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The Multimodal Future of On-Street Parking

A Strategic Approach to Curbside Management

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Executive Summary – Curbside Management in the German Context

Germany has a long tradition of multimodal transportation planning. On the whole, the modal split in Germany reflects the use of diverse vehicles, with many Germans choosing between rail, bus, biking, and driving as appropriate to the specific needs of their trip. Shared mobility service companies have seen good market growth in Germany and the mobility as a service concept is becoming more popular. But the allocation of public curbside parking space between modes continues to be a barrier to integrated mobility approaches and ultimately the shift toward sustainable transportation modes and preparation for an autonomous vehicle future.

The vehicles and businesses competing for curbside access are currently advancing at a far faster pace than the policies governing curbside access. Curbside Management is a framework for understanding the conflicts and optimising for all the diverse needs. Without engaged municipalities, ready to find space for sustainable mobility options at the curb, private fossil-fuel powered cars will continue to have the advantage.

This report is divided in two chapters. The first highlights the latest developments in curbside management and makes the case for municipalities to invest in curbside management programs including incorporating spaces for today's newest mobility services. Many of these innovations are already being developed in Germany but need engaged municipalities to reach their full potential. The second chapter outlines a proposal for curbside policies that are broader and better equipped to incorporate any number of new vehicles or mobility services.

Given that most curbside management policies are centralised in the federal Road Traffic Regulations (StVO), this policy proposal is not readily implementable by local level government, as it would in some European Countries, the UK, or the US. Still, Germany is seeing a shift toward localisation of curbside management authority, starting with the new allowance for the Federal States to set the range of resident parking fees. As German cities further engage in curbside management discussions, the ideas presented here about incorporating all vehicles and all mobility business-models will be relevant, whether those policies are written at the municipal, state, or federal level.

Introducing Curbside Management

In the early part of the 20th century, the automobile took over Europe's streets and public squares, and the space at the side of the roadway where horses were hitched and carriages waited, became places for car parking. In the late 20th century, cities reclaimed some of that space for tree planting, outdoor dining, and other small social spaces. Now in the 21st century, cities face a new set of transportation options. The pace of mobility innovation today rivals the early 20th century when the bicycle and automobile were introduced, when roads were first paved, and the traffic signal was developed. The development of shared mobility services, data collection and analytic tools, and electric and autonomous vehicles are all part of this new mobility landscape.

The term 'curbside management' is starting to take on the meaning of a holistic approach to managing the space at the side of the roadway, the area where cars are typically parked. The unifying term is used to signify a focus on the space itself. The U.S. Institute for Transportation Engineers offers the following definition: "Curbside Management seeks to inventory, optimize, allocate, and manage curbspaces to maximize mobility and access for the wide variety of curb demands" (Institute of Transportation Engineers, 2018).

In transitioning from parking management to curbside management, planners and engineers are asked to consider the broadest range of roadway users and use cases: drivers, cyclists, delivery companies, transit operators, trash haulers, pedestrians, and many more. Furthermore, the presence of a transitional edge to the roadway is itself not always the best use of that space. Along many blocks, that space may be more useful as extended pedestrian space, tree planting, or as a bike or bus lane, without there being a dedicated transition area between vehicular space and walking space.

Determining when a curbside transitional zone is needed and then what mix of uses it should serve is a complex challenge in optimization, and one that will evolve based on vehicle types, travel patterns, and the needs of abutting properties. This position paper presents the latest trends in curbside management and a perspective on how the underlying policy documents that govern curbside space can be revised in simple terms to accommodate the breadth of potential uses and users.

1. Curbside Management – A Worthwhile Municipal Investment

The influx of new private mobility operators that do not fit 20th century categories has necessitated a renewed thinking about how curbside space is utilised. Curbside parking is a perennial problem for cities of all shapes and sizes, one often focused on the competing needs of different groups of automobile drivers. Curbside management widens the view to the full set of conflicting activities. As such, developing a municipal curbside management program requires a willingness to engage in broad collaboration among diverse local stakeholders and with new partners and find space for all these activities.

Curbside management is a growing topic of discussion both in Europe and North America, as cities try to find space for the newest uses of curbside space. The examples here are drawn primarily from the US, UK, and Germany. These discussions are playing out in other EU countries and globally, and the application of these same principles can be seen in cities across every populated continent. As more communities begin to consider investing in multimodal curbside management programs, they will be able to draw upon the experience of the pioneering initiatives describe here.

1.1 Curbside Management in Local Planning

Curbside Management Planning is starting to become a subtopic of Transportation Planning Offices and Transportation Plans. Transportation advocates and consultants are building up their capacity for curbside management and developing guidance documents for cities. The City of Toronto, Canada issued a Curbside Management Strategy in 2017 as an implementation step from their Congestion Management Plan (Toronto Transportation Services, 2017). In the United States, the City of Washington DC and the City of Seattle both have staff with curbside management in their titles to implement their communities' curbside management plans.[1]

In 2020, the Centre for London, a non-profit advocacy group, issued an extensive report entitled, Reclaim the kerb: the future of parking and kerbside management, with one of the stated goals of promoting a curbside management plans within all of the municipalities that make up Greater London. The Centre for London writes,

> "Parking can be viewed as a service to car-owning residents, and it is one that many Londoners rely on. However, almost half of London households do not own a car. Yet we all use our streets walk to the shops, visit our neighbours, and as public spaces to play, rest and socialise. This report argues for kerbside management to respond to the needs of all users and create a greener, healthier and more pleasant environment for the benefit of everyone"
> (Barrett, Wills, & Washington-Ihieme, 2020).

Curbside management planning takes place across several scales. The inch-by-inch optimization of a single block is where the majority of the work takes place, negotiating between the different uses of the physical space. Much of the guidance, innovation, and strategy development has focused on this

[1] Seattle's Curbside Management Team produces a detailed annual report. (Seattle Department of Transportation, 2020)

implementation level. The Curbside Management Practitioners Guide, from the U.S. Institute for Transportation Engineers describes a broad range of treatments that can be applied to improve the functionality of curbside spaces as well as a recommended process to select appropriate implementation tools (Institute of Transportation Engineers, 2018).

Then there are corridor and district-wide planning efforts. San Francisco's SFpark program is one of the early examples of this level of curbside management planning. In the SFpark program, parking space regulations were digitized and turned into a dynamic pricing system with prices adjusting to meet an availability target: 20-40 % of parking spaces open at any given time (San Francisco Municipal Transportation Agency, 2014). Companies like Coord in the United States have sprung up to help cities inventory and reallocate curb space on the district scale. Coord is now working with 15 North American cities to collect, analyse, and rethink curbside information at the districtwide and citywide level, with district pricing schemes like SFpark as one of the products they offer (Coord, 2020).

Real-time availibility for parking spaces in SF

@SFpark #app #utility by sdufaux, licensed with CC BY-NC-ND 2.0

The SFpark dynamic pricing program was an early district level curbside management program. Users could use the app to find available parking and the parking rules.

In May 2020, Coord also launched the Curb Index, a set of indicators that look at how well a block is served in terms of access for people, access for commerce, and access to curbside amenities (Coord, 2020). Using a digitized inventory of curb uses across a district, the curb index offer a snapshot of which blocks have the strongest access for businesses versus individuals versus communal space, that can help planners check to see if the curb uses on the ground are aligning with their expectations for a particular area.

Finally, there is the policy level, at which curbside management planning is considering the regulatory hurdles to make changes to curb uses. Depending on the country, curbside policy decisions may be made at the national, regional, and/or municipal levels. Curbside Management planning in Germany right now includes a discussion of which competencies should be assigned at each level of the federal system. As of October 2020, the federal states in Germany will be allowed to set their own ranges for resident parking fees, a major step toward local control (Bauer & Bracher, 2020). Chapter two of this paper engages at the policy level, aiming to find a common starting point in curbside management policy documents from which the broad diversity of uses can be accommodated.

1.2 Mobility Hubs – Spaces for Shared Mobility

Mobility Hubs are a way of integrating shared mobility services into curbside management. These intermodal stations are well-marked points where the public can access a range of public and shared mobility services. The Mobility Hub concept is growing strongly in Europe, with EU research support for pilot projects in range of locations – city centres, newly built residential districts, at transit stations, etc. Mobility Hubs are not always curbside, but curbside mobility hubs tend to be particularly visible, which translates into use.

The City of Bremen, Germany is an early leader in the development of curbside mobility hubs. Bremen began with building their mobil.punkte (mobility points) out of public parking lots, contracting with carshare providers to offer cars and larger cargo-vans for rent from central locations around the city centre starting in 2003. The idea of the mobil.pünktchen (little mobility points) came later as a way of getting station-based carsharing deeper into residential neighbourhoods. A 2018 study confirmed that "the proximity of the car/sharing stations to the users' residences is of decisive importance" to the successful growth of car-sharing use in Bremen (Team Red, 2018).

A typical Bremen curbside mobility hub has 2-3 carshare parking spaces and a few public bike racks. Bremen is not worried about offering all possible vehicles at a mobility station, but rather tailoring the stations to each location. As such, each implementation is combined with urban design interventions to improve walking, cycling, and driving manoeuvring around the station. The fire department is involved in ensuring that these installations are used to improve emergency vehicle access through Bremen's typical tight intersections as well. As of 2018, Bremen had 27 mobility hubs in public space, and the number increases annually, with the neighbourhood councils often pushing for system expansion faster than the mobility providers can expand service (Cambio of Bremen, personal interview, 2020), (City of Bremen, personal interview, 2020).

A mobil.pünktchen, or little mobility point, in one of Bremen's residential neighbourhoods.

Munich, Germany is also working on curbside mobility hubs. Munich has 15 stations as of 2020, with a variety of models. In the newly constructed district of Domagkpark, two curbside mobility hubs were found successful. The Domagkpark curbside station model includes:

- At least one space for station-based carshare
- Six to nine spaces for free-floating carshare
- 2 charging stations for private electric car charging

In total 18 parking spaces were converted into the two curbside mobility stations, and from the project team's experience they would aim to keep future stations to no more than 12 parking spaces in length (City of Munich, personal interview, 2020).

Curbside mobility hubs are also beginning to focus on shared micromobility. Berlin, Germany developed a model curbside rental e-scooter parking station. These stations are currently much simpler than the carshare based mobility hubs, designated with a simple black and white e-scooter sign, pavement markings, and safety posts. As a result, they are not yet the default parking place for shared e-scooters, the way mobility hubs either are the only available parking place for carshare or are highly encouraged. The car-share based mobility hubs have large signs and sometimes interactive displays to get the public's attention. In comparison, the e-scooter stations will often have parked scooters just a few meters away from the station limits.

Parking space
Bergmannstraße

This parking space dedicated to rental e-scooters and bikes on Bergmannstraße was the first of its kind in Berlin in June 2020.

1.3 Pick-up/Drop-off Zones – Spaces for On-Demand Mobility

Pick-up/Drop-off Zones are the curbside access answer to today's ride-hailing and tomorrow's autonomous vehicles. A pick-up/drop-off zone is much like a bus stop but for smaller vehicles. The vehicle can only stop for a few minutes while passengers enter or exit the vehicle. The only physical infrastructure needed for a pick-up/drop-off zone are signs at either end, but the placement of the zone can affect its operational efficiency. Parallel parking takes much more time than the vehicle needs to be at the curb, and so it is best to provide space for the vehicles to navigate into and out of the curbside space. Since these navigable spaces are longer than the space needed at the curb, placing a pick-up/drop-off zone at a corner is much more efficient (Institute of Transportation Engineers, 2018).

The International Transport Forum (ITF) issued an extensive research report on the future need for pick-up/drop-off zones entitled, The Shared-Use City: Managing the Curb. Their work included a traffic microsimulation model looked at the challenges posed by a scenario in which a downtown sees a major transition from 'driving and parking' to 'ride-hailing and drop-off'. This modelling effort is useful now to understanding the implications of current ride-hailing services like Uber and ride-pooling services like CleverShuttle, as well as a future uptake of autonomous vehicles.

Pick-up/Drop-off Zones create space for ride-pooling services like Clever Shuttle to load passengers.

CleverShuttle, Hamburg by Matti Blume, licensed under CC BY-SA 4.0

Taking Lisbon as a model, ITF estimated the impacts of a 10 %, 20 %, and a 50 % market shift to ride-hailing like services. In their first scenario, 'street release', all passengers enter and exit the vehicle from the travel lane, with traffic queuing behind or going around. This represents an extreme scenario, where every ride begins and ends with double-parking. In their second scenario, 'curb release', 3 % of parking spaces in central Lisbon are converted from car parking to pick-up/drop-off zones, distributed throughout the downtown, and no double-parked passenger pick-up/drop-off occurs. In comparing the two models, some of the valuable findings include:

- Curb access reduces vehicle delay for both the ride-hail vehicles and general surrounding traffic as compared to the in-lane/double-parking scenario
- A well-designed and well-located downtown pick-up/drop-off zone can process up to 95 vehicles per hour
- In their model, less than 5 % of the access zones processed more than 50 % of the demand, suggesting pricing could be used to distribute

demand to less active access points nearby (OECD International Transport Forum, 2018)

The model introduces the idea that a city could initiate a network of pick-up/drop-off zones that are given the same differential pricing management seen in parking management programs like SFpark to balance traffic to these locations.

The finding that pricing could still play an important traffic management role in a future with pick-up/drop-off, is welcome news, as many cities currently rely upon parking revenue to fund transportation projects and general municipal operations. There are technical hurdles to overcome to make payment collection for pick-up/drop-off zones practical for all vehicles, but such systems are already in development. Minute-by-minute payment is possible with the use of on-vehicle or in-road sensors. The UK firm AppyWay has developed and deployed a sensor-based system in Harrogate in North Yorkshire, that has allowed drivers to pay only for the time they use the space. The average stay is now 1 hour, 10 minutes, just a little beyond the former 1 hour parking limit down to the minute, and 43 % of Harrogate users say they stay longer as a result of not having to worry about getting a parking ticket (AppyWay, 2020) (AppyWay, personal interview, 2020). On vehicle pay-by-minute technology is being utilized for delivery vehicle fleets to access dynamic loading zones described in the next section. With such operational improvements it will be possible to shift to a pay-for-access system, no matter if that access is hourly parking as is today's custom or the 3- to 5-minute pick-up/drop-off activity expected in the future.

1.4 Dynamic or Smart Curb Zones – Spaces for Flexible Uses

One of the most challenging and interesting aspects of curbside management is that it is temporal as well as spatial. Rules of curbside use routinely change depending on the time of the day. In business districts it is not uncommon for a space to be used for commercial loading hours in the early morning, paid hourly parking during the day, and free overnight parking starting in the late evening. Driver confusion is typical, if not expected when the signs at the space convey all the possible options depending on the time.

The idea of a dynamic curbside zone is that the rules for the space are specifically not published in the physical environment, but instead are published digitally and changed to optimize use of the space. The technology to put these spaces into operation is still very much in development and the pilot programs depend upon city partners willing to test technology in public streets.

Such pilot projects need to work through several challenges, including how to support those who do not have smart phones or in-vehicle navigation tools and what tools for network connectivity are needed to operate such a system at scale. One such challenge is how to gather and present parking space availability in real-time. The Berlin start-up Bliq is developing a tool that gathers real-time parking space availability from dashboard cameras and still complies with Germany's strict data-privacy standards (Bliq, personal interview, 2020). Success of such a tool could eliminate the need for in-street occupancy sensors, a barrier to widespread smart zone implementation especially in snowy places.

The easiest deployment of dynamic curbside zones has been in loading zones for delivery vehicles. Delivery fleets are already using GPS tracking within

their operations and connecting the dynamic parking regulations into a corporate entity's navigation system is much easier in test phases than convincing individual drivers to use a new navigation tool.

Parkunload, an EU funded project to develop the technology platform for dynamically regulated loading zones, launched in 2019 and is in pilot implementation in Dublin, Ireland. Delivery companies in Dublin can outfit their trucks with the Parkunload Smart Parking Button, which pair to the Parkunload app in the drivers' smartphone, allowing one click payment of minute-by-minute parking fees in the smart loading zones. The app further tells drivers about open loading zones to help drivers save time searching for a place to park and reducing the risk of double parking (Parkunload, 2020). The City of Dublin sees a great deal of potential in the pilot so far; Colm Ennis, Dublin City Council SBIR Project Manager has stated:

> "this solution has a lot of potential because it enables cities to manage both digital parking permit maximum parking time in the smart zones depending on several criteria, such as: vehicle emissions, vehicle type and tonnage and driver's profile, accurate location and time of the day" (Smart Dublin, 2019).

Several US cities are experimenting with reservable curbside loading zones. Washington DC has been working with the start-up firm CurbFlow. In 2019, Curb Flow created nine temporary reservable loading zones in a business area of the city. That 3-month long pilot registered a 64 % drop in double parking in the area where the loading zones were placed. A new pilot in 2020 has focused on restaurants and drivers for food delivery companies. Cameras are used in the 2020 study to track the occupancy of the smart loading zones, enhancing the real-time information that drivers can use to ensure a quick turnaround when coming to a restaurant to pick up an order (Aratani, 2020).

Washington DC has used signs like these at their 2019 and 2020 pilot reservable loading zones for delivery vehicles.

CurbFlow test zone, Barracks Row by Mike Licht, NotionsCapital.com is licensed with CC BY 2.0.

These technologies are so far focused on business operations. Package and food delivery companies recognize the importance of reliable curb access because the lack of it has been costly. UPS received 51,000 parking tickets in Boston, USA between 2016 and 2019, each with a price of $15 to $120, which translates to a minimum of about $200,000 in fines each year (Dungca, et al.,

2019). Easily located loading zones that can be navigated into and out of quickly also reduce the time needed for each delivery, increasing the number of deliveries a driver can conduct in each shift.

1.5 The Outlook for Municipalities

These additions to the curbside management toolkit demonstrate that demand for curbside space is strong. The curbside management innovations mentioned in the previous sections are driven in large part by investments from the mobility technology sector with partnerships in municipal government, but engaged municipalities are critical to scaling up not only the newly developed management tools, but also new vehicles and mobility businesses.

Enforcement is essential for these new curbside access spaces to function properly, especially as they scale, and curbside enforcement is a service provided almost universally by municipalities. Enforcement agencies will need new tools, training, and funding to keep up with the continued diversification of curbside activity. Some European countries are advancing the operations of curbside enforcement faster than others. In the Netherlands officers now conduct digital scans to check vehicle permits, seeing an increase from 70 vehicles checked per hour to 1250 with the new technology (ITS International, 2016). Penalties for parking in the wrong location in Switzerland and the Netherlands are now above €100 per offence (€113 and €140 respectively). In comparison the price of a parking ticket in Germany has been just €30. In 2020 the fine was raised to €70, with the hopes of inducing better parking behaviour (Agora Verkehrswende, 2020). In addition to addressing all of the current challenges in curbside enforcement, new conventions will be needed to ensure officers have the capacity to address parking offences when those are occurring in minute-by-minute increments or do not involve a driver.

Digital curbside enforcement vehicle

Several Dutch cities now use digital curbside enforcement vehicles like the one shown here.

2017 Opel Ampera-e 'Parkeercontrole' by harry_nl, licensed under CC BY-NC-SA 2.0

Municipal governments today are operating one or two steps behind the private sector and are largely put in a reactive position when it comes to accepting mobility innovation onto public streets and at the curbside. Mobility hubs are a response to the development of shared mobility service

business models. Pick-up/drop-off zones are a response to the development of ride-hailing and ride-pooling business. E-scooters and cargo-bikes are prompting new designs for micro-vehicle spaces that are different than the standard bike rack. The new demands are challenging to keep up with, as these technologies and service models are evolving quickly.

The value of curbside management is broadly recognized within the business world, if not yet within the municipal sector. Some of these technological improvements in curbside management, especially smart loading zones, have resulted in private sector companies having more accurate data about the curbs than cities themselves. Both the UK's AppyWay and Germany's Bliq, are working on curbside mapping technologies and finding that the customer market is currently stronger among delivery companies than cities, despite the fact that the information collected is about a public resource that municipal governments manage (AppyWay, personal interview, 2020), (Bliq, personal interview, 2020).

2. Building a Future-Proofed Policy Basis

While the latest developments in curbside management are all direct reactions to current trends in private sector mobility service, there is still a broad range of unknowns about how the mobility future will look. This chapter outlines a strategy for introducing municipal curbside policies that are flexible enough to incorporate any innovation at the curb.

One of the first challenges to contend with is that there simply is a lack of terminology to connect across the diversity of stopped vehicles on public roads. In English, German, and French, the verb 'to park' and the noun 'parking' are used exclusively to refer to stationary cars. The term 'curbside management' is starting to signify a focus on the space itself, not just parking, but there is still a limited vocabulary to refer to how vehicles use that space.

The City of Seattle introduced a set of zoned priorities for the 'flex zone,' as they have called the curbside. The system is an attempt to grapple with how much the needs at the curb relate to the surrounding land use context. Places to stop a vehicle are divided into a few different categories in this scheme, with bike parking, bus stops, taxi zones, passenger loading, and short-term parking all listed under 'access for people', loading zones listed under 'access for commerce', food truck parking listed under 'activation', and long-term parking and reserved parking spaces listed under 'storage' (City of Seattle, Washington).

	Residential	Commercial & Mixed Use	Industrial
1	Support for Modal Plan Priorities	Support for Modal Plan Priorities	Support for Modal Plan Priorities
2	Access for People	Access for Commerce	Access for Commerce
3	Access for Commerce	Access for People	Access for People
4	Greening	Activation	Storage
5	Storage	Greening	Activation
6	Activation	Storage	Greening

Source: own diagram.

As much as this system is a substantial step forward, it still falls into the same conventions that have dominated parking policies for decades – areas for

cars are organised by the needs of the drivers, while all other vehicles are treated as singular categories. The diversity of parking activity drivers engage in exists for cyclists, scooter users, and other vehicles as well. The generic term to 'lock up' these vehicles is used no matter what type of stopping or parking behaviour is observed. These smaller vehicles engage in short-term parking, long-term parking, overnight parking, loading, and passenger drop-off just like larger motor vehicles because these terms explain link between the vehicle and the mobility of the person using that vehicle.

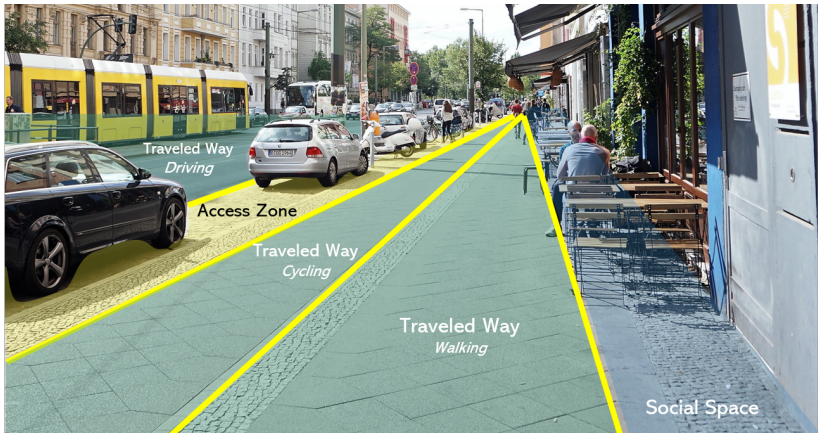
At the simplest level, all vehicles must stop in order for them to be useful. If a person gets on a bus and it goes in a circle, returning to the same spot, it is called a tour, because the rider was able to see other areas of the city but not access them. Vehicle access is a critical component to urban mobility; without this access people would be limited to where their feet can carry them.

Stopping a vehicle is necessary for that vehicle to provide human mobility.

Curbs came into existence as a means of channelling water out of the street but have come to signify the division between vehicular space and walking space. As such curbside access has come to mean the dynamic zone in which the transition in and out of vehicles occurs and where vehicles are stored while their operators continue on foot. It is for this reason that curbside management becomes an appropriate term to capture the diversity of activity happening in that space.

The term recommended here to describe this portion of the roadway is the 'access zone'. As the subsequent sections will clarify, what differentiates parking activities across all types of vehicle and all mobility businesses is the amount of space and the length of time they need at the curb to have meaningful access. What is nice about the idea of an access zone, is that it is applicable across all vehicles and can be used to bring the multimodal approaches seen in transportation planning at large to the curbside.

The access zone can also include both sides of the curb, encompassing not just the roadside access areas but the vehicle parking and loading areas integrated into pedestrian space, such as bike racks, bus stops. This portion of the sidewalk is sometimes called the furnishing zone in English, with the furniture there associated with the transition in and out of a vehicle or associated with public social space. The access zone is a broad enough term to encompass those activities associated with vehicles, allowing other social space to be designated as such. A graphic on the next page demonstrates the zoning of a street cross-section.



On the Berlin street above, the Access Zone includes areas for car parking, paved in cobblestone at the same level as the driving lanes, and raised areas for bicycle and motorcycle parking. In this instance all social space is on the building side of the sidewalk. In other cases, like the photo below from Düsseldorf, a portion of the access zone was converted to social space.

© Rachel Nadkarni

2.1 Current Types of Curbside Access

As discussed, the curbside, or access zone, has a wide range of uses. Under current policies, vehicular access to the curb are broadly divided in two ways:

- Differentiation by vehicle operability – used to distinguish variations in private car parking
- Differentiation by mode and use case – used to designate space for vehicles other than private cars

This presents a particular challenge in a future scenario where autonomous vehicles will operate alongside human-operated vehicles, because autonomous vehicles are always mobile whether or not the occupant is present and there is no guarantee that autonomous vehicles will fit into the car category; both cargo-specific delivery vehicles and autonomous dumpsters, that transport themselves to the waste management centre are in development.[2] Since neither innovation is analogous to a passenger vehicle, their ability to use existing curb access spaces is unclear in today's systems.

2.1.1 Types of Curb Access for Private Cars

Space for private cars is divided into a broad range of regulations, often with multiple regulations for the same space depending on the time of day. Broadly, curbside access for private cars is divided into the following range of activities, here presented with American-English terminology:

[2] Nuro, grocery delivery vehicles are being tested in Houston, Texas and Ursa Robotics recently exhibited a prototype autonomous dumpster at the Berlin GreenTech festival. (Nuro), (GreenTech Festival)

Types of Curb Access for Private Cars

Access Type	Activity Description	Private Car Example
Parking	Vehicle is left unattended and immovable	Engine off, locked, driver leaves to go shopping
Stopping	Vehicle is left unattended, but movable	Lights flashing, engine running, double parking, driver goes briefly to shop
Live Parking	Vehicle is stopped, and the occupant is present	Driver waits in the vehicle while a passenger attends to an errand
Loading	Vehicle is stopped, operator is present, and access is allowed while goods are being loaded into or out of the vehicle	Driver stops to move a piece of furniture or unload groceries
Standing or Pick-up/ Drop-off	Vehicle is stopped, operator is present, and access is allowed while passengers are getting into or out of the vehicle	Driver waits to pick up a child from school
Valet	Vehicle is stopped, attended by one other than the operator	Driver uses a valet parking service at a cultural venue or restaurant

Source: own diagram.

2.1.2 Other Types of Curb Access

There are many other curbside access points that are designated for modes other than privately-owned cars. These activities are generally named by the specific vehicle that the space serves or the specific use case, but the actual access types overlap with those defined for private cars.

Other Types of Curb Access

Access Type	Activity Description	Equivalent Car Access Type
Bus Stop	Vehicle is stopped, operator is present, while passengers get on and off	Standing or Pick-Up/Drop-off
Bicycle Parking	Vehicle is left unattended and immovable	Parking
Bicycle Rental Station	Vehicle is left unattended and immovable	Parking
Commercial Loading Zone	Vehicle is stopped, operator is present, while goods are being loaded into or out of the vehicle	Loading
Taxi Stand	Vehicle is stopped, and the occupant is present	Live Parking
Electric Vehicle Charging	Vehicle is left unattended and immovable	Parking
Carshare Station	Vehicle is left unattended and immovable	Parking
E-Scooter Rental Station	Vehicle is left unattended and immovable	Parking
Ride-hailing Space	Vehicle is stopped, while passengers get in or out of the vehicle	Standing or Pick-up/Drop-off

Source: own diagram.

Such mode-based and business-specific distinctions work when the vehicles are clearly distinct. It is easy enough to understand that a bicycle parks at a bicycle rack and a brightly labelled taxi 'live-parks' at a taxi stand. However,

these distinctions are already beginning to break down and are expected to be further challenged in the years to come because the forms of vehicles are changing, and the business models used to provide mobility are changing as well.

The Berlkönig

The Berlkönig is an on-demand ride-pooling service from the BVG, Berlin's public transport operator.

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Consider, for instance, the pilot public transport projects in Berlin, Germany, and the ability of these new vehicles to utilize bus stop spaces. First there is the Berlkönig on-demand shuttle service operated in partnership with ViaVan. Second, is the See Meile autonomous shuttle pilot operated along a 1.2 km circuit between the Alt-Tegel subway station and Lake Tegel. The question of whether these vehicles should have access to standard bus stops for loading and unloading passengers is ultimately complex. Do the new vehicles automatically have access to bus stops because they are providing public transport? Are the new vehicles prohibited from using that space because they are vans or autonomous shuttles and not a bus? Should the on-demand vans be prevented from using that space at certain times because they could disrupt the scheduled services? Does the speed of the loading matter: the van has individual seats like a car, but the autonomous vehicle is a walk-on vehicle with the same doors as the bus?

See Meile autonomous vehicle

The See Meile autonomous vehicles operated at 15 kmph on a loop from Lake Tegel to the nearest subway station in Berlin.

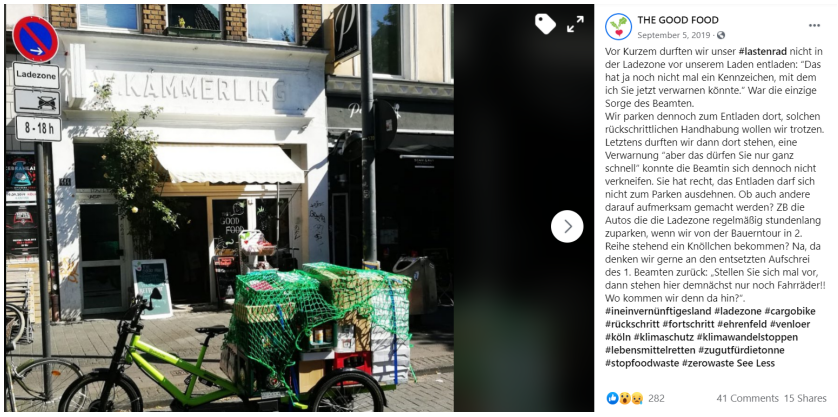
© Martina Hertel

These questions point to the lack of a rationale behind most curbside access standards. Simply saying this space is for a bus to use and this other space is for cars, or this space is for vehicles owned by companies and this space is for vehicles owned by individuals leaves a lot of questions when confronted with the diversity of mobility innovation occurring today. One must consider the limits of seemingly simple definitions – like what defines a bus vs. a car vs. a van, and what defines a corporate vehicle from a private vehicle.

2.1.3 Illustrating the Challenge – The Good Food, Cologne

A good example of how this disconnect across policies plays out today is found in the story of the Good Food, a carbon neutral grocer in the City of Cologne, Germany (The Good Food, personal interview, 2020). The Good Food, working through government incentives purchased a e-cargo-bicycle capable of carrying 300 kg at a time, in order to eliminate greenhouse gas emissions from their trips between the wholesaler and their store. Their store is situated on a street with somewhat narrow sidewalks, and between two restaurants, each with outdoor dining tables. As such, there was little sidewalk space available on which to pull the bike to the side during loading. The company then worked with the City to establish a loading zone directly in front of their business. However, when seen loading or unloading goods from their bike parked in the loading zone, they routinely have faced conflict with the parking control officers, precisely because their bike is in the loading zone and not on the sidewalk.

The Good Food shared their story on social media



The Good Food shared their story about their cargo-bike not being allowed to use the loading zone in front of their store on social media.

© The Good Food

This is a simple conflict in the writing of the traffic regulations. At its base, the loading zone is defined by the use case it is intended to serve – loading/unloading goods, but it also included an assumption that the vehicles used for this purpose would fall into the 'motor vehicle' category. Despite the fact that the Good Food was operating within the intended purpose and even had a vehicle with a motor, officially, they were not allowed to operate in that space because the e-cargo-bike did not meet all the criteria associated with the motor vehicle designation: weight, size, speed, engine class.

The company and the City of Cologne have found a solution in the April 2020 update to the national traffic regulations. The update included a new 'cargo-bikes allowed' sign and the City is now in the process of installing those signs at loading zones to remove this barrier.

2.2 Innovation, Parking, and the Limitations of Definitions

If one examines the current definitions used to distinguish between vehicles and mobility services strictly in the context of how those definitions affect parking and curb access, the lines between definitions begin to seem arbitrary. Certainly, the classification by vehicle weight or engine size and speed are logical when considering how these vehicles travel through public streets, but when they are stationary, those distinctions matter very little. The same can be said for the distinction between a privately owned car and a car that has been rented.

2.2.1 Parking and Vehicle Definitions

It is typical in many parts of the world for parking areas to be divided between different types of vehicles. That said, many parking regulations have an assumed vehicle in mind: a privately-owned, four-wheel, petroleum-powered, car. In Berlin, it has been estimated that there are 23 times as many car parking spaces as bicycle parking spaces.[3] At the same time, just under 50 % of Berliners have cars at home, while 75 % of Berlin households own bikes (Nobis & Kuhnimhof, 2018).

In German law, the baseline rationale for dividing vehicles into those that park in the street and those that park up on the sidewalk appears to be pedestrian safety. Vehicles that park on the street edge of the curb are those that due to a combination of weight and potential speed, are riskier to be operating in the same space as pedestrians. In contrast, those vehicles that can be pushed along the sidewalk (schieben) are required to park on the sidewalk unless in otherwise designated areas: bicycles, mopeds, and motorcycles included (Schurig, 2015).

In a context with narrow sidewalks, as is the case in many historic city centres, placing a vehicle like a moped on the sidewalk is very likely to block the route of someone using a wheelchair, be a tripping hazard for someone with a visual impairment, and disrupt the flow of any group walking together. Even though the moped can safely navigate into parking on the sidewalk, it could still be a serious disruption or safety hazard for other people. Despite have a similar impact to mobility as double-parking, blocking the sidewalk is rarely taken as seriously as double parking, fines for doing so are lower, and there is often less enforcement.

[3] Ratio calculated from data collected by the Moovel Lab and displayed at the Berlin Futurium. (Szell & Bogner, 2020)

Despite the sign this vehicle parked fully on the sidewalk

Despite the sign clearly indicating that parking on the sidewalk is prohibited, this vehicle parked fully on the sidewalk forcing passing pedestrians to move single file through the narrow gap between the car and the building or to walk in the street.

The lack of regulatory flexibility to place all parked vehicles in the street also poses a serious challenge to the development of new vehicle types. This has been playing out across the world in the last few years with debates over space for e-scooters. In the Netherlands, the conflict is around so-called microcars – initially introduced as electric scooters for those with disabilities, and now popularized as a daily vehicle for families (Not Just Bikes, 2020). The popular Italian Biro brand vehicle, is electric, carries two-people and a small amount of cargo, but is just 1.03 m wide and 1.84 m long (Birò, 2020). That is 40 % narrower and almost 60 % shorter than a VW Golf (Automobile-dimension.com, 2020). Two of these microcars easily fit in a standard car parking space if turned lengthwise, but if pulled in head-first, three would comfortably fit. In Amsterdam, these vehicles are now being given cheaper access to car parking spaces because they are so much more sustainable, and the city is starting to create designated small parking spaces (Not Just Bikes, 2020).

The breadth of vehicles within the existing classifications is also important when considering where parking should occur. The spaces at the corners of intersections that are kept clear to maintain sight-distances are prime candidates right now for bicycle or small electric vehicle parking. This works if these vehicles are always spindly like current e-scooter models because their form allows sightlines through to the traffic beyond. But a row of roofed electric mobility scooters like the assistive device pictured below would be problematic in the same spot, despite generally meeting the criteria for a small electric vehicle like the stand-on e-scooter.

Enclosed seated scooter

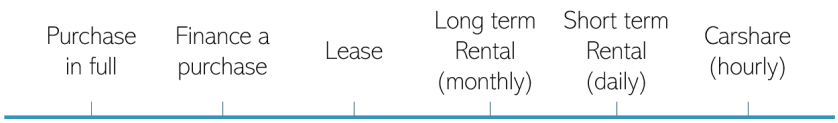
This enclosed seated scooter has all the exterior features of a car but surrounds a single seat inside with extremely limited cargo space.

Interesting fully enclosed mobility scooter by keith_and_kasia, licensed with CC BY SA 2.0

The continued diversification of the vehicle market necessitates a more rigorous debate about what differentiates vehicles for the purpose of designating parking areas and locations. There are many features of future vehicle development that are unknown. Thinking about what vehicles will be used in 10 years, the presence of seats, mirrors, steering wheels, roofs are all uncertain, as is the size, power, and power source of next generation engines. As such none of those features should be utilized to define which vehicles park where.

2.2.2 Parking and Ownership Definitions

The future of vehicle ownership is another open question. There is a continuum from purchasing a vehicle 'in full' to financing it over a few years to leasing to renting to carshare, rented by the hour.



Source: own diagram.

Resident parking permits are a prime example where the definition of a personally owned car creates a relatively arbitrary limit on mobility options. In Germany, the US, and the UK, it is typical that a residential parking permit is only granted when the car is registered at the resident's address (City of Boston, 2020), (The Royal Borough of Kensington and Chelsea, 2020), (City of Stuttgart, n.d.). Registration requires proof of 'ownership' or 'primary use' which can generally only be granted if a vehicle is purchased outright, financed, or leased. Because drivers who do not make that commitment are then prevented from using the resident only parking spaces in their

neighbourhood, there is an incentive to commit to a car long-term even if a resident might only want a car for a few days, weeks, or months. Having a car at home translates into more driving, so the resident parking policy incentivises the exact opposite behaviour that most cities desire – more traffic, more pollution, and more carbon emissions. Some cities have counteracted this incentive through programs allowing carshare vehicles to park in residential districts, and a few cities have specific exceptions (Frankfurt allows borrowing cars from immediate family, Berlin allows rental cars with an additional forms), but still the general long-term commitment requirement remains for vehicles on the private market (City of Frankfurt am Main), (City of Berlin).

Testing the limits of resident parking policies is also the issue of providing equal mobility and access to non-car owners. Large portions of urban populations live without cars. Across Germany's largest cities, 42 % of households live car-free (Nobis & Kuhnimhof, 2018). Only 40 % of residents in inner London boroughs own a car and 66 % of those cars are parked on streets (Barrett, Wills, & Washington-Ihieme, 2020).

Now at least some of London's majority non-car owners have a way of utilising curbside resident parking spaces too. Greater London, following Rotterdam's example, has taken steps to incorporate cyclists into resident parking programs. Several of the Boroughs in Greater London now offer residents the option to rent space in a curbside bike hangar in their neighbourhood. The program is immensely popular, especially after the Corona Crisis. There were 35,000 on waitlists for space in these hangars across Greater London in July 2020 (Almendros, 2020).

Bike hangar in Vauxhall

These units provide 12 covered and secured resident bike parking spaces in the space of a car parking space.

The costs of getting a space in a bike hangar are however not on par with those of getting a car parking permit. Access to a resident bike space is £30–£40 per bike per year, and with twelve bikes in a standard car parking space, the space then generates at least £360. Meanwhile, the cost to residents for a 1-year car parking permit is £51–£230 in the inner boroughs. Since the costs to maintain a parking space in central London is estimated at £336 per year, the bicycle-owning residents are more or less fully covering costs while the car-owning residents' access that space at a subsidised rate (Barrett, Wills, & Washington-Ihieme, 2020).

As more diverse vehicles become available, cities should consider how they will explain why some residents have access to that space for storage of their personal property and others do not. In order to be confident that the rationale is based in a fair service provision to residents, it is helpful to think about the limits defining which vehicles are allowed to access resident zones, which are not, and why not. Curbside resident parking takes that space out of public use. Space that could be used for wider lanes for pedestrians, cyclists, or drivers, or space for adding trees and social space to a neighbourhood street. If it the intent is to provide special allowances to residents, then permits could be tied to the resident's identifying information rather than the vehicle's, so a resident could occupy that space with any private activity (including a barbeque or a storage box). If the intent is to provide for only private mobility options, then some form of mobility criteria should be met.

The table below offers a conceit – what criteria are essential for a device to be considered as a private mobility vehicle worthy of a resident curbside access permit. This exercise is meant to challenge conventions, because those conventions may not be present in the future.

Resident Parking Criteria – A Conceit

Criteria	Challenge	Discussion
Wheels		Wheels are logical since a vehicle should expand the resident's mobility, but maybe an exemption should be granted for a storage container or dumpster deployed by a company is providing a mobility assist during a move or construction. Furthermore, what if hover technology ultimately develops to be a more sustainable option.
Engine		An engine expands a vehicle's range, but selecting sustainable minimum criteria is difficult. Then there are vehicles like the pictured baby stroller, that may be important mobility assists for families with multiple young children, and impossible to place in an apartment.
Routine Use		In Germany, cars spend an average of 23 hours parked, 20 of those at home. On weekends, 75 % of cars are never moved (Nobis & Kuhnimhof, 2018). In Berlin, there is no requirement to routinely move the vehicle for street cleaning. Without that, is there any way to check that vehicles are in working order and actually in use?
Theft Prevention		Once locked, a car is relatively difficult to steal, and the same cannot yet be said for all vehicles. Should theft prevention be the reason to limit where a vehicle is allowed to park if an owner is willing to take the risk? Should locking posts be available for larger vehicles too?

Criteria	Challenge	Discussion
Licensing and Registration at the Address		A license plate provides authorities a way of quickly tracking each unique vehicle, when so many look alike, and the registration ties a vehicle to a legally responsible entity. This system was applied to e-scooters in Germany in 2019, including privately owned e-scooters. If a resident received a license and registration for one of vehicles shown here, could they park in a resident zone? Could a parking permit directly address the identification and responsibility questions for vehicles that do not require an operators' license?

Photos: Colonel Mike Farrell rides a hovercraft" by USACE HQ; KinderVan, along Sinatra Drive, Hoboken, New Jersey, by John Wisniewski; Covered car suburbs, by Allan Rostron – all licensed at Creativecommons.org. Final two photos by Rachel Nadkarni

2.2.3 Access to Space and Time

There is just one, remarkably simple fact about parking that is consistent across all possible mobility futures: every vehicle will need access to the curb, and they will use a visible amount of space for an observable amount of time. Focusing on the observable characteristics of parking behaviour is the easiest ways to ensure clear and traceable criteria are utilised.

Every vehicle uses a visible amount of space for an observable amount of time.

© Rachel Nadkarni

Distinctions between vehicle types will continue to be essential for safety on the road, where there is often still a need to segregate fast-moving motor vehicle traffic from slower human-powered and electric-assisted vehicles. Given all of the unknowns, stationary vehicles are only really distinguished by the amount of space they use and the length of time they use it. Looking into the future, it should not be a city's parking policy that stops the transition to vehicles that do not fit in the 20th century idea of a motor vehicle.

Returning to the example from Section 2.1.3, the store trying to use a cargo-bike in a loading zone. The store reported that one parking control officer said, "Imagine if this whole street was filled with bikes – what would we do then?" (The Good Food, personal interview, 2020). To most working in sustainable transportation, they would be thrilled with such a result, but to that officer, such a scenario represents chaos because they do not have the

tools to address any vehicle that is not a motor vehicle, whether cargo-bikes or autonomous cargo-delivery vehicles.

The process of preparing an access zone policy that is future-proofed and ready for whatever mobility innovations come next, starts with using a vocabulary that is vehicle agnostic. Naming spaces based on the expected vehicles that will use them sets up a pattern that blocks similar but unfamiliar vehicles from accessing that space. Rather than naming parking spaces and bicycle racks, cities could consider naming those spaces large vehicle parking and micro-vehicle parking.

Spaces by size categories

By redefining spaces by size categories, there is flexibility to accept newly developed vehicles that do not meet historic conventions at the curb.

© Rachel Nadkarni

The benefit of a system based in vehicle sizes and length of time at the curb is that it is simple, observable, and consistent no matter what vehicles are in use or what contract for use is in the background. In addition to identifying spaces by a size category and an allowed time, cities may still find a need to add exceptions to the standard. In such cases, setting a clear rationale for the exception should be front of mind, connecting those exceptions to the specific target group or goal that is intended. Rather than relying on federally organised vehicle licensing and registration designed to track road safety issues, perhaps cities could develop resident access permits that could be attached to any vehicle and issue those allowances to resident curb access zones that include spaces for vehicles of all size categories.

As simple as the access equals space and time framework may be, there is still a substantial gap in the technologies to implement such a simple idea for all vehicles. Collaborations with innovators like those described in chapter one of this paper should continue to explore new techniques for bringing the power of digitalization to curbside management. From documenting and tracking curbside use, to optimizing the distribution of access zone regulatory exemptions based on prioritised municipal targets for mobility or emissions, digitalisation will be a key component of making this simplified framework actionable.

2.2.4 Model of Simplified Access Zone Terms

Part 1: Access Zone Spaces - Size Classification		
Micro Vehicles	0.8- 1.0 m by 2.0-2.25 m	Dividing up the length of the curb into vehicle size categories creates space for new and diverse vehicle models. Micro and Small Vehicle parking may occur on the sidewalk level but should continue to have clear signage as a vehicle access zone.
Small Vehicles	1.5-2.0 m by 2.0-2.25 m	
Large Vehicles	5.5- 6.0 m by 2.0-2.25 m	
Oversize Vehicles	10.0-12.0 m by 2.0-2.25 m	

Part 2: Length of Stay		
Stopping	Up to 5 min	Parking spaces for all sizes should indicate what lengths of stay are allowed and at what times of day. Dynamic Access zones are an opportunity to create flexible time limits. Curbside areas intentionally left clear, should be marked for 'no vehicle access' or otherwise constructed to prevent vehicles from stopping in that space, e.g. with plantings.
Time-Limited Access	Min-by-min or hourly	
Long-Term Access	Daily	
Dynamic Access	Posted online / in-app	
No Vehicular Access	No Vehicles	

Part 3: Categorical Exceptions		
User-related	Connected to a user. (e.g. resident, or business)	It is common practice to create exceptions to the posted access zone standards. If exceptions are utilized, they should directly connect to the user and/or timeframe of the exception. Where exceptions are issued, they should apply across vehicles. • A resident exception should be granted to a small vehicle or a large vehicle, and it should be granted directly to the resident to allow for vehicle changes. • If zero-emissions vehicles are granted permits free of charge that should apply to bicycles, e-motorcycles, and electric cars. In the field, the simplest descriptions of exceptions possible should be utilized on signage, e.g. 'Except by Issued Permit,' in order to allow a city's exception programs to evolve over time.
Event-related	Linked to specific event timeframe (e.g. moving)	
Emissions-related	Tied to vehicular emissions	

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