users of the development will put pressure on that parking.

A further unintended consequence reported by Foletta and Field (2011) is that in some developments where access is permitted only for loading and unloading, residents in some streets nonetheless park outside their homes. The degree to which this occurs depends considerably on peer pressure (or the lack of it), but these developments, including Scandinavian housing cooperatives, normally have some form of elected management committee which can exert pressure on residents who do not comply with such rules.

### **6.3.2. Parking time limits, permits and pricing and on- and off-street**

Our literature review did not identify any evidence on the effect of parking time limits or permits on car km or modal split. There was however evidence of the impact of parking pricing on car km and modal split, from both modelled and observational studies such as Ecorys, 2022; Pfaffenbichler and Schopf, 2011; Kodransky and Hermann, 2011; Swiss Federal Office for Spatial Planning, 2021; and McCahill *et al.*, 2016. The reported changes in travel behaviour from these studies are summarised in Section 6.1, above.

In terms of lessons for the smooth(er) implementation of parking pricing, several papers made some helpful points. The key barrier to implementation identified was (lack of) public acceptability (Palmer and Ferris, 2010). It was argued that parking pricing should be part of

an integrated transport policy rather than standalone so that, for example, reduction in numbers of parking spaces goes hand-in-hand with improvements in the public realm (Tully *et al.*, 2022). Khandokar (2016) pointed out that public consultation that clearly informs people about the planned changes in parking prices and availability and how these will affect them personally will help to build acceptance, as will ringfencing of the money raised for environmental and transport improvements (Kodransky *et al.*, 2011). Certain papers conducted attitudinal research and found that the rationing of parking through permits and/or making these permits tradeable was seen to be fairer than pricing parking (e.g. Brands *et al.*, 2021). Better information about available parking that already exists is also an important part of reducing the negative impacts and therefore increasing the acceptability of new on-street pricing schemes (Albalade and Gragera, 2018).

Few papers mentioned unintended consequences in relation to parking pricing, with the exception of the issue of overspill parking. Several pointed out that overspill parking can occur if workplace or other off-street parking is priced in a location where there is available, free on-street parking (e.g. Melia and Clark, 2016 looked at the impact of parking pricing and parking space reductions on the University of West of England campus in north Bristol). However, the most detailed evaluation of the introduction of new on-street parking controls, including pricing, in Vienna noted that overspill parking outside the new zones was less than had been expected, because the zones were large enough to make a shift of mode the lowest-cost response for people from outside Vienna who had previously driven into the now-priced zones (City of Vienna, 2020).

### 6.3.3. Parking levies

There are very few examples of parking levies in the world. For this review we found examples from Nottingham, England as well as Perth, Sydney and Melbourne in Australia. The parking levy is a tax levied by a local or regional authority on certain types of off-street parking. In Nottingham, it is levied on parking provided by employers (with the exception of some, such as the NHS) that provide 10 or more parking spaces for their staff. In 2023, it was set at £522 per space per year. In the Australian cases, the levy applies to all long-stay off-street parking, public or private, in the city centre and inner city, except off-street residential parking.

In both cases, the tax is levied on the owner and/or operator of the parking space and there is no obligation to pass it on to the driver who parks there; in 2009 the charge in Melbourne reached AS\$800 per year and then increased with inflation, whilst in Sydney in 2012 it was over AS\$2,000. The stated purpose of the levies is to reduce congestion (although of course some revenue is also raised), but the degree to which congestion is reduced is obviously related to whether or not the final user of the parking space has to pay. Young, Currie and Hamer (2014) suggest that the proportion of users who actually pay the charge in the Melbourne case is low. In Nottingham, the charge is passed on to users for about 53% of spaces, concentrated at the largest employers. In both cases, the levy has seen a fall in the number of liable (levied) parking spaces as employers and operators took them out of use or changed them to other forms of parking (visitor, short-stay) and, in Melbourne, it has led to a slowing in the growth of private non-residential parking supply.

Research by Loughborough University (Dale, 2017) shows a statistically significant link between the introduction of the levy in Nottingham and a fall in congestion. There is also some evidence of modal shift away from car as a result (see Section 6.1 above). However, even when passed on, the levy is a small proportion of total travel costs and many other factors affect congestion (roadworks, changes in economic activity and so on) (Nottingham City Council, 2019). In Melbourne the levy has contributed to a reduction in car mode share for trips to the city centre but as part of a package of measures including much improved public transport (Young *et al.*, 2014). There is no such evidence in Sydney (Ison *et al.*, 2014). The authors suggest this is because, even when the cost is passed on to users, they are not aware of it (it is a salary deduction, for example).

Implementation appears to have been relatively straightforward in the Australian examples, perhaps because the levy represents a small part of the cost of providing parking. In Nottingham, it was introduced in 2012 after approximately 10 years of preparation, a key part of which was working with employers on travel planning. In addition, the first line of a new tram and improvements in local bus services, cycling infrastructure and a new station were all delivered before the levy went live, and the promise of the revenue raised by the levy has helped to lever in central government funds. The levy was designed to be simple to administer and by only including employers with 10 parking spaces or more, it is not a burden on the smallest businesses. There is no evidence that companies have relocated because of the levy, and economic growth in Nottingham has continued to be higher than in competitor English cities (Nottingham City Council, 2019).

The main unintended consequence of the Australian schemes was a big growth in discounted “early-bird” commercial parking offers, giving those who arrived early at public off-street parking a discount because of the operating hours specified in the parking levy legislation. The literature we reviewed does not reference any unintended consequences associated with the Nottingham scheme.

#### **6.3.4. Park and ride**

Park and ride is intended to reduce car use, particularly for travel to city centres, by enabling drivers to park before reaching their destination and change to public transport for the final part of the trip. To make them attractive to users, fast and frequent public transport to the final destination is required, which may require subsidy as well as priority over other traffic. Park and ride will attract more users where city centre parking availability is reduced and/or the price is increased over time. For example, Oxford’s P&R system benefits from a long-standing policy of very limited new off-street public and private parking in the city centre (Parkhurst, 2011). Nonetheless, even if the P&R is well-used, if it is located close to the destination, it is unlikely to have reduced vehicle km, due to the unintended consequences outlined below (Zijlstra *et al.*, 2015).

Park and ride sites located close to the final destination, for example on the fringes of a city, may not reduce vehicle km because:

- People who previously made their whole trip by public transport now drive most of the way to take advantage of the better and cheaper public transport from the P&R.

- Some users are people who walk in from nearby residential areas.
- The P&R may be used for parking for other land uses nearby.
- If bus-based, the bus trips themselves generate additional traffic.
- In the longer term it may stimulate more car-based development in the origin location that otherwise would have been in the city centre.

The literature (e.g. Hanssen *et al.*, 2016) is therefore clear that P&R should be located close to trip origins so that public transport is used for the majority of the trip length.

Nonetheless, such P&R facilities are typically rail-based and therefore raise the problem of whether valuable land around stations—especially in town centres—should be used for car parking; and whether these P&R also stimulate more car-dependent lifestyles by enabling long-distance commuting. Hanssen *et al.* (2016) therefore include in their paper some guidance on how to locate and design P&R to minimise risks that it will have these unintended consequences.

### 6.3.5. Parking capacity reductions at city or neighbourhood level

This topic relates to the idea of taking away parking spaces (on-street in particular) and devoting the space to other uses: pedestrianisation, wider footways, bike lanes, green space and so on. When carried out on a large scale, this intervention is clearly associated with lower car use (see Pfaffenbichler and Schopf, 2011). However, only nine papers were found dealing directly with this topic and, of these, only four provided information on implementation lessons, barriers and unintended consequences. The most comprehensive guidance on implementation is contained in Rye *et al.* (2022), where the experience of several cities across Europe in reducing on-street parking supply is described. To quote directly from pp 47-48 of that publication:

“There are ways, however, to address these concerns and the almost inevitable complaints that will be heard when new parking management measures are proposed (although bear in mind that once the new measures are implemented, experience shows that almost all these complaints will die away as people realise that the measures work). To be prepared, however, the following points need to be taken into account:

- The phrase “there is not enough parking” will come up. It is important therefore to have carried out some basic surveys to measure parking occupancy in the busiest streets and off-street car parks at different times of day; but also in the general vicinity (within 5-10 minutes’ walk) of these busiest areas. Invariably this shows that whilst in the busiest areas there are times of day when demand exceeds supply, it also shows that there is almost always spare capacity (including off-street car parks that few people are aware of). It can also show that long term parkers occupy space that could be used for shoppers and visitors.
- It is crucial to communicate the changes in parking management fully, including the reasons for them and the expected benefits.
- The planned parking management measures need to be easy to understand. If they are not, misunderstandings will occur and these will create myths about the new scheme which will make them more difficult to implement.

- For the two reasons above, cities may wish to consider contracting in some specialised marketing and public relations assistance – people who know how to “sell” a message, and also who know how to deal with negative reactions, particularly on social media.”

Specifically with regard to the removal of on-street parking, the literature also suggests that experimentation can be useful, with temporary changes to parking spaces to other uses; and that it is crucial to demonstrate what the space has been used for instead of parking.

The most-feared unintended consequence of parking capacity reductions (and parking pricing) is negative impacts on retailing – that customers will no longer travel to the businesses where on-street parking has been removed and changed to other uses. However, the literature that was found on this topic was unanimous in its findings that parking availability is much less important to retail vitality than factors such as quality of the urban environment and retail offer (e.g. Witte and Mingardo, 2017; Olimstad, and Gjellebæk, 2015); and that retailers usually overestimate the importance of parking for their custom.

## 7 Conclusions and recommendations

### 7.1 Conclusions

The research has gathered evidence on the effectiveness of different parking management interventions in reducing car use. The findings can support development of parking policies by Scottish Government and Local Government partners with a view to achieving the Scottish Government's and COSLA's joint target of reducing car kilometres. Following the discussion, table 2 summarises the findings on impactful interventions.

#### 7.1.1. Impact on car use

Overall, strong evidence was found for five parking intervention types of impact on one or more of the following: car kilometres travelled, modal split or car ownership. These were parking standards, off-site or non-adjacent provision of residential parking, and low-car and car-free housing; on- and off-street parking pricing; parking levies; park and ride; and parking capacity reductions at city or neighbourhood level. In the case of all but P&R, the impact was found to be positive. In the following paragraphs, specific conclusions are provided for each of the five intervention types.

There is evidence linking **parking standards, off-site or non-adjacent provision of residential parking, and low-car and car-free housing** to positive impacts on car kilometres travelled, car ownership and modal split. Parking availability and location can influence car use; car-free developments have been found to have car use levels at less than half of city-wide averages, while parking located at 50m or more from dwellings was associated with 25% fewer car trips.

There is also strong evidence of the effect of parking availability and location and price on car ownership. Having a parking space on one's own property, as opposed to only having access to on-street parking, has been linked with car ownership levels that are 34 percentage points higher in nationwide Norwegian studies. Marked differences in levels of car ownership have also been found in the context of car-free developments when compared to city-wide levels. Cars were also found to have a lower modal share in car-free areas; in the Netherlands and Germany, car-free development were found to have car use levels at less than half the city averages.

**Parking pricing** can contribute to car kilometre reductions and modal shift, particularly when combined with capacity reduction measures. Parking pricing of the order of €1 to €3 per day can reduce car kilometres by between 0.3% and 3% at entire city or nationwide scale, while other modelled studies identified city-wide reductions of between 6% and 16% when parking pricing changes were accompanied by on-street capacity reductions or implemented in low-traffic neighbourhoods. The reduction level associated with pricing measures is highly sensitive to the proportion of drivers who are affected by the charge and whether or not it is implemented alongside overall parking capacity reductions.

Parking pricing has also been linked to car ownership. Car parking costs, including search time, were found to account for 30% of the variation in car ownership across four Dutch cities.

Workplace **parking levies** were found to have a positive impact on mode share. Public transport improvements implemented in tandem with WPL schemes were identified as significant contributing factors in encouraging modal shift.

**Park and ride** was found to generally increase VKT when located close to destinations. However, when located close to journey origins, it was associated with reductions in vehicle kilometres of the order of 1.5km per park and ride user.

There is evidence that **parking capacity reductions at city or neighbourhood level** have an impact on car kilometres travelled and modal split. As explained in conclusions on parking pricing, when implemented in tandem with on-street pricing measures, on-street parking capacity reductions have been linked to area wide VKT reductions of between 6.4% to 16%. There is also evidence that the availability of parking spaces at a city scale influences mode split, with an increase in supply of between 0.1 and 0.4 parking spaces per person across US cities being associated with a 30% increase in car mode share.

In the context of workplaces, there is strong evidence that the provision of parking is linked to an increase in car mode share. In nationwide Norwegian studies, car mode share stood at 58% when parking was available, versus 20% when it was not, while a 15 percentage point difference was identified by research conducted in Switzerland. It is also notable that in the context of employee provided parking, there is strong evidence that workplace travel plans have a greater impact on modal split when they include some form of parking management.

It should be noted that all of the reviewed literature reported on studies conducted in urban settings, which correspond to the categories of Large Urban Areas and Other Urban Areas in the Scottish Government's Urban Rural Classifications (Scottish Government, 2020)<sup>14</sup>. There is therefore a lack of evidence on whether or not the intervention types identified in this section would have similar impacts on car use in rural areas.

### 7.1.2. Equity and equality issues

There is extremely limited evidence on whether the reductions in car km and changes in modal split achieved by parking interventions are shared across social groups, and it is not possible to draw conclusions on this topic. In total, only five papers discussed such issues, (including the impacts of parking on accessibility and housing costs), while only one study included findings on the impact of parking pricing on lower income groups.

Given the lack of evidence on the impact of parking interventions outside urban contexts it also not possible to draw conclusions on how different intervention types may align to inequality reduction goals focussing on island communities and remote rural and rural

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<sup>14</sup> The document classes 'Large Urban Areas' as having populations of over 125,000 plus and 'Other Urban Areas' as having populations of between 10,000 and 124,999 inhabitants (Scottish Government, 2020).



areas, as per the Scottish Government's Urban Rural Classifications (Scottish Government, 2020).

### **7.1.3. Alignment to policies and strategies**

Parking standards, offsite or non-adjacent provision of residential parking, and low-car and car-free housing interventions align to goals set out in NPF4 on the basis that they help encourage walking, wheeling and cycling, and play an integral role in low-car and car-free developments. Parking capacity reductions at a city and neighbourhood level also align with the goals of NPF4, which seek to reduce levels of car dominance.

Interventions contributing to reduced traffic volume in city centres, such as parking pricing and, in some cases, P&R will have positive effects on congestion and air pollution levels, aligning to NTS2 goals around improving health and wellbeing. Furthermore, workplace parking levies have the potential to contribute to goals set out in NTS2's Sustainable Travel and Investment Hierarchies, for example if funds from the levies are invested in local public transport improvements that correspond to the hierarchies' aims.

### **7.1.4. Support for place-based approaches**

There is a lack of explicit evidence in the reviewed literature on the application of place-based approaches in parking interventions. However, some of the impactful intervention types, such as parking standards, off-site and non-adjacent residential parking, and low-car and car-free housing; and parking capacity reductions at city or neighbourhood level, may be better positioned to support the use of a place-based approach based on their potential contributions to minimising the space dedicated to car parking in a particular locality.

Table 2. Summary of findings on impactful interventions

Intervention type	Impact			Policy and strategy alignment	Success factors	Intervention barriers	Unintended consequences	Lessons for policy and implementation
	Car km	Modal split	Car ownership					
Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Decrease	Positive	Decrease	Yes. Alignment with NPF4 goal of supporting walking, wheeling and cycling.	Developments located close to urban centres and well connected by public transport. Provision of cycling and walking routes within developments. Higher relative permeability of developments by public transport and active travel than private vehicle. Parking located away from dwellings. Availability of car and cargo bike sharing. Binding or non-binding agreements for residents.	No findings	Overspill parking; where parking is not available outside residences, on-street parking may be used as an alternative.  Use of loading/unloading areas for unauthorised parking in the case of low-car or car-free residences.	Incorporating parking management increases the effectiveness of workplace travel plans. The most effective approaches were those limiting off-street parking.
Parking pricing, on-and off-street	Decrease	Positive	Decrease	In some instances <sup>1</sup> . Can contribute to car use reduction. Can contribute to congestion reduction and inner-city air pollution reductions, as per NTS2 goals.	No findings	Public acceptability levels.	Overspill parking where off-street parking is priced and alternative options are free.	Parking pricing should be part of integrated transport policy. Public consultation and provision of information are important for increasing public acceptability. Ring fencing money for environmental

Intervention type	Impact			Policy and strategy alignment	Success factors	Intervention barriers	Unintended consequences	Lessons for policy and implementation
	Car km	Modal split	Car ownership					
								and transport improvements also contribute to acceptability levels. Permit rationing and trading schemes can be seen as fairer than pricing. Better information about available parking decreases negative impacts and increases acceptability.
Parking levies	Decrease	Positive	No findings	Yes. Can contribute to goals set out in NTS2 Sustainable Travel and Investment Hierarchies.	No findings	No findings	A growth in discounted commercial parking offers was identified in Australian cases.	No findings
Park and ride	Increase <sup>i</sup>	Negative	No findings	In some instances <sup>i</sup> . Can contribute to car use reduction. Can contribute to congestion reduction and inner-city air pollution reductions, as per NTS2 goals.	No findings	No findings	P&R sites close to final destinations can increase car kms travelled. P&R may stimulate more car-based development in the origin location. Rail-based R&R facilities may lead to valuable land	P&R sites should be located close to trip origins so that public transport is used for the majority of journey lengths. P&R will attract more users where city centre parking availability is

Intervention type	Impact			Policy and strategy alignment	Success factors	Intervention barriers	Unintended consequences	Lessons for policy and implementation
	Car km	Modal split	Car ownership					
							around stations being used for parking.	reduced and/or the price is increased over time.
Parking capacity reductions at neighbourhood and city level	Decrease	Positive	No findings	Yes. Aligns with NPF4 goals of reducing levels of car dominance.	No findings	Public acceptability levels, based on the common perception that existing parking provision is already inadequate.	Retailers often overestimate the importance of parking availability to retail vitality. Factors such as quality of urban environment and retail offer are found to be more important.	Parking occupancy surveys, conducted in advance of interventions, provide valuable insights. Planned parking management interventions need to be easy to understand to reduce scope for rejection. Specialist marketing and public relations assistance can be valuable. Experimentation, featuring temporary changes to street use, can be useful to demonstrate benefits and test outcomes.

i Six out of eight of the papers providing evidence of a link between park and ride and car use found that park and ride was associated with increases in VKT when the site is located close to the journey destination. One further paper found no impact on VKT. Only when park and ride sites were located closer to journey origins did the literature find evidence of reductions in VKT.

## 7.2 Recommendations

In considering the merit of implementing the intervention types with the greatest impact on car use we recommend:

1. **In removal of on-street parking** to first consider implementing temporary changes to parking spaces where infrastructure allows. This would allow the approach to be tested and for gathering of further practical data on the implementation of measures.
2. **To promote parking management in the context of workplace travel plans** given the significant difference that including parking measures in this type of plan has been found to make to modal shift outcomes.
3. Future decision-making around **park and ride should consider the significance of site location** relative to journey origins and destinations to optimise the contribution of this intervention type to car use reduction targets.

## 7.3 Research gaps

During the project we have identified the following areas needing further research:

- The intervention types lacking strong evidence (positive or negative) around impact on car use reduction. Specifically, these intervention types are: parking pricing in relation to vehicle characteristics; parking pricing in relation to household or user characteristics; residential parking in historic areas that are pedestrianised; shared-use parking; effective and fair parking enforcement; parking for electric vehicles; mobility hubs; 20-minute neighbourhoods and 15-minute cities; and parking and road space transformation/reallocation.
- The impact of different types of parking intervention on equality and the equitable reduction in car kilometres.
- The implementation of parking interventions in rural contexts.
- How, and to what extent, different intervention types support place-based approaches.

### 7.3.1. Research recommendations

It is recommended that consistent before-and-after studies should be conducted when trialling parking interventions. This would help provide an evidence base to inform decision making. The studies should also aim to collect data on aspects, including barriers to intervention, success factors, unintended consequences and lessons for policy, and implementation. As noted above, the reviewed literature often did not provide data on these areas of research. Such before-and-after studies could also collect data on public attitudes towards the interventions. Recent research (van Wee, Annema and van Barneveld, 2023) has found that support for controversial policies in the area of transport often increases following implementation. Further research around parking measures could provide additional insights into public attitudes and levels of support.

Further research should also be conducted into current parking policies in Scotland to provide a detailed baseline to inform future policies. Apart from a recent unpublished report commissioned by Transport Scotland (Systra, 2021), which provides some brief summaries of parking interventions in local authority areas, there is a lack of up-to-date research in this area.

Research should be commissioned into the impact of different types of parking intervention on equality and the equitable reduction of car kilometres. This should consider whether reductions in car use are shared across social different social groups and whether the interventions contribute to broader equality goals.

Related to this last point, research should be commissioned into the impact of parking interventions on car use in rural settings. As explained above, all of the reviewed literature had an urban focus. Research conducted in rural contexts should help confirm whether the same measures would be applicable in non-urban settings from the perspective of car use reduction. It should also provide data on how and to what extent the interventions align to Scottish Government goals of reducing urban-rural inequalities.

Finally, research should be commissioned into how different types of parking intervention support place-based working. This could begin with research on measures identified in this report as having potential to minimise space dedicated to car parking in particular localities, namely parking standards, off-site and non-adjacent residential parking, and low-car and car-free housing; and parking capacity reductions at city or neighbourhood level.

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## 9 Appendices

### 9.1 Appendix A. Methodology

#### 9.1.1. Literature search and sift

The main phases of research included a systematic literature search, a sifting process to identify relevant papers among the search results and a review of the selected papers. Forty individual searches were conducted on Google Scholar, using strings of search terms containing Boolean operators and created to reflect the 14 intervention types identified during the project's inception phase (see Section 4.2). The searches yielded over 4,700 results.

The papers were then sifted by title with the aim of selecting the most relevant papers. The title sift resulted in 927 papers. Once duplicates, which had been found in multiple searches, were removed, a total of 386 papers remained. These papers were then sifted again based on the contents of their abstract. The criteria applied during the abstract sift were:

- country of study (with specific interest in OECD countries, particularly smaller northwest European ones);
- references to parking intervention types of interest to the study;
- relevance to research questions; and
- indications of methodological rigour (see Section 9.1.2).

The papers were assigned a priority rating from a four-point scale based on the level of relevance to the study. Seventy-eight Grade 4 papers (include in the review) and 85 Grade 3 papers (possibly include in the review) were identified.

In addition, searches were conducted using Google's regular search engine in English, Catalan, Dutch, German, Norwegian, Spanish, and Swedish with the aim of identifying papers, particularly in the grey literature, which may have been missed during the systematic search. This resulted in 34 additional sources being identified.

Requests were also made to contacts of the research team working in relevant academic fields for recommendations on papers which may be of interest to the study. This resulted in 31 papers being recommended, 25 of which were subsequently reviewed.

### 9.1.2. Literature review

The review included the 78 Grade 4 papers, in addition to 25 contact-recommended papers and the 34 papers identified during Google searches. Two Grade 3 papers were also reviewed following a more in-depth sifting of the Grade 3 sources carried out with the aim of identifying those that were most relevant to the research. This gave a total of 139 papers.

During the review, data relevant to each of the seven research questions was extracted from each source. The papers were also assessed on the basis of robustness of methodology and strength of evidence in order to provide an overall indication of the strength of the research that the review's findings are based on. A qualitative robustness of methodology scale was applied as shown in the following table.

Research characteristic	Level of robustness
Qualitative study with <10 data sources	Low
Qualitative study with >10 data sources	Moderate
Mixed quantitative and qualitative methods	High
Quantitative with sample size > 100	High
Use of meta-analyses and systematic reviews	High
Quantitative with control group	Very high

The strength of evidence assessment was based on the extent to which individual papers included findings on the impact of a given intervention on car kilometres travelled, modal split or car ownership, either providing evidence of positive or negative findings. Papers that contained clear findings linking interventions to either positive impacts, (this is to say reductions in VKT, modal shift away from car use or reductions in car ownership) or negative impacts (for example increases in VKT) were considered to have provide strong evidence of impact. On the other hand, those containing inconclusive findings or findings indicating a weak link between interventions and car kilometres travelled, modal split or car ownership were considered to provide weak evidence.

The review also provided a final opportunity to sift out papers that were not considered sufficiently relevant. In the case that a source did not provide any relevant data related to the research, it was discarded and not included in the subsequent analysis. Ultimately, 39 papers were discarded, leaving 100 to be analysed.

### 9.1.3. Limitations

Time and resource constraints placed some limitations on the literature search. The decision was made to conduct the systematic search using only Google Scholar as it is the largest academic database. This meant that the search process did not have to be repeated for multiple databases. Google Scholar was considered to offer the broadest reach, in terms of the size of the database, but it is possible that some literature that may have appeared during searches in other databases and search engines was not present in the results generated by Google Scholar.

It should also be noted that our searches were informed by the list of intervention types finalised during the inception phase, which include 14 different categories of measure (see Section 4.2). The way that intervention types were described and grouped at this stage influenced the subsequent formulation of the Boolean search terms that were used in the search. It is possible that different descriptions and groupings of intervention types may have generated a greater number of relevant results.

Time constraints also influenced how the sifting of search results was conducted. As we were required to sift a large number of results, sifting was first conducted by title. During the title sift, some papers may have been incorrectly excluded due to limited amount of information informing the selection. During the subsequent abstract sift, the likelihood of this happening was reduced due to the larger amount of information available. This said, some papers may still have been incorrectly excluded during this process.

Limited amounts of data was available on the impact of some parking interventions on car kilometres travelled, and on the impact of parking measures on equality. This has limited the responses to some of the research questions and allowed for the identification of gaps in the literature.

## 9.2 Appendix B. Summary of papers providing evidence of impact on car use

The following tables provides a breakdown of the papers that provide evidence of an impact on car kilometres travelled, modal split and car ownership, based on strength of evidence, robustness of methodology and intervention type.

### 9.2.1. Car kilometres travelled

Number of papers with evidence of change in car kilometres travelled	37
Robustness of methodology (number of papers)	Low 0 Moderate 14 High 21 Very high 2
Strength of evidence (number of papers)	Low 7 Moderate 14 High 15 Very high 1
Interventions most often linked with change in car km <sup>i</sup>	Parking pricing on- and off-street (11 papers) Park and ride (8 papers) Other (4 papers) Parking levies (4 papers) Parking capacity reductions at city or neighbourhood level (2 papers) Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing (3 papers)

	Effective and fair enforcement (1 paper)
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<sup>i</sup> The total can sum to more than the total number of papers as some of the reviewed papers deal with more than one intervention.

### 9.2.2. Modal split

Number of papers with evidence of change in modal split <sup>i</sup>	47
Robustness of methodology (number of papers)	Low 3 Moderate 17 High 26 Very high 1
Strength of evidence (number of papers)	Weak 11 Moderate 22 Strong 14
Interventions associated with change in modal split <sup>i,ii</sup> .	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing (17 papers) Parking time limits, permits and pricing and on- and off-street (14 papers) Parking levies (10 papers) Park and ride (6 papers) Parking capacity reductions at city or neighbourhood level (3 papers) Other (3 papers) Parking and road space transformation/reallocation (2 papers) Parking pricing in relation to household or user characteristics (1 paper) Shared use parking (1 paper)

<sup>i</sup> The total includes papers mentioning traffic reduction and congestion reduction.

<sup>ii</sup> One paper may cover more than one intervention hence totals may not sum to 47.

### 9.2.3. Car ownership

Number of papers with evidence of relationship between parking and car ownership	17
Robustness of methodology	Low 2 Moderate 7 High 8 Very high 0
Strength of evidence	Weak 5 Moderate 9 Strong 3
Interventions associated with differing levels of car ownership <sup>i</sup> .	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing (13 papers)

	Parking time limits, permits and pricing and on- and off-street (7 papers) Other (3 papers) Mobility hubs (1 paper)
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i One paper may cover more than one intervention so totals may not sum to 17.

### 9.3 Appendix C. Bibliography

The following table contains a full list of papers included in the literature review. It indicates the intervention types described by each paper and the area of impact (car kilometre reduction, modal split, car ownership), if any, that the paper provides evidence on.

Reference	Intervention	Area of impact
Agora Verkehrswende., 2018. Umparken - den öffentlichen Raum gerechter verteilen Zahlen und Fakten zum Parkraummanagement. Agora Verkehrswende, Berlin	Parking time limits, permits and pricing and on- and off-street	Modal split
Albalate, D. and Gragera Lladó, A., 2018. Misinformation and Misperception in the market for parking. IREA–Working Papers, 2018, IR18/12.	Parking time limits, permits and pricing and on- and off-street	Car kms
Andersson, J. and Nilsson, E., 2021. Promoting Sustainable Mobility in Urban Areas—the Role of Residential Parking (Masters Thesis, Chalmers University of Technology)	Other	Car ownership and modal split
Ardeshiri, A., Safarighouzhdi, F. and Rashidi, T.H., 2021. Measuring willingness to pay for shared parking. Transportation Research Part A: Policy and Practice, 152, pp.186-202.	Shared-use parking	Modal split
Assemi, B., Baker, D. and Paz, A., 2020. Searching for on-street parking: An empirical investigation of the	Parking time limits, permits and pricing and on- and off-street	Car kms



Reference	Intervention	Area of impact
factors influencing cruise time. <i>Transport Policy</i> , 97, pp.186-196		
Babb, C. and Brown, G., 2022. The Perth Parking Policy: Towards 25 Years. <i>Australasian Transport Research Forum 2022 Proceedings</i>	Levies/taxes on off-street parking	Not mentioned
Barron, M., 2014. <i>Parking Pricing (Undergraduate Dissertation, Cardiff University)</i>	Parking time limits, permits and pricing and on- and off-street	Modal split
Bartle, C. and Chatterjee, K., 2019. Employer perceptions of the business benefits of sustainable transport: A case study of peri-urban employment areas in South West England. <i>Transportation Research Part A: Policy and Practice</i> , 126, pp.297-313.	Other - workplace travel plans	Modal split
Brands, D., Verhoef, E. and Knockaert, J., 2021. Pcoins for parking: a field experiment with tradable mobility permits. <i>Tinbergen Institute Discussion Paper</i>	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Burns, T. and Cracknell, V., 2019. Reducing car use: what do people who live and drive in cities and towns think? <i>Sustrans</i>	Other	Not mentioned
Cairns, S., Newson, C. and Davis, A., 2010. Understanding successful workplace travel initiatives in the UK. <i>Transportation Research Part A: Policy and Practice</i> , 44(7), pp.473-494	Parking time limits, permits and pricing and on- and off-street	Modal split and car kms

Reference	Intervention	Area of impact
Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A. and Goodwin, P., 2008. Smarter choices: assessing the potential to achieve traffic reduction using 'soft measures'. <i>Transport Reviews</i> , 28(5), pp.593-618.	Other	Car kms, car ownership, modal split
CE Delft., 2018. Anders Reizen. NS, Delft	Parking time limits, permits and pricing and on- and off-street	Car kms
Christiansen, P., Engebretsen, Ø. and Hanssen, J.U., 2015. Parkeringsstilbud ved bolig og arbeidsplass. Fordelingsffekter på bilbruk og bilhold i byer og bydeler. TØI rapport, 1439	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing; parking time limits, permits and pricing and on- and off-street; parking pricing in relation to household or user characteristics	Car ownership and mode split
Christiansen, P., Engebretsen, Ø., Fearnley, N. and Hanssen, J.U., 2017. Parking facilities and the built environment: Impacts on travel behaviour. <i>Transportation Research Part A: Policy and Practice</i> , 95, pp.198-206	Parking time limits, permits and pricing and on- and off-street	Modal split
Christiansen, P., Hanssen, J.U. and Skollerud, K., 2015. Boligparkering i store norske byer-parkeringsstilbudets effekt på bilhold og bilbruk. TØI rapport, 1425	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Modal split
City of Amsterdam (2019) Shared mobility for Sluisbuurt Amsterdam.	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Not mentioned

Reference	Intervention	Area of impact
City of Vienna., 2020. Ausweitung der Parkraum-bewirtschaftung in Wien Nachher-Untersuchung 11. City of Vienna. Vienna, Austria	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Clayton, W., Ben-Elia, E., Parkhurst, G. and Ricci, M., 2014. Where to park? A behavioural comparison of bus Park and Ride and city centre car park usage in Bath, UK. <i>Journal of Transport Geography</i> , 36, pp.124-133	Park and ride	Car kms
Coles, K., 2015. Parking Policy Acceptability in Wellington CBD. (Masters Dissertation, Victoria University of Wellington).	Parking time limits, permits and pricing and on- and off-street	Not mentioned
CROW., 2021. Leidraad parkeren bij knooppunten en mobiliteitshubs. CROW, Ede, Netherlands	Mobility hubs	Car ownership
Dale, S., 2017. Evaluating the impacts on traffic congestion and business investment following the introduction of a Workplace Parking Levy and associated transport improvements (Doctoral dissertation, Loughborough University).	Levies/taxes on off-street parking	Modal split
Dale, S., Frost, M., Gooding, J., Ison, S. and Warren, P., 2014. A case study of the introduction of a workplace parking levy in Nottingham. In: Ison, S.G. and Mulley, C. eds., 2014. <i>Parking: issues and policies</i> . Emerald Group Publishing	Levies/taxes on off-street parking	Not mentioned

Reference	Intervention	Area of impact
Dale, S., Frost, M., Ison, S. and Budd, L., 2019. The impact of the Nottingham Workplace Parking Levy on travel to work mode share. <i>Case Studies on Transport Policy</i> , 7(4), pp.749-760	Levies/taxes on off-street parking	Modal split
Dale, S., Frost, M., Ison, S. and Warren, P., 2014. Workplace Parking Levies: The answer to funding large scale local transport improvements in the UK?. <i>Research in Transportation Economics</i> , 48, pp.410-421	Levies/taxes on off-street parking	Modal split and car kms
Davis, A (2019) Essential Evidence 4 Scotland No.21 The importance of car parking policies for active travel. Edinburgh Napier University	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Davis, A (2019) Essential Evidence 4 Scotland No.42 Residential Parking: Use of Maximum Standards. Edinburgh Napier University	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership and modal split
De Gruyter, C., 2016. Travel plans for new residential developments: Insights from theory and practice. Springer.	Other	Modal split and car kms
Dijk, M. and Parkhurst, G., 2014. Understanding the mobility-transformative qualities of urban park and ride policies in the UK and the Netherlands. <i>International Journal of Automotive Technology and Management</i> 21, 14(3-4), pp.246-270	Park and ride	Modal split and car kms

Reference	Intervention	Area of impact
Ecorys., 2022. Exploring the quantitative impact of behavioural measures on mobility. Report for Ministry of Transport, The Hague, Netherlands	Parking time limits, permits and pricing and on- and off-street	Car kms
Foletta, N. and Field, S., 2011. Europe's vibrant new low car(bon) communities. Institute for Transportation and Development Policy, New York.	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car kms, car ownership, modal split
Genter, J.A. and Donovan, S., no date. How minimum parking standards underpin car dependence: the new parking management paradigm. Unknown	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Not mentioned
Gonzalez, J.N., Gomez, J. and Vassallo, J.M., 2022. Do urban parking restrictions and Low Emission Zones encourage a greener mobility?. Transportation Research Part D: Transport and Environment, 107, p.103319	Parking time limits, permits and pricing and on- and off-street	Modal split
Goodman A., Lavery A.A., Furlong J., Aldred R., 2023. The Impact of 2020 Low Traffic Neighbourhoods on Levels of Car/Van Driving among Residents: Findings from North Lambeth, London, UK. Transport Findings, June	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car kms
Gunnarsson-Östling, U., 2021. Housing design and mobility convenience—The case of Sweden. Sustainability, 13(2), p.474.	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership and modal split

Reference	Intervention	Area of impact
Hamer, P., Currie, G. and Young, W., 2009. Exploring travel and parking impacts of the Melbourne CBD parking levy. Planning and Transport Research Centre (PATREC).	Levies/taxes on off-street parking	Modal split and car kms
Hanssen, J.U., Tennøy, A., Christiansen, P. and Øksenholt, K.V., 2016. How can P & R facilities contribute to reduced emissions of greenhouse gases. In European Transport Conference	Park and ride	Car kms
Islam, S.T., Liu, Z., Sarvi, M. and Zhu, T., 2015. Exploring the mode change behavior of park-and-ride users. Mathematical Problems in Engineering.	Park and ride	Modal split
Johansson, F., Henriksson, G. and Envall, P., 2019. Moving to private-car-restricted and mobility-served neighborhoods: The unspectacular workings of a progressive mobility plan. Sustainability, 11(22), p.6208	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership and modal split
Kansen, M., Waard, J. and Savelberg, F., 2018. Sturen in parkeren. Kennisinstituut voor Mobiliteitsbeleidj. KiM	Parking time limits, permits and pricing and on- and off-street	Car kms
Katoshevski-Cavari, R., Bak, N. and Shiftan, Y., 2018. Would free park-and-ride with a free shuttle service attract car drivers?. Case studies on transport policy, 6(2), pp.206-213	Park and ride	Modal split

Reference	Intervention	Area of impact
Khandokar, F., 2016. Determinants for intention to change travel mode choice behaviour of NHS hospital staff (Doctoral dissertation, Loughborough University).	Parking time limits, permits and pricing and on- and off-street	Modal split
Khordagui, N., 2019. Parking prices and the decision to drive to work: Evidence from California. <i>Transportation Research Part A: Policy and Practice</i> , 130, pp.479-495	Parking time limits, permits and pricing and on- and off-street	Car kms
Kirschner, F. and Lanzendorf, M., 2020. Parking management for promoting sustainable transport in urban neighbourhoods. A review of existing policies and challenges from a German perspective. <i>Transport Reviews</i> , 40(1), pp.54-75	Parking time limits, permits and pricing and on- and off-street; parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership and modal split
Kirschner, F., 2021. Parking and competition for space in urban neighborhoods. <i>Journal of Transport and Land Use</i> , 14(1), pp.603-623	Parking capacity reductions at city or neighbourhood level and use of resulting space	Not mentioned
Klementschtz, R. and Stark, J., 2009. Commuting and car use: car park regimentations as a potential lever. <i>The Baltic Journal of Road and Bridge Engineering</i> , 4(1), pp.31-35.	Parking time limits, permits and pricing and on- and off-street	Modal split
Kodransky, M. and Hermann, G., 2011. Europe's parking u-turn: from accommodation to regulation. Institute for Transportation and Development Policy, New York.	Parking pricing in relation to vehicle characteristics; parking and road space transformation/reallocation; shared-use parking; parking time limits, permits and pricing and on- and off-street; parking standards, off-site or non-adjacent provision of residential	Modal split and car kms

Reference	Intervention	Area of impact
	parking; low-car and car-free housing; levies/taxes on off-street parking	
Kuss, P. and Nicholas, K.A., 2022. A dozen effective interventions to reduce car use in European cities: lessons learned from a meta-analysis and transition management. <i>Case studies on transport policy</i> , 10(3), pp.1494-1513	Levies/taxes on off-street parking; parking and road space transformation/reallocation.	Not mentioned
Lambe, B., Murphy, N. and Bauman, A., 2017. Smarter Travel, car restriction and reticence: Understanding the process in Ireland's active travel towns. <i>Case studies on transport policy</i> , 5(2), pp.208-214	Parking capacity reductions at city or neighbourhood level and use of resulting space	Modal split
Leibling, D., 2014. Parking supply and demand in London. In: Ison, S.G. and Mulley, C. eds., 2014. <i>Parking: issues and policies</i> . Emerald Group Publishing	Parking time limits, permits and pricing and on- and off-street	Car ownership
Leicester City Council 2021. <i>Leicester Workplace Parking Levy: Business Case</i> . Leicester City Council	Levies/taxes on off-street parking	Modal split
Litman, T., 2009. <i>Parking requirement impacts on housing affordability</i> . Victoria, British Columbia, Canada. Victoria Transport Policy Institute	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership
Litman, T., Carlson, D., Blumenthal, A. and Lee, J., 2010. <i>Evaluating Seattle Parking Tax Options</i> . Victoria Transportation Policy Institute.	Levies/taxes on off-street parking	Car kms



Reference	Intervention	Area of impact
Litman, T.A., 2006. Parking taxes: evaluating options and impacts.	Levies/taxes on off-street parking	Modal split
Marsden, G. 'Parking policy'. In: Ison, S.G. and Mulley, C. eds., 2014. Parking: issues and policies. Emerald Group Publishing	Parking time limits, permits and pricing and on- and off-street	Car ownership and mode shift
McAslan, D. and Sprei, F., 2023. Minimum parking requirements and car ownership: An analysis of Swedish municipalities. <i>Transport Policy</i> , 135, pp.45-58.	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Car ownership
McCahill, C.T., Garrick, N., Atkinson-Palombo, C. and Polinski, A., 2016. Effects of parking provision on automobile use in cities: Inferring causality. <i>Transportation Research Record</i> , 2543(1), pp.159-165	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Modal split and car kms
Meek, S., Ison, S. and Enoch, M., 2008. Role of bus-based park and ride in the UK: a temporal and evaluative review. <i>Transport reviews</i> , 28(6), pp.781-803	Park and ride	Car kms
Meek, S., Ison, S. and Enoch, M., 2011. Evaluating alternative concepts of bus-based park and ride. <i>Transport Policy</i> , 18(2), pp.456-467.	Park and ride	Car kms
Meek, S., Ison, S.G. and Enoch, M., 2008. Park and Ride: Lessons from the UK experience. <i>TRB Paper</i> , 08-0730	Park and ride	Modal split
Melia, S. and Clark, B., 2016. Evaluation of the change in parking policy on Frenchay campus. Centre for	Parking time limits, permits and pricing and on- and off-street	Modal split

Reference	Intervention	Area of impact
Transport and Society, University of the West of England.		
Melia, S. and Shergold, I., 2016. Pedestrianisation and politics: Evidence gaps and a case study of Brighton's Old Town. UTSG: January 2016, Bristol	Parking and road space transformation/reallocation	Modal split
Melia, S., 2014. Carfree and low-car development. In: Ison, S.G. and Mulley, C. eds., 2014. Parking: issues and policies. Emerald Group Publishing	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Modal split
Mills, G. and White, P., 2018. Evaluating the long-term impacts of bus-based park and ride. Research in Transportation Economics, 69, pp.536-543.	Park and ride	Car kms
Milosavljević, N. and Simićević, J., 2016. User response to parking policy change: A comparison of stated and revealed preference data. Transport Policy, 46, pp.40-45	Parking time limits, permits and pricing and on- and off-street	Car kms
Morris, D., Enoch, M., Pitfield, D. and Ison, S., 2009. Car-free development through UK community travel plans. Proceedings of the Institution of Civil Engineers-Urban Design and Planning, 162(1), pp.19-27.	Parking capacity reductions at city or neighbourhood level and use of resulting space	Car ownership
Nottingham City Council (2019). Transport Scotland Bill: Workplace Parking Levy Amendments. Submission from Nottingham City Council	Levies/taxes on off-street parking	Modal split

Reference	Intervention	Area of impact
Olimstad, M. and Gjellebæk, I., 2015. Hva betyr gateparkering for handelen? Oppsummering av norske og internasjonale studier. SVV, Oslo.	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Oost, T., 2022. How to make car-free neighbourhoods work: the factors that contribute to the success of a car-free neighbourhood (Masters dissertation, University of Groningen).	Parking standards, off-site or non-adjacent provision of residential parking; low-car and car-free housing	Modal split
Ostermeijer, F., Koster, H., Nunes, L. and van Ommeren, J., 2022. Citywide parking policy and traffic: Evidence from Amsterdam. <i>Journal of Urban Economics</i> , 128, p.103418	Parking time limits, permits and pricing and on- and off-street; parking capacity reductions at city or neighbourhood level and use of resulting space	Car kms
Ostermeijer, F., Koster, H.R. and van Ommeren, J., 2019. Residential parking costs and car ownership: Implications for parking policy and automated vehicles. <i>Regional Science and Urban Economics</i> , 77, pp.276-288	Parking time limits, permits and pricing and on- and off-street	Car ownership
Palmer, D. and Ferris, C., 2010. Parking measures and policies research review. Wokingham: Transport Research Laboratory	Parking time limits, permits and pricing and on- and off-street; park and ride; parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing; parking pricing in relation to household or user characteristics; parking capacity reductions at city or neighbourhood level and use of resulting space; shared-use parking	Modal split and car kms

Reference	Intervention	Area of impact
Pandhe, A. and March, A., 2012. Parking availability influences on travel mode: Melbourne CBD offices. <i>Australian Planner</i> , 49(2), pp.161-171.	Levies/taxes on off-street parking	Modal split
Parkhurst, G. and Meek, S., 2014. The effectiveness of park-and-ride as a policy measure for more sustainable mobility. In: Ison, S.G. and Mulley, C. eds., 2014. <i>Parking: issues and policies</i> . Emerald Group Publishing	Park and ride	Modal split and car kms
Parking Brussels., 2020. <i>Parking Policy in the Brussels Capital Region - Benchmarking Report</i>	Parking pricing in relation to household or user characteristics	Not mentioned
Pfaffenbichler, P. and Schopf, J.M., 2011. Einfluss der Parkraumorganisation und der Anzahl der Stellplätze auf die Nutzung des motorisierten Individualverkehrs und die Erreichung verkehrs-, umwelt-und siedlungspolitischer Ziele (PAN). Austrian Energy Agency, Vienna	Parking capacity reductions at city or neighbourhood level and use of resulting space	Car kms and car ownership
Piccioni, C., Valtorta, M. and Musso, A., 2019. Investigating effectiveness of on-street parking pricing schemes in urban areas: An empirical study in Rome. <i>Transport Policy</i> , 80, pp.136-147.	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Richardson, E., no date. The role of parking in limiting traffic growth and congestion. Unknown	Other	Modal split

Reference	Intervention	Area of impact
Rijkswaterstaat., 2018. Parking Policy Factsheet. Den Haag, Report wvl0218zb025	Effective and fair parking enforcement; parking capacity reductions at city or neighbourhood level and use of resulting space	Modal split and car kms
Rye, T., Tully, S., Godin, G., Schmalholz, N. and Hertel, M., 2022. Parking and SUMP. Using parking management to achieve SUMP objectives effectively and sustainably. European Platform on Sustainable Urban Mobility Plans.	Park and ride; parking capacity reductions at city or neighbourhood level and use of resulting space	Modal split
Santos, G., Hagan, A. and Lenehan, O., 2020. Tackling traffic congestion with workplace parking levies. Sustainability, 12(6), p.2200	Levies/taxes on off-street parking	Modal split
Spence, B., 2017. Are we still paving paradise? New techniques in parking management. IPENZ Transportation Group Conference, Hamilton 30th – 31st March 2017	Parking time limits, permits and pricing and on- and off-street	Modal split and car kms
Strategy Development Partners and Martens, M., 2019. Parkeerbeleid als stuurmiddel voor woon-werkverkeer. Ministry of Infrastructure and Water Management, The Hague	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing; parking time limits, permits and pricing and on- and off-street	Modal split
Swiss Federal Office for Spatial Planning., 2021. Shaping Mobility in Agglomerations: Parking Management	Parking time limits, permits and pricing and on- and off-street	Modal split and car kms

Reference	Intervention	Area of impact
Taylor, E., 2018. Transport Strategy Refresh: Background paper –Car Parking. RMIT University, Centre for Urban Research	Parking time limits, permits and pricing and on- and off-street; shared-use parking; parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Car kms, car ownership, modal split
Taylor, E.J. and van Bommel-Misrachi, R., 2017. The elephant in the scheme: Planning for and around car parking in Melbourne, 1929–2016. <i>Land use policy</i> , 60, pp.287-297	Parking standards, off-site or non-adjacent provision of residential parking, low-car and car-free housing	Car kms
Tennøy, A., Gundersen, F., Hagen, O.H., Knapskog, M. and Uteng, T.P., 2017. Effects on traffic and emissions of densification in nodes in Bergen, Kristiansand and Oslo. TØI-report, 1575	Other	Car kms
Thorwaldson, L., Thomas, F. and Carran-Fletcher, A., 2021. Evaluating the Greenhouse Gas Emission Reduction Benefits from Land Transport Mode Shift Programmes and Projects: A Research Note. Waka Kotahi, NZ Transport Agency, 4.	Parking time limits, permits and pricing and on- and off-street	Modal split and car kms
Witte JJ and Mingardo G., 2017. Parking policy, parking duration and spend of shoppers in the Netherland. Erasmus University Rotterdam, working paper	Parking time limits, permits and pricing and on- and off-street	Not mentioned
Young, W., Currie, G. and Hamer, P., 2014. Exploring the impact of the Melbourne CBD parking levy on who pays the levy, parking supply and mode use. In: Ison,	Levies/taxes on off-street parking	Modal split and car kms

Reference	Intervention	Area of impact
S.G. and Mulley, C. eds., 2014. Parking: issues and policies. Emerald Group Publishing		
Zijlstra, T., Vanoutrive, T. and Verhetsel, A., 2015. A meta-analysis of the effectiveness of park-and-ride facilities. European Journal of Transport and Infrastructure Research, 15(4).	Park and ride	Modal split and car kms

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