Future trends in mobility: challenges for transport planning tools and related decision-making on mobility product and service development

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Preface

The objectives of this document are twofold. First, we will take stock of future trends in the supply side (technology and business models) of mobility. More specifically, we will deal with three major developments that could be real game changers: the rise of the collaborative or shared economy, the breakthrough of technologies for automated mobility, and major improvements in electric mobility. Second, we will assess the challenges these developments pose for transport planning and policy.

Let us start with the sharing economy. In a few years’ time, shared mobility services have escaped from their niche status. Some urban transport planners are already wondering to what extent these new market models will undermine the assumptions of their current work. Moreover, several sectors (ranging from taxi drivers to car manufacturers) are already affected by the phenomenon. Moreover, there are indications that shared mobility may not only replace some forms of private travel, but may also facilitate other forms of private travel. Hence, the net environmental and transport impacts remain contentious.

The second major trend is the rise of automated road mobility. Several major players have developed prototypes of automated cars that can function in (controlled) operational circumstances. Although there is a lot of controversy regarding their future speed of adoption no one seems to doubt that, in the long run, they will replace human operated vehicles. Although no one questions that their impact will be profound, there is a lot of debate on whether these impacts will be beneficial or detrimental. As we shall discuss below, it is likely that the beneficial impacts will only be fully captured if autonomous vehicles are integrated in a “shared mobility” business model and if they are complemented by high-capacity transit systems.

A third major game changer are the major breakthroughs in battery technology that have improved the competitive position of EV, even though the most performant models still target mainly an affluent niche audience. Until recently, electric vehicles faced two major disadvantages compared to ICE vehicles: their limited range and their large acquisition cost. Interestingly, “shared mobility” market models are better equipped to deal with these two issues than mobility models based on personal car ownership.

Summarizing, a strong case can be made that three important developments in the mobility sector (shared mobility, autonomous vehicles, electric mobility) can be mutually reinforcing, and lead to profound changes in our mobility systems.

In the next two chapters, we shall succinctly discuss each of these developments – we refer to the technical annex for a deeper discussion. Electric mobility will not be discussed separately, but only in its relationship with shared and automated mobility.

After having reviewed the expected trends, we shall discuss what they imply for transport modelling (and thus for the planning profession) and for the management of transport demand.
Chapter 1: The rise of the sharing economy: implications for transport

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1. Introduction

Shared mobility means different things to different people. Key terminology in the field is often used without rigorous definitions, and this can be a source of confusion. In this text, we will use the definition proposed in Shaheen et al. (2015a): shared mobility is a “transportation strategy that enables users to gain short-term access to transportation modes on an “as-needed” basis”.

This concept covers a wide range of services, ranging from ‘traditional’ services such as carsharing, carpooling, microtransit and bicycle sharing to services that have just emerged in the last few years, such on-demand ride services. In broader definitions, it also includes the smartphone apps that enable the implementation of these services (Shaheen et al.2015a).

In this chapter, we thoroughly review the existing evidence, drawing from the peer reviewed scientific literature, the “grey” literature and discussions in the popular media. We shall follow the classification used by Shaheen et al. (2015a):

- Carsharing
- Scooter sharing
- Bikesharing
- On–demand ride services
- Ridesharing: carpooling and vanpooling
- Alternative transit services
- Courier network services
- Trip planning apps

We shall not explicitly cover the topic of parking place sharing: this is a business model that allows people and businesses to rent out parking spaces while they are unoccupied. Possible approaches would be to have building blocks renting excessive parking capacity to carsharing systems, to install bicycle parking, or to manage a shuttle system from the housing block to public transit stations. Neither shall we discuss business models where individual components of a car are rented (such as batteries), rather than the car in its entirety.
2. Carsharing

2.1. Definitions

Compared to traditional car renting, the distinctive features of carsharing are the emphasis on short term access to the car and on the possibility for the members to access the cars without intervention of the third-party organisation from which they rent the car.

2.2. Key advantages and drawbacks

Carsharing takes several burdens and uncertainties associated with car ownership away from the car user, such as finding (and paying for) permanent parking, periodic vehicle inspection and maintenance, and taking care of adequate insurance cover.

More importantly, carsharing reduces the fixed cost of car use to periodic membership fees. Variable costs therefore become relatively more important and salient in travel decision making, and may lead to a decrease in car travel. As an indirect consequence, carsharing thus supports active lifestyles by encouraging bicycle and pedestrian travel modes.

Carsharing also increase mobility options for people with limited financial resources who do not travel a lot (which was actually the motivation behind the first carsharing schemes). For mobility impaired people, sharing a wheelchair accessible car allows to spread the (high) acquisition cost of this car.

Although a decrease in car use is a most important environmental benefit, there are also some indirect environmental gains. For instance, because shared cars are used more intensively, there is a quicker turnover of the fleet, and older models are replaced more quickly by (presumably) cleaner new models. Vehicle sizes can also be adapted to the trip purpose and the number of passengers. As a result, it is expected that manufacturers will build smaller and lighter vehicles, or that larger vehicles will have higher occupancy rates.

Moreover, as shared vehicles have a higher annual mileage than privately owned cars, there is a stronger incentive to increase energy efficiency or to switch to powertrains with lower variable costs (such as battery electric or hydrogen fuel cells). Moreover, if shared vehicles are mostly used for short trips, one of the main barriers to the use of battery electric vehicles (range anxiety) disappears.

The main drawback is that it is not always possible to predict demand. The user may for instance overestimate the time needed for his trip, and thus pay for time that was reserved but remained unused. On the supply side, carsharing operators can offer no guarantee that a car will always be available when and where desired. However, if fleet sizes increase further and prediction techniques become more performant, pricing mechanisms could be developed that could better match the users’ willingness to pay for reduced risk of unavailability.

2.3. A (very short) history of carsharing

The first carsharing scheme began in Zurich (Switzerland) in 1948, but it is only in the last five years that carsharing has really started growing exponentially. This can to a large extent be attributed to advances in digital technology which have made reduced the hassle linked to reserving, paying for,
and locating cars. Internet technologies and mobile apps have also played a key role in the establishment of trust and the provision of peer review (ITS America 2015).

The rapid growth of carsharing is illustrated in Figures *** and ***. The growth from around 250,000 members of carsharing systems in 2006 to more than 2,000,000 members in 2014 is certainly spectacular. However, to put these figures somewhat in perspective, in 2011, the total number of people in the EU29, Liechtenstein, Norway and Switzerland that had reached the “driving license age” (18 year or older) exceeded 400 million. Thus, actual membership of carsharing systems in Europe amounts to around 0.5% of the population of driving age.

Thus, while carsharing has grown rapidly, we need to take seriously the possibility that mobile apps have helped this business to break through one ceiling, just to hit another one in the near future. Alternatively, one may argue that positive experiences with carsharing will lead to further growth, and that critical mass will lead to step changes in the efficiency of carsharing efficiency, which could lead to a virtuous circle.

![European Trends](image)

*Figure 1- European trends in carsharing. Source: Shaheen and Cohen (2016)*
2.4. Business models in carsharing

The traditional business model is “round trip carsharing”, where vehicles must be returned to the place where they had been picked up. In this model, cars are usually reserved in advance (via smartphones or websites). The fleet is centrally owned (or leased) by a professional carsharing operating entity and dedicated parking spaces are allocated to the vehicles. If the dedicated parking spaces are on-street, permission from the street network manager is required, and obtaining this permission is of strategic importance for carsharing operators.

In “one-way carsharing” (or point-to-point carsharing), members are allowed to return a vehicle at another location than the pick-up point. A variant is “one-way free-floating,” where the vehicle can be returned anywhere within a geo-fenced area. Free-floating car sharing models are more flexible than traditional station-based carsharing. Moreover, they can be used to improve first- and last-mile connectivity of public transport modes. This is especially important if one wishes to promote carsharing as a complement to public transit, rather than as a competitor.

One-way carsharing has mainly grown since 2012, and has been enabled by a combination of technological factors (smartphone applications, keyless vehicle access, in-vehicle and mobile global positioning system (GPS) receivers) and progressive public policies that enable private firms to reserve on-street parking. Interestingly, several major car manufacturers (including Ford, Daimler and BMW) have entered this market segment, and are rapidly expanding their services.

Point-to-point carsharing however suffers from tidal flows which can lead to clustering of vehicles. Thus, one-way carsharing requires more non-revenue generating movements to re-position vehicles.

Figure 2- Roundtrip and one-way global fleets Source: Shaheen and Cohen (2016)
and users run the risk that a car will be unavailable for a return journey. Some carsharing systems therefore experiment with financial incentives (such as free rentals) to customers to re-position vehicles. Compared to roundtrip systems, this need to reposition the vehicles could also reduce the benefits in terms of reduced distance travelled and emissions.

A specific sub-segment within the carsharing market is personal vehicle sharing (PVS), which provides short-term access to privately-owned vehicles. In this case, the commercial service offered is the matching of demand and supply. An important barrier to the development of this market segment is that demand for this type of services tends to be higher than supply. The main motivation for those who are willing to rent out their vehicles is economic, as this allows to spread the high acquisition cost over a higher customer base. One may argue that PVS could support the growth of electric cars, whose acquisition cost is particularly high compared to its variable costs. However, especially in the upper segments of the market, owners are probably reluctant to rent out cars to strangers – and it is precisely in this market segment that the potential economic benefits of sharing are the highest.

One possible solution to the problem of trust in PVS is “fractional ownership”, where a company owns cars, which are then subleased by individuals, who take on a portion of the operating and maintenance expenses. This model targets more expensive car models, which most households would not be able to afford otherwise.

There is evidence (at least in the US) that carsharing companies tend to locate in areas with a high share of “typical” carsharing users (small households with few vehicles per household, but highly educated and with higher incomes). With the exception of firms operating in the P2P market, they also appear to concentrate on the downtown areas rather than the suburbs. All companies involved in carsharing operate mostly in large metropolitan areas (1 million inhabitants or more). It is not clear to what extent these observations are also valid for Europe.

2.5. Characteristics of the demand side

There is robust evidence that, compared to the general population, users of round-trip carsharing service are:

- Well-educated,
- Young adults, predominantly between ages 25 and 45,
- Living as single-person or childless-couple households,
- Living in middle or middle/upper income households,
- Living in carless or single-car households,
- Living in urban neighbourhoods,
- Relatively heavy users of non-car forms of urban transport (e.g. Public transport, walking and cycling).

The socio-economic profiles of the users of other types of carsharing appears to be broadly similar, but the evidence base is less reliable.
2.6. **The B2B market**

Next to the B2C market, a second market segment is business carsharing (or corporate carsharing). Since its start in the Netherlands in 1995, the market has grown worldwide, and there are indications that the B2B market segment is now the fastest growing.

For business, the main advantages of participating in B2B carsharing are broadly comparable to the advantages for private persons. Moreover, B2B carsharing allows companies to offer employees other mobility options for professional travel than their personal vehicle, which eliminates the need for complicated reimbursement and insurance arrangements. It also eliminated the perverse incentives linked to providing company cars, especially if personal use (on top of business use) is used as an employment benefit.

For the operators, a key advantage is that B2B carsharing smoothens the temporal profile of overall carsharing utilisation during periods when the demand for personal use of carsharing services is low. Fleet utilisation rates are thus higher if an operator offers both B2C and B2B services.

2.7. **Assessing the impacts**

The potential environmental advantages of carsharing operate through two channels (Firnkorn and Shaheen 2015). First, fewer cars have to be produced to satisfy the same overall demand for automobility. Second, with carsharing, people use cars more selectively because the marginal costs loom larger than when they own their car (and the fixed costs thus dominate the marginal costs).

Unfortunately, empirical studies on the net impacts of carsharing face numerous challenges. Indeed, as pointed out by Shaheen et al. (2015a), when assessing these impacts, it is necessary to know:

- How individuals travelled before and what behaviours they changed due to carsharing and
- How individuals would have travelled in the absence of carsharing.

In the short term, carsharing may induce new travel as zero-car households start to drive shared-cars. In the longer run, households may shed their private cars, which can lead to a decrease in car usage. However, the transition to a stable situation may take years (Firnkorn and Shaheen 2015).

Firnkorn and Shaheen (2015) argue that recognizing these issues could improve policy-decisions. It would for instance avoid the termination of carsharing-system, because of an early static impact-snapshot not reflecting the long-term sustainability-gains that a city would achieve by keeping the carsharing-system”. It would also avoid the use of the “before-and-after” evaluation-tradition used in the Western world in growth markets, “where a growing number of middle class households will either purchase a first private car or alternatively stay private-car-free and selectively use carsharing (where offered)”. Such a “before-and-after” evaluation-tradition could only find a VKT-increase through carsharing-systems, whilst a hypothetical impact study would find the opposite result.

Another key methodological issue is **self-selection bias**. Studies evaluating the impact of carsharing are plagued by this type of bias, because the adoption of carsharing is likely coupled with
neighbourhood characteristics (such as good access to public transport and living in dense urban areas), which may themselves reflect a deliberate decision to avoid a car-dependent lifestyle. Thus, the people who chose to use carsharing services may have value systems that differ from those of the “average” citizens, and the behavioural changes observed amongst early adopters may therefore not be representative for what is achievable at societal level.

Grischkat et al. (2014) have argued that it is therefore necessary to segment the population into groups sharing similar attitudes and preferences. This could provide valuable information about “which segments are receptive of which services and how the services should be promoted in order to attract the respective user groups”. Moreover, they point out that “segmentations that include attitudes provide better starting-points for interventions to reduce car use”.

In their discussion of a recent survey they had undertaken, Grischkat et al. (2014) have concluded that “some services, such as car-sharing, seem to have a much lower potential in the general population than is estimated in some scenario studies.” Their study also provides support for the hypothesis that “information and communication strategies for behavioural change can be addressed more effectively on the basis of psychological variables than on that of spatial or sociodemographic characteristics”. For instance, campaigns emphasizing the negative attributes of private cars may well be counterproductive when addressed to people who value the car for symbolic-emotional reasons. Other groups, however, may well respond to information concerning the environmental and safety implications of their mobility choices.

The most robust evidence can be found with respect to the effect of roundtrip carsharing. Several studies find that members of roundtrip carsharing organisations shed one or more personal cars (estimates range from 25% to 30%) or postpone the purchase of a personal car (estimates range from 25 to 66%).

Moreover, joining a roundtrip carsharing organisation is followed by reductions in Vehicle Miles Travelled (VMT) – depending on the study, estimate range from 27 to 80 %. Although carsharing leads to an increase in driving by some (e.g. people who otherwise would not own a car), this is more than compensated by a decrease in driving by others (e.g. those who otherwise would be car owners).

Roundtrip carsharing is also associated with an important increase in non-motorized modes and carpooling. The estimates of the impact on transit use are more mixed, and some studies even find decreases in the use of transit.

The details of the conclusions can also vary widely, depending on the region and time period under evaluation. In general, it is difficult to compare results because methodologies vary. Keeping in mind the methodological challenges discussed in the previous sections, reported figures need thus to be interpreted with care.

There are some indications that most of these results also hold when controlling for self-selection bias due to differences in observed characteristics of the respondents. However, we are not aware of any work correcting for selection bias due to unobservable variables such as the attitudes of the decision makers.

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The impacts of one-way systems have just recently begun to be studied, and reported results lack robustness. Some studies for instance find that users of carsharing systems who did not own a car before joining the scheme, walked less, cycled less and used less public transport after joining it. Other studies concluded that free-floating carsharing users are both more multimodal (use different forms of transport for different journeys) and intermodal (use multiple forms of transport to complete a single multi-stage journey) compared to non-car-sharers.

However, it may well be that it is the multimodal and intermodal preferences of these users that have brought them to join the carsharing schemes in the first place. Thus, due to endogeneity bias, the reported results may well overestimate the actual impacts of shared mobility.

It has been suggested that targeting services and their promotion to the group identified as “low-hanging fruits”, may induce significant multiplication effects on other person groups. Assessing the potential of such multiplication effects would require an explicit modelling of the impact of “social influences” on travel behaviour, as discussed in Section 5.4 of Deliverable no. 2.1. To the best of our knowledge, this has not been done yet.

Evidence on the effect of personal vehicle sharing is very limited and does not appear to be very robust.

2.8. Shared electric mobility (and other alternative fuels)

The use of electric or hybrid vehicles in carsharing schemes could have a multiplier effect in terms of these environmental benefits. Several operators already include a number of electric vehicles in their fleet.

With battery ranges varying between 100 and 200 km, electric cars are adequate for most carsharing trips (which tend to be short term and inner city). With carsharing, the high acquisition costs can be spread over the members of the carsharing operator. As the variable costs of electric cars then to be lower, they are more likely to be financially competitive with gasoline or diesel cars if they drive a lot annually, which is indeed the case in shared modes. Moreover, carsharing operators could gain additional income from the provision of Vehicle-to-Grid (V2G) services, which involves stabilising the electrical power grid by the storage, feeding and charging of electricity from electric vehicles – these services are especially valuable if power generation uses a high share of intermittent renewable resources.

The carsharing segment could also serve as an advertisement for electric vehicles, as customers gain experience with the technology and range anxiety decreases. Here as well, there is a need for further research on the actual “social learning” process to understand how such propagation could take place.
One of the challenges to overcome is that the need for a charging infrastructure partly offsets one of the big advantages of carsharing: the reduced need for parking. This may lead to some resistance from city authorities.

2.9. Organisational and institutional issues

Carsharing operators can develop partnerships to expand their earning model.

One possibility would be to get paid for acting as a “safety valve” when high traffic volumes can be anticipated (for instance, due to major events): in such cases, “the road network manager could simply block-book some or all of a carsharing system’s fleet, in effect paying the private sector operator to keep their vehicles parked during some period of time.” (Le Vine et al. 2014) A drawback of such a system is that it would reduce the reliability of carsharing from the users’ point of view.

Operators also set up partnerships with retailers. In one example reported by Le Vine et al. (2014), a discount card stored in the shared car can be used in designated shops. As shared cars are often used with “shopping” as trip purpose, such partnerships could well expand in the future.

Another example is a carsharing scheme that the Co-wheels Car Club has set up with the Cumbria County Council, The Lake District National Park Authority and Cumbria Tourism. The scheme offers two-person electric vehicles, Renault Twizys. These vehicles are agile, compact and light weight, and offer tourists to visit the Lake District, supposedly with a minimal impact on the local environment.

From a policy perspective, an interesting and subtle advantage of time-based pricing models of carsharing is that they are actually a form of congestion pricing, as users who drive during the peak hours (and thus experience longer travel times due to congestion) will have to pay more. Thus, a wider use of carsharing would in effect “privatise” time- and place-differentiated road pricing, which (despite some successful implementations) remains politically unpalatable.

On the other hand, carsharing often requires active support measures from public authorities (such as making parking space available in the case of “one way” systems). Compared to the support that is required for public transit or for the construction of new infrastructure, this type of measures can easily be reversed if necessary, or if evidence shows that the schemes do not lead to the desired outcomes.

Governments could also promote the modes that “complement” car sharing, for instance through investments in pedestrian and bicycling infrastructure. Similar considerations apply to the need to integrate carsharing with other shared-use mobility modes and with transit – we shall come back to this issue in our discussion of Mobility as a Service.

National governments could also provide support by giving their staff access to carsharing, by sponsoring demonstration projects and providing policy guidance.
3. Scooter sharing

Shaheen et al. (2015a) refer to the existence of several scooter sharing systems in Europe and two in the United States, all of which offer one-way and roundtrip short-term scooter sharing, including insurance and helmets. Some also offer electric motorcycle sharing and Scoot Quads (two-seater “Twizy” vehicles from Renault, branded as Nissan in the United States).
4. Bicycle sharing

Shaheen et al. (2015) define bikesharing as systems which “allow users to access bicycles on an as-needed basis from a network of stations, which are typically concentrated in urban areas. Bikesharing stations are usually unattended and accessible at all hours, granting an on-demand mobility option. In these systems, the operators are typically responsible for bicycle maintenance, storage, and parking costs.”

The first documented “bikeshare” system was launched in Amsterdam in 1964. In the absence of any payment or security function, the system was vulnerable to theft and vandalism, and was quickly abandoned. The second generation of bikesharing system was initiated in Copenhagen in 1995 and used a coin deposit system. This system remained vulnerable to theft. The third generation of bikesharing system used dedicated docking stations, automated credit card payment and other technologies to track the bicycles. These systems did get off the ground. So-called fourth generation systems include dockless systems\(^1\), easier installation, innovative systems for bicycle redistribution, GPS tracking, touchscreen kiosks, electric bikes and transit smartcard integration.

According to Fishman (2016), the current global bikeshare fleet is estimated at 946,000 bicycles, of which 750,500 are in China. According to Marsden et al. (2015), as of 2014, there were 414 bikeshare programs in Europe, compared to 50 in North America. Although the growth of bikesharing has been impressive, even the largest schemes (such as the Velib’ scheme in Paris) attract at the most 5% of the population of the city.

Most existing schemes are not financially self-supporting. Some are operated in the framework of a public-private partnerships (for instance, with an advertising company), while other require some support from non-profit organisations, public transport operators or local governments.

Convenience has been reported as the major perceived benefit of bikesharing from a users’ perspective. Proximity between work and the closest docking station has been identified as the second strongest motivator, but having a docking station close to home is also important. Finally, financial savings are also a motivating factor, especially for low income members.

Surveys of users of bikesharing schemes generally reveal that their profiles are very similar to those of carsharing members. Moreover, self-selection bias may play a role in bikesharing as well, and it is very uncertain whether the motivation of existing users are good indicators of future growth potential. Most members of bikesharing schemes also turn out to be infrequent users. This indicates that most members do not use shared bikes as primary or even secondary transport mode, but at the most as an occasional complement.

\(^1\) In such systems, “the entry and checkout function is packed into a small computer terminal on board each bike, rather than at fixed system-branded racks (i.e., docks).” For an example, see http://urbanland.uli.org/economy-markets-trends/bike-sharing-pedals-toward-fourth-global-generation/
Very little data are available on the profiles of those who do not use bikesharing, and therefore, there is also a paucity of evidence regarding to the barriers to using bikeshare systems. For instance, a low level of bikesharing in a given area may reflect that (a) existing levels of bicycle ownership are already high (b) for most destinations, a unimodal trip with one’s own bicycle may be more convenient than a multimodal trip with public transport and shared bicycles (for the first and/or last mile). Moreover, non-users often find driving too convenient. The absence of docking stations close to the respondents’ homes can also act as an important barrier.

Although bikeshare does indeed appear to reduce car and taxi use, most of the modal shift appears to be away from trips made by public transport and walking, although there are also examples of increases in the use of public transit. The causal links that are at play are similar to those of carsharing. On the one hand, bikesharing can be used to solve the first/last mile problem in public transport – this is most likely to be interesting in low density areas surrounding the city centres. On the other hand, bikesharing can also be used to completely replace the public transport trip, especially in dense downtowns areas.

Whether the shift away from public transport is a good or a bad thing from a policy perspective is highly situation specific. For instance, if public transport is overcrowded during peak hours, this shift may improve the travel comfort for other passengers. However, if the move is away from services that are marginally financially viable, then this move could lead to the shutdown of services, and a shift from the remaining passengers to private cars (or to the disappearance of the only mobility option that was available to low income passengers).

Bikesharing has also been reported to bring health benefits to the users. There is also some evidence that bikesharing is associated with higher safety than using private bikes, but the underlying reason for this result is not completely clear. To the best of our knowledge, there are no quantitative assessments of avoided emissions following the introduction of bikesharing system.

One of the challenges facing bikeshare systems is that, over the day, the distribution of bicycles over docking stations may become unbalanced. Station activity can be affected by factors such as the weather, the presence of restaurants and the topography of the city. The need to rebalance docking stations by dedicated trucks or vans can reduce the environmental and congestion benefits of the system (although we are not aware of studies quantifying these effects). During weekdays, users are bound to their work schedules and the potential for price incentives to users to redistribute bikes remains limited.

Installing GPS on shared bicycles may reduce the need for physical docking stations, and may help operators in the relocation of the bicycles. The data provided by the GPS may also be useful for general transport planning purposes.

Sharing electric bikes could expand the market to new segments of the population, and reduce the barriers linked to trip length and excessive heat. Because they reduce the difficulties caused by a city’s topography; e-bikes can also reduce the problems related to re-balancing in hilly cities.
Taking into account its low price (when compared to ownership), bike sharing could also help in the fight against “mobility poverty”. However, the requirement to pay with credit card could be a major impediment for the population segments that suffer most from “mobility poverty”. Moving back to cash payments could lower the barriers for those social groups.
5. On-demand ride services

On-demand ride services\(^2\) are the quintessential example of transport services that would probably never have existed without mobile apps. Arguably, this type of services was initiated by Uber in 2009, and it has been in the spotlight ever since, not just because of innovative nature of the services offered, but also because of the controversies that some of the new business practices have stirred. It is therefore important to understand the distinctive features of these services.

Before discussing these on-demand ride services in detail, we will first sketch the main characteristics of the traditional taxi markets, to which they are the closest competitors.

5.1 The traditional taxi market

The taxi market is very heterogeneous, and, depending on the country or even the city, the market segment that is being referred to as the “taxi” market can actually have quite different meanings.

The following market definition corresponds to the way the services are offered (see for instance Aquilina (2011); Salanova et al. (2011); Rayle et al. (2016)):

- **Street and rank hiring.** This refers to taxi services provided through random picking for hire on the streets (‘hailing’) or through a ‘first in, first out’ allocation system at taxi ranks. Consumers are usually not in a position to compare different possible offers before choosing a taxi. Therefore, they have no bargaining power as regards the price, and taxi drivers face no incentives to improve the quality of their services. In the sub segment of the ‘hail’ market, an additional problem is that a lot of empty taxis cruise the streets looking for passengers, adding to congestion and air pollution. Moreover, in the absence of regulation, the barriers to entry in the market are low. There is a risk that drivers will try to maintain profits through unsafe driving behaviour and the neglect of maintenance.

- **Pre-booking segment.** In this segment, consumers can shop around by phone or on the Internet before booking, which increases not only competition on price, but also provides incentives for investing in brand reputation.

This classification does not apply to all local situations. For instance, in some cities, large companies operate in both market segments, and taxis cruising on the streets can be directed to patrons through the central booking system.

In cities where the two markets are clearly delimitated, the first market segment is often subject to some type of regulation (maximum prices, limited entry) to compensate for the lack of effective competition and the externalities caused by the search for clients. However, the pre-booking segment usually is not regulated beyond standard safety requirements. The regulation of taxi markets is the subject of a vast literature. Several authors have argued that restricting access to the market (for instance, through a ‘medallion’ system) only further reduces competition, and creates monopoly rents for the medallion owners.

\(^2\) While some media use the term “carsharing” to describe this type of service, we will maintain the convention in the scientific literature to use “carsharing” in its more restrictive meaning.
On the positive side, taxis offer some advantages compared to mass transit, especially in terms of door-to-door attribute speed, privacy, and comfort.

The taxi market is often a “gap filling” mode, which provides transportation when neither private cars nor public transit are realistic or attractive options (for instance, for older citizens or lower-income groups who do not own a car). Therefore, taxis can be both substitutes and complements to collective travel modes (for instance, to fill the first and/or the last mile).

5.2 Ridesourcing / Transportation Network Company (TNC) Services

These services are variously referred to as ridesourcing, TNCs, ride-hailing, and ride-booking, with companies such as Lyft and UberX as most renowned examples. Their defining features can be described as follows (Rayle et al. 2016):

“Ridesourcing allows travellers to request a ride in real-time through a smartphone application, which communicates the passenger's location to nearby drivers. After a driver accepts a ride request, the passenger can view the vehicle's real-time location and estimated arrival time. The app provides GPS-enabled navigation, which helps non-professional drivers find destinations and reduces the chances of them taking a circuitous route. The payment—and sometimes tips—are automatically charged to the passenger's credit card. The driver keeps a portion of the fare, with the balance going to the ridesourcing company. (...) Drivers and passengers rate each other at the ride's completion, creating an incentive system that rewards polite behavior. Unlike taxis, ridesourcing services like UberX, Lyft and Sidecar typically use drivers who lack a commercial vehicle license, drive their personal vehicle, and work part-time.”

TNCs have experienced a spectacular growth over the last few years. For instance, in April 2015, Uber operated in 301 cities in 57 countries (ITS America 2015). Their success is attributed to a large extent to the “efficiency and reliability of the matching platform and pricing mechanisms, along with the accountability of the rating system” (Rayle et al. 2016).

Another characteristic of these services, which differentiates them from the traditional taxicab market, is the use of dynamic pricing or “surge pricing”: during periods of peak demand, prices increase to balance supply and demand. In concrete terms, the purpose of “surge pricing” is to provide incentives to drivers to accept drive requests when demand increases, for instance due to poor weather or to the beginning or end of mass events. Whilst “surge pricing” is, strictly speaking, a simple move from “rationing through queuing” to “rationing through prices”, it has turned out to be one of the more controversial aspect of the TNCs’ business models.

The financial consequences of the competition from TNCs for taxi drivers can be dramatic if the taxi drivers are independent contractors who pay fixed fees to rent the vehicles from the companies owning the taxis. However, several key features of the TNCs business model, including the matching app, can be replicated by competitors, and this is exactly what is currently happening. For instance, several major car manufacturers are now also entering this market. Moreover, the ‘traditional’
The taxicab market is also increasingly using mobile apps. As a result, waiting times for taxis have been brought in line with those of ridesourcing/TNCs.

A variant on the basic business model is so-called “ridesplitting”. In this system, the client of the TNC splits a ride with other clients who have requested a similar route, and accepts that the route may be changed in real time to meet new requests. In such cases, users are often provided with monetary incentives to congregate at designated intersections or major arterial streets.

5.3 Impacts

The controversies raised by on-demand ride services have been widely publicized in the popular and professional media.

On the one hand, some claim that on-demand ride services have improved the overall efficiency of the transport system.

On the other hand, it has been claimed that TNCs compete almost directly with traditional taxi services, but without being subject to the same regulatory framework (for instance, regarding safety, screening of the drivers, vehicle maintenance, etc.). Other points of criticism include the opacity of the pricing practices, the focus on young and affluent market segments, and negative impacts on safety. Moreover, in cities where TNCs have important market shares, congestion supposedly has worsened, partly due to induced traffic, but also due to practices such as double parking in bike lanes and bus stops when passengers are taken on board or dropped off.

However, due the novelty of these services, independent scientific assessments of their impacts remain rare.

Anyway, most of the problems associated with TNCs can be dealt with through dedicated regulation which does not touch on the fundamental innovative aspects of the business model.

For instance, the Municipal Government of Sao Paulo has recently proposed a decree that could mitigate the negative congestion impacts of TNCs with market based instruments. Indeed, TNCs would be required to make an estimate of the vehicle-kilometres driven by their fleet in the two coming months, and would have to pay a fee to obtain periodic credits. These credits could then be traded; TNCs who exceed their credits would have to pay a surcharge. This system is equivalent to a system of distance based road charging. It would thus allow the city to capture the rents that TNCs gain from using public roads. Note that this system is far from perfect. There is for instance no specific reason (except political feasibility) why other road users should not be subject to the same scheme, as they also benefit from their use of publicly funded infrastructure.
5.3.1. Relevant market segment

From a policy point of view, it is important to understand which are the modes TNCs are actually competing with.

The limited independent evidence to date indicates that the respondents tend to be younger and better educated than the general population, and are younger and more urban than frequent taxi users. Important reported user benefits from ride sourcing include shorter and more consistent waiting times. This appears to be especially true in outer parts of the city, which suggests that, in these areas, ride sourcing is filling a supply gap in these neighbourhoods. Note that, wherever ridesourcing is filling gaps, it may lead to induced travel.

Ridesourcing does not appear to have an important effect on car ownership to date, but it does substitute for private car use in specific situations (for instance, to avoid drinking and driving). The existing evidence suggests that ridesharing mainly acts as a substitute for traditional taxi services rather than for private car ownership, but this may mainly be due to the novelty of the services.

TNCs act both as complement and substitutes to public transit, for exactly the same reasons as traditional taxicabs. A lot depends on how public transit companies and transport authorities deal with them. It is possible for these companies and agencies to set up cooperation forms with TNCs that take advantage of the strong points of TNCs (such as the high door-to-flexibility) to complement their own strong points (such as their capacity to move large quantities of people). This is actually happening. For instance, the Pinellas Suncoast Transit Authority in Florida has started a six month pilot subsidizing half an Uber ride to or from a transit station. In order not to exclude riders without smartphones or credit cards, the agency also works with a taxi company, up to $3. The six-month pilot, which started in February 2016, also works with United Taxi, so riders who don’t have a smartphone or credit card can access the discount as well.

5.3.2. Efficiency

Anderson (2014) argued that the overall (ecological) efficiency of ridesourcing would depend on the net effect of two opposing forces:

- On the one hand, the supply of drivers is more flexible than in the traditional taxi market and “flexible drivers can simply go offline when business is slow” (instead of cruising the streets), which should lead to a higher efficiency. Drivers can also use multiple ridesourcing apps to increase their potential market, or work as delivery drivers.
- On the other hand, riders who come from outside the city border may “remain in their cars, in the city, waiting for the next period of demand”. Moreover, it is possible that “drivers use the ridesharing income to support their own use of a private vehicle—or even to purchase a vehicle, as some do”. In this case, ridesourcing induces new private automobility.

A first attempt to compare the efficiency of ridesourcing versus traditional taxi markets has been undertaken by Cramer and Krueger (2016), who conclude that “the capacity utilization rate is 30 percent higher for UberX drivers than taxi drivers when measured by time, and 50 percent higher
when measured by miles, although taxi data are not available to calculate both measures for the same set of cities.”

They argue that four factors “likely contribute to the higher capacity utilization rate of UberX drivers”:

- Uber’s more efficient driver-passenger matching technology (mobile internet technology and smartphones compared to a radio dispatch system or sight-based street hailing);
- the larger scale of Uber than taxi companies in the cities that were surveyed; as a result “pure chance would likely result in an Uber driver being closer to a potential customer than a taxi driver from any particular company given the larger scale of Uber” (in other words, there are “network efficiencies from scale”)
- inefficient taxi regulations which “prevent taxi drivers who drop off a customer in a jurisdiction outside of the one that granted their license from picking up another customer in that location”
- Uber’s flexible labour supply model and surge pricing which closely matches supply with demand throughout the day.

However, as already discussed above, traditional taxi services are increasingly adopting the web based matching of TNCs. Moreover, they could just as well improve their efficiency through the offer of shared rides (“taxi sharing”). Thus, business innovation in the taxi market could close some of the measured differences in efficiency.

5.3.3. Data sharing

The platforms that “match” services and clients have huge amounts of data available, for instance on the following topics: accidents, driving patterns, real-time trip data, driver availability... If these data would be shared with city authorities, they could lead to improvements in the transportation network, to the development of apps showing all available transportation options, and the identification of areas that are poorly served by transport services.

Some claim that, if TNCs can freely use the road infrastructure constructed and maintained with public money, it is only fair to request that the TNCs make their data publicly available as a form of counter service. For instance, Sao Paulo has proposed a municipal decree which would require TNCs to provide the city authorities with data that could be used by the municipality to optimize the management of the road network and to vary the fees for TNCs.

It is also possible to conceive of partnerships between cities and TNCs that would share their data. For instance, in exchange for anonymized TNC data, the transport authority could include the TNC in its official route planning apps.

5.3.4. Synergies with electric mobility

We have already referred before to the possible complementarities between electric mobility and carsharing systems. If rides with on-demand ride services mainly consist in trips over relatively short distances, then this complementarity may also exist in this market segment.
5.3.5. People with physical disabilities

The mobility of people who are physically impaired, due to age or to other reasons is a policy issue that is likely to grow in importance. Traditional policy responses include (a) making public transport infrastructure more accessible (b) the provision of Demand Responsive Transport (DRT).

As DRT services are often provided by taxis, this raises naturally the question whether TNCs could also be involved in this market segment. In the United States, for instance, some cities are working on regulations that would ensure that TNCs also provide services to people with physical impairments. While some cities have considered mandating a minimum percentage of wheelchair accessible vehicles in the fleet of each TNC, this has not yet been implemented in practice, mainly due to the practical difficulties. An alternative approach, which has been chosen by Dallas, is to “include a general clause in the transportation ordinance that explicitly stated TNCs could not deny service to those requiring special assistance. If a particular TNC does not have wheelchair accessible vehicles readily available, they have the option to refer passengers to another company that can provide wheelchair accessible cars” (Rainwater et al. 2015). Another approach has been chosen by Washington DC, which requires TNCs to pay into an accessibility fund which pays for wheelchair accessible for-hire vehicles (Rainwater et al. 2015).

At the other end of the spectrum, some have suggested that public transport companies should outsource all DRT activities to TNCs, because TNCs would be better equipped to use the latest technologies than PT operators. However, this idea is controversial. For instance, it can be doubted that the typical clients of DRTs (elderly and disabled people) would be willing to adopt the smartphone-centred approach of the TNCs.
6. Ridesharing

Shaheen et al. (2015a) define this type of services as the facilitation of “shared rides between drivers and passengers with similar origin-destination pairings.” An essential element in ridesharing is its non-profit nature. As carpools are difficult to record and count, there are few quantitative data available on this transport mode, which is sometimes referred to as the “invisible mode” (Chan and Shaheen 2013).

For the participants, the financial benefits can be substantial – up to two-thirds compared to the cost of commuting alone. Other important user advantages of ridesharing include: travel-time savings from high occupancy vehicle lanes (where applicable), and reduced commute stress.

Until recently, the coordination of ridesharing was mostly informal and disorganized. The coordination of itineraries and schedules was a major inhibiting factor, especially because schedules may change at short notice. At the end of the 1990s, private Internet based matching agencies emerged. Since 2004, technology has enabled these matching agencies to build partnerships with public agencies and large employers-and to offer incentives to try carpooling. Specialised internet services now also connect potential car poolers directly (“peer-to-peer ridesharing”). As there is a clear similarity between the matching process in the case of on-demand ride services and in the case of web-based carpool systems, it is not surprising that TNCs are also entering this market.

The combination of mobile applications and GPS also enables the implementation of dynamic ridesharing, which can still serve the needs of participants if their travel needs change. Thanks to these technologies, someone can submit a ride request that can be matched with a driver who is close to the requested pickup point, and who follows a similar itinerary. One potentially important barrier to dynamic ridesharing is the absence of guarantee of finding a drive back from certain destinations.

The further development of ridesharing faces a number of behavioural barriers, the most important of which are (Chan and Shaheen (2013); ITS America 2015):

- The flexibility and convenience of the private automobile;
- The desire for personal space and time and an aversion to social situations
- The reluctance to share rides with strangers or use one’s own vehicle to pick up more than one stranger

Chan and Shaheen (2013) identify three areas that will affect influence future developments of ridesharing:

- Technological developments such as improved interoperability among ridesharing databases and standards for sharing open source data among ridematching companies will help to overcome the critical mass barrier. Other innovations include: “ridematch aggregators” (websites or other interfaces that search all ridesharing databases) and multimodal integration (the seamless connection of ridesharing with other transportation modes, such as public transit and car-sharing).
“Meeting places”, such as casual carpooling sites could also lead to a higher modal share of ridesharing because they do not require prearrangements.

Supportive policies could promote ridesharing. Chan and Shaheen give the following examples (but without discussing their cost-effectiveness): free or reduced-price access to high-occupancy toll lanes, parking cash-out (employees can opt out of a parking space and receive compensation from their employer who leases/owns the space), and pretax commuter incentives (commuter is not taxed on ridesharing expenses).

Digital recordkeeping, links with on-line social networks and rating systems could address some security and liability concerns.

From a policy point of view, the main benefits would appear to be mitigation of traffic congestion and reduced air pollution. However, in a discussion focusing on the situation in Europe, Marsden et al. (2015) conclude:

“This is such a new area that peer reviewed data on impacts is not robust. There are aspects of ride sharing which will act to reduce demand (through wasted single occupancy trips) but also aspects that will increase demand (through cheaper journeys) and make shared cars more cost efficient than public transport. (…). This may be of particular relevance to those of the EU-13 Member States where current car ownership levels, although growing, are still lower, and where there is a range of ride-share services advertised”

Again, we have to conclude that the net impacts on the transport system are ambiguous, and are highly situation specific. This suggests that, in the end, it is public policy that will determine whether the technological developments of the last decade will result in an improvement or in a further deterioration of the transport system.
7. Alternative transit services

In many jurisdictions, there exist “semi-collective” transport services in parallel with “official” public transport, such as Demand Responsive Transit (or paratransit), jitneys (or dollar vans), and shuttles.

We will focus here on Demand Responsive Transit (DRT) – note that in the US, the term paratransit is used to design these services. DRT corresponds to transport services that, contrary to regular public transport services, can be flexible in terms of timing and/or route choices. The origins of DRT lie in the provision of transport services to mobility impaired people, but the services offered by DRT have significantly expanded in the last decade or two.

“Jitney” services refer to broadly similar services, but which are usually associated with commercial operators who have filled niches in commuting transport in poor communities with low auto-ownership rates but that are also ignored by public transport. Shuttles focus specifically on transport to transport hubs or employment centres.

Although all these services are broadly similar, Shaheen uses the term ‘micro-transit’ to refer specifically to services that use innovative ICT technologies3 to “incorporate flexible routing, flexible scheduling, or both.” An example of such a service is “Bridj, a mobile application that enables customers to request a ride in select neighbourhoods (...). After the Bridj system receives pickup requests, its algorithm sets a central passenger meeting spot (...). Customers then walk to the meeting spot and share a ride with other passengers that have a similar route or destination as defined by the algorithm.”

7.1 Demand Responsive Transit (DRT)

Although there does not appear to exist a generally accepted definition within the literature, some common elements are (Davison et al. 2012):

- DRT can be situated between regular public transport services (which are usually served by buses) and completely personalised services provided by taxis.
- DRT services can be flexible on any of the following features (or combination of these features): route, origin–destination pattern and timetable. When routes are fixed, they fall in the category of jitneys. When times are fixed but routes are variable, they fall under the denominator of vanpools.

There are also ‘hybrid’ forms of DRT, combining a fixed route core allowing pre-booked deviations (up to a predefined maximum distance) and hail and ride on the fixed route section (Mulley et al. 2012).

Potential target markets for DRT services are:

- Market segments where demand is too low for conventional buses (e.g. rural areas, night and weekends) or where greater flexibility is needed than what can be provided by conventional buses. In these cases, DRT targets the general public, with schoolchildren as important subsegment. In rural areas; DRT can also serve provide feeder services to conventional public transport.

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3 Personal e-mail correspondence between Shaheen and the author.
The elderly and mobility impaired (including non-emergency patient transport services), and, more in general, those who can afford neither private cars nor taxis. In Europe, this would be the typical clientele of DRT in an urban context.

DRT, especially when uniquely focusing on mobility-impaired people, is costly, and often requires public financial support. Another approach to ensure financial viability is to rely on volunteers to drive the vehicles. A case study in The Netherlands has revealed that those volunteers are often retired themselves. Performing these services gives them a purpose and also helps them maintain social contacts. Thus, volunteer-based systems are not just a way to save money, they can also improve social cohesion in rural communities (Schotman and Ludden 2014).

Examples of European practices in the field of DRT are given by the INTERREG project FLIPPER\(^4\).

"Mainland European schemes typically benefit from a commitment to funding at a national level and a robust planning framework at a regional or sub-regional level (e.g. by a small number of call centres that take bookings from passengers anywhere in the country); and have been implemented within the context of an integrated network of PT. (...) In the UK, the licensing of taxi operators is locally regulated and operated. DRT services in the UK tend to be small-scale, door-to-door, and only for a defined region or specific community of people. (...) In recent years, since the deregulation of public transport services, a greater range of local stakeholders appeared to be involved in planning DRT services, and the focus has shifted more towards rural locations in order to fill the gap caused by the withdrawal of conventional bus services (Davison et al., 2014), whilst the voluntary sector continued to address the need for more specialized travel (Brake and Nelson, 2007)."

Strict eligibility restrictions for DRT targeting audiences such as the mobility impaired can lead to higher costs of provision. In some European countries, specialised flexible service have broadened the eligibility restrictions in order to reduce the unit costs of provision.

Depending on the market served, DRT services are provided by minibuses or mid-size vehicles (22 to 30 seats) but also by taxi operators. In regions with high seasonal variability (such as touristic areas), taxis can replace buses during the low demand season.

Although people over 65 years have become more active and mobile, increased life expectations have also resulted in an increasing number of people over 85 years. As important reductions in mobility are observed when people reach the age of 80, the general expectation is that the demands for DRT will continue to grow. For elderly people, barriers to the use of public transport also include the stress of getting to the bus stop, of using new technologies, and the fear of physical harm (either as a results of accidents or violence).

In practice, DRT still confronts a range of challenges, the most important of which are:

- When they are overly flexible in terms of schedule and/or route (and their travel times thus become too variable), they can become unsuitable to serve as feeder service to public transport hubs in urban areas.
- The routing decisions for DRT are very complex to model and optimize. Some of these complexities arise from the difficulty to predict behavioural responses to late-running services or no-shows by the clients.
- Despite the gradual extension of the scope of the services, there is a strong perception in some countries that DRT is only for mobility impaired people. This hampers the inclusion of DRT in the standard public transport offer or in transport planning apps.

\(^4\) http://www.interreg4cflipper.eu/
• When DRT is provided by public transport companies who are used to serve captive markets only, there is insufficient experience with marketing to attract new clients.

On the other hand, there are also some trends that increase the potential for DRT:

• With increasing sprawl, conventional public transport can become unviable.
• Public authorities show an increasing interest in DRT as a means to address inclusion of some specific targets groups, but also to achieve modal shift.
• In Europe, there is potential to use DRT in orbital journeys in suburban and peri-urban areas while ‘traditional’ PT is used for radial routes.
• DRT could expand into goods delivery (e.g. of library books, prescriptions and post/parcels) as an additional source of income. There may also be untapped potential for transport in the “night time economy”.
• Although DRT is more expensive than public transport along the main transport axes, it is cheaper than low volumes fixed route public transport.
• The most important component of variable costs are the wage costs of the drivers (at least, in the schemes that are not volunteer-based). With automated mobility, this issue will disappear, and this will increase the potential of DRT as a feeder mode for high capacity public transport.

7.2 Impacts

Studies of alternative transit services show that the same key questions (“are they a complement or a substitute for public transit”, “what is the impact of shared mobility on urban sprawl”) re-emerge, and, once again, we have to conclude that the answer to these questions is context-specific. It certainly depends on the policy context, and more specifically, the pricing of transport.

One interesting experiment is currently ongoing in Kansas City in the US. In February 2016, a one-year pilot project was announced as a partnership between the Kansas City Area Transit Authority (KCATA), Bridj, and Ford. In this pilot, Kansas City residents will be able to reserve seats on Bridj vehicles (Ford vans), using the Bridj app, but driven by employees of the KCATA. One noteworthy point about this pilot is that the public agency appears to be completely open minded about how the outcome will fit in its own offer. In other words, there is no prior expectation that the service will focus on the “last mile”. It is also interesting that the project has given thought to the issue of the accessibility of the system for people without smartphones or credit cards. One option that has been considered is to distribute phones with limited capability beyond the reservation of a van’s service.

Another possibility is for public transport authorities to organise their own shuttle services, as is currently the case with the Santa Clara Valley Transportation Authority (VTA) in Silicon Valley. In January 2016, the VTA has launched the VTA FLEX pilot. It combines features associated with microtransit: 26-seat shuttle busses, summoning and paying by smartphone, dynamic routing, combination of rides in real time and optimization of pick-ups and drop-offs. New itineraries are generated each day according to changes in origin-destination pairs. Compared to “commercial” microtransit system, however, there is a “public service” component: the vehicles are wheelchair accessible and have bike racks, users can also use computers or “traditional” phones for hailing the service and prices are lower than what would be the case for commercial services.
Building further on a study of shared *automated* mobility (see further), the ITF (2016) has developed alternative scenarios of shared mobility where two types of shared vehicles operate together with "high capacity" transit (rail and subway services):

- Six-seat vehicles ("Shared Taxis") that offer on-demand, door-to-door shared rides
- Eight-person and 16-person mini-buses ("Taxi-Buses") that serve pop-up stops on demand and provide transfer-free rides; clients would have to walk at the most 300 meters to the stop

Both concepts can be considered as forms of micro-transit.

They key findings of the study are: the disappearance of congestion, a reduction of traffic emissions by one third, and 95% decrease in the need for public parking. The car fleet would be reduced by 97%. The vast majority of trips would require no transfers, and the cost of city trips could decrease by 50% compared to current prices.

The study has also explicitly looked into the issue of social inclusion, from three perspectives: the number of jobs in the city that can be reached within 30 minutes starting from each grid cell\(^5\), the number of healthcare facilities and the number of schools. For all three metrics, the simulated system performed much better than the existing system. The authors attribute this to the efficient centralised dispatching system, which enables targeted services.

\(^5\) *In the model, the city is divided in a homogeneous grid of 200m x 200m cells which are linked to the transport network.*
8. Courier network services

Shaheen et al. (2015a) define Courier Network Services (CNS) (or “flexible goods delivery”) as “for-hire delivery services for monetary compensation using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with freight”.

As we have already discussed, using DRT for parcel delivery is one of the strategies that is used to improve their financial sustainability. The emergence of CNS is another example that the boundaries between freight and passenger transport are becoming increasingly blurred. Creating synergies between private passenger transport and delivery of small loads is clearly a promising approach to improve load factors without increasing vehicle routes and travel times of freight delivery vehicles.
9. Trip planning apps

9.1 Definitions

Shared mobility expands the choice set for travellers, but also leads to an increasing number of variables to reckon with, and to even more potential decisions. We have already discussed in MIND SETS Deliverable 2.1C that one of the reasons why people make less than fully rational decisions, is precisely because it is cognitively impossible to perfectly and immediately process all the information that is relevant in decision making.

As a result, the potential benefits of shared mobility can only be realized if progress is made in making real-time information available to the user. Mobile trip planning apps play a key role in the provision of this information.

Shaheen et al. (2015a) distinguish two broad categories of planning apps:

- **Single-Mode Trip Planning.** These are designed for a particular mode, and include public transit and driving route-assistance apps. As busses and trams are increasingly connected to the network, an increasing number of such apps provide real time information on delays in transit systems, congestion on the road network and incident data. This creates the opportunity to provide turn-by-turn assistance.

- **Multi-modal trip aggregators.** These offer a single platform for planning trips involving different modes. The range of modes included varies from app to app. The information provided to the travellers includes time and cost, but in some cases also fuel consumption and calories burned. Other features that are included in some apps include the possibility to book and pay directly for third-party services.

9.2 Advantages

Tracking the position of vehicles by GPS has enabled the development of an increasing number of apps providing information in real time, rather than static timetables. Providing riders with real time information on public transport leads to reductions in the perceived waiting time, but also reduces the actual waiting time as riders can better schedule their trips. Mobile apps can thus improve the general experience of using public transport.

The development of travel apps using real-time location based data and anticipation of travel patterns based on historic data feeds has largely been the result of top-down initiatives taken by industry. More recently, “collaborative travel apps” use crowdsourced information to quickly integrate information on unexpected obstacles or other sources of delays. Some apps provide incentives to the users for providing such information (“gamification”), such as online music and gift cards.
The integration of historic personal data with real-time crowdsourced data can be used to warn travellers in advance that there are interruptions or delays on the routes they take usually, and to provide them with suggestions for alternative routes. Such apps could also provide the travellers with financial incentives to take alternative modes or routes than their usual ones if these are overcrowded.

Transit operators also increasingly allow electronic ticketing, reducing waiting times and lowering the overhead costs of ticketing machines.

### 9.3 Challenges and emerging services

An important risk with travel apps is the general lack of integration between the providers of transportation services. Especially in situations where operators compete for the same customers; it can be difficult to integrate systems without the intermediation of a neutral third party (which could be the organising authority).

Another issue has already been anticipated in MIND SETS Deliverable 2.1C: if people are less than perfectly rational, it is not just the information provided by the app that affects their actual behaviour; but also its design. Convenience is a key factor in the eventual outcomes. Until now, little is known on how app design could affect mobility choices in practice.

### 9.4 Mobility as a Service

The development of apps that offer an increasingly wide range of mobility services can eventually result in a move to Mobility as a Service (MaaS). Kamargianni et al. (2015) propose the following definition:

> The term “Mobility as a Service” stands for buying mobility services based on consumers’ needs instead of buying the means of transport. Via “Mobility as a Service” systems consumers can buy mobility services that are provided by the same or different operators by using just one platform and a single payment. The platform provides an intermodal journey planner (...), a booking system, a single payment method (single payment for all transport modes), and real time information. MaaS users can use the Service either as Pay-As-You-Go or they can purchase mobility packages based on their or their family’s needs.

The actual level of cooperation within a MaaS system can range from the simple provision of discounts for combined subscriptions to full integration with mobility packages where customers can pre-pay for specific amounts of each service tailored towards their needs (Kamargianni et al. 2015). Some services only provide integrated planning, while others can also be used for paying purposes.

Several MaaS projects are currently running in Europe, ranging from local initiatives to country-wide systems. Several providers of MaaS services have concrete expansion plans, and cities such as Helsinki have already announced the intention to eliminate the need for privately owned cars by 2020 through the implementation of MaaS.

Deliverable 3.3 / version 1.1.
Chapter 2: Automated mobility

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10. Definitions, history and current status

Currently, Automated Vehicle (AV) technologies are under development, not just by auto manufacturers, but also by technology firms such as Google. At the time of writing, about 30 companies were reported to be working on automated vehicles. Plans are not limited to automated cars, but also include automated busses and mini-busses. There are some examples of concrete plans for the operational deployment of AVs, albeit in a (relatively) controlled environment such as campuses and business parks.

A lot of progress is also being made in the area of partial automation, which includes automated steering, braking, and acceleration capabilities on the one hand, and the ability to communicate, not just with other cars, but also with the infrastructure on the other hand. These current level of automation (or levels that will soon be operational) actually go already a long way in the direction of what consumers currently expect from automated mobility.

The relatively modest expectations at the consumer level need to be put in the perspective of the cost of further automation. Greenblatt and Shaheen (2015) reckon that the technology needed to enable full automation currently costs around 133,000 EUR. This cost premium exceeds the average purchase price of luxury brands, and is about a factor 5 larger than the average for all price segments.

As often, there is thus an important difference between the availability of a technology and its widespread adoption. In the case of automated mobility, the uncertainty concerning the timing of latter step is huge, and subject to controversy. We shall come back to this in the Section on the long term outlooks.
11. Potential impacts

Proponents of AV have claimed numerous potential benefits, including:

- Increased safety: if avs could eliminate all human causes of crashes, accident-rates could fall by 80 to 90%.
- Better use of travel time, for instance because the travel time can be used for work or for relaxation.
- More efficient-road use and decreased congestion, thanks to a combination of shorter headways and a decrease in accidents.
- Decreases in driving-related stress.
- Energy savings up to ~80% from platooning, efficient traffic flow (and thus less sporadic acceleration and braking) and parking and automated ridesharing. Additional energy savings are possible if increased safety reduces the need for safety equipment and occupant protection mass (and thus allows for lighter vehicles).
- Decreases in polluting emissions, especially if avs enable greater use of battery-electric vehicles (bevs) or hydrogen fuel cell vehicles (hfcvs).
- Provision of mobility services to people currently unable to drive.
- A reduction in the need for parking space and the disappearance of congestion due to vehicles searching for parking space.
- If individual (modular) avs could be coupled, vehicles could be “right-sized” for the services they provide, leading to additional energy savings.
- The high cost of avs may accelerate the move to shared mobility.
- Roadway infrastructure could be managed dynamically. For instance, directions could be modified on individual road lanes depending on aggregate AV flows. Thus, lanes that are used for the traffic driving in-town in the morning could be switched for driving out of town in the evening.
- Because avs would give highest priority to pedestrians in terms of safety, AV reduce the need for pedestrian areas, thereby increasing door-to-door mobility for mobility impaired people.
- In a fully automated system, travel times will become perfectly predictable (or estimates will be instantaneously adjusted in case of incidents), reducing the wait time at intermodal interchanges, and thus promoting intermodal transport.

Not all of these benefits require full automation. For instance, the use of vehicle sensors and vehicle-to-vehicle communications could already lead to increased highway capacity.

There are also downsides of AV:

- Increased congestion and pollution caused by travel by those currently unable to drive, such as young people without driving license, the physically impaired, and elderly people.
- It is not clear to what extent autonomous cars will really lead to shorter headways: one should not compare the theoretical safety distance between avs with the theoretical safety

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Brown et al. (2014) define “platooning” as “method of groups of vehicles travelling close together at high speed. This has the potential to reduce energy intensity resulting from aerodynamic drag.” Brown et al. emphasize that the actual energy saving from platooning will be highly context-dependent.
distance between vehicles driven by humans as a lot of people drive closer to the preceding car than is justified on safety grounds;

- A shift away from public transit due to the lower cost of time spent in a car
- Longer trips (and especially commutes), inter alia because the opportunity cost of the time spent in traffic decreases; longer commutes will lead to further urban sprawl, and to buildings with a larger environmental footprint
- After having dropped their passenger, the avs will now have to drive to places where parking is available (or cheaper), or to catch other users (which could be other family members, or, in the case of shared cars, third parties); this “repositioning” could have an important impact on traffic flows.

Another problem is related to security: automated vehicles could be used for terrorist attacks (as car bomb for instance) without any physical risk and with much lower risks of detection for the terrorist. Moreover, automated vehicles could be hacked for malicious purposes.

Thus, the net effect from automated mobility on energy use is ambiguous. Greenblatt and Shaheen (2015) refer to work that estimates that threefold increases in energy use are possible, but consider themselves that such extreme negative outcomes are unlikely. Brown et al. (2014) estimate that the net effects could range from more than 90 % fuel savings to more than 150 % increase in energy use. Morrow et al. (2014) reckon that the net effect on primary energy consumption could range from a decrease by roughly 80% to an increase by 100%. In an even more recent assessment of net impacts, Wadud et al. (2016) find “that automation might plausibly reduce road transport GHG emissions and energy use by nearly half – or nearly double them”.

11.1 Long term outlook

There is considerable uncertainty regarding the future pace of adaption of automated vehicles. Taking into account the high cost of full automation, few authors expect that the market share of AVs will be high enough for system wide impacts before the period 2035-2040. Studies that explicitly model the uncertainties in the underlying assumptions come up with estimated market shares by 2045 that vary from 25 to almost 90%.

Besides cost, another issue is user acceptance. There is substantial evidence that, on average, people enjoy manual driving, that their current willingness-to-pay for full automation is orders of magnitude smaller than the extra cost, and that they would not accept a vehicle that a human cannot take over for manual driving when needed.

11.2 Synergies with shared mobility

Shared Automated Vehicles (SAVs) that drive themselves to the carsharing users would reduce the time needed to access a carsharing vehicle, which is an important barrier to carsharing. More importantly, as they would not need to be parked, they provide first- and last-mile connectivity to public transit and fill service gaps in the transportation-network.
There is thus an urgent need to better understand the travel implications of SAV, both when they constitute a small share of the market and when they dominate the market.

Recent research has addressed the travel demand impacts when less than 10% of trips use SAVs, which is probably representative for the situation in the next 15 to 25 years. Depending on the structure of the city and the relocation algorithms, it has been estimated that one SAV could replace 9 to 11 conventional vehicles, while adding up to 8-10% in travel distance due “repositioning” for the next traveller. However, if dynamic ride-sharing (DRS) is allowed, net vehicle travel could decrease if SAV membership would increase (which would allow for improved efficiency of the system) and if users would tolerate more flexibility in trip timing and routing.

Several authors have also considered the travel demand implications of (nearly) fully automated fleets, even though this may only become reality in several decades from now. Compared to current levels, vehicle ownership could drop drastically, with estimates ranging from 10% to 33% of the existing fleet. However, total vehicle distance travelled would increase, except if the SAVs are embedded in a system with high capacity public transport (train, metro) and combined with ridesharing. In the worst case scenario (no high capacity public transport and no ridesharing), distance travelled during peak hours would even double, which is considered infeasible. The sharing of automated vehicles would spread the cost of automation over a broad range of drivers, and thus drastically reduce the unit cost of automation. Right sizing shared vehicles could lead to further drops in the system’s cost. The decrease in the number of vehicles would free up to 80% of current parking space for alternative uses, and thus also lead to a fundamental reconsideration of the use of urban space.

### 11.3 Synergies with electric mobility

Currently, two important barriers to a fuller uptake of battery electric vehicles (BEVs) are their limited range and their high acquisition costs when compared with conventional vehicles. We will now discuss some recent work that studies whether additional synergies are possible if the shared vehicles are also automated.

Brown et al. (2014) argue that AV can reinforce the competitive position of BEV, but mainly indirectly: they make carsharing more attractive, and (as already discussed) the economics of BEV are more favourable with shared vehicles than with privately owned ones. Moreover, an AV can be dispatched to meet a user’s specific need, only serving trips within range. Finally, AVs would be ‘aware’ of the availability and location of charging options, reducing the issue of ‘range anxiety’.

Further efficiency improvement are possible through the dynamic pricing of SAV use, which would penalize trips that incur more relocation miles (and thereby increase subsequent trip wait times) and incentivize trips that coincide with strategic relocation (and thereby decrease subsequent trip wait times) – see Kockelman et al. (2016).
The impact on GHG emissions can be important. For instance, it has been estimated that GHG emissions per mile could be around 90% lower than with current vehicles – this estimate takes into account the effects of right-sizing the car for individual trips\(^7\), and uses the expected fuel mixed used in the production of electricity in the US in 2030. Of course, with different fuel mixes, the results could be different.

On the downside, a large fleet of SAEV would also require large parking while charging during peak hours. However, it is still expected that the net overall demand for parking will decrease (Joskow and Wolfram 2012).

Kockelman and Chen (2016) also point out that SAEV operators may gain by offering differentiated services: high quality services at a premium price to travellers with a high Value of Travel Time (VOTT) and basic services at lowers prices to low VOTT travellers. Although such schemes may induce higher revenues, they can also come at the cost of a lower modal share SAEV. The trade-off between revenue seeking and increasing modal share depends on the objectives of the operators. This is an element that may strongly be influenced by policy choices.

\(^7\) The estimates do not take into account the possible beneficial effects of ridesharing, however.
Chapter 3: Policy implications

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12. Implications for transport modelling research

In the sections above, we have seen several examples of models simulating the impacts of shared mobility and/or of AVs. All these models seem to concur on the essential qualitative impacts: a widespread use of AV will lead to important decreases in the number of vehicles (and a corresponding decrease in the need for parking space) coupled with an increase in vehicle miles travelled, unless it goes hand in hand with an uptake of car- and ridesharing and an important modal share of high capacity transit systems.

However, these models have been applied to a very limited number of highly stylized transport networks, and have only considered rather extreme scenarios. Transport planners need however to be able to assess what will happen in the network they manage, including in the (probably) long transition period to a (almost) completely automated and connected transport system.

There are however important gaps in current transport modelling that will need to be addressed in order to deal with the new situation. We will briefly discuss the most important emerging research needs.

12.1 Growth potential

Marsden et al. (2015) conclude that the “(e)vidence on the impact of carshare on travel dynamics is disparate and lacking robustness given the limited quality and quantity of peer reviewed literature on the topic.” The lack of high quality evidence is partly due to the fact that shared mobility has only recently become an issue to reckon with.

We have shown above that growth of shared mobility has been very important in the last few years, but has until now remained limited to a niche, with often very specific socio-economic profiles and value systems. It is not clear at all to what extent the behavioural changes observed in this niche are representative for the whole population. We do not know whether the quantum leap that has been made possible with mobile apps and increasing modelling capacity has already reached the entire possible target population, or just the “early adopters”, who will be followed in due time by a broader audience.

12.2 Valuation of time

We have already mentioned that the greater comfort provided by AV (and the possibility for the traveller to engage in leisure of work instead of driving) may reduce the Value of Time spent in traffic. This will affect travel behaviour through several channels:

• People will tolerate long travel times, and especially longer commutes. This can in itself lead to longer distances travelled, and, indirectly, to more urban sprawl. This sprawl can be the result of people moving out of city centres, but the same may happen with companies.
- People will become more tolerant of “wasting” time during congestion, and this may lead to higher traffic in peak hours.

It is thus really important to better understand how the values of time will change as a result of automation.

### 12.3 Modelling of parking

As AVs do not need to be parked by the traveller, an important fixed cost at the end of the trip would vanish, which could induce additional demand for private travel (on top of the additional miles due to the relocation of the vehicle). These effects require a more detailed modelling of parking in the current models, and especially a full consideration of all the options that are now possible for the traveller (parking an AV that is privately owned, letting a privately owned AV cruise until the traveller has finished the activity that was the object of the travel, letting the privately owned AV drive back home, making the privately owned AV available for carsharing in a P2P system, renting a SAV on the way up and another SAV on the way back etc).

### 12.4 What is a “travel mode”?

The simultaneous emergence of new technologies and new business models leads to a virtually boundless number of possible combinations. We have seen some examples above: privately owned AVs, SAVs without ridesharing, automated vans and minibuses, privately owned AVs integrated in a P2P carsharing system, etc. Each of these combinations will be characterised by specific monetary and time costs. Traffic planners will thus face difficult choices in determining what defines a mode in their models.

### 12.5 Impacts on road capacity

It is a common assumption in the literature that autonomous vehicles would drive more efficiently than human drivers, and this can be represented as additional roadway capacity. However, some authors think that, certainly in initial phases, AVs will be programmed to drive more cautiously and conservatively than humans. Moreover, it has been argued that the positive impact on road capacity are overestimated, because humans don’t respect required safety distances anyway.

### 12.6 Reactions from other economic actors

The studies we have surveyed until now focused on a limited number of key decision makers, assuming other decision makers will remain passive. However, several stakeholders are likely to change their price settings as a response to AVs: public transport operators, managers of parking facilities, electric network operators... In the long distance segment, air and rail are also likely to modify their price policies.
12.7 Impact on the built environment

We have already reminded here that AVs may encourage further urban sprawl.

Another critical impact is that the reduced need for parking space may lead to a dramatic change in the urban landscape. As there are many competing potential uses for the space that will be freed, policy will be key in determining the eventual outcome. To give just a few examples:

- Using the freed space for parks, community gardens or other forms of “green space” will have a direct impact on the attractiveness of cities, and may counteract the trend towards increased sprawl. Moreover, they will help in countering “urban heat island” effects which will become increasingly important with climate change.
- The freed space could be used to increase the size of permeable areas in cities, and thus reduce the risk of flash floods (which, again, are more likely to occur as the result of extreme weather events).
- Part of the freed space will need to be made available for recharging stations for electric vehicles.
- If the freed place is to be used to increase road capacity, this will lead to new induced traffic.
- In cities with a lack of affordable housing in the centre, the freed space could be used to provide for additional housing.

12.8 Ownership versus sharing

Current model results have shown that the benefits of AV are more likely to be realised (and the negative side-effects counterbalanced) if AV are fully integrated in a sharing approach (car sharing combined with ridesharing). However, there is nothing inevitable about this, and we have seen above that there are some important barriers to a fuller uptake of shared mobility. It is thus important to understand these barriers, and to make realistic assessment of the share of people (and of their socio-economic profiles) who will continue to prefer full ownership in the future.

12.9 The importance of stated preferences

Current models are estimated and calibrated against data that represent the current situation, and are thus ill-suited to model the implications of radical departures from the status quo. In the absence of observed choices, stated preference surveys will be crucial in order to understand the effects of AVs. In more general terms, we would say that there is an increasing need to understand the fundamental mobility motives of people, and that travel surveys that limit themselves to past and current behaviour will become increasingly useless.
13. **Implications for transportation demand management**

Throughout this chapter, we have repeatedly emphasized that changes in transport technology and innovative business model do not emerge in a policy vacuum: we need to understand what type of policies will promote specific solutions. On the other hand, these new technologies and business model also raise new policy issues, which will need to be addressed. We will discuss some of the key issues and controversies.

### 13.1 Shared mobility as complement or substitute

We have seen that shared mobility, in its various forms, can be both a complement and a substitute to transit modes.

Wherever shared mobility is a complement, it is because it can be an effective tool to bridge the last and the first mile in a transport chain.

The “first/last mile” problem can have a dramatic effect on door-to-door travel time, and is therefore an important barrier to a shift from private car use to public transit. Solving (or at least seriously mitigating) the “first/last mile” problem can therefore be seen as one of the keys in reducing the negative externalities of transport.

However, the first and the last mile are also important barriers to mobility in general for poor households who cannot afford private cars. As access to mobility in turn affects access to jobs if there is an important spatial mismatch in job accessibility, then the “last mile” problem can effectively worsen the employment prospects of poor people. This creates a vicious circle: if certain neighbourhoods are struck by an important increase in unemployment (for instance, because an important share of the population in the neighbourhood works in a company that has shut down), serving this neighbourhood by public transport may become unprofitable. However, once the neighbourhood is no longer served by public transport, it can become virtually impossible for most unemployed people to find access to new jobs, effectively creating pockets of poverty.

As a result, for low income households, solving the “last mile” problem can signify a step change in their prospect that should be weighted higher than the time savings of households who already have access to private mobility.

However, if shared mobility turns out to be mainly a substitute for public transit, the move to an increasing use of shared solutions could create a new vicious circle of decreased transit patronage and decreased service levels.

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Arguably, the most important question in transport policy in the next few years will thus be whether policies can be designed that harness the strengths of shared mobility solutions to solve the “first/last” mile problem, and thus to promote alternatives to unimodal car mobility. We have seen several examples of transit authorities or operators who are trying to do exactly this. Their experiences will need to be monitored really closely. The concept of Mobility as a Service also fits within this pattern. Even if one does not go as far as the implementation of a “complete” MaaS, partial measures (such as integrated ticketing and the provision of real-time multi-modal travel information) already goes a long way.

Public authorities can also reinforce the complementarity by providing the necessary infrastructure of bike-, ride- and carsharing in the neighbourhood of important public transport hubs.

**13.2 The regulation of on-demand ride services**

We have discussed that several dimensions in the business model of on-demand ride services are controversial.

Some of these problems (such as insurance coverage and the qualification and screening of the drivers) can easily be solved through the development of specific regulations that would not touch the fundamentals of these business models.

Others, such as labour regulations, are more complex. These may require new approaches to labour legislation, such as defining hybrid categories between employees and external contractors. However, these issues are broader than the mobility sector, and are common to several sub-sectors within the “shared economy”. Anyway, with the rise of automated vehicles, many of these issues will become obsolete. Moreover, we have seen that there are already new entrants in this market with new approaches to labour relations than the incumbents, and that traditional taxi markets are also adopting some of the innovations used by on-demand services.

The issue of data sharing is also important, there are already concrete examples of public-private cooperation that can lead to mutually beneficial exchanges between the transport authorities and the providers of on-demand services.

All in all, it does not seem unsurmountable to deal with potentially problematic aspects of on-demand services without touching the essence of their innovative approaches.

**13.3 Alternative powertrains**

We have seen that, under certain circumstances, a widespread use of AVs could lead to an increase in vehicle distance travelled. Although this is not a certain outcome (and is in part dependent on public policies that we discuss here), the mere risk of this happening reinforces the need for policies that promote a further greening of the vehicle fleet.
This is not the place to discuss the relative merits of different technical approaches to reducing emissions of pollutants and greenhouse gasses from vehicles. Let us just remind here that we have shown that electric vehicles are more likely to be a competitive alternative to vehicles with internal combustion engines (ICE) in a shared fleet than when owned privately. Thus, the simultaneous promotion of shared solutions and electric mobility can be mutually reinforcing.

Several elements affect this competitive position.

First, there is the issue of cost. Compared to ICE vehicles, EV have a higher acquisition cost but lower operating cost. The threshold where electric vehicles become competitive to ICE vehicles is not a constant. For instance, with current low petrol prices, the breakeven point has become higher. On the other hand, public policies such as differentiated road pricing or higher fuel taxation could further increase the competitive position of EV if charges were differentiated according to emissions. Such price instruments are not always within the remit of local authorities. However, local authorities can still use planning and zoning rules to promote the uptake of electric mobility, for instance, by dedicating part of the existing parking facilities to charging infrastructure.

Our discussion of electric mobility has almost exclusively focused on electric car mobility. At the other side of the spectrum, electric bicycles could become attractive substitutes for “classical” bicycles, especially in cities where the relief and high temperatures make cycling unattractive. In places where wet weather is an important barrier to cycling, so-called bio-hybrids could be an alternative.

### 13.4 Pricing policies

The uncertainty concerning the net impacts of shared mobility solution and of automated vehicles implies that correct pricing of transport will become more important in the future rather than less important. A correct pricing of all transport modes according to their social costs will ensure that society will be able to capture the benefits of these innovations, while avoiding the possible disadvantages (which are mostly related to the risk of increased traffic volumes if automation does not go hand in hand with increased sharing and high quality public transit)

To some extent, optimal pricing will be privatised if SAV become the dominant mode. Indeed, if the operators of SAVs are allowed to set their prices freely, one would expect that they would apply “dynamic pricing”, where VMT travelled during the hours of peak demand would be priced more than VMT travelled outside the peak hour. Thus, the widespread use of SAVs would effectively result in a pricing of mobility that would come close to the economists’ ideal of dynamic distance based road sharing.

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9 This refers a 1+1 seater, which is similar to a bicycle with an electrically-assisted drive system but with two front and rear wheels, a luggage compartment and a roof for weather protection. It could be used on cycle tracks. - http://intelligentmobilityinsight.com/news/CWb

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On the other hand, the pricing of distance travelled will need to be coordinated with the pricing of other services. For instance, parking spots will also need to be subject to “smart pricing”. With electric vehicles, smart pricing of electricity would also be needed.

13.5 Public transit

We have argued above that policies are conceivable that could reinforce the position of public transit by solving the “last/first” mile problem through shared solutions. However, there are definitely some niches where shared solutions such as microtransit are likely to outperform traditional transit services. Moreover, the rise of AVs will reduce the opportunity cost of time spent in car travel, and this will further undermine the competitive position of some transit services.

Without going as far as the scenarios assumed by the ITF (2015), we can reasonably expect that, in the future, transit will increasingly concentrate on the task it is best at: moving huge quantities of people from one transport hub to the other. Whether this can only be implemented by metro, light rail, or BRT systems, or whether traditional bus services still have a role to play in such a landscape, remains an open question.

13.6 Accessibility

Until recently, the mobility of elderly or mobility impaired people confronted governments with two costly options. Either they could require buses and trams to be made accessible to everyone, or they could organise Demand Responsive Transport. While DRT services have the advantage that they do not require the complete rolling stock to be made accessible, they remain costly. DRT systems are also used to improve the accessibility of areas with very low population densities. When allowed, informal alternative transit systems cater to the transport needs of the urban poor who are not well served by traditional public transport.

Modern communication technology holds the promise of improving the efficiency of DRT or other alternative transit systems, because they enable to group rides of people with similar origin-destination pairs. Preliminary work by the ITF (2016) confirms that such types of shared mobility hold the promise of improving accessibility to jobs, healthcare and schools. Shared mobility could thus play an important role in the fight against social exclusion.
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