6 Urban Mobility and Parking Demand

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Abstract

Parking demand, both current and future, depends on two aspects: the long-term impact of urbanization and urban planning on parking demand, which is not addressed here, and, secondly, the choice of mobility modes, which is discussed here. The choice of mobility modes may, on one hand, require smart parking management and parking information, which is a result of the tracking technology discussed before. On the other hand an informed or incentivized choice of mobility modes may even lead to less parking demand.

Keywords

Active mobility, disruptions to motorized mobility, mobility as a service

6.1 Introduction

Of the triad of instruments to counter parking pressure (avoiding parking demand – shifting mode choice – improve parking space supply, (National Transport Development Policy Committee, 2012)), this chapter will point out the potential of emerging geospatial technology to either avoid, or at least reduce, the demand for parking in urban areas, or to ease the use of other forms of urban mobility than using the private car. People travel into the city for a reason. They wish to participate in activities offered by the city – work, learn, shop, entertain – and are received by scarce space due to the high price of land. The challenge of high demand on one hand, and low supply on the other is exacerbated by the general preference to travel in private cars, and by, on average, low occupancy rates in these cars, which jointly produces competition for inner-urban street space as much as for parking space.

With our focus on geospatial technology we leave out a wide range of other measures – including other technological measures – to reduce this parking pressure on urban centers. For example, we abstain from discussing urban planning and design questions here, although they are absolutely critical to foster active mobility. A city that is not 'walkable' (Speck, 2013) or 'bikeable' (McNeil,

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2011; Winters et al., 2016) will not convince citizens to change their mobility behavior just by providing information services.

We also abstain from discussing non-geospatial technologies that may impact actual travel demand, such as technologies supporting working from home, online learning, or tele-health. Their theoretical potential has been dramatically shown in the lockdowns in the 2020 pandemic. The imposed work-from-home regulations in Melbourne, Victoria, for instance, led to a reduction of inner-city traffic by 88 % in the first lockdown (March), or by 85 % in the second (July), respectively[1]. Such data is corroborated by Google's *COVID-19 Community Mobility Reports* from around the world[2], which are based on phone activities and are heavily aggregated, hence less specific. According to Google, Melbourne's mobility trends in relation to workplaces had decreased by 48 % on 21 August 2020 (in the middle of the second lockdown) compared to a longer-term baseline. On the same day, the average for the whole of India has been down by 32 %, despite less reliable internet and thus less reliable technologies for working from home.

Instead, we look at providing services that support the current level of mobility demand by making better decisions on mode choices or travel behavior. In this chapter we will look at:

- technologies that support more active mobility (again, we abstain from urban planning and design questions here);
- technologies that change the nature of motorized mobility and as a by-product the demands for parking; and
- technologies that ease the interaction with urban mobility and improve the coordination between modes of urban mobility.

With these foci, we highlight opportunities that are fully aligned with the sixth of the ten Aalborg Commitments[3], which were agreed at the Fourth European Conference on Sustainable Cities and Towns (2004) and signed by more than 700 mayors from across Europe and Africa. This sixth commitment simply states "Better mobility, less traffic – We recognize the interdependence of transport, health and the environment and are committed to strongly promoting sustainable mobility choices. We will therefore work to:

1. reduce the necessity of private motorized transport and promote attractive alternatives accessible to all.
2. increase the share of journeys made by public transport, on foot and by bicycle.

[1] `https://ab.co/34YXcuY` – Australian Broadcasting Corporation, 22 July 2020
[2] `https://www.google.com/covid19/mobility/`
[3] `https://sustainablecities.eu/the-aalborg-commitments/` – ICLEI, 2004

3. encourage transition to low-emission vehicles.
4. develop an integrated and sustainable urban mobility plan.
5. reduce the impact of transport on the environment and public health."

In order to discuss mode shifts towards sustainable mobility choices one might think that a certain theoretical equilibrium might exist for a sustainable city, for instance, 30 % for the active modes such as walking and cycling, and 30 % for public transport. Such aspirational targets, however, are missing from the Aalborg Commitments and for good reasons. One reason is that such figures would also ignore the largely different starting conditions in the cities around the world (Langeland, 2015) – Table 6.1 illustrates this argument by mode share figures, without diving into the reasons for these observed mode shares.

Table 6.1: Mode share in various cities.

	walking	**cycling**	**public transport**	**private car**	(year)
Melbourne[4]	4 %	2 %	19 %	76 %	2016
Mumbai[5]	7 %	6 %	52 %	15 %	2011
Münster[6]	16 %	38 %	10 %	36 %	2007

In fact, sustainable transport research provides a range of tools to improve urban mobility but in a sustainable manner (e.g., Goldman and Gorham, 2006; Litman, 2007; Malasek, 2016). A remaining challenge – for the research community as well as the society at large – is to define what a sustainable activity is, including urban mobility. Broad agreement prevails that current urban mobility is not sustainable (e.g., Greene and Wegener, 1997), and that *more sustainable* solutions have to be found: solutions that are *less harmful* to the environment, society, and less detrimental to sustainable economic development, especially, when considering the future generations.

Litman (2007), referring to some indicators, defines a sustainable transportation system as one that satisfies the mobility needs in a society safely and inclusively in a manner that "limits emissions and waste within the planet's ability to absorb them, minimizes consumption of nonrenewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise" (Litman, 2007, p. 11). Note that these terms are still, and unavoidably, accepting some non-sustainable consumption of resources and land.

[4] Commuter trips, `https://en.wikipedia.org/wiki/Modal_share`
[5] Commuter trips, `https://en.wikipedia.org/wiki/Modal_share`
[6] Data is taken from (Langeland, 2015).

Urban parking has hardly been addressed in the research on sustainable transport. But this is unjustified. Parking is only a by-product of urban mobility, but – returning to Litman's definition of a sustainable transportation system above – parking contributes significantly to the space consumption of urban mobility, and its contributions to urban traffic and emissions are widely acknowledged as well. Accordingly, the mechanisms to address parking in the context of sustainable transport are by reducing individual car usage and thus to reduce both cruising for parking and the demand for space for parking. The following sections focus on these mechanisms.

6.2 Active Mobility

Active mobility (or *active transportation*) is the generic term for all non-motorized travel modes. Prime examples are walking and cycling. Active mobility involves moving around (e.g., by walking or cycling), transporting other people (e.g., by rickshaw runners – where *rickshaw* literally means *human-powered vehicle*), or transporting goods (e.g., by bicycle couriers). The first category – moving around – uses in its purest form only locomotion: human physical activity without further means of support, such as walking or running or – in aquatic environments – swimming. Other forms of moving around are supported by some agent or non-motorized vehicle. These forms include traveling on the back of an animal, or using mechanical vehicles such as bicycles, roller skates, kick scooters, wheelchairs, or carts. The other two categories – being moved around – rely on somebody else' physical activity. A categorization has been made in Table 6.2.

Table 6.2: Categories of active mobility, with examples.

	locomotion	**vehicle**
self	walking	bicycling
other	riding	rickshaw

Often active mobility is promoted for health reasons. A proverb attributed to Hippocrates says "Walking is man's best medicine". (More) walking helps prevent non-communicable diseases that are dramatically increasing globally, including Type II diabetes, obesity, and coronary heart diseases (Batman, 2012; Giles-Corti et al., 2016; Pucher et al., 2010).

In the context of this book other aspects are more relevant though. Most importantly, the different modes of active mobility have a significantly smaller footprint on parking space demand compared to private cars (see for example Figure 8.2), with locomotion having no parking space demand at all. On the other hand, the various forms of active mobility have different ranges compared to the private car, i.e., they do not directly replace the car. The obvious argument is illustrated by Table 6.3, which shows the use of specific modes dependent on the distance traveled, based on household travel survey data from England (Department of Transport, 2020). For instance, in England 81 % of all trips shorter than 1.6 km (1 mile) were undertaken on foot, 1.1 % on a bicycle, 11.4 % on driving a private car, and 6.7 % as a passenger in a vehicle (including public transport). These percentages shift significantly towards either driving a car or being a passenger with increasing travel distances.

Table 6.3: Percentages of trips by mode, in distance ranges.

	$\leq$1.6 km	$\leq$ 3.2 km	$\leq$ 8 km	$\leq$ 16 km	$\leq$ 40 km	$\leq$ 80 km
walk	80.9 %	33.4 %	4.7 %	0.3 %	0.1 %	0.0 %
bicycle	1.1 %	3.1 %	2.8 %	1.6 %	1.0 %	0.6 %
driver	11.4 %	39.9 %	60.5 %	65.4 %	68.3 %	67.7 %
passenger	6.7 %	23.6 %	31.9 %	32.7 %	30.6 %	31.8 %

While these numbers illustrate that active mobility will not replace the car, their magnitudes will differ between cultures, between social groups, between age groups, and also between towns and countries. However, urban planners work with an often cited 5-minute rule (van Soest et al., 2020). It suggests that people are willing to walk distances of 400 to 800 meters, corresponding to five to ten minutes, before considering other modes of mobility. This rule of thumb is often used for catchment planning of public transport stops: five minutes for bus or tram stops, and ten minutes for rail. Specific studies tend to confirm this broad rule, and shed more light on the causes of this variability. This rule can also be inverted to assess the quality of a public transport system in a city. For example, El-Geneidy et al. (2014) show that Montreal has an average distance of 524 m between home-based trip origins and the public transport stop taken, and 1,259 m for home-based commuter rail trip origins. But the willingness to walk depends also on the purpose: According to Table 6.3 people are willing to walk farther than only 400 m to 800 m. Obviously the willingness to walk to public transport, shopping, or personal errands is on the shorter side, while people are willing to walk farther for other purposes, such as recreation.

Pedestrian and cyclist behavior – i.e., the willingness of people to choose active modes of mobility – will also be influenced and shaped by the information provided to them: information creating a better awareness of the urban layout and travel options (Laurier et al., 2016; Peiravian et al., 2014), integration with data on environmental or health risk levels (Wang et al., 2020), integration with live public transport data (Daniels and Mulley, 2013; Mavoa et al., 2012), and record keeping for personal fitness or competition purposes (Gu et al., 2017; Higgins, 2016).

Last but not least, active mobility is a matter of choice only for the physically abled, and excludes the elderly (Musselwhite and Haddad, 2010), parents with children, and other people handicapped in their mobility. An inclusive society has always provided alternative modes of mobility. Accordingly, a significant part of research and the development of services are focused on the integration of active mobility (walking, mostly), and public transport. An underdeveloped area, however, is the integration of walking and driving a private car, which is relevant for this book as well. When driving a car, the first and last leg of a trip are always traveled on foot. This walking part has a tendency of being ignored when choosing the car, at least in the literature. When literature studies the perceived costs of parking, the focus is solely on the cruising for “cheap” parking (Shoup, 2005). We are not aware of initiatives combining parking with encouragement for active mobility.

But let us have a closer look at walking, which is by far the most frequent form of active mobility according to Table 6.3 and all similar data. Such a closer look reveals an astonishing complexity in human mobility behavior: there is a lack of (accessible) network data, and gaps in conceptual research – all in comparison to the better understood and modeled motorized forms of mobility, and even cycling, which, at least in cities, is happening in shared spaces with cars.

Obviously, the digital infrastructure of a smart city requires a comprehensive representation of the complex domain of pedestrian access. The common fundamental data structure for representing mobility space is a *graph*, consisting of *nodes* representing locations, *edges* representing access connections between these locations, and any constraints on these connections. A graph, as a linear structure, is the result of a projection of a volume – the space pedestrian movement takes – to the plane – a plan or map – and a further projection of the two-dimensional map space to the linear structure of a graph.

Yet, even now, pedestrian mobility studies rely on graphs derived as by-products of primarily road network data or indoor floor plans, rather than from primary mapping. But walking in urban space happens to a large part also in separation from the road network (Chin et al., 2008), and in both elongated and more compact spatial forms (Table 6.4). Walking spaces are spaces such as sidewalks, laneways closed for vehicles, pedestrian zones, city squares, park paths, park greens, pedestrian under and overpasses, private passages with restricted access, such as passages through malls or train stations, and corridors or halls (Figure 6.1). Pedestrians do move freely in these spaces, which they consider open for their locomotion – inspiring Seamon to call it a *place ballet* (Seamon, 1980) and others to identify simple rules of motion that aggregate to this complex behavior (Moussaïd et al., 2011). Pedestrians are also less constrained by traffic regulations than, for example, cars or bicycles. For example, they can turn around at any time and anywhere. Pedestrians also use shared space with vehicles when they cross a road. Road crossings can be unmarked (e.g., a suburban crossroad), marked, regulated by zebra crossings, or controlled by traffic lights. Also, in many countries it is legal to cross a road anywhere.

Figure 6.1: Pedestrian movements in large spaces (here a pedestrian zone (top) and an airport terminal (bottom)) form complex patterns, in contrast to regulated road traffic. Source (top): `https://bit.ly/3vStqUL` (© Mattes, 2005, public domain, modified). Source (bottom): `https://bit.ly/360dLHm` (© Minseong Kim, 2016, CC BY-SA 4.0).

Given the complexity of walking pathways these derivation processes introduce significant under-specification (Brezina et al., 2017; Pafka, 2017; Marshall et al., 2018) and contradictions from the various levels of detail of the maps (Ericson et al., 2020). The competing, varied modeling approaches of pedestrian mobility space (e.g., Stoffel et al., 2007; Becker et al., 2008; Jensen et al., 2009; Liu and Zlatanova, 2012; Isikdag et al., 2013; Kim et al., 2014; Yang and Worboys, 2015; Walton and Worboys, 2012; Stahl and Schwartz, 2010) lead to incompatible graphs (Vanclooster et al., 2016), ranging from purely topological connectivity graphs to numerous forms of geometrically embedded graphs (Figure 6.2). In addition, pedestrians conceptualize indoor and outdoor environments differently, which leads to a confusion between graph elements and mental concepts (Guidice et al., 2010; Schaap et al., 2011; Rüetschi and Timpf, 2005).

To derive comprehensive graph representations of the pedestrian mobility space in a city – in support of more active mobility – requires mechanisms to capture and integrate data on the pedestrian mobility space. The graph should maintain desirable detail for active mobility, such as width, surface, and barriers – which is essential information for parents pushing perambulators, for wheelchairs, or for

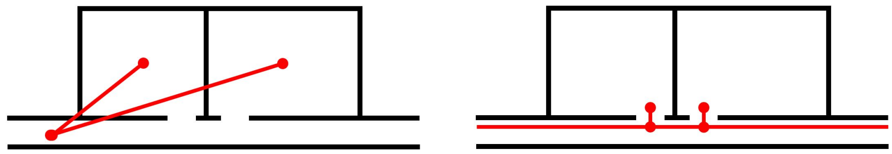

Figure 6.2: A graph connecting the spaces that can be accessed from each other (topological connectivity – left) and a graph closely approximating human movement (Stahl and Schwartz, 2010) (geometrically embedded graph – right).

skateboards – and the restrictions on private pedestrian mobility spaces, such as temporal ones (e.g., opening hours), or authorization ones (e.g., key or smart card access, or payment gates) (Richter et al., 2011). Furthermore, the integration of various data sources (or various graph models; see above) requires conceptual mappings of any of the various modeling approaches listed above onto an agreed standard model, and as long as this standard model does not exist globally (Harrison et al., 2020; Beil and Kolbe, 2017) at least within the information domain of the jurisdiction of a (smart) city a common model needs to be agreed upon.

Table 6.4: Categories of pedestrian traffic space, with examples, with various complexities of pedestrian movement behavior.

	public	**private**
elongated	sidewalk	passage
compact	city square	train station hall

Such graph representations of active mobility spaces – here of walking – are essential for smart city applications. Developing support for other forms of mobility than the private car, especially for short-distance trips in inner-urban areas, will help to reduce demand for the private car, and thus for parking a private car in inner-urban areas. A data infrastructure covering the active mobility spaces in these areas enables the deployment of mobile location-based services to motivate people for physical activity. These services could apply data analysis to suggest personalized activities either to achieve set goals, or to adapt to physical capabilities. Network analysis, combined with pedestrian counters in the inner-urban areas (see Section 3.3), offers to simulate pedestrian mobility, for example, to prepare for disasters (evacuation planning) or to upgrade the pedestrian infrastructure (urban planning). Finally, this graph can be integrated with graphs of other modes of transportation, enabling the development of multimodal travel planners – with a special focus on encouraging the walking components of trips (integrated transport planning). The positive effect on parking pressure would primarily emerge from avoiding short-distance car trips.

6.3 Motorized Mobility

Intelligent transportation systems must cater for improvements of the capacity of the *parking* infrastructure as well. Improvements of the environmental impact of the existing transport infrastructure would at least cope with the negative impact of parking-related behavior, such as cruising for parking. Thus, we will review here three emerging technologies that will significantly impact on urban parking: electrification of vehicles, autonomy, and collaboration. All three together will have a significant impact on urban mobility, as we will discuss in the next section.

6.3.1 Electrification

The current electrification of vehicles has an immediate effect on the environmental impact of motorized traffic in a city: emissions – both greenhouse gases and particles – are no longer generated by the vehicles themselves (but potentially in the energy generation process if it is not renewable). Also, noise emissions by vehicles are reduced. But resource consumption is still a challenge, since the replacement of fossil fuels by renewable energy increases the demand for batteries, and the current techniques for battery recycling are still highly loss-making – as long as mining the resources is cheaper. Hence, while the life-cycle assessment of the ecological performance of electrical vehicles is controversial, the aspect of importance in our context is that electric vehicles have different parking patterns due to their battery recharging needs. At least in the introduction period of electrical vehicles not every parking spot will be equipped with a charging station (Figure 6.3), meaning that electrical vehicles will, at least initially, travel further in search of parking.

Figure 6.3: Parking with a charging station for electrical vehicles. Source: `https://bit.ly/3rfRnSu` (© Aschroet, 2019, public domain, modified).

6.3.2 Autonomous Vehicles

The Society of Automotive Engineers defined six levels of driving automation that are widely adopted or referred to. They range from 0 (fully manual) over levels of driver assistance systems and partial automation to automation under certain conditions (Level 3), high automation where cars do not require human interaction in most circumstances (Level 4 – mostly operating in limited environments) and full automation (Level 5). At the time of writing this book, Level 4 vehicles are already commercially available and on the road, for example the early adapting self-driving passenger shuttles. Level 5 vehicles are currently being tested but are not yet commercially available. Furthermore, the regulatory frameworks for their legal operation on the road are still missing. Autonomous vehicles will be electrical vehicles because of better integration of the two technologies of energy and automation. An electric engine is simpler and has fewer moving pieces than a combustion engine. Also, wireless charging of batteries integrates seamlessly with autonomy.

The main driver for the development of autonomously driving vehicles is the elimination of the human factor in the driving process, which is perceived as a risk for safety: the computer controlling an autonomous vehicle never gets tired or distracted, and is generally faster in data processing. But autonomous driving at Level 5 has an economic impact as well: the computer is significantly cheaper than a commercial human driver, and not bound to hours of work.

Most importantly, however, autonomous vehicles (Level 4 or 5) impact urban parking. They no longer need a parking spot at the destination of a trip, but can autonomously search for a parking spot after dropping off their passengers – or continue traveling, and pick up other passengers, i.e., not require a parking spot at all. This disjunction of travel demand and parking demand will reduce the pressure on parking in high-demand destinations such as city centers. It will also disrupt commercial parking business models that have made significant real-estate investments in city centers. It will not, however, reduce the traffic in city centers since vehicle kilometers traveled will increase – by empty cruising.

An autonomous vehicle heavily relies on the geospatial foundations that we have discussed so far. Equipped with a large range of sensors (Chapters 4, 5), it is constantly tracking its own location (Chapter 3) both in a global reference frame, as well as in a local reference frame, i.e., relative to the road marks and to other vehicles or road users around (Chapter 2).

6.3.3 Connected and Collaborating Vehicles

Finally, autonomous vehicles will have another opportunity to shine, namely when enabled with vehicle-to-vehicle communication (see Section 3.2.2). While communication between human drivers is severely limited by lack of a suitable communication channel, as much as the time people require to communicate, vehicle-to-vehicle communication (V2V, as well as all other V2X variants) facilitate near real-time collaboration between autonomously driving vehicles. Vehicle-to-vehicle communication, since it is radio-based, has short latency – critical for safety relevant applications – and is not bound to lines of sight. Coming back to parking, however, collaboration opens new avenues for crowdsourcing and sharing parking information (Bock and Sester, 2016; Bock and Di Martino, 2017).

Collaboration, however, can extend beyond other vehicles. It can involve traffic management platforms that maintain a real-time awareness of traffic and interact for management purposes, or intermodal transport platforms that coordinate connectivity in transit, or vehicle makers that can maintain an awareness of the health of a vehicle and interfere for maintenance purposes. A significant domain of collaboration, however, is with people. This kind of collaboration, can express through modes that are directly perceptible by the human senses, such as sound, light, or driving behavior – e.g., (Gupta et al., 2019) – but also radio-based, with a smart communication device on the other end mediating this communication with people. This latter collaboration, with people, can be applied for example to coordinate the movements in road space between vehicles, pedestrians and cyclists. It can also be used, as we will see in the next section, for coordinating with people on their mobility demands.

Vehicle-to-anything communication (V2X) can be put into two categories: the local communication of a vehicle to another vehicle or other road users, or reaching out to global communication channels (vehicle-to-infrastructure, vehicle-to-network) for global vehicle coordination and collaboration. In the domain of urban parking, both have their merits. A parking information system requires a global picture of available parking spaces, and if this system should be fed by vehicles in a crowdsourced manner a communication channel to the central system is required. However, there is a strong reason to consider local collaboration, and this is because only nearby parking spaces are relevant for a vehicle currently searching for a parking space. The high demand for urban parking, especially on-street parking, means that any information is caught between *velocity* and *veracity* of big data (Li et al., 2016; Zhu et al., 2019), gets outdated fast, and hence, is of value only in a local context.

Local communication and collaboration about detectable spatial information (such as occupancy of parking spots) is the domain of mobile wireless geosensor networks (Duckham, 2013), a specialization of the more general wireless sensor networks (Zhao and Guibas, 2004). Other terms used in the literature, which are less emphasizing the sensing aspect and more emphasizing the carrier, are vehicular ad-hoc networks, or VANETs (Hartenstein and Laberteaux, 2010). Their ability of ad-hoc connectivity is also emphasized by wireless ad-hoc networks, or WANETs, or mobile ad-hoc networks, MANETs. All these networks rely on Wi-Fi, mobile telephony, and other communication services. The principle is explained by (Toh, 2001): "An ad-hoc wireless network is a collection of two or more devices equipped with wireless communications and networking capability. Such devices can communicate with another node that is immediately within their radio range or one that is outside their radio range. For the latter scenario, an intermediate node is used to relay or forward the packet from the source toward the destination. An ad-hoc wireless network [. . .] can be [formed and] de-formed on-the-fly without the need for any system administration."

Adding sensors to the communication network, and looking at parking occupancy as detected by vehicles, we can again distinguish two kinds of observations. The vehicle can observe its own behavior, e.g., when leaving a parking spot (see Chapter 13), or the vehicle can observe parking spots nearby, in passing. The prior observation is part of a trajectory, and thus an observation in a Laplacian frame of reference, while the second kind of observation happens in a Eulerian frame of reference (see Section 3.4). In addition, a vehicle can be an intermediate node, transferring information that it has not observed itself.

6.4 Disrupting Urban Mobility

Many reasons speak against owning a private car. Here is another one: What if we could move with the comfort, privacy and flexibility of a vehicle without the necessity to own it? To maintain it? To park it? And – because this is about driving without a driver – for significantly lower costs than current taxis or their gig counterparts, the ride-hailing services? In fact, for lower costs than taking our own car? Since with autonomous driving most of the parking-related costs are gone, and yet the passenger gets dropped off at their destination there is no additional loss of time in searching for a parking space and walking back.

This is the promise of autonomous driving, connected and collaborating vehicles: they will provide mobility services on demand by sharing themselves as a resource. The sharing goes beyond current car sharing schemes (Millard-Ball et al., 2005) by vehicles that do not need to be parked by the driver and that, autonomously and collaboratively, re-balance following the actual or anticipated demand (Agatz et al., 2012). The sharing of the resource can happen exclusively with an individual or a group ('taxi'), or allow for pooling of individuals with different but compatible travel needs ('shuttle'). In this future scenario too, the boundaries between ridehailing and ridesharing disappear: Ridehailing services are providing taxi services outside the regulated taxi market where a commercial driver offers transportation (Clewlow and Mishra, 2017; Henao and Marshall, 2019; Young and Farber, 2019) while ridesharing services provide a resource sharing of a driver with her own mobility demand (Chan and Shaheen, 2012; Furuhata et al., 2013). If, in the future, no driver is required, due to full automation, ridehailing and ridesharing merge with carsharing (Shaheen and Cohen, 2007; Millard-Ball et al., 2005), leaving the car as the only commodity. In addition, this (shareable) commodity itself will become cheaper, due to the mechanically simpler electric motor and the use of cheap energy from renewable resources (Granovskii et al., 2006; Bösch et al., 2018). Another perspective on urban mobility – that of equity in access and participation – suggests that we also rethink the commodification of transport, and instead set up basic services. Cheap and shared vehicles could provide these mobility services. For example, in areas that are currently not well served by mass transport (outer suburbs), or in areas with highly diverse demands (city centers). Literature studies already propose ridesharing as a solution to the first/last leg problem (Shaheen and Chan, 2016; Navidi et al., 2019).

For these reasons it is becoming clearer that autonomous and collaborating vehicles will have a significant impact on urban mobility, so much that some call the impact *disruptive* (Meyer and Shaheen, 2017). While this can be said for the economic arguments just made, another reason for disruption lies in the need for redesigning of urban traffic space as well as of regulatory frameworks to adapt to (full) autonomy. Again another reason lies in the opportunity for rethinking the mode collaboration and integration – options for a *mobility-as-a-service* (Jittrapirom et al., 2017) – and reshaping people's interaction with urban mobility.

6.5 Interacting with Urban Mobility

An intelligent transportation system, with its design goal of making smarter use of existing transport infrastructure, is not just intelligent because it is able to operate autonomously ("to use data to improve the capacity, safety, and environmental impact of existing transport infrastructure resources", as we said in Chapter 3.1). It is also intelligent because it communicates with people on their terms (Turing, 1950; Winter and Wu, 2009).

Such an abstract expectation – communicating on human terms – means different things to different groups of people. Road authorities and transport managers have a different view on urban mobility, including parking, than the travelers themselves. A managerial interaction with urban mobility includes dashboards and life maps supporting human decision making, and traffic interventions that realize these human decisions. These tasks can be further automated to some degree but still need to communicate to the people overseeing the urban space and the mobility happening in this space. Travelers, on the contrary, interact with the mobility options available to them, and the travelers' decision making is limited to their own transport benefit. They seek information about their options, choose, pay, and adapt flexibly to changing circumstances. They may look at their urban mobility options from a system's perspective, across modes and providers, which is the emerging domain of Mobility-as-a-Service (Exposito-Izquierdo et al., 2017). Or they may look at their urban mobility options from a pre-conceived mode's perspective, such as a car driver's perspective, which is addressed by mode specific navigation tools. They also interact with embodied intelligent systems: “Intelligent” vehicles. Examples are driver assistance systems communicating to their drivers, autonomously driving vehicles interacting with their passengers, or pedestrians interacting with autonomously driving vehicles.

Each of these tools should consider parking as a core component in their own way. From a transport management perspective, this includes tracking parking lot occupancy and providing parking guidance systems. For a traveler, when a mode mix includes a private car this car has to be parked somewhere. Thus, intelligent travel support systems ease the finding of a suited and unoccupied parking space.

One interface to intelligent transportation systems is a particular human one: common language. While conversational assistants have made some inroads to general question-answering already, conversations about spatial and spatiotemporal configurations remain a challenge. The challenge has multiple reasons, but for a start, already Klein (1982) and Wunderlich and Reinelt (1982) identified four phases in the communication between a human wayfinder and an informant, which go beyond the design of current question-answering principles:

- the initial phase: a wayfinder asks an informant for directions,
- the center phase: the informant provides route directions,
- the securing phase: either the wayfinder or the informant want to make sure that the wayfinder has understood the given route directions, and
- the closing phase: participants look for closure and separation.

The question (initiation) and answer (center phase) are covered in this structure, although conversational assistants are already challenged to just answer spatial questions (Hamzei et al., 2019). The neglected, and truly challenging part, however, is the securing phase: a capacity of the machine to engage in discourse on spatial configurations, temporal relationships, and movement.

Besides a verbal channel of communication, intelligent transportation systems can also communicate graphically with people. The transition of a traditional interaction with taxi services (hailing at the curbside, or calling) to map-based interfaces of ridehailing platforms has significantly shifted the goalposts and were critical to the market success for ridehailing services. But even these map-based interfaces can be scrutinized and improved (Rigby et al., 2016; Rigby and Winter, 2016). A further step in complexity is required from mode- (or platform-) specific interfaces to intermodal mobility. For example, Pandey et al. (2019) illustrate that ridehailing operators would benefit from integrating their services on a meta-platform.

6.6 Conclusions

This chapter discussed the technologies and incentives that affect peoples' mode choice behavior, and thus, the potential impact on parking demand within the city. It covered the push for active mobility as a focus area, the future demands of motorized mobility, and the future usability of urban mobility systems from an interaction perspective. It did neglect aspects of urban planning and transport systems planning that will have a more long-term impact on parking demand.

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