8 The Nature of Urban Parking

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Abstract

Parking is a result of derived and often induced demand, and thus suitable for active management by tools of data and information services that influence demand and search behavior. But what is the subject of this management? This is the topic of the current chapter.

Keywords

Parking, cruising, occupancy

8.1 Demand for Parking

As we said in the introduction to this part, parking is a necessity. A vehicle is a means to an end, and once the end has been accomplished – the travel destination reached – it can be disposed of, or *parked*, for reuse. Economists call such dependency a *derived demand*: a demand for a service in one sector (here: temporarily occupying some real estate) occurring as a result of demand from another sector (here: movement). In these terms parking is a second derivative, since movement of people or goods has already been considered a derived demand: Transport facilitates access to satisfy other individual needs (such as work, education, or recreation) or other economic needs (such as delivery of goods). Such stationary demands as parking, derived from the derived demand of mobility is also called an *indirect derived demand* (Rodrigue et al., 2017).

This dependency of parking from mobility makes the management of parking a harder problem: any interference with demand or supply for parking has implications also for mobility, and vice versa. Some of the effects of interference with this complex system between mobility and parking can even be counterintuitive. Most prominently, easing parking in the city center, e.g., by means of smart parking management, will most likely attract more demand for parking: this step *induces* demand. Induced demand describes an increase in the demand of a good after supply increases, and is well known in transportation studies (Goodwin, 1996). If more roads are provided, more people tend to use

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their car because space has become cheaper. If more cheap on-street parking spaces are made available, or the currently non-occupied on-street parking spaces can be found easily, more people choose the convenience of their own car instead of public transport. Induced demand can easily outweigh the benefits of an intervention, leading to the well-known paradox originally postulated by Braess (Braess, 1969). This paradox states that traffic, after any intervention, always returns to an equilibrium. In practice this means that all forms of cities experience pressure on road space and parking space, independent of their current offering – and the cities vary largely in their car (parking) friendliness. This cycle between further investment, e.g., in parking management, and then returning to operating at capacity limits is illustrated in Figure 8.1.

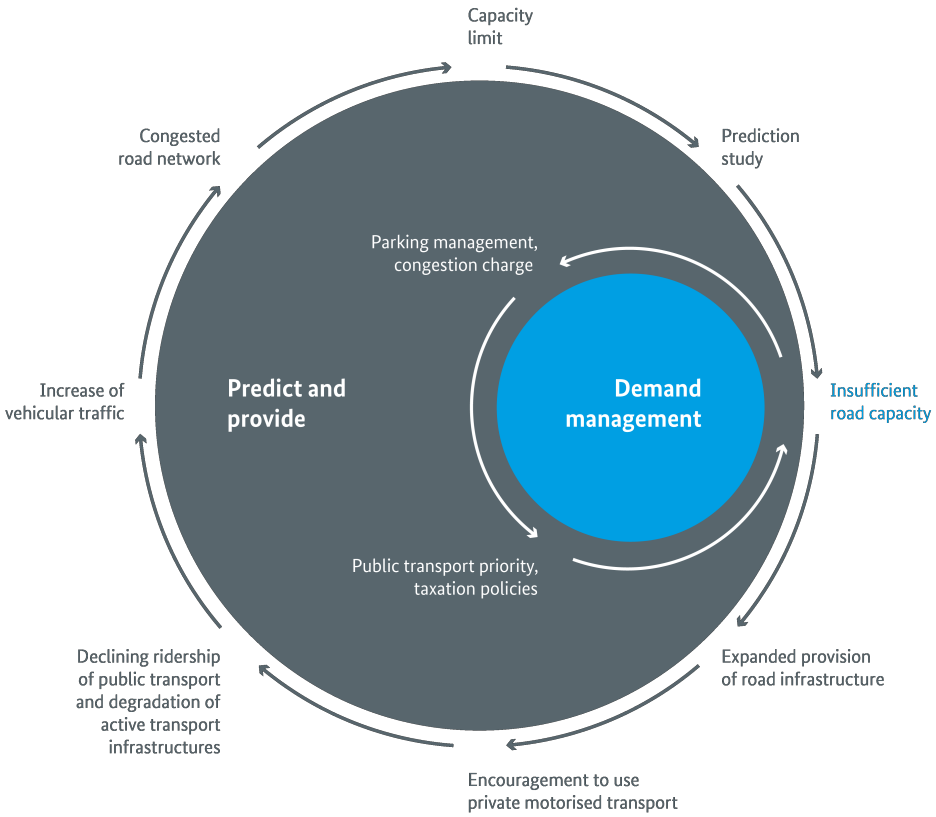

Figure 8.1: The cycle that induces demand. Source: `https://bit.ly/2NIL1gV` (© Transformative Urban Mobility Initiative (TUMI), 2019, CC BY-SA 4.0, modified).

While investment in smart parking induces demand, there is not much point in considering whether parking supply created the demand or whether parking demand created the supply. A critical factor for specifying this demand is the level of motorization in a city, and the mix of vehicles used. While parking was already an issue with horse-carts in earlier times, it is still an issue in the cities of our

times where person-directed vehicles – i.e., vehicles with parking requirements – cater to a large range, including private cars, motorbikes, bicycles, scooters, three-wheelers, and, at least in some parts of the world, animals and tour buses. That is, demand for parking is not limited to private cars only and includes other vehicles above. An answer to the problem of parking pressure in high-income countries, with their saturation of private car ownership at about 0.5 cars per capita, is the increasingly active management of parking supply. This approach is using technology for efficiency gains, which is seen as sufficient. The bigger challenge is probably the dramatically growing private car ownership in other countries, where more efficient management of the existing parking supply is not sufficient. While twenty years ago the car ownership rate in countries with lower economic standards of living was at 0.06 (60 cars per 1000 persons) (Ingram and Liu, 1999), these rates are now closer to 0.2 for cities such as Delhi and Shanghai (Trouve et al., 2018), and even 0.3 for Jakarta (Kresnanto, 2019).

Obviously, parking requirements depend on the type and size of the vehicles (a similar consideration has often been made for street space). Bicycles' parking space is a fraction of a car's (Figure 8.2). An on-street parking bay for a private car can cater up to ten bicycles, which gives a strong motivation for cities to repurpose car parking space.

Figure 8.2: Bicycle parking footprint. Source: `https://bit.ly/3gnWNr4` (© HensleyStudios, free use, 2021).

A more subtle point has to be made about the size(s) of private cars. US American cities, which have grown largely with the private car around, i.e., during the twentieth century, have also grown with, on the average, larger cars, and thus have not only more, but also larger parking spaces than elsewhere. The older European or Asian cities had to adapt to the private car, and have generally smaller parking spaces for more compact cars. The average on-street standard parking space is about 14 square meters – less in Europe, and more in the United States of America. Residential parking spaces vary also in size, determined by local building regulations, but are generally smaller than public on-street parking spaces.

But then cars have become, on average, larger over time as well, while existing parking space cannot grow. For example, the building regulations in one European country set minimum requirements for a parking space on residential property to 4.8 m $\times$ 2.3 m – big enough for a Volkswagen Golf I (1974), which had a length of 3.72 m and a width of 1.63 m without mirrors. But the Volkswagen Golf VIII (2020) has already a length of 4.29 m and a width of 1.79 m without mirrors (Figure 8.3). As a consequence, getting into the vehicle in the same parking space has become more difficult. Luxury limousines of today now exceed 5 m in length, and do not fit on the smaller car parking spaces any longer.

Figure 8.3: Cars are getting bigger – parking spaces becoming smaller.

Another consideration concerns the location and the quality of the parking space required. For example, valet parking services relieve from the demand for parking space in the immediate vicinity of certain trip destinations without varying the size of parking demand itself (except by inducing demand). A taxi serves, on average, a similar number of passengers as a private vehicle and thus requires as much road space as a private vehicle for a similar service, but does not require a parking space near a requested destination. Similarly, future autonomously driving vehicles do not require a parking space nearby a requested destination, because they can offload their passengers and then look for a cheap parking opportunity elsewhere if they do not continue cruising empty – but the latter can be controlled by dissuasive market mechanisms to avoid the undesirable impact on road space consumption. Furthermore, since autonomously driving vehicles will be electrically powered they presumably also expect a parking infrastructure with charging stations. At least for the next few decades, such infrastructure will be supplied only for a subset of urban parking spaces. Finally, autonomously driving vehicles might be operating similarly to other carsharing systems, which means that they have higher occupancy rates than private cars and thus lower parking time needs compared to private cars. Simulations (with certain assumptions: that all autonomous vehicles are shared but no rides are shared) showed 70 %-85 % reduction of parking space demand (Kondor et al., 2018), a variability that depends on passenger waiting time tolerances. Similarly, current carshare systems already contribute to reduced private car ownership, and thus, may indirectly reduce required parking space. Stated preference sur-

veys indicated that up to 20 % of car drivers are willing to give up their car for carsharing (Liao et al., 2020).

According to all these considerations, today's parking demand has potential for change in the future without significant impact on mobility and access.

But a vehicle does not need only one parking space. It occupies different parking spaces at different times, for example, one at home, one close to work, and at the supermarket. Some of these parking spaces are time-shared, but others are reserved (for example, the private garage). Since parking spaces are not occupied all the time – for example, the private garage tends to be empty during daytime – but a vehicle is, on average, parked 95 % of all time (Shoup, 2005). A vehicle needs, on average, more than a single parking space.

It has also been estimated that over time the parking of a vehicle takes up twice as much space than driving this vehicle (Meyer et al., 1965). This is partly due to the fact that it is not just the parking space that is taken over. Accessing the parking space – searching for a parking space, and maneuvering into a parking space – take space as well. These maneuvers, because of their lower speed, send significant waves through road traffic (Lighthill and Whitham, 1955). In addition, the temporal signature of parking demand impacts these space costs. Short-term parking, requiring frequent maneuvering in and out a parking space, impacts traffic and street use more than long-term parking.

This means the searching for parking space has to be included in the costs of parking. These costs are hidden costs because they are difficult to detect. For example, the point in time when a driver switches from goal-directed driving to cruising for parking can hardly be identified, among other reasons because people show very different strategies when searching for parking space (Krapivsky and Redner, 2019). This challenge alone makes it hard to estimate the search time of drivers for a parking space (Polak and Axhausen, 1990; Shoup, 2006; Belloche, 2015). However, Shoup reports cruising times between 3.5 and 14 minutes to find an on-street parking space in urban centers, and he estimates that vehicles cruising for parking contribute between 8 % and 74 % of the inner-urban traffic (Shoup, 2006). This number is significant not only with regard to road space use and contributions to congestion, but also with regard to the passengers' times, fuel costs, and emissions produced – all factors that are frequently not considered when comparing modes of traveling or the impact of free or cheap on-street parking (Belloche, 2015).

8.2 Supply for Parking

Looking into parking demand is one side of the coin, and is, as we have seen, already complicated enough. The other side of the coin is looking at parking space supply.

It is reported that in US cities about 30 %-60 % of the ground surface is used for roads and parking, reserving for each car about two off-street and two on-street parking spaces (Rodrigue et al., 2017). These numbers are justified by demand: currently 95 % of US households own a car, and 85 % of Americans commute by car (US Department of State[1]). Motorization rates and thus, the demand for road space is lower elsewhere. Compared to an average of 30 % of road surface in the car-reliant North American cities, Western European cities show 15 %-20 % use of road space, and cities in low and middle-income countries, about 10 % (Rodrigue et al., 2017). The city-state of Singapore, which has smarter policies on car usage, better public transport, and only inner-city traffic, still has 2.1 % of its precious surface reserved for parking spaces (Kondor et al., 2018). This way Singapore is deliberately keeping parking demand down.

Public on-street parking is only one response to the scarcity of inner-city parking spaces. The commercial sector adds parking spaces for one of two reasons. Where the scarcity in supply increases the willingness to pay, private infrastructure is provided for the direct benefit of parking fees. Alternatively, the private sector invests in parking spaces for indirect returns, for example by providing free parking at shopping centers. Private parking spaces are always provided off-street, in a large variety of forms: private parking spaces at homes, car parks, parking houses, or valet parking systems. The free or cheap public parking spaces are typically not managed, but in commercial parking spaces information technology is often deployed for guidance and coordination, and for optimizing space use. This optimization can include parking management strategies (Litman, 2008). Among the latter are pricing strategies, such that at times of high demand, higher fees should shift some of the demand to times when demand is low. Other competitive advantages can come from better service strategies that improve the usability of the dedicated parking space. For example, an improved design or increased capacity can improve a park-and-ride system and attract higher patronage. Similarly, intelligent guidance systems can improve the usability of a large parking house or a distributed parking infrastructure (Rizvi et al., 2019).

Drivers searching for parking – even if they tend to ignore some factors (see above) – will generally consider the costs involved in parking: the cruising, the parking fees, the time spent in managed parking facilities (cruising, walking, paying), and the travel time spent between parking space and trip destination. These costs for the individuals, some tangible (parking fees, consumption), some intangible (time, tear-and-wear, emissions), form a complex system for self-interest driven decision making on the choice of travel mode and parking choice. Neglected in this decision process (but not by public and private suppliers) are the costs involved in the provision of parking spaces, be it private investment in a garage, the provision of on-street parking spaces, or the commercial supply of

[1] `https://bit.ly/3lHKZSN` – US Government, 2010

managed parking. These costs are often recovered through internalizing externalities, for the public hand, for example by investing income from fuel taxes. Another common way for city councils to counter the tragedy of the commons is regulation, especially by:

- limiting parking periods;
- requesting parking permits for access of parking spaces;
- impacting demand by congestion taxes or other mechanisms to limit access to city areas;
- zoning codes requiring the private provision of parking spaces with construction and development.

8.3 Parking Space in the City

Parking is regulated by acts, rules and regulations set by countries, states, and cities. Accordingly the regulations vary largely across the globe. Parking is also at the intersection of a range of domains, such that related legislation can be found in domains such as road safety, housing, congestion levies, or land conservation. This variety is also an indicator that the act of parking can happen on public grounds, on private grounds, under the open sky, under trees or roofs, in parking houses, or garages. Obviously, any parking space must have access to a road, wherever located and however regulated. But not every space accessible from the road is permitted for parking.

When we use in this book the terminology of *on-street parking* and *off-street parking* then we distinguish not only the spatial configuration of a place used for parking a vehicle (i.e., on the street or off the street), but automatically also refer to the ownership of this place. Since road space is owned by the public, on-street parking is always happening on public grounds. Off-street parking, in contrast, can happen on public or on private grounds. On private grounds the owner sets access regulations, traffic regulations, and parking regulations.

Parking is typically restricted. Some of the restrictions are applicable generally (and thus, they are not signed), and others are applicable locally (and thus, signed). Generally applicable restrictions concern, for example, minimum distances from intersections or driveways, or allowing adequate space for vehicles to pass, or the prohibition of double parking. Locally applicable parking restrictions concern, for example, time limits, parking fees, and places – if parking bays are marked, parking is only allowed within the marks.

The definition of a parking space is relatively broad, though. A parking space is any space that is either currently *used* for parking a vehicle, or a space *set aside* for parking a vehicle. Correspondingly, a parking space does not need

to be marked out, and in many cases is not. Parking at the street curb, for example, is happening often on shared road space. Where a space is set aside for parking and has no markings, some standard size of a parking space (in the local regulations) determines the capacity of the parking space. In Victoria, this standard size is 25.2 sq/m.[2]

8.3.1 On-street Parking

On-street parking is a private use of public resources. The resource is provided either for free or for comparatively cheap parking fees, with its own challenges of inducing traffic (Shoup, 2005). The establishment and maintenance costs of on street parking space include land opportunity costs, capital costs, and operation and maintenance costs. Since these costs are 'common for all', public parking is susceptible to what economists call the tragedy of the commons (Hardin, 1968), referring to a behavior of individuals that depletes common resources by self-interest. In contrast to off-street parking, the (public) on-street parking cannot grow arbitrarily with demand because the road space in cities is limited. "[On-street] parking is not a right, but a privilege" (National Transport Development Policy Committee, 2012).

The prototypical form of a parking space is the marked out one. Marked out parking bays on streets comes typically in one of three forms: bays parallel to a curb, bays perpendicular to the curb – which produces more spaces per street length – or bays at an angle to the curb – which is easier to park into, i.e., requires less street space for maneuvering, but also allows narrower aisles. Only these individually marked parking bays allow for parking management: used for fees, tracked by parking sensors, and counted in parking guidance systems. The marking requires some standardized size of the space reserved for one vehicle, which depends on local regulations. In Germany, for example, the bays for parallel on-street parking (Figure 8.4) are 2 m wide and 5.70 m-6.70 m long, and the bays for angle on-street parking are wider (2.50 m) and shorter (5 m). However, regulations are lagging behind the actual size of vehicles, which is growing.

Figure 8.4: A vehicle parking in a marked on-street parking bay.

Space set out for parking can also be marked by a separating line between traffic and parking space (Figure 8.5), or may be taken in a more opportunistic way from shared road space (Figure 8.6).

In the latter two instances the number of available parking spaces remains

[2] https://www.legislation.vic.gov.au/in-force/acts/congestion-levy-act-2005/017

Figure 8.5: A vehicle parking on a marked on-street parking strip.

Figure 8.6: A vehicle parking at the curbside of the road, on shared road space.

undefined. The above mentioned standard sizes help to determine a theoretical capacity of a parking space, but this capacity may not be reached depending on where the first vehicles park and how that constrains the remaining spaces (Figure 8.7).

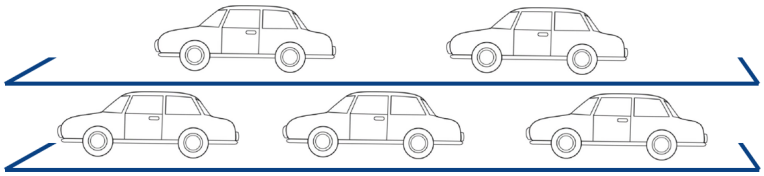

Figure 8.7: The number of vehicles that can be parked in unmarked parking spaces depends on other factors.

With our broad definition of a parking space – a space that is currently used for parking, or a space set aside for parking – the notion especially of the unmarked parking spaces becomes vague: A currently used space is not necessarily also set aside for parking. In countries with high parking pressure informal and illegal parking 'convert' street space or sidewalks temporarily into parking places. To what extent this behavior can be used to legalize and dedicate parking space where demand is high has been shown as well (My Thanh and Friedrich, 2017).

8.3.2 Off-street Parking

Large outdoor parking spaces, common at shopping malls for example (Figure 8.8), or at large business premises, are typically marked out in bays but rarely managed. They are also rarely the solution to inner-city parking pressures, where both, high demand and high real-estate prices, justify the erection of parking garages (Figure 8.9) or of automated vertical parking systems.

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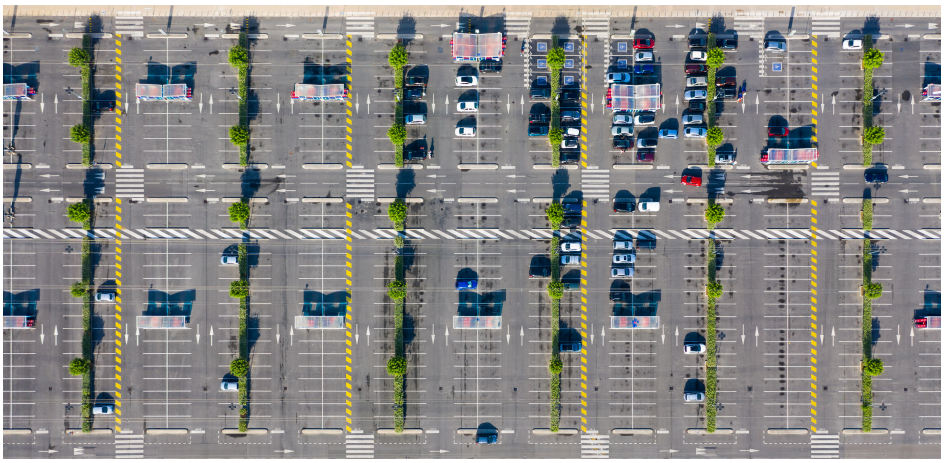

Figure 8.8: A private parking space at a shopping mall. Source: `https://bit.ly/3lWtRsZ` (© Benh Lieu Song 2019, CC BY-SA 2.0, modified).

rarely managed. They are also rarely the solution to inner-city parking pressures, where both, high demand and high real-estate prices, justify the erection of parking garages (Figure 8.9) or of automated vertical parking systems.

Figure 8.9: A private parking garage. Source: `https://bit.ly/3rfWMZX` (© Rachmaninoff 2016, CC BY-SA 4.0, modified).

Further private off-street parking concerns smaller parking lots of companies, and the parking in driveways or garages. Public off-street parking is bound to road-related spaces that are publicly accessible and dedicated to parking.

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