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Measure No.18: New models of car use



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Shared use of cars (or other vehicles), to reduce the volume of traffic, and to improve access to mobility.

Shared use can include multiple uses of individual vehicles belonging to an operator or to a 'club', or multiple people travelling in a vehicle sharing a journey. Potential benefits for a city include fewer vehicles travelling and reduced demands on parking.

18.1 Context and background

This review will look at a range of interventions that are aimed at providing access to the benefits of individual mobility, without some of the negative elements of such mobility. In particular it considers interventions known as carsharing and carpooling. It should be noted, that these terms (and that of ridesharing) can have different and similar meanings depending on the country they are deployed in.

Key messages:

- There is strong evidence of positive effects of Carsharing schemes on vehicle kilometres travelled, CO2 emissions, car ownership, the incidence of driving alone and the numbers of vehicles on the streets.
- Free-floating Carsharing seems to have additional important advantages for larger urban areas (related to parking and one-way journeys), although evidence here is limited at present.
- Carshare schemes are run on both profit and not-for-profit bases. The proliferation of carshare schemes across the globe, often run by private companies, suggests that they can be commercially viable.
- Carshare schemes will be more expensive to operate in cities where parking spaces are expensive.
- Carsharing offers users financial advantages in comparison to owning a private vehicle; e.g. avoiding maintenance costs and unpredictable repair bills.
- Carpool schemes can reduce congestion, parking demand and fuel use/CO2 emissions. However there is the possibility of induced trips replacing these.
- The evidence reviewed does not give a clear indication of economic benefits to societies and municipalities of carpooling, instead focusing on benefits for the individual user.

Potential interventions

- Cars (and sometimes other vehicles) provided by an operator and used by a range of individuals when they have a need for a vehicle. Can be a not for profit operator, a commercial entity, or even a motor manufacturer.
- Systems whereby those making journeys with spare capacity in their vehicle can offer that space to others (sometimes in return for payments). New entrants in one area of this market are highly technology driven, for example rideshare providers such as Uber and Lyft.
- Both types of scheme may be implemented for individuals, or through workplace-based schemes.

A carsharing scheme is one in which a number of cars are owned by an organisation. The organisation then rents the vehicles to members of the scheme. The terminology for carsharing is complicated as the term means different things in different countries. In the UK 'carsharing' refers to individuals sharing their personally owned vehicles whereas 'car clubs' refer to organisationally owned cars being rented out. Outside of the UK however 'carsharing' is the term applied to organisationally owned cars being rented out, and carpooling or ridesharing refers to individuals sharing personal, non-organisationally owned, vehicles. For this review the non-UK definition of carsharing and carpooling will be used.

This review includes studies on two types of carsharing. These are station-based carsharing, and free-floating carsharing. In station-based carsharing, the rented car has to be returned to the parking space from which it was taken. Hence the vehicle must be used for there-and-back or circular journeys. By comparison in free-floating carsharing the car can be left at any location, within a prescribed urban area (Firnkorn & Muller, 2011). In effect this means that the rented vehicle can be used for a one-way journey. This is beneficial because otherwise carsharing can be unappealing when the user wishes to travel only a short distance but then stay at the destination for some time (Ecoplan, 2012). Other features of free-floating schemes are users not having to prior book to use a car, no fixed costs (i.e. users only pay if and when they use a vehicle), and real-time GIS information showing the present location of available cars (Firnkorn & Muller, 2011). Firnkorn & Muller suggest that evidence relating to station based and free-floating carsharing should to some extent be considered separately as findings relating to one may not necessarily apply to the other.

Carsharing patronage in Europe has expanded rapidly in recent years. In 2015 it was reported to stand at more than two million, having increased from 75,000 in 2005 (Dings, 2015). It is a measure that can be used to address the adverse effects of excess private vehicles on roads. This means it can address 'social, environmen-

tal and land use issues' Klinevicius et al. (2014 p.54). While reducing the car use of many of its members, and reducing vehicle kilometres driven overall, it can also provide a degree of car mobility for those on lower incomes, unable to afford private car ownership.

Carpooling is a form of ridesharing (Chan & Shaheen, 2012). It has been defined by Macdonald et al. (2010, p.3) as 'the practice whereby individuals combine to share private vehicles for specific journeys.' Thus the vehicles aren't hired from a central organisation. Ridesharing also contains vanpooling (Chan & Shaheen, 2012). Vanpooling is where a larger vehicle is used for the shared journey. Vanpooling groups are often financially self-sufficient, although can be subsidised by employers.

Carpooling has different forms (Chan & Shaheen, 2012, p.94). These include 'acquaintance-based' carpooling in which family members, friends, or known colleagues may share a trip. 'Organisation-based carpooling involves the trip maker joining a carpooling organisation, either through becoming a member or through using a website. This may include the trip maker traveling with different people and in different vehicles, on different days. 'Ad hoc' ridesharing is when the trip makers are not familiar but does not require membership of an organisation. It often takes the form of 'casual carpooling.' Carpooling is often associated with commute journeys although it can be used for other types of journey.

18.2 Extent and Sources of Evidence

Fourteen items were examined for this review. A reasonably wide literature base exists on the topic of carsharing. There is less academic work on carpooling. Seven of the fourteen studies reviewed are journal articles and two are conference papers, written for the Transport Research Board meeting. Four reports are also included, two of which were written on behalf of transport authorities, another on behalf of a British motoring organisation and a fourth was part of the E.U. CIVITAS project.

The items reviewed cover a range of studies, ranging from overviews to investigations of specific interventions: Three studies on carsharing were on solitary schemes, two looked at carsharing within a specific city, three looked at carsharing at a national level, one looked at the whole North American continent and one was a general overview. Of the documents on carpooling, one was a report on carpooling in a number of cities. Another was to investigate the possibility of an area wide carpooling scheme. A third was a stated preference study and the fourth was a review of carpooling in the U.S.

Within Europe, two of the studies on carsharing were based in Germany, two in the UK, and one was based in Sweden and written in Swedish. Outside of Europe, carsharing has been particularly popular, and researched, in North America. Hence two studies reviewed were based in San Francisco, U.S., one was based in Montreal, Quebec, and one was based on the North American continent in general. Of the studies into carpooling, one was based in Australia, one in the U.S., one in Portugal and one across European cities.

Of the fourteen studies reviewed, ten were published in the last five years. Two were published last year. This suggests that carsharing and carpooling is receiving ongoing research, although there may be more being conducted on the former. Free-floating carsharing is a relatively recent development, and as yet there has been little data collection and research in relation to it. It is likely that such research will continue to arise in the coming years. The studies reviewed provide current research and related to contemporary forms of carsharing and carpooling.

18.3 What the Evidence Claims

18.3.1 Carsharing

Cervero & Tsai (2004) conducted a study on carsharing in San Francisco, U.S. They compared the impacts on travel demand and car ownership levels, amongst carshare users and non-users two years after implementation of a carshare. The study reported on the mileage that users travelled by different modes. 6.5% of their

trips and 10% of their vehicular miles were travelled in the carshare cars. One caveat on the reduction of car use by carshare members is that this reduction may be less noticeable at traffic peak times of day (although it may be that car sharers may become more likely to commute by bus or cycle). They also found that 50% of trips that used car share cars had previously been on public transport, walking or cycling. 18% were previously made by driving.

Ter Schure et al. (2012) also focused on car sharing in San Francisco. In that city, many residential developments are required to provide carshare facilities. The study compared the travel behaviour and car ownership of those living in developments with carshare to those in developments without carshare.

Klincevicus et al. (2014) assessed the effects of carsharing on household car ownership in Montreal, Quebec. They used a different methodology to most of the other studies as will be discussed below. They found that where there are a higher number of carshare vehicles within a 500 meter radius of a household there is a lower chance of car ownership.

Three of the studies reviewed are reports using mainly fact finding and qualitative strategies. These are Integrated Transport Planning Ltd (2004), Cairns (2011) and EcoPlan (2012).

Integrated Transport Planning Ltd (2004) is a report investigating carsharing in the UK, using qualitative interviews. Most of the carsharing schemes the report includes were in rural areas, although one was in London. Qualitative insights include general feelings of the carsharing schemes being a success and members viewing carshare as providing access to a car without the drawbacks of ownership. Members interviewed reported selling their private vehicles. One of the reported attractions of carshare was having access to vehicles of different sizes. The schemes studied varied, some were considered a success financially whilst others had very low take up and were not economically sustainable. Cairns (2011) also provided an overview of carsharing in the UK. She reports that

there had been 'exponential growth' (p.11) in the popularity of carsharing schemes in the UK. According to Carplus data there were around 32,000 members of carsharing schemes in 2007 in the UK. By 2010 the figure had risen to 146,000 members. Ecoplan (2012) produced a report to provide a basis for decisions around what level of support should be given to carsharing schemes in Sweden. The research included interviews with four car sharing companies and with other stakeholders. The study is an overall investigation of carsharing but with a focus on Sweden.

Litman (2000) conducted a general international evaluation of the potential of, and barriers to, carsharing. The study concludes that carsharing is a beneficial alternative to private vehicle use if less than 10,000 km (6,000 m) are driven annually. Two of the studies reviewed examined free-floating carsharing specifically, as defined above (Firnkorff & Muller, 2011, Schmoller et al., 2014). Schmoller et al. (2014) examined booking data of free-floating carshare cars in Munich and Berlin, Germany. They found increasing bookings of the cars, during the study period, due to increasing numbers of members. They comment that free-floating carsharing addresses two problems with station-based systems. These are that in free-floating systems cars can be booked spontaneously, without reservations, and that one way trips become possible. The latter advantage is particularly important as their data suggested that only around 10% of trips made were round trips.

Firnkorff & Muller (2011) examined free-floating carsharing in Ulm, Germany. The study used survey respondents' predictions of their own behaviour given differing scenarios. They found indications that the scheme was popular. Almost 10% of residents in Ulm signed up to the scheme, although not all of these were active users. More than 25% of respondents stated they would forgo purchasing a car if the scheme was offered permanently. Firnkorn & Muller conclude that free-floating carshare is able to interest a greater share of people than station-based schemes.

Martin & Shaheen (2011) focused specifically on effects of carsharing on Green-

house gas emissions (GHG) across the North American continent. The study found that car sharing leads to a net decrease in GHG emissions and vehicle kilometres travelled. Whilst a majority of households taking up car sharing increased their emissions when joining carshare, a minority decreased their emissions. The decreases tended to be of greater magnitude than the increases, to the extent that the overall effect of carsharing was a decrease in emissions. This finding is supported by Litman (2000). Martin & Shaheen (2011) used two measures of the effects on emissions. The 'observed' impact included the observable changes in household driving behaviour. The 'full' impact took account of wider effects on behaviour, such as car purchase being forgone because of carshare membership. Statistically significant reductions of the mean emission level were found using both measures. 'The mean observed impact is -0.58 t GHG/year per household, whereas the mean full impact is -0.84 t GHG/year per household' (p.1074). Cervero and Tsai (2004) also suggest that GHG emissions would be reduced by carsharing, partly because of the carshare vehicles having lower emissions than average vehicles, although their study is less specifically focused on this specific outcome of carsharing.

Firnkorff & Muller (2011) used scenarios to estimate CO₂ emissions resulting from a free-floating carshare scheme. Even the worst case scenario resulted in a net reduction of CO₂. They estimate that the effect on CO₂ emissions of the scheme would be average reductions of between 312 and 146 kg CO₂/year per weighted average car-sharing user. The study suggests these results are similar to conventional car sharing schemes. However it also comments that the free-floating scheme type would be more popular than a conventional station-based scheme and thus would have greater benefits. The reductions in CO₂ that Firnkorn & Muller (2011, p.1526) predict lead them to suggest that 'the difference between the emissions of car2go' (the carshare company) 'and public transport is small enough to rethink the paradigm that public transportation is invariably superior to cars in environmental terms'. Firnkorn & Muller highlight cold starts of engines that lead to high levels

of harmful emissions compared to normal running. Thus if the periods between use of the carshare cars are small, emissions will be lower than if everyone used their own vehicle and let it cool between journeys. Firnkorn & Muller (2011) concede that they did not take account of the CO₂ emissions involved in setting up and maintaining the infrastructure of a carshare scheme.

Having briefly introduced the separate items reviewed and having discussed impacts on CO₂ emissions, some common trends within the evidence, across the studies on carsharing, will now be summarised. The evidence reveals positive trends regarding the effect of carsharing on total distances travelled in cars, car ownership, numbers of cars being effectively removed from the streets, mode use of carsharers and reductions of drivers driving alone.

The evidence suggests that carsharing can reduce vehicle kilometres travelled overall. Martin & Shaheen (2011) found that mean vehicle kilometres travelled per year decreased by 27%. They note that carshare member tended to drive very small distances in carsharing vehicles. Ecoplan (2012) cite the International Energy Agency as suggesting that carshare users reduce their annual mileage by about 3,000 miles on average after joining a carshare. Cervero & Tsai, (2004) also found carshare users overall mileage was found to be reduced by joining carshare. They suggest that this may be due to a number of outcomes of carsharing, including reduced car ownership and more selective car use in general. Integrated Transport Planning Ltd (2004) suggests that carshare members tend to minimise their use of the carshare vehicle as they have to pay for each individual journey. Showing similar evidence of low mileage, Cairns (2011) reports that on average carsharers made five or six car driver trips of less than 25 miles per month. This was compared to an average of 56 such trips for non-carshare drivers. Litman (2000) similarly concludes that carsharing tends to reduce vehicle use by 40 to 60% due to the low fixed costs but high variable costs involved in using carshare vehicles. It can be observed that this proportion of fixed to variable costs is different for private vehicle use, where

there are high fixed costs. Hence one of the problems of private vehicle use, which is ameliorated by a switch to carshare, is owners tending to maximise their mileage in their vehicle in order to get the best value from their investment.

As noted above, one reason for a reduction in total distance driven by carsharers includes impacts on car ownership. The studies reviewed suggest that carsharing can be associated with lower levels of car ownership. Ter Schure et al. (2012, p.96) suggest that carshare members had 'significantly lower levels of vehicle ownership than non-members did.' They found the average member household owned 0.47 vehicles per household while for non-members the figure was 1.22, more than twice as many. Cervero and Tsai (2004) found that around a third of carshare users had reduced the number of cars owned by one or more. Two thirds reported that during the two years since carshare implementation they had opted not to purchase another car. Similar behaviour is reported by Cairns (2011). She found that 85% of respondents reported not owning a car after joining a carshare, compared to 63% prior to joining. 25% reported giving up a privately owned vehicle during the membership and 30% reported forgoing buying a vehicle that they would have purchased if not for being carshare members. Similar results were found by the various datasets that Cairns reports on.

A potential outcome of some carsharers reducing car ownership is that one carshare vehicle may replace numerous privately owned vehicles on the streets (Another reason may be that carsharers drive less than car owners who are not members.) Cervero and Tsai (2004) estimate that the 74 vehicles in the scheme they examined had probably removed more than 500 vehicles from the local area. That is about seven private vehicles removed for every carshare car. A scheme investigated by Ecoplan (2012) suggested that each carshare vehicle replaces between ten and fifteen privately owned cars.

As well as reducing car use and ownership, carshare use is associated with generally desirable modal behaviour. Ter Schure et al. (2012) found that there were statistical-

ly significant differences in the mode used for commute between carshare members and non-members. 83% of members used non-auto modes for their journey to work compared to 70% of non-members. 43% of carshare members took public transport compared to 23% of those without. Cairns (2011) found that members walked, cycled and used public transport more than the population in general. Some of those interviewed by Integrated Transport Planning Ltd (2004) also reported using walking and public transport more having joined a carsharing scheme.

Carshare may also affect incidence of driving alone. Ter Schure et al. (2012) found that carshare members were 40% less likely to drive alone for trips than non-members. Cervero and Tsai (2004) suggest that members' overall mileage may have been reduced after joining carsharing due to more journeys being made with more than one person in the car (i.e. combining different trips).

Carsharing would not be popular unless it offered benefits for the customer. Litman (2000) suggests that carsharing can be attractive by avoiding the need for maintenance of a privately owned vehicle and unpredictable repair bills (see also Ecoplan, 2012). The main benefit for the customer though is likely to be financial advantages of membership, in comparison to owning a private vehicle. These will depend on the amount of transport that the individual needs a car for (Ecoplan, 2012). Environmental concern may also be a motivator (Integrated Transport Planning, Ltd., 2004).

Very few disbenefits of carsharing schemes are revealed in the studies reviewed. One logical disbenefit is that whilst carsharing is more environmentally beneficial than private vehicle ownership, it is less beneficial, from environmental, street ambience, road safety and public health perspectives than walking and cycling, which it may in some instances replace.

Other issues are mentioned in relation to small scale rural carshare schemes. These include the difficulties of finding staff to administer the scheme who have the prerequisite skill sets and also making

the scheme financially viable (Integrated Transport Planning Ltd, 2004). However evidence suggests that financial viability in urban areas is less problematic. A key factor for the economic sustainability of a station-based scheme is that each car should be patronised by a sufficient number of householders in its vicinity.

In conclusion on the main findings on car-sharing, the evidence suggests a number of strong benefits of the intervention type. These benefits apply to the global environment (CO₂ and other emissions) the local society (reductions in numbers of vehicles driving in the city) and the individual member (reduced hassle and expense from reduced private vehicles owned.)

18.3.2 Carpooling

Macdonald et al. (2010) report on a number of carpool interventions carried out in European cities as part of the CIVITAS project and comments on their success levels. Across eight cities, five (Burgos, Krakow, Debrecen, Potenza and Preston) involved the introduction of a new car pooling system whilst three (Stuttgart, Toulouse and Norwich) involved the expansion or adaptation of an existing carpooling scheme. The carpooling interventions included: facilitating carpooling amongst students or educational institutions (Debrecen, Krakow, Norwich) using or creating website or web-based tools (Burgos, Debrecen, Krakow, Norwich, Potenza, Preston, Toulouse) and promotion, marketing or advertising (Burgos, Debrecen, Krakow, Norwich, Potenza, Preston, Stuttgart). The cities reported beneficial effects of the interventions. These were expressed in various formats: Norwich reported 304 tonnes of CO₂ being saved, Preston reported an average reduction in emissions of 7.7g of CO₂ per shared journey and Toulouse reported 0.338kg of CO₂/km for a medium sized car being saved. Krakow reported that fuel consumption had been reduced by 32% (although the document comments this figure should be treated with caution). Norwich reported savings in car running costs of £99,369 (estimated from the vehicle miles saved).

A number of cities reported increases in average car occupancy following the inter-

vention. In addition there were increases in total numbers of people using the carpool system. These increases varied greatly by city: increasing up to 1,800 in Toulouse and 1,700 in Stuttgart, but only up to 34 in Potenza. The different cities reported people's attitudes to carpooling in relation to the intervention. In Burgos the percentage of people willing to share their own vehicle rose from 57% to 87%. In Krakow, awareness of carpooling increased from 34% to 66%. However, in Krakow, interest in carpooling did not vary as a result of the intervention and in Stuttgart, awareness of carpooling declined during the researched intervention period. Overall though, Macdonald et al. (2010) conclude that in each city the intervention achieved its aim of successfully establishing or increasing a carpooling facility.

Correia & Viegas (2011) used a stated preference survey in Lisbon, Portugal, to examine carpooling. They tested whether there was a level of trust needed for carpoolers seeking matches. They suggest that sharing a car with a non-acquaintance can be a barrier to take-up. This can be reduced in if the carpool is organised by an employer, so that the other trip-maker is a colleague. Correia & Viegas also examined the importance of being able to join different carpooling groups for a user whose schedule has changed. They suggest that carpooling systems can be inflexible, particularly when users want to change their destination or timing of trip. This problem can mean only a small percentage stay with carpooling long term.

Chan & Shaheen (2012, p.96) give an overview of carpooling in the U.S. They suggest that carpooling can be claimed to have a number of 'societal benefits' such as reduced CO₂ emission and energy use, amelioration of traffic congestion and reduced demand for parking. However, they conclude 'the magnitude of such benefits is unclear.'

DeGruyter (2006) investigated the potential for a CBD (central business district)-wide carpooling scheme in Melbourne. He reports on a survey that preceded the possible intervention. The proposed intervention was addressing the problem that carpools specific to individual employers

would not be effective in a CBD area, full of small shops etc. Thus an alternative would be to have a joint carpool for the companies in the area. 6% of workers in the area said they would be very interested in the carpool, 23% said they would be slightly interested. Almost half of the staff who would be interested in the carpooling were in lower as opposed to higher paid jobs. More women than men were interested in the scheme.

The extent to which carpooling schemes may reduce total vehicle kilometres travelled is debatable. Whilst shared car trips may be longer than individual journeys (in order to pick up fellow travellers) this will not lead to as many vehicle kms travelled as if each trip maker made a separate car journey (DeGruyter, 2006). However DeGruyter also notes that some new carpoolers may switch from public transport. In the case of the Melbourne CBD he examined, the survey responses suggested that because most of those surveyed who were interested in the scheme presently used public transport, the overall result of the scheme would be likely to be an increase in total vehicle kms travelled.

A common theme in the studies examined is that carpooling can have both attractive and unattractive aspects for the individual user. Attractive elements can include the idea of reducing congestion and pollution (DeGruyter, 2006), reducing personal travel costs (both financial and travel time, Chan & Shaheen, 2012, DeGruyter, 2006), the potential of increased social interaction (DeGruyter, 2006), reduced stress of driving the commute (Chan & Shaheen, 2012) and the enjoyment of priority parking, subsidised parking costs, use of high occupancy vehicle lanes and other incentives (Chan & Shaheen, 2012, DeGruyter, 2006).

Potentially unattractive aspects for the user include a lack of journey flexibility in carpool arrangements, personal safety concerns, having to rely on fellow travellers, not wishing to interact socially during the commute (Chan & Shaheen, 2012, DeGruyter, 2006) and the time spent collecting fellow travellers (Correia & Viegas, 2011, DeGruyter, 2006). So some elements of carpooling work towards and

some against, the popularity of the scheme type. Discussion now turns to the nature and quality of the research methods used to reach the above findings.

18.3.3 Nature of research methods – Car-sharing studies

This section will discuss two main approaches of generating data used by the study: comparing before and after behaviour and comparing the behaviour of carshare members and non-members. It will then discuss some of the strengths of the methods used, and then some of the weaknesses, before drawing brief conclusions.

An obvious strategy when seeking to understand the impacts of carsharing schemes is to compare members with non-members. This can be done in two ways: those who are presently members can be compared with those who presently are not members. Ter Schure et al. (2012) and Cervero & Tsai (2004) took this approach. Ter Schure et al. (2012) compared those who were members of a carshare through their residential development with those who had no such facilities. Alternatively the behaviour of those who are presently members can be compared with their behaviour before they became members. Cairns (2011) and Martin & Shaheen (2011) took this approach. Cervero & Tsai (2004) measured changes in members' behaviour in their first two years of membership and also compared this to a control group of non-members. This in effect used both approaches.

It could be argued that the method of comparing members' behaviour to non-members' does not prove a cause and effect between membership and altered travel behaviour. It may be that those who carshare are less likely to drive as far or are more likely to use other modes for reasons other than their carshare membership. This issue is maybe less of a factor in the surveys comparing before and after behaviour. This method may contain its own biases though due to its component of self-report.

The methodologies used included a number of strengths. One of these is

the collection of data from large samples of carshare members. For example, Martin & Shaheen (2011) used a survey of 6281 responses, Cairns (2011) drew data from around 5,000 survey responses, Ter Schure et al. (2012) used 298 survey responses, Cervero & Tsai (2004) used around 500 survey responses, and Firnkorn & Muller (2011) used 308 responses. Martin & Shaheen (2011) and Firnkorn & Muller (2011) record efforts to make their samples representative.

Another strength in the evidence reviewed is the range of methods by which it was gathered. This range included, surveying members about their travel behaviour, qualitative fact-finding investigation, using computerised booking data and using census level information.

The majority of the studies were peer reviewed and, when using statistics, used appropriate methods. These included simple descriptive statistics and chi-square tests (Ter Schure, 2012), Binomial logit models (Cervero & Tsai, 2004), sensitivity analysis and paired t-test (Martin & Shaheen, 2011), cluster analysis and linear regression models (Schmoller et al. 2014) and multiple regression models (Klincevicus et al. 2014).

Perhaps the main weakness of a number of the studies reviewed is that they relied on surveying carshare members' attitudes and self-reported behaviour. Klincevicus et al. (2014, p.49) suggest that this reliance may lead to bias as it may involve the members' 'interpretation and speculation and may not correspond to measurable effects overall in the city.' There is the impression that some of the fact finding reports, such as Integrated Transport Planning Ltd. (2004), were researching people who were particularly positive about the scheme type.

However, not all the studies relied on surveying carshare members. Klincevicus et al. (2014) sought correlations between levels of car use and household characteristics at a population level, using census data, and behaviour and car ownership data. Another exception was the study by Schmoller et al. (2014). They used computerised booking information of a free-

floating carshare system. This information consisted of start and end times of journeys, journey duration and lengths and the location of start and end points.

Other weaknesses also exist in specific studies reviewed. For instance one carshare scheme researched by Integrated Transport Planning Ltd (2004) had only 34 members, so drawing conclusive evidence about behavioural changes was difficult for this case. However, that scheme was only one of a number investigated in the report. Other data was drawn that might have had motivation for bias. For instance Cairns (2011) used data from an organisation that is aimed at supporting rethinking car use. However, this study also drew on data gained from other sources. Similarly (Ecoplan, 2012) drew data from carshare companies, that might have motivation to be biased.

Although a number of the studies did rely on self-reported behaviour, this information has the strength of relating, theoretically, to actual or real-world behaviour. An exception was the study by Firnkorn & Muller (2011), which asked participants for predictions of their behaviour given different scenarios. This data might be considered of slightly less worth in this respect than the reports of actual behaviour. Some of the studies discounted members who didn't use the carshare vehicles, despite being members (Martin & Shaheen, 2011). This is understandable in terms of focusing on members whose travel behaviour is actually affected by involvement in a carshare. However it would seem important that research into carsharing should recognise that a proportion (Martin & Shaheen, 2011, estimate 15 to 40%) of those joining carshare never or rarely use the carshare vehicles. Other studies concede that their respondents may have been more likely to be those using the carshare more regularly (Cervero & Tsai, 2004).

Isolating the effects of carsharing on behaviour can be difficult because of other factors that may influence the trip maker (Klincevicus et al. 2014). For instance, Firnkorn & Muller (2011) concede that their study did not take account of seasonal variation. Integrated Transport Planning

Ltd (2004) suggest that carshare uptake may depend on local economic conditions, which can be difficult to understand. Some studies did seek though to take account of factors affecting behaviour such as weather and demographics (Schmoller et al., 2014) and moving house (Martin & Shaheen, 2011.)

In conclusion caveats that must be applied to the evidence have been outlined. The largest being that a number (although not all) of the studies rely on the self-reported behaviour of carshare members. Despite this, due to the range of methodologies and the consistency of the finding that car-sharing can provide benefits while causing few disbenefits, the conclusion that car-sharing is a measure with important positive potential can be held with some confidence. This positive verdict on carsharing would seem, from the studies reviewed, to be rationally generalisable to locations other than those researched.

There are some gaps in the evidence surrounding carsharing at present. Two studies on free-floating carsharing have been summarised. However, the literature base on this form of the scheme remains small. It is likely to increase in coming years, as the scheme type has been successful. Another gap in the research is a before and after study which compares individuals' (actual rather than self-reported) travel behaviour before becoming involved in carshare and then after they have become members. This is due to the obvious difficulty in predicting who, in the future, will join carsharing schemes.

18.3.4 Nature of research methods – Carpooling studies

A strength in the evidence reviewed concerning carpooling is that it represents a range of approaches: from surveying to reports on figures of membership, and from a stated preference study to an historical overview. However the nature of the data collected in relation to carpooling is weaker than that relating to carsharing and contains greater gaps. One of these gaps is that the evidence often focuses on the benefits of, and attitudes towards, carpooling for the individual user rather than the local authority or society as a whole.

The effects of carpooling for the local area, in terms of congestion, economic impacts etc. is not greatly quantified in the evidence reviewed.

Macdonald et al. (2010) use data from carpooling interventions in 8 European cities. The strength of this data is it draws on empirical data gathered after the interventions had been implemented. It includes total number of carpool users, results from surveys asking for people's attitudes to the carpool schemes, and comments about the scheme implementation in each city. Correia & Viegas (2011) obtained a good number of respondents for their survey (N=996.) However a weakness with it the data is that it is stated preference, rather than data on real behaviour. Chan & Shaheen (2012) do not provide empirical data, but provide an overview of carpooling using other sources. Degruyter (2006) collected survey data on people's attitudes to carpooling in a CBD, prior to an intervention.

18.4 Lessons for Successful Deployment of this measure

18.4.1 Carsharing

It is possible that evidence provided by research can be accurate for the location studied but is not legitimately generalizable to other settings. For carsharing though, most of the evidence suggests the scheme type could benefit other cities and countries than those covered in the research. It should be conceded that many of the studies examined schemes in countries where carsharing was becoming widespread, such as Germany and the U.S. Some of the study areas are particularly conducive to carshare. For example Cervero & Tsai (2004) question whether their findings in San Francisco would be generalizable elsewhere because the city has 'congested streets, limited and expensive parking, good public transit options, numerous non-traditional households and a fairly socially progressive population'. It could be argued though that these urban characteristics are quite common in many European cities and thus the findings from San Francisco may be relevant to much of Europe. Overall it is likely that the positive effects of carsharing found in the cities and

countries researched could be replicated in other cities and countries. Firnkorn & Muller (2011) suggest that free-floating car-sharing could become a widespread solution to mobility problems in the future, provided some technological and organisational problems were sorted out.

The range of studies shows that carsharing can be organised at a range of scales, from small urban schemes to large international companies. However very small rural schemes may have problems with financial sustainability.

Most of the evidence reviewed suggests that carsharing is significant as a measure in its own right. However it would be unusual for members to rely purely on carsharing for their transport needs, carsharing tends to be part of a multi modal lifestyle (Ecoplan, 2012). Thus the scheme may be most effective alongside effective provision for public transport and active travel. The review now examines the characteristics of carshare within a PESTLE analysis (which summarises political, economic, social, technological, legal and environmental factors).

The studies reviewed suggest a range of different interactions between relevant political bodies and carshare schemes. A shaping political factor surrounding carshare schemes can be that of parking (Ter Schure et al. 2012). Cairns (2011) suggests that in the UK, carshare schemes sometimes rely on local authorities for the provision of parking spaces. She also notes that local authorities can help to promote the schemes and can make use of them, as an organisation, themselves. Supporting carshare can be attractive to local authorities if they wish to create local areas that are walkable and which support public transport (Ter Schure et al. 2012).

Carsharing schemes relating to residential developments have been required of developers by some local authorities (Cairns, 2011, Ter Schure et al. 2012). However, Ter Schure et al. add that including residential based carsharing facilities can be attractive for developers, even when not legally required.

Political bodies and other organisations may be motivated to investigate and aid carsharing due to concerns over GHG emissions. The positive impacts of car-sharing on these emissions have been discussed above.

Economically, the contemporary proliferation of carshare schemes across the globe, often run by private companies, demonstrates that they can yield profit. Some schemes are run on a profit and some on a not for profit basis (Ecoplan, 2012). As a caveat to the economic viability of carshare, Integrated Transport planning Ltd (2004, p.110) found that one small rural scheme they investigated was not proving to be economically sustainable. This was due to outgoings (including repairing office equipment and work on parking places etc.) outweighing income. However, the rurality and small scale of this scheme should be stressed. It is much easier to achieve sufficient membership and income in dense, urban areas, and a London scheme investigated in the same report was found to be economically successful.

Ecoplan (2012) suggest that the cost to the carsharing organisation will depend to a great degree on the location of the car parking space. In this respect cars will be more expensive to run in larger cities where parking spaces can be expensive (unless local authorities help in this respect, as discussed above). If as Ecoplan (2012) suggest one carshare vehicle replaces seven private vehicles, this suggests that carshare could theoretically release valuable land that otherwise would be needed for parking. This effect is intensified by carshare cars often being smaller than average, thus allowing more to be parked in a given space (Firnkorner & Muller, 2011). It has been argued that this release of land could help create more liveable streets (Litman, 2000). It is likely though that in many cities the demand for parking so outweighs the provision available, that any extra land would quickly be used up by latent demand for parking.

Schmoller et al. (2014) report that the carsharing they examined received greater use on Saturdays than other days. They suggest this might be due to the vehicles being used for shopping trips. There

may be a two way link between carshare schemes and local retail: The vehicles may encourage greater shop patronage and thus sales. Conversely a strong local retail economy may increase carsharing popularity.

Carsharing can have benefits for social equality. Litman (2000) suggests that carshare may enable low income households to be able to have some car mobility. This is due to high variable costs but low fixed costs of membership. This may mean that these householders can have the ability to search for jobs and education for example (Litman, 2000). The scheme type may also help to decrease incidences of low income household members driving without insurance.

Another social impact that small, local carsharing schemes can have is that they can facilitate new friendships (Integrated Transport Planning Ltd, 2004). Additional potential benefits of carsharing are positive impacts on road safety (Ecoplan, 2012). These may result from carshare vehicles tending to be more modern, and driven less than typical privately owned vehicles. However, Ecoplan (2012) concede that such benefits have not been quantified.

The carsharing schemes investigated relied on technology of various forms. This can include in-car computer systems that can be used for bookings (Integrated Transport Planning Ltd, 2004, Firnkorn & Muller, 2011). Firnkorn & Muller suggest that eventually touch screens in free-floating carshare vehicles could display local public transport connections and even handle the purchase of tickets for public transport. In addition environmentally friendly driving of the vehicles could be recorded by computer and rewarded. The review now turns to some of the elements necessary or beneficial for successful operation of a carshare scheme.

A strong theme within the studies reviewed is that carsharing can have a synergistic relationship with measures to improve public transport (Cairns, 2011) and active travel infrastructure and facilities. Carsharing is likely to prosper where public transport and active travel are well provided for (Ter Schure et al., 2012). It can

also arguably encourage travel by these modes (Martin & Shaheen, 2011, Firnkorn & Muller, 2011). Other studies suggest that carsharing can lead to new carsharers using public transport less, but active modes more (Martin & Shaheen, 2011a). Martin & Shaheen found that this pattern was not uniform across different carsharing organisations. The overall statistic also masked disaggregate trends within their findings: They found that lots of new carsharers used public transport more, but even more carsharers used it less.

It is important for carshare and public transport to be well integrated (Firnkorn & Muller, 2011). Opportunities exist to offer carshare members discounts on public transport tickets (Cairns, 2011, Ecoplan, 2012, Litman, 2000). The interaction between carshare and public transport is highlighted by some carshare companies already being operated by public transport companies (Ecoplan, 2012). Bremen, Germany, is a successful example where a 'Bremer Karte plus Autocard' enables use of the trams, buses and car-share within the city, at low price (Hurley, 2014) (Multi-modal ticketing is discussed in detail under measure 12). As well as public transport, Litman (2000) suggests other measures that carsharing can be synergistically combined with. These include electric vehicles, dense land use and unbundled parking.

A number of studies highlight the need for marketing if a scheme is to be successful. Some false perceptions may need to be addressed in order to convince people to use the scheme. These include the perception that carshares may be for environmental enthusiasts only (Integrated Transport Planning Ltd, 2004, p.104) and underestimations of the costs of private vehicle ownership costs (Ecoplan, 2012). Some schemes have found carshares can be more successfully marketed in relation to practical and personal, rather than environmental motives (Integrate Transport Planning Ltd, 2004).

It has been noted that a key attraction in carshare membership is financial. Thus to be successful a carshare scheme should carefully consider its pricing in relation to other forms of car rental such as taxi and normal car rental (Cervero & Tsai, 2004,

Ecoplan, 2012). Carshare schemes are likely to particularly successful in dense urban areas, where there is parking scarcity (Cairns, 2011, Litman, 2000) and arguably where there may be lower household incomes (Litman, 2000). Schmoller et al. (2014) suggest that socio-demographic data can be used to partly forecast demand. Some of the rural schemes investigated by Integrated Transport Planning Ltd (2004) were not considered economically sustainable, although Cairns (2011) reports that rural carshares can be successful.

18.4.2 Carpooling

The studies of carpooling suggest some factors that might affect its more general implementation. In terms of its patrons, Correia & Viegas (2011, p.81) found that 'carpooling is still attached with lower income strata and that saving money is still an important reason for participating in it.' Age and gender may also be significant in take-up. Correia & Viegas found young persons would be more willing to join a carpool. In terms of the organisation instigating the pool, DeGruyter (2006, p.1) suggests that employer based schemes work well when there are lots of employees in the company, when they travel far to work and when a lot of employees use car prior to the intervention. Factors that can make such carpooling successful include, 'support from senior management, reimbursement of parking charges for carpoolers, provision of priority parking for carpoolers, efficient management of the carpooling scheme through a dedicated coordinator. Degruyter (2006, p.2) also suggests external conditions that can encourage carpooling. These include 'presence of high occupancy vehicle (HOV) lanes, lack of parking, absence of convenient alternative modes, increase in petrol price, having the carpooling scheme as part of a wider package of initiatives.'

The number of members that a given carpool scheme can achieve is vital. For instance Macdonald et al. (2010) report the importance of getting corporations involved. This is for the obvious reason that people working at the same location may share trip destination (to work) or origin (from work).

Marketing is also of vital importance in enabling the success of carpooling schemes (DeGruyter, 2006, Macdonald et al. 2010, Chan & Shaheen, 2012). All the cities in Macdonald et al.'s summary considered that achieving public awareness and acceptance of carpool schemes was vital for success. Marketing can be focused at target groups. It can offer strong messages such as the potential for trip makers to save money (Macdonald et al. 2010). Such messages can be conveyed and supported by local media or by car club websites (Macdonald et al., 2010).

The cities reported by Macdonald et al. (2010, p.22) considered that carpooling should be integrated within wider transport strategies, including 'work travel plan strategies'. It can be integrated along with supporting policies such as free or cheap access to high occupancy toll lanes, cash rewards for opting out of parking spaces and other financial incentives. As part of wider strategies there is the potential for synergistic relationships between carpooling and carsharing and public transport (Chan & Shaheen, 2012).

Strong political interest can support implementation of carpool schemes (Macdonald et al. 2010) This can be motivated by the need to reduce single occupancy car commute use, and policy objectives to reduce congestion and emissions. DeGruyter (2006) in his Australian study identifies local government and transport management associations as suitable bodies for implementing area-wide carpooling. Macdonald et al. (2010) report that there can be resistance and lack of acceptance from some politicians and other stakeholders. These can be resolved through stakeholder meetings. It is desirable that clear delineations of responsibility for aspects of the carpool are drawn amongst the authorities involved (Macdonald et al. 2010). Macdonald et al. (2010, p.22) suggest that in 'initial stages' carpooling schemes may not economically self-sufficient without local authority support. Financial factors such as increases in costs of car ownership and increasing fuel costs can influence uptake of carpooling by trip makers.

Chan & Shaheen (2012) conclude that technology will be important in the future of

carpooling. Open source data sharing may provide the wide pools from which users can find matches that are crucial to success and acceptance of the scheme type. Technology can enable easy ride matching for the user. In Stuttgart, technical software issues were felt to be a 'barrier to transferability' of the scheme. (Macdonald et al., 2010, p.19). However, there are now extensive web based platforms that enable carpooling. For instance, Pickuppal had over 156,000 members in 120 countries in 2012 (Chan & Shaheen, 2012).

18.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- Access to mobility: Carshare and carpool schemes can also provide a degree of auto-mobility and accessibility benefits for those on low incomes. This may provide access to the search for and take-up of jobs and education.
- Land-take: Carshare vehicles are seen to replace multiple private vehicles, suggesting that schemes could lead to the release of valuable land that otherwise would be needed for parking. This effect is intensified by carshare cars often being smaller than average.

18.6 Summary

18.6.1 Carsharing

In conclusion, the studies provide strong evidence that carsharing can have desirable impacts on car traffic related problems. They suggest that carshare can lead to reductions in vehicle kilometres travelled, CO₂ emissions, car ownership, incidence of driving alone and numbers of vehicles on the streets. The degree of these reductions, at a societal level, will depend on the popularity of the scheme and the extent of its provision. Conversely the scheme type can also provide a degree of auto mobility and the attendant accessibility benefits for those on low incomes. The free-floating form of carsharing seems to have important advantages for sizeable

urban areas, although due to its recent emergence there is still a relatively small body of evidence concerning it.

One caveat about the methodologies of most of the studies is that they tend to rely on the self-reported behaviour of carshare members. This may lead to a bias towards positive reports of the effect of carshare. However some of the studies did not use this method and provide useful triangulation for the approach. These studies also found beneficial behavioural outcomes of carshare membership.

What is also noticeable is that the studies do not highlight many drawbacks or undesirable aspects of the scheme type. One logical caveat regarding the scheme is that it does not in the long term offer the same environmental or public health benefits as walking or cycling. Whilst one carshare vehicle may replace multiple privately owned vehicles, it is still a polluting vehicle. Some carshare trips will have previously been walking and cycling trips (Cervero & Tsai, 2004).

The studies reviewed do suggest that there can be practical issues involved in successfully implementing a carshare scheme, but the large number of successful carshare schemes globally demonstrates that these can be overcome. The review has highlighted that to maximise the success of carshare it is beneficial to price the use of vehicles carefully and to implement the schemes in suitable areas. A particularly strong theme within the studies is the importance of good integration between carshare facilities and public transport. These two forms of mobility can interact synergistically. The importance of good marketing is another operational practicality that has been discussed.

There is no reason to consider that the positive outcomes of carsharing schemes could not, indeed have not, been replicated in other countries and settings than those reviewed, although small rural carshares may struggle for sufficient membership.

Whilst there are some weaknesses in the methodologies reviewed, these do not negate the fact that the studies consist-

ently show carsharing to have positive, rather than negative, effects at social and individual levels. In addition most of the weaknesses have been themselves caveated, and each methodological weakness applies to only some of the studies reviewed. In combination then, the studies form a consistent picture of strong benefits of carsharing schemes.

18.6.2 Carpooling

The evidence suggests that some vehicle trips, with the attendant costs of CO₂ emissions, congestion, parking demand and fuel loss, can be saved through carpool schemes. However there is the possibility of induced trips replacing these and trip makers switching to carpool from public transport. Thus it is hard to conclude the extent of the benefits from the evidence reviewed.

A number of factors acting as facilitators or barriers to carpool schemes have been discussed. The number of potential members is important, as larger pools of members increase the likelihood of a user finding a suitable match for their journey. For this reason marketing and other strategies to raise public awareness of the scheme are important to success, as is engagement with local employers. Uptake of carpool use may be affected by factors external to the scheme, such as fuel prices, car ownership prices, parking availability. Some of these can be managed by local authorities, and can be combined with carpooling, and carsharing as an integrated transport strategy. As with carsharing, technology, particularly web based technology, has become important for the future of carpooling.

The evidence reviewed does not give a clear indication of the benefits to societies and authorities of introducing carpooling interventions, but tends to focus on the benefits for the individual user. More specifically it does not give an indication of economic CBA of carpooling schemes.

The evidence surveyed suggests that there may be good synergistic relations between carpooling and carsharing; both enable car travel while avoiding the least sustainable uses of the mode.

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