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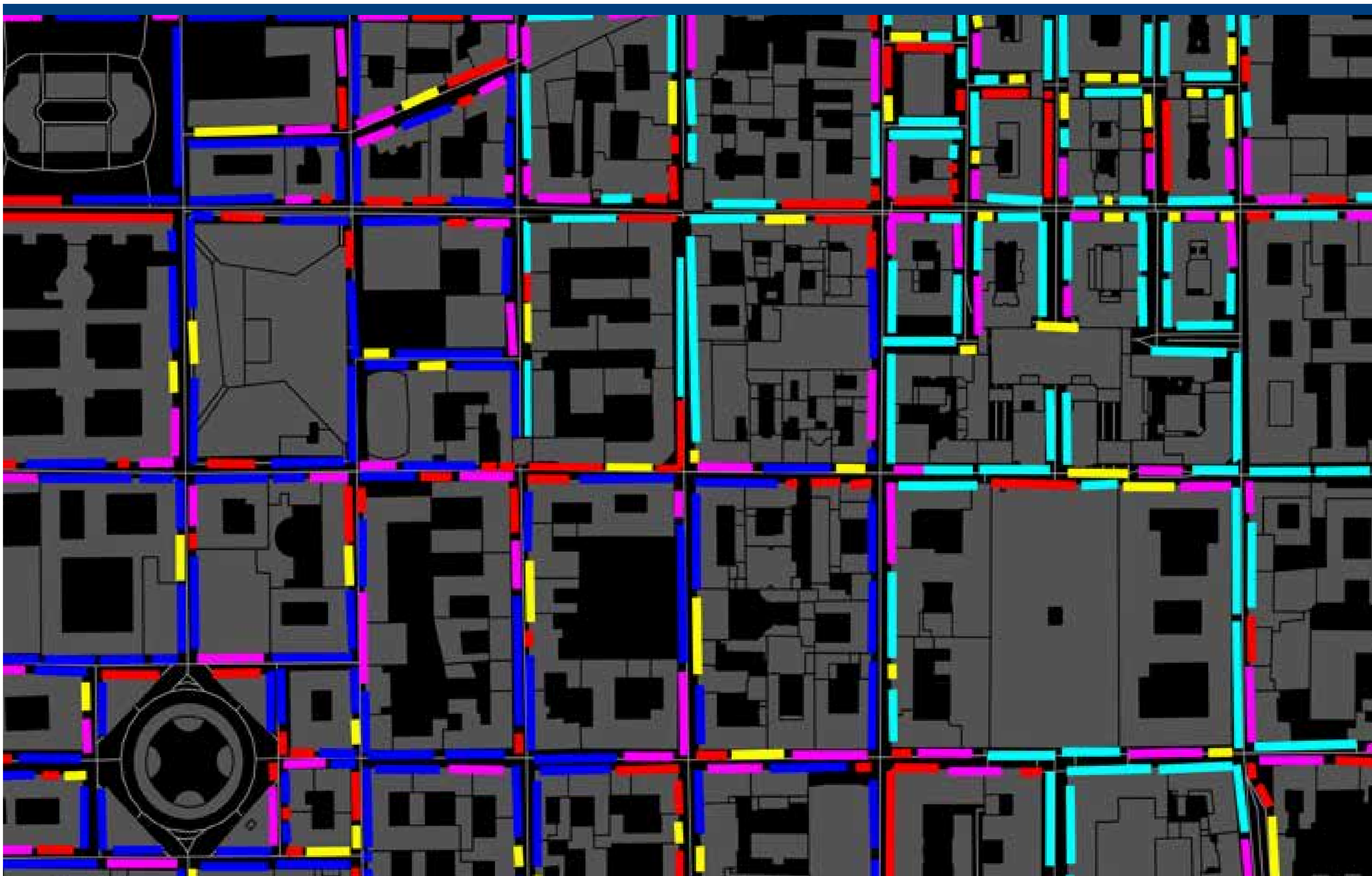
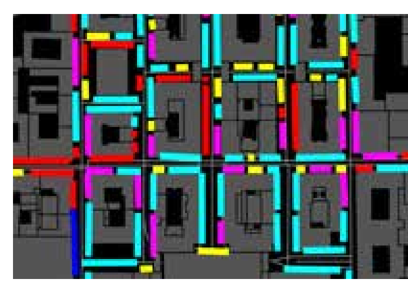


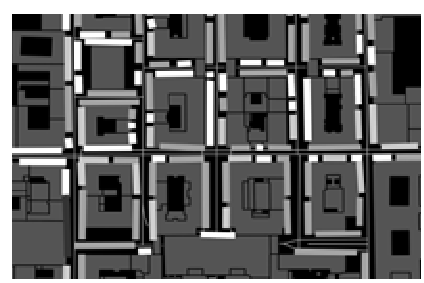


The Shared-Use City: Managing the Curb

Corporate Partnership Board Report

OECD

The Shared-Use City: Managing the Curb



Corporate Partnership Board Report

About the International Transport Forum

The International Transport Forum at the OECD is an intergovernmental organisation with 59 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. It is administratively integrated with the OECD, yet politically autonomous.

ITF works for transport policies that improve peoples' lives. Our mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion and to raise the public profile of transport policy.

ITF organises global dialogue for better transport. We act as a platform for discussion and pre-negotiation of policy issues across all transport modes. We analyse trends, share knowledge and promote exchange among transport decision makers and civil society. ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.

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The report draws conclusions from the ITF CPB Workshop "Designing (and funding) the shared use city" held 6-7 September, 2017 and hosted by PTV-Group at their headquarters in Karlesruhe, Germany. Participants of the workshop included:

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Executive summary

What we did

This report discusses how to manage growing competition for curb access in cities. The rise of ride services and the growth in urban goods delivery are challenging traditional ways of managing curb space. We describe how curb use is changing, how our capacity to monitor its use may need to evolve and discuss what the future of the curb may look like. We explore the implications of a large-scale uptake of ride-sharing services and other innovative mobility options in urban settings for street design and pricing. Growing competition for that scarce resource makes the parking of private vehicles at the curb in dense urban cores less and less tenable. The increasing diversity of those who pay for the curb and those who benefit from its use requires new approaches.

This study looks at the potential for a shift away from curb use focused on street parking to more flexible allocation that includes pick-up and drop-off zones for passengers and freight. It presents the results of quantitative modelling of alternative curb-use scenarios and discusses their relative efficiency, contribution to wider policy objectives and implications on city revenues. The work builds on a workshop held in September 2017, and outreach to numerous experts. It also provides insights from a modelling exercise to quantify the impact of re-allocating curb space from parking to pick-up and drop-off zones.

What we found

In many cities across the globe, the curb is an increasingly contested piece of urban real estate. Where motorisation rates are high, the curb serves to store vehicles that are not in circulation. Where motorisation rates are lower, curb space is used for many other activities, including commerce and socialising. Often, these uses take place in parallel, especially where car use is rising rapidly. Attempts to re-allocate, reduce or price these uses are often contentious. This is the case especially where incumbent users face tangible losses and where benefits from different curb uses will flow to as-yet unclear, unorganised or diffuse beneficiaries.

Giving more room to ride services at the curb will initially have mixed impacts that must be managed. Over time, however, a greater diversity of transport choices should in most cases decrease pressure stemming from single car use. Evidence suggests that ride service and public transport use may grow alongside under certain conditions. There are also indications that ride services often replace lower-quality and lower-frequency public transport trips. Impacts of better access of ride-sharing services to the curb on traffic flows are mixed, but modelling results indicate that pressure on traffic could decrease as the percentage of shared rides increases.

Knowledge of the curb is generally poor. Appropriate metrics and data collection to support decisions about the (re-) allocation of curb space are generally lacking. Where data exist, they are often generated and collected by non-public actors. This limits the ability of public authorities to assess whether allocation mechanisms are effective or how this space could be made available to uses that are more efficient.

With the contested curb a focus of public authorities, many cities risk addressing these hotspots in a piecemeal fashion and underestimating longer-term changes that are underway. These changes will require an increasingly strategic approach towards the allocation of public space in cities, on their streets and, ultimately, at the curb.

What we recommend

Establish a system of street designations according to their primary purpose

City streets serve a broad range of functions, from through-traffic routes to pedestrian thoroughfares. Many have mixed uses where motorised and non-motorised traffic compete for space. Treatments to ensure safety and manage traffic flow will vary according to the principle purpose of each street section. Arrangements for curb access will range from no-stopping zones to residential on-street parking. Policy towards access for shared ride services will vary with location. Identifying and categorising road sections by primary purpose will greatly facilitate policy-making on curb access management.

Anticipate and plan for the revenue impacts of shifting curb use from car parking to passenger pick-up and drop off.

The curb of the future may be used quite differently than today. Changes in curb use will initially be localised, but if they gain traction, the knock-on effects are likely to be significant. One of the impacts will be on revenues from car parking which can constitute important sums of money for a city. Public authorities should anticipate this shift, assess whether they wish to price curb usage, and decide which instruments they will use. These instruments have yet to be developed in many cases. Pricing curb use can help cities retain the ability to manage traffic and transport demand by replacing parking pricing mechanisms.

Make room for ride services at the curb where this fits strategic priorities

A pressing question for many cities is whether they should make room for ride services at the curb. In most cities, the answer is yes. However, cities should move forward with such changes based on a broader strategic re-assessment of the priorities regarding access and use shared public assets, including streets and curbs, they wish to give to different modes.

Build on or create adjudication bodies to manage diverse demand for curb space in flexible ways and ultimately in real time

New uses of curb space should involve broad stakeholder consultation with adapted processes. It should also be accompanied by bodies that are empowered to allocate this space with great degrees of flexibility – eventually in real time and automatically. Institutional experience and public consultation processes employed for parking management and street design should be leveraged where they are already in place. Early pilots give some useful indications of how to manage this process.

Help develop common standards for encoding information about curb use

It is imperative to digitise knowledge about streets and curbs. Such regularly updated inventories should be accessible for public as well as private actors. They would allow the rapid and automatic integration of curb and street use rules directly into third-party apps and algorithms by making regulatory intent available directly in machine-readable language. Common referencing standards for curb data would enable detailed knowledge of curb use rules and facilitate their monitoring.

Rethink streets and their curbs as flexible, self-adjusting spaces and plan accordingly

Wih new technologies, new rules and new use cases, curbs are no longer static, inflexible installations. Instead, curb use will resemble dynamic, highly flexible, self-solving puzzles. The move from a “parking city” to a “pick-up and drop-off city” is only one part of a broader shift to re-think and manage streets and curbs as flexible-use and self-adjusting spaces. This will require changes in how these spaces are designed, regulated, monitored and priced.

Manage curb space dynamically so it adapts to different uses and users

The flexible allocation of curb space for different uses over the course of the day is not in itself new. Flexibility targeting new mobility services specifically is much less common, however. Current live trials and the results of our modelling exercise, suggests this is likely to change. Technology will *bring* flexible use of space to the curb and help manage it. Over the longer term, curb and streets should be designed *for* such dynamic and flexible use.

Establish effective tracking and monitoring of overall transport activity, including ride services.

Licensing of operations for public transport and ride services, including taxis, should be contingent on licensees providing sufficient data or trusted insight so as to monitor the impact of these services on public policy objectives. This should extend to all registered and licensed transport operators, including public transport, taxis, ride services and freight delivery.

Introduction: A brief history of the curb and its future

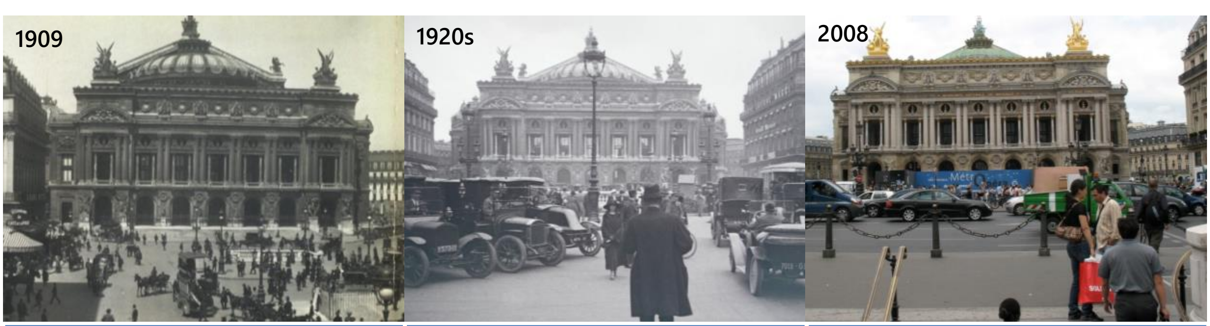
The street and the curb

As long as there have been cities, there have been conflicts regarding the allocation of public space amongst different uses and different users -- nowhere has this been more acute than regarding the allocation of street space. Historically, streets have served as conduits for movement as well as destinations in their own right. The principal function of the street between these two, sometimes exclusionary, uses, has swung back and forth with alternating periods of stability and short periods of rapid change (Garden, 2006). These shifts are typically prompted by changes in technology such as street lighting, urban rail, the car, and, soon perhaps, the arrival of automated vehicles. These shifts also result from broader economic or social changes that impact the use of public space (e.g. a shift to large in- and out-of-town shops and, now, to on-line shopping). They are frequently contentious as they imply shifts that typically favour new uses and users to the detriment of established uses and existing users.

Streets are both extremely familiar and relatively poorly understood. There is a tremendous body of knowledge regarding the engineering and construction of road networks in urban areas and a broad, well-established body of knowledge regarding how streets and roads contribute to economic activity and personal welfare. Much of this knowledge, however, focuses on the transport function of the street and often ignores streets and roads as complex urban spaces serving many purposes (commerce, social space, public meeting areas, etc.). This has led to a historic focus on how well streets and roads serve to move vehicles and little understanding or appreciation for other non-transport uses of public rights-of-way. Much of the knowledge regarding the transport function of streets builds on their existing use and thus may not accurately guide policy in the future, especially as successive and co-synchronous changes relating to the broader digitalisation of transport and society ultimately play out on our streets.

What role streets and roads play is not just an abstract consideration regarding the ways in which our cities and their transport networks may evolve in the future. It is one that public authorities are already having to address now as new uses of these public easements are putting pressure on the ways in which cities allocate this space. And one area where this is happening most acutely is at the curb.

Figure 1: **The evolution of the street and the curb – Place de l'Opéra, Paris**



1909	1920s	2008
Much of the street space is devoted to mixed (horse-drawn) transport, commercial and social uses. The demarcation between the sidewalk and street is weak and fluid.	Growing motorisation rates has put pressure on mixed use of the street, safety concerns emerge as car-pedestrian crashes rise	The allocation of street space is now formalised. Most of the space is reserved for vehicles in movement. Pedestrian access across this space is tightly regulated and controlled. The curb has become a hard border materialising the transition between transaction space and mobility space.

Source: ITF and Wikicommons photos

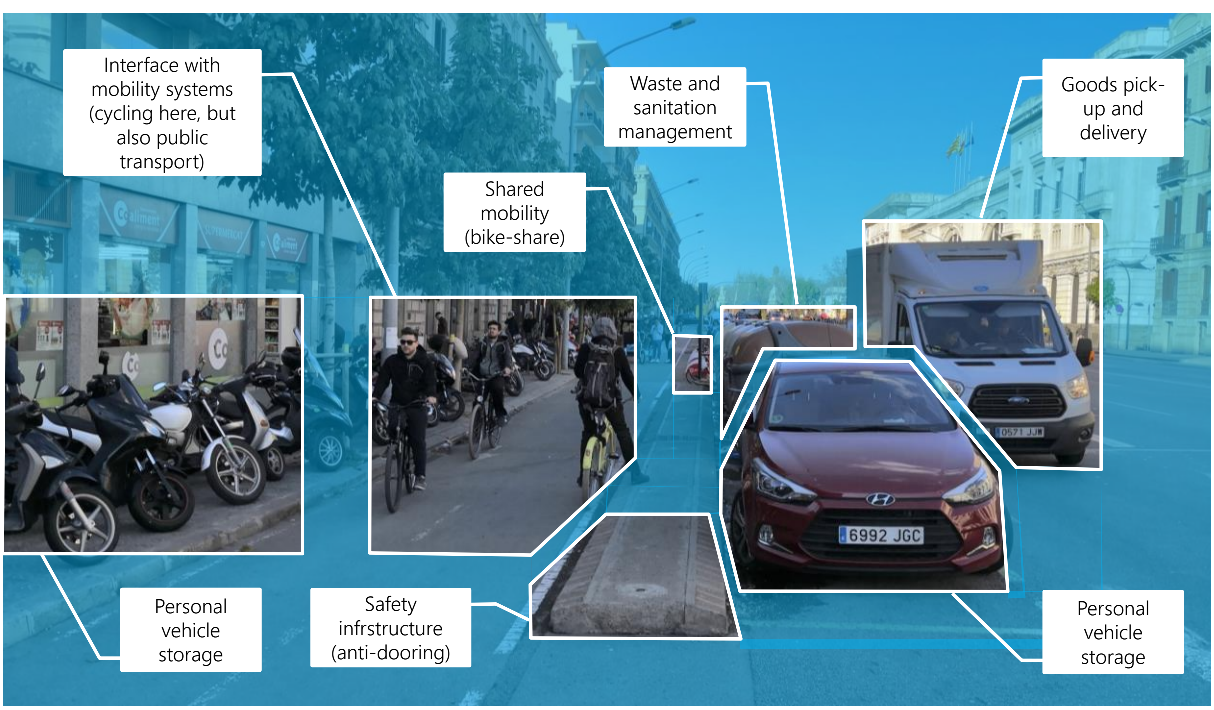
The curb as interaction space

The curb materialises the interface between the transport function of the street and its other uses. As such, curbs are the points where streets generate value for citizens and cities. This is because transport systems don't necessarily generate value through movement *per se*, but rather, do so when people or goods *stop* moving when they arrive at their destination. The transition from movement to value-generating activities can happen in many locations – the home driveway, the quay of a metro or rail station (and the city beyond), the port crane and – in the case of most city streets – at the curb.

The curb itself is simply a demarcation between two spaces – the roadway and the sidewalk. Historically, the physical manifestation of the curb had little to do with transport but rather was created to better channel wastewater flows in dense and oftentimes insalubrious urban settings and to prevent backflow from the streets into buildings. Before the mid-to-late 19th century, many streets were curbless and the demarcation between transport and other uses of the street were much more fluid. Though there has been a recent move to return to a curbless shared allocation of street space in some controlled and traffic-calmed contexts (based on the dutch "Woonerf", or "living street" concept), this remains the exception today (Vinci 2018) (DVRPC 2018) (Jaffe, 6 Places Where Cars, Bikes, and Pedestrians All Share the Road As Equals 2015).

Any observer of urban dynamics will quickly note that the curb is a highly contested piece of urban real estate in many cities across the globe. Where motorisation rates are high, the curb often serves to store vehicles that are not in circulation, sometimes for minutes, oftentimes for hours. Where motorisation rates are lower, curb space may encompass many other activities, including commerce and socialising. In many contexts, especially where car use is rising rapidly, all of these uses are concurrent. Moves to re-allocate, reduce or price these uses are often contentious, especially where implied losses for incumbent users are tangible and where benefits from changing curb use will flow to as-yet unclear, unorganised or diffuse beneficiaries.

Figure 2: **The curb environment encompasses many heterogeneous uses: Example from Barcelona**



Source: ITF, Photo Philippe Crist

Access to the curb is often regulated, though compliance rates with curb access regulations are highly variable around the world and often low. It is sometimes priced, especially as concerns parking and especially where demand for access is high. And it is often the purview of local and regional governments where multiple agencies and departments often share responsibility for overall management of curb space, reflecting the multiple and heterogeneous uses to which it is put. The curb is a valuable public asset in its own right, reflecting the scarcity of space in many city centres. As such, public authorities should manage this asset efficiently and in line with broader strategic objectives.

Looking forward, three central questions come to the forefront when thinking about how the use of the curb will evolve.

- The first and perhaps most fundamental question is whether changes in transport activity, or more broadly, in society will have an impact in the way in which people and businesses derive value from curb access.
- The second is whether we have the right metrics and monitoring systems in place to measure curb use productivity and efficiency, and if not, what these might look like.
- The third is what implications these changes will have for public authorities, not only from the point of view of regulation, but also from a revenue perspective.

This report investigates these three central questions and tests some model-based scenarios that seek to shed light on these.

The curb today: Parking city to pick-up drop off city

The starting point for this report are the curb-use patterns that can be observed in many highly motorised countries. The focus is on the impact on demands for curb access that the uptake of platform-based ride services, especially ride hailing services such as those proposed by Didi Chuxing, Uber, Lyft, Ola and Grab will have. The scope of analysis also includes new forms of digitally-enabled micro-transit, bike sharing (docked and dockless) and more traditional forms of public transport and private vehicle storage. A secondary focus, and one that will certainly require further analysis, is on the changing pattern of (online) shopping, its impact on goods delivery and how this leads to increased pressure for access to the curb.

The curb is used to store vehicles…but not only

At the outset of the 20th century, the curb was essentially a transaction space, where loading of passengers and goods occurred but where long-term stopping was expressly forbidden (Hey Ridge 2016) (Garden 2006). This was understandable given the fact that most transport was horse-powered and that prolonged stopping on the right-of-way was difficult and insalubrious. When cars and trucks gained popularity, they were required to be stored off street (as were horses) in public or private garages often converted from transformed livery stables. Short-term street parking was largely unregulated and unpriced. Free access to the curb was tolerated and the anarchic occupation of public space grew with motorisation. This led to an expectation by the public that they should be able to freely park their cars at their destinations for the duration of their activity there.

Chaotic occupation of the curb by parked vehicles quickly led to calls for controls and regulation and by mid-century, on-street parking in central business districts and at other popular destinations was time-bound and often priced. Faced with the dilemma of where to store vehicles when not in use, urban planners required new commercial and residential developments to provide generous minimum levels of off-street parking – a practice that has since been linked to increased traffic volumes and car dependency (Shoup, 1997, 2006).

After more than a century of motorisation in OECD countries, a significant share of linear curb space is devoted to the short- to medium-term storage of vehicles in most urban areas. For instance, a recent study estimated that 14% of the incorporated area of Los Angeles county is devoted to on-street, off-street residential and off-street non-residential parking. This 16-mile diameter "parking crater" is equivalent to 1.4 times the area devoted to roads in the city and 20% of this parking is comprised of curbside on-street parking (Chester et al., 2015). In Europe, a 2013 assessment the overall parking stock estimated that there were 33.7 million regulated parking spaces in municipalities of 20 000 inhabitants or more. Of these, 36% were on-street, curbside parking spaces (EPA, 2013).

Despite these two (and other) assessments, accurate and robust estimates of the share of on-street parking in the overall parking stock – or even a reliable assessment of the space devoted to curbside parking -- are difficult to come by. Data on curb use, including for parking, is significantly fragmented and generally poor – an issue we address in section 3. Information about parking held by multiple departments and other outside parties such as property and real estate developers, commercial enterprises and universities or public service bodies. Uncertainty regarding the size of the stock of on-street parking and, more importantly, its use also reflects the broad heterogeneity of local contexts, rates and rules amongst municipalities.

Nonetheless, if cars are generally inactive most of the day (lying unused approximately 95% of the time) a significant share of that time is parked away from home, oftentimes at the curb. This occupation of curb space delivers value directly to car owners and indirectly to employers and businesses that benefit from having workers and customers accessing workplaces, shops and businesses. But it also prevents other alternative uses of that curb space. These uses are multiple and include the following:

- Pedestrian access to/from sidewalk
- Emergency vehicle access
- Access to public transport
- Goods delivery and pick-up
- Interface for cycling infrastructure
- Pick-up and drop-off of passengers from taxis, ride services, private vehicles
- Repair and maintenance work access (infrastructure, utilities)
- Waste management and surface water runoff
- Commercial activities (kiosks, restaurants, food trucks, cafés, etc.)
- Leisure, green and planted space (trees and parklets)

These and other concurrent demands for curb space involve a wide range of stakeholders and authorities whose coordination is often disjointed and infrequently aligned with broader strategic objectives. This was a sub-optimal but tenable position when the overall structure of trips in urban areas remained largely unchanged. This position is increasingly tenuous, however, under recent developments. For instance, the rapid deployment of docked and dockless bike share systems, alongside the deployment of bicycle infrastructure in many cities, has changed how, and how many, people need to access the curb.

More fundamentally, a rapid shift to online shopping and the resultant volume of small parcel deliveries has dramatically increased pressure by goods delivery vehicles for access to curb space (Conway et al., 2016; Zaleski, 2017). These shifts are concurrent with the uptake of ride services and new forms of mobility service delivery that also require access to the curb. These changes are layered in technological developments, principally those powering platform-based or crowd-sourced service models and automated driving. The long-term implication of all these changes is perhaps that we are moving from a "parking" city world to a pick-up/drop-off city world. This shift is one that must be anticipated and planned for since it will require new strategies to manage public space devoted to transport and other functions and appropriate regulatory frameworks that enable innovation and meet public policy objectives.

Pick-up and drop-off city: What place for ride services?

As noted previously, this report primarily focuses on the implications for curb use linked to the uptake of innovative mobility services, and of ride services in particular.

Ride services – both ride-hailing and on-demand micro-transit – represent a minority share of overall trips in all cities where they operate but are growing rapidly. Since their first appearance in 2009, these services have spread rapidly across the globe in an increasingly complex playing field of large regional and global actors. These services match supply and demand for rides in several very different contexts and with an increasingly diverse set of services ranging from upper-tier premium door-to-door services, to shared use of vehicles along semi-fixed routes. They depend on professional licensed drivers in some contexts (including taxi drivers) or are open to all drivers meeting a minimum set of qualifications in others. Several ride service companies have stated their intention to offer these services via automated vehicles when these are technologically ready. Many platform-based ride services are seeking to develop the technology themselves. Similarly, automobile manufacturers and technology companies such as Ford, Waymo, Renault-Nissan, Toyota, General Motors and Daimler have also signalled their intent to deploy self-driving fleets of shared-use vehicles. Finally, micro-transit operators such as Chariot, Via, and hybrid operators such as Citymapper are also deploying on-demand, semi-fixed route-based services. All of these are converging at the curb – mostly occupied by parked cars today.

Public authorities initially viewed the early manifestation of these ride services as an issue of competition within taxi and for-hire markets (ITF, 2016). This focus is gradually giving way to a broader realisation that the long-term interaction effects of these services will extend to public transport, car use and active mobility (ITF, 2017c). These services are popular wherever they are present around the globe. At the same time, authorities are struggling to adapt regulatory frameworks and anticipate future developments against a backdrop of uncertainty regarding the impacts of these services and how they can contribute to a shared vision for urban space.

Evidence of ride service impacts is an essential input to policy seeking to regulate new mobility services generally and re-allocate street space and curb access regimes more specifically. If the uptake of ride services leads to an erosion of traffic conditions and an increase in congestion, then this should condition the willingness of public authorities to give regulatory and physical space to these services. If, on the other hand, these services reduce congestion, lessen car dependence, free up space for other productive uses and improve the quality of life in cities, then public authorities should actively seek to give space and regulatory licence for these services. Limited international evidence on these impacts exists to-date as research on ride services is a new and developing field and publicly available data permitting an assessment of ride service impacts is extremely limited.

What have been the quantified impacts of ride services on travel, congestion, and use of other modes?

At present, evidence on ride service impacts has been essentially limited to North American markets where they have first been deployed and where they have been most popular. Evidence from these markets provides insights on those impacts have been observed in North America at a relatively early stage of deployment and within a particular set of circumstances. How transferable these are beyond North America is not clear and how well they describe the impacts that would be observed at a later stage of deployment and market maturity – especially if policies and the regulatory context regarding urban mobility and land use evolve at the same time – is uncertain.

We focus on the findings of the most recent and robust of these studies in the following sections.

"Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States" (R R Clewlow and et G. S. Mishra, 2017)

In October 2017, the Institute of Transportation Studies at the University of California, Davis released a study looking at the impacts of the adoption of ride-hailing services on travel behaviour and activity (Regina R. Clewlow and Mishra, 2017) This report investigated evidence based on an internet-based survey carried out on a representative sample of inhabitants in Boston, Chicago, Los Angeles, New York, the San Francisco Bay Area, Seattle and Washington, DC. Sampling accounted for different urban contexts and demographic characteristics and the survey was carried out in in two phases between 2014 and 2016.

Ride service users

With respect to the adoption of ride-hailing services, the study found that 30% of respondents had used ride-hailing services themselves or with friends that had installed the app. Younger people were more likely to use ride hailing services than older people. One in four of ride hailing adopters use these services at least once a week. Among the principal motivations for using ride-hailing services amongst car-users was the avoidance of parking hassles and costs, alongside avoiding drink-driving for social outings. The survey also found higher rates of ride-hailing adoption in more urban neighbourhoods as compared to more suburban neighbourhoods.

Impacts on car ownership and travel

The study found that there were minimal differences in vehicle ownership between ride-hail adopters and the rest of the population, perhaps reflecting the demographic status of many ride-hail adopters who tend to be slightly wealthier than the rest of the population. Further, most ride-hailing adopters have not made any changes regarding vehicle ownership. Those that have reduced the number of cars they own and their car travel have substituted the latter with use of ride-hail services with unknown impacts on overall vehicle travel.

Impacts on public transport

The study found also found an overall negative impact on public transport use with a 6% reduction of public transport by ride-hail adopters. This reduction was not uniform across all forms of public transport – bus use decreased 6%, light rail use decreased by 3%, whereas use of commuter rail increased by 3% among survey respondents. This seems to indicate that ride hail services were seen as a substitute to slower and relatively infrequent (and possibly less reliable) public transport trips and as a complement to faster, longer-distance public transport. Survey respondents also indicated that since adopting ride-hail services, they walked more (an increase of 9%). Based on the survey responses, the authors conclude that should the context for ride-hailing remain as it was at the time of the survey, further adoption of these services would likely increase the number of vehicle kilometres travelled by cars. The authors make no judgement as to the overall welfare effects but any improved outcomes for individuals who gain access to convenient, reliable and comfortable travel (and opportunities for drivers) would ultimately have to be balanced against the negative societal impacts stemming from increased travel, congestion and environmental impacts.

"Empty Seats, Full Streets: Fixing Manhattan's Traffic Problem" (Schaller, 2017) and "Making Congestion Pricing Work for Traffic and Transit in New York City" (Schaller Consulting, 2018)

Two reports released in late 2017 and early 2018 by a consultancy led by the former Deputy Commissioner for Traffic Planning at the New York City Department of Transport investigated the quantitative impacts of ride services on New York City traffic and public transport use . Both reports (as well as a previous one by the same author) use data collected and made available by the New York City Taxi and Limousine Commission on taxi and ride service trips along with ancillary data on travel speeds collected by the New York City Department of Transportation. Trip level details for both taxis and ride services include zone-based points of origin and trip start times. Additional information collected for taxi trips include trip destination zone and end time along with distance, fare and the number of passengers on board. Since June, 2017, ride services must also report trip destination zone and trip end time. Before June 2017, the report author uses various methods to estimate trip destination zone and trip duration for ride services. This rich dataset (over 30 million trip records) allows for a fine-grained analysis of the performance of both taxis and ride services, including the amount of time taxis and ride services are occupied or unoccupied.

The study finds that combined taxi/ride service vehicle kilometres travelled per average June weekday (all the data that follows are for the same reference period) has increased 36% from 2013 to 2017, more than doubling the growth in trips (+ 15% over the same period). This growth is the net result of a 34% decrease in taxi kilometres driven offset by a significant number of new ride service trips (representing 82% of the 2013 distance travelled). The report identifies four factors as contributing to this growth – more frequent and longer trips contributing directly and lower traffic speeds and a smaller share of kilometres travelled with passengers on board contributing indirectly.

Evolution of ride service trips

From 2013 to 2017, taxi and ride service trips increased by 15%. At the same time the overall number of vehicles operating within the central business district has dropped. The combined effect of more taxis and ride service trips in the CBD and fewer overall vehicles indicate aa rise in the share of taxi and ride service vehicles in the CBD during daytime hours – the report estimates these may represent approximately half of all vehicles travelling north or south into the CBD during the day. The report also notes that average distance travelled per trip has also increased, especially for ride service trips.

Relationship to travel speeds

The report cites NYC Department of Transport data indicating 15% drop in average vehicle speeds (2013-2017) with a 18% reduction of average daytime speeds. There are many plausible explanations for this reduction of average travel speeds. An increase in vehicle registrations for NYC suggest more vehicles are potentially travelling – including, but not limited to, those providing ride services. A previous study by NYC Department of transport had also noted that an increase in planned and unplanned roadworks also contributed to congestion (NYC Department of Transportation, 2016). Finally, it also seems plausible that a shift to more online shopping has also contributed to more freight and parcel deliveries. In the context of dense urban areas such as NYC, this growth is accompanied by more double-parking by delivery vehicles and a rise in congested travel conditions (Holguín-Veras and Sánchez-Díaz, 2016).

Evidence on ride service and taxi utilisation rates

Against this backdrop, overall taxis and ride service vehicle operating hours grew by 59% in the central business district of Manhattan from 2013 to 2017. The number of hours taxis and ride services spent with passengers on board rose by 48% in NYC between 2013 and 2017 but this increase was eclipsed by an even stronger rise in unoccupied vehicle hours (+81%). In 2013, 67% of taxi operating hours were with passengers on board. By 2017, the combined Taxi/ride service utilisation rate had dropped to 62%.

Taxi/Ride service trips by time of day

Taxi and ride service trips and distance travelled increased most strongly in the late afternoon and early evening with the lowest relative growth occurring in the morning peak and during the middle of the day. The number of taxi and ride service trips in the CBD more than doubled between 16h and 18h between 2013 and 2017 trips increasing by at least 50% per hour over the same period. The number of occupied vehicle hours doubled in the CBD between 16h and 18h while at the same time, growth in occupied vehicles hours tripled between 2013 and 2017. Part of the explanation for this growth was a relaxing of shift rules for taxi drivers that previously had meant that most drivers were either coming off or coming onto their shift with a concurrent temporary drop in taxis in service.

What can be drawn from the NYC data and analysis?

The first thing is that use of taxis and rides services in NYC seems to be less important for commute trips, especially those in the morning. Use, and kilometres travelled increases principally in the late afternoon, suggesting that these trips serve non-work use, particularly leisure trips. This is a reasonable assumption based on the findings of the UC Davis study and the Transportation Research Board study described below. If that is the case, then use of taxis and ride services may serve as a complement to certain uses of public transport – even though this may entail an overall drop in public transport use (without making any explicit link to causality, the reports note that subway and bus ridership has dropped for 2016 and 2017). Presumably, travellers using taxis and rides services find these to be more suited to their needs, travel schedules and preferences for certain trips – likely those poorly served by public transport.

The report author also singles out unoccupied hours of service and kilometres driven by taxis and ride service vehicles as a particular point of concern. Taxis intuitively have a certain incompressible threshold of unoccupied vehicle time that results from their street hail operation (though app-hailed taxi trips are on the rise). Potential passengers will also seek out higher trafficked thoroughfares to increase the likelihood of finding an available taxi. Ride service vehicles, however, typically pick-up passengers from their doorstep which entails an additional amount of empty travel and wait time. This additional time represents the premium that ride service passengers are willing to pay in return for door-to-door service, but it also contributes (to an unknown but possibly significant extent) to more congestion and lower travel speeds for all.

Remedies that address empty travel by ride services could include limits on the number of vehicles operating or licensed to operate. Rationing vehicle numbers and licences has already been tried in taxi markets, often with unsatisfactory results for passengers and from a competition policy perspective (ITF, 2015). Another option would be to price time in service, differentiated by in-use and non-passenger transporting time as outlioned in (Schaller 2018).

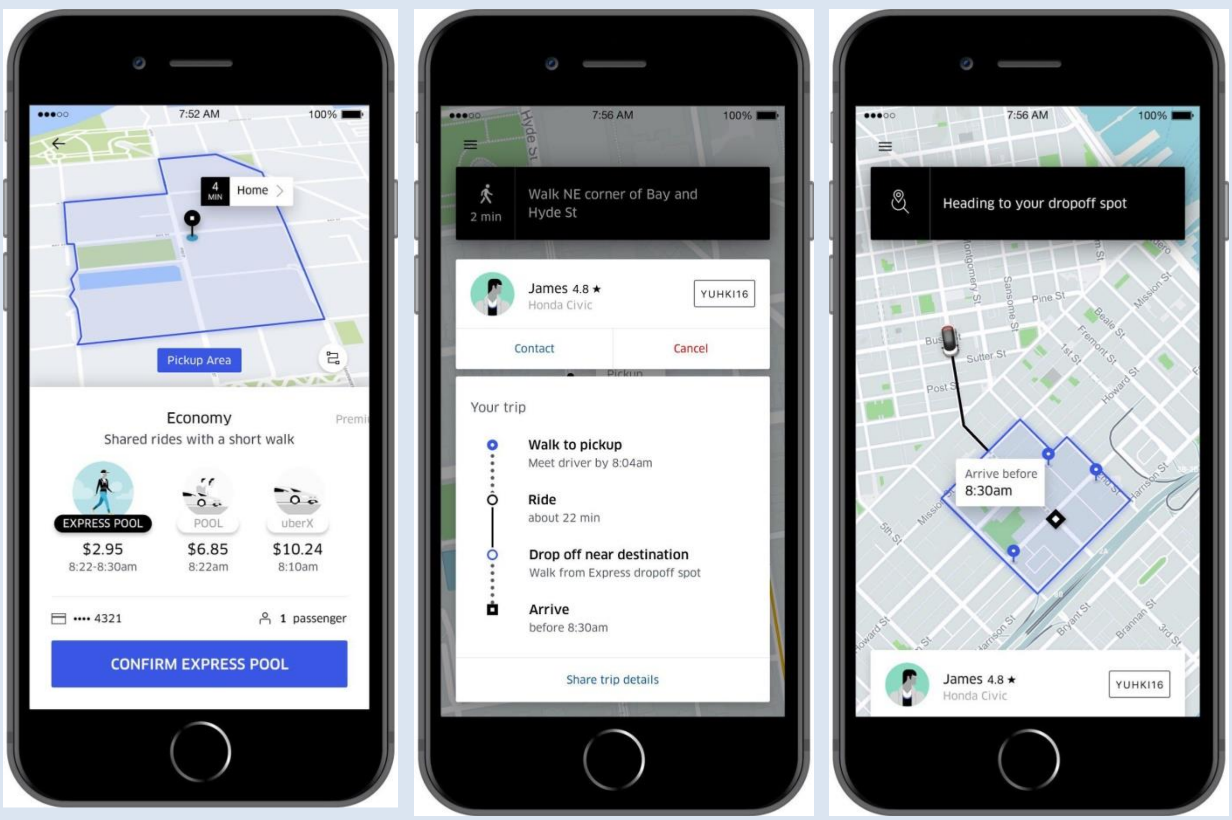
There is a double incentive to decrease wait times both from a passenger perspective and from a driver perspective. Building on the former, ride service companies have started to guide users to convenient pick-up locations that would decrease wait times and increase overall efficiency. This is done in-app and allows riders to be guided to nearby pick-up points that are easier to service and help optimise overall routing (see Box 1). Depending on the ride service provider, these pick-up points can be set for individual requests or for pooled ride service requests, or for both.

Box 1: Uber Express POOL: guiding riders and optimising rides

Several ride services provide a shared ride option – in the case of Uber, the Uber POOL service launched in 2014. In order to better optimise sharing and improve routing, Uber launched a variation of their POOL product – Express POOL – which guides POOL riders to designated pop-up pick-up stops. Riders wait a few minutes before their trips begin as the dispatch optimises requests and then walk a short distance to a nearby spot for pick-up and drop off. Walking and waiting helps Uber make more optimal matches and provide better, straighter, faster routes with fewer detours.

Once a trip is requested, the dispatch algorithms spend the next few minutes selecting the most compatible co-riders and a driver nearby, and the best spot for pick-up within a few blocks of the passenger's location. When the optimisation is completed, riders are given walking directions in the app and an estimated time for the pick-up where other riders and the driver will be converging. The same process is repeated for the end of the trip with riders dropped off at an optimal location for all. Riders are then given in-app walking directions for the last few blocks to their final destinations.

Express POOL was piloted in San Francisco and Boston, and is available in Los Angeles, San Diego, Denver, Miami, Philadelphia, and Washington as of February 2018.



Source: Uber

The dispatching algorithms used by ride service platforms can also be adjusted to decrease empty running and down-time for individual drivers. Such adjustments have already been made by Uber in the case of airport drop-off and pick-ups to pre-match drivers with rider requests and thus avoid empty trips to off-site staging areas. Against the backdrop of dispatch efficiency optimisation, ride service platforms also seek to increasing fares. Such surge pricing may decrease wait times for individuals, but it may also lead to a temporary oversupply of drivers at certain periods that could conceivably increase empty kilometres driven and contribute to congestion. These are untested hypotheses that cities are seeking to clarify by mandating more data discovery on the part of ride service platforms (ITF, 2017a, 2017b, 2017c).

Besides setting quotas or solely depending on in-app and on-platform dispatch optimisation, the author suggests a third mechanism that could constrain the growth in vehicle kilometres driven by ride services, possibly rebalance some of those trips back to public transport and allow dynamic adjustment of supply and demand.

Some cities implement cordon pricing schemes that effectively price access to the city centre (London, Stockholm) or more broadly (Singapore). Similar pricing schemes have been discussed for NYC but have failed to be agreed. Nonetheless, discussion continues around the ways in which road pricing can help to moderate notoriously bad and growing congestion. One approach outlined by a commission named by the Governor of New York has centred on a mixture of cordon charges for cars and trucks and a per-trip surcharge for taxis and ride service vehicles (Androutsopoulos and Zografos, 2009)

Citing relatively low elasticities of demand with respect to price for taxi trips – a 10% increase in fares would lead to a 2-2.5% decrease of demand, and assuming the same elasticity holds for ride service trips -- the report author estimates that the per-trip fee proposed by the Governor's commission would have a noticeable, but small impact on taxi and ride service traffic, and a therefore small impact on overall congestion.

Another approach suggested by (Schaller Consulting, 2018) calls for an hourly charge to be levied on taxis and ride services (and commercial delivery trucks) in the CBD to incentivise less empty running and more ride service sharing. To be effective, this charge should at a minimum reflect the costs of operating a personal vehicle at the most congested times and locations within the city – including off-street parking costs. In New York City, (Schaller Consulting, 2018) suggests that per hour rates that meet that criteria would be on the order of USD 20 outside of Midtown Manhatten and USD 50 in Midtown could reduce traffic by 8%.

Such an hourly charge is certainly an innovative measure that has the potential to balance demand for taxi and ride service trips with other modes, including active travel and public transport. Nonetheless, it seems that a more robust assessment of the welfare impacts and equity implications of this measure should be undertaken. At a minimum, the level of such an hourly charge should be well-calibrated with charges facing individual motorists so that it does not result in an unwanted incentive favouring car use.

"Broadening understanding of the interplay between public transit, shared mobility and personal automobiles"

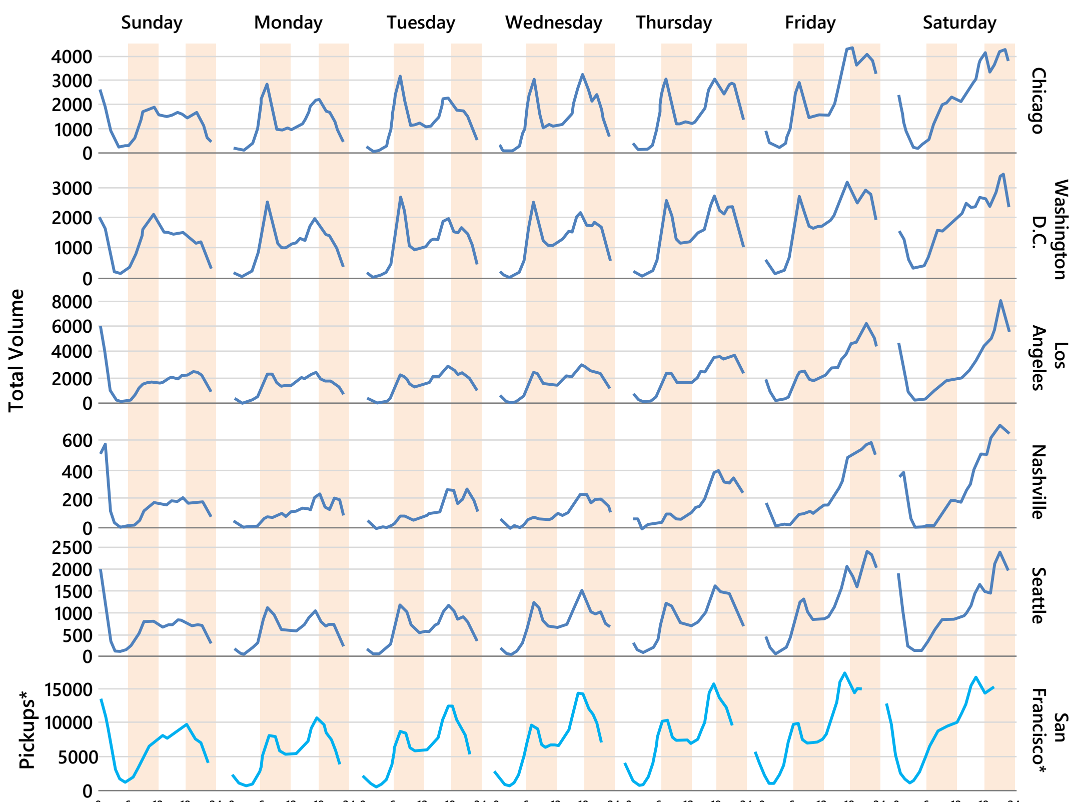
In January 2018, the Transportation Cooperative Research Program of the United States Transportation Research Board released a comprehensive study carried out by the Shared Use Mobility Center (SUMC) looking at evidence on the impact of ride services on car use and public transport in five urban regions (Chicago, Los Angeles, Nashville, Seattle and Washington, DC). The report also includes similar analysis undertaken for San Francisco County (based on modelled ride service use as described in (County of San Francisco, 2017)). The report builds its analysis on data provided by a major ride service company operating in the five metropolitan regions (aggregated at the level of zip codes), the modelled data for San Francisco and draws on two convenience surveys of public transport users and ride service adopters.

The diversity of urban regions, in size, density and provision/quality of public transport services helps contextualise the observed impacts of ride service use and gives some insights into the transferability of the findings to other, similar, contexts. Chicago, San Francisco and Washington DC all display high population densities relative to most other US cities, higher use of public transport and lower levels of single driver car commuting, especially at the core (50%, 35% and 34%, respectively). Nashville has the lowest population density and the highest level of single driver car commuting (79% at the core, 82% overall, reflected limited public transport options and quality). Los Angeles and Seattle lie somewhere between the extremes presented above in terms of car ownership, density and public transport use apart from the compact core city in Seattle displaying patterns similar to denser cities.

Ride service use by time of day and day of week

Ride service use by day of week and time of day was found to be in line with the other two studies cited here. Highest use occurred on weekends and in the late afternoon/early evening, peaking around 21h-22h across all cities (Figure 3). In all cities but Los Angeles and Nashville, a clear secondary peak occurred in the morning rush hour suggesting some ride service use for commuting trips, either alone or as a feeder or connector to a public transport trip. In Los Angeles and Nashville, the ratio of peak-hour ride service use to all ride service use is lowest, reflecting much less commuting and higher leisure use of ride services.

Figure 3: **Ride service trips by day of week and times of day (based on real data for Chicago, Washington, DC, Los Angeles, Nashville and Seattle and on modelled pick-ups per hour for San Francisco), different scale for each city.**



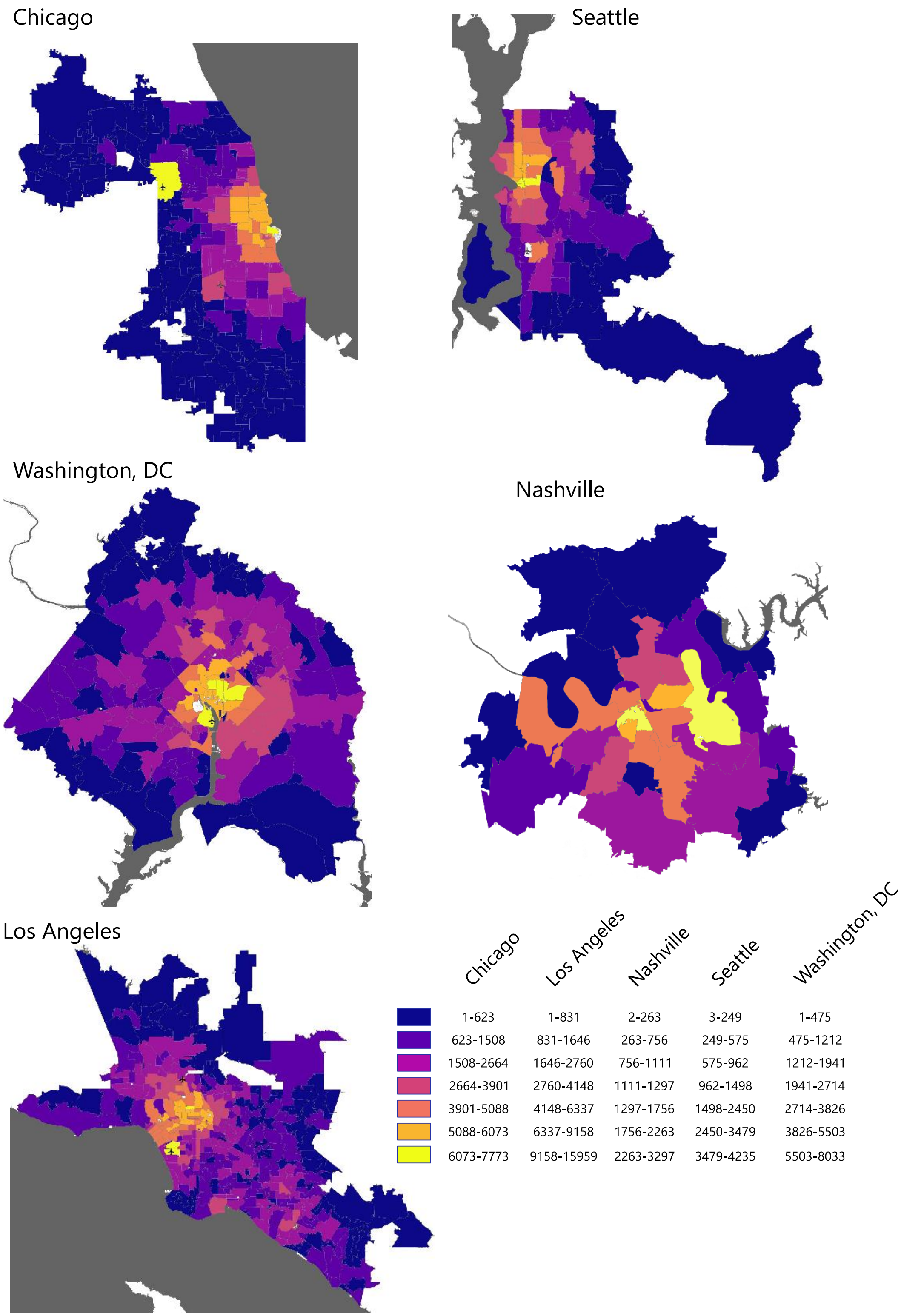
*San Francisco data is comprised of *modelled pick-ups*

Source: adapted from (Feigan and et C. Murphy, 2018).

Frequency of ride service use

In most cities, with the exception of Nashville, ride service use falls behind other shared transport modes, notably rail-and bus-based public transport. Survey responses indicate that frequent use of ride services (more than once a week) overall is less common than frequent use of driving or public transport. This would suggest that those who drive or use public transport use these modes as part of their routine travel choices, including for commuting, whereas ride services are used more infrequently to complement other modes and for trips poorly suited for driving or public transport. The observed peak in evening use suggests ride service use for leisure trips, as confirmed by survey responses.

Figure 4: **Ride service trip origins by zip code, hourly flows (different geographic scales)**



Sources: Adapted from (Feigan and et C. Murphy, 2018).

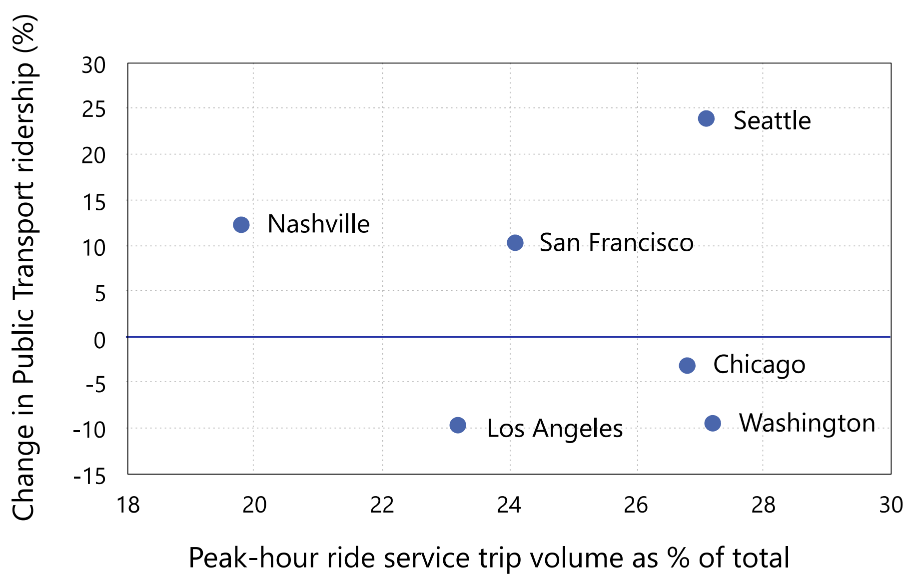
Ride service trip characteristics

The ride service operator data indicates that all regions generate trips but that the majority of these occur in dense, core areas and at airports (Figure 2.3). Further, the highest trip concentration typically takes place within zip codes, rather than between zip codes, even at the core. Short trips dominate ride service use, with the median trip distance falling between 3.5 and 5 kilometres. Low density and low public transport use are correlated with longer average trips, as in the case of Nashville. Survey responses also indicate that average ride service trips are relatively short, though they are longer than average bus trips. Trip length increases during those times when public transport services are infrequent or unavailable.

Impact on public transport use

The study found no discernible relationship between peak-hour ride service use and longer-term patterns of public transport use at the metropolitan regional level. Between 2010 and 2016, public transport use grew by more than 10% in Chicago, Nashville, San Francisco and Seattle – just as ride service grew from zero. In Washington and Los Angeles, public transport ridership decreased by nearly 10%, though the drop in Washington was concurrent with large-scale maintenance-related track closures (Figure 2.4). This observation period coincides with the early deployment of ride services in these markets and the impact of ride services on public transport may evolve as markets mature. For certain types of trips – notably airport trips, evidence indicates that ride services are displacing other forms of access, even for those with rail links.

Figure 5: **Peak hour ride service use compared to public transport ridership change, 2010-2016**



Sources: Adapted from (Feigan and et C. Murphy, 2018) based on Ride service trip data, SFCTA modelled ride service trip data, US National Transit Database UPT counts.

According to the Public Transport Agency survey responses cited by (Feigan and et C. Murphy, 2018), those who had replaced public transport use with ride services fell into one of three categories; those who replaced a public transport leg feeding into another public transport service, those who replaced an entire public transport trip and public transport users who switched because there was no public transport route, convenient schedule or was after public transport service hours. Table 1 details the Four Agency survey responses.

Table 1: **Trip category for the most recent ride service trip taken instead of public transport**

	BART (San Francisco rail)	MARTA (Atlanta)	NJT (NE New Jersey)	WMATA (Washington, DC)
Connecting to PT	16%	6%	8%	3%
Instead of PT	11%	16%	17%	39%
PT not an option	32% (26% hour, 6% route)	16% (8% hour, 8% route)	19% (not specified)	13% (4% hour, 9% route)
Haven't used ride services	41%	62%	56%	45%

Source: 4 Agency Survey (Feigan and et C. Murphy, 2018)

The surveys only refer to those public transport trips offered by each operator administrating the survey and do not consider substitution effects with other public transport operators in each metropolitan region (i.e. Muni in San Francisco). Both BART and WMATA stand out from the others. BART survey responses indicate a high number of feeder trips that are replaced with ride services. Closer scrutiny of the data shows that despite this, the overall net impact on BART is negative as many of the trips replaced by ride services were new trips or were previously taken on public transport (and walking and cycling). Washington area survey responses reveal a significant shift away from public transport altogether, although this could partially be due to the relative poor state of repair and frequent delays of WMATA's Metro. The main reasons cited by survey respondents for choosing a ride service trip were lower wait times and faster overall travel, especially for those who substituted a public transport trip altogether. Reliability was also cited as a major reason to switch away from public transport to ride services, especially in Washington, DC.

Impact on car ownership and use (and other modes)

The survey responses indicate that ride service use, especially frequent ride service use, is generally corelated with low car ownership rates with respect to those that do not use ride services. The lowest car ownership rates are found amongst those that combine ride service use with public transport. The exception is for those who combine ride service use with frequent solo driving with rates nearly as high as for those who only drive. Overall, the increase in car ownership attributable to becoming a driver for a ride service was outweighed by the number of cars respondents indicate they decided not to buy, postponed buying or gave up without replacing. Respondents indicated they decreased their use of cars (-10%, -4%, -20%, for BART, MARTA and WMATA, respectively), curtailed their use of taxis (-33%, -6%, -61% for BART, MARTA and WMATA, respectively) and cycled less (-4%, -2%, -2% for BART, MARTA and WMATA, respectively).

What lessons for different-sized US cities?

With the caveat that our understanding of the impact that ride services have on traffic, mobility and urban areas is evolving – as are the maturity of the market, the regulatory framework and longer-term behavioural changes, (Feigan and et C. Murphy, 2018) offer a set of conclusions targeted to large, mid-sized and smaller urban areas.

Large urban areas

Central parts of large metropolitan areas (and airports) are where the greatest density of ride service trips occur. These are also zones where many other public transport, car, cycling and walking trips occur. Competition for the curb and the street is particularly acute in these areas and the ways in which authorities regulate access to these two public spaces should be aligned with broader public policy goals. The imperative remains to prioritise the most efficient uses of these spaces irrespective of whether they are provided by public transport or other commercial operators, as well as active travel. Where ride services comprise part of the shared transport offer (for pooled ride services, for example), they would fit into that priority scheme. Further, the integration of ride services, especially shared ride services, should be prioritised over individual motorised transport. However, this should not erode the performance of high-capacity, efficient services or degrade the cycling and walking environment where these are present or should be enhanced.

The authors recommend the following specific actions to facilitate ride service deployment and management in large cities:

- **Designate specific, visible and managed ride service/taxi pick-up and drop-off zones at the curb**, especially near public transport stops and popular destinations.
- **Establish agreed and enforceable curb space allocation and management rules**. These may establish time- and location-specific flexible use of these spaces.
- Public authorities and transport service operators should **explore ways to integrate ride services to improve overall service quality, outcomes and cost-efficiency**. This includes partnering around on-demand micro-transit, para-transit, and late-night, early morning and out-of-public transport service area trips.
- **Facilitate the move to an open mobility as a service model** (MaaS) model for urban mobility that is competition-friendly and aligned with broad public policy goals regarding equity, congestion mitigation, urban access, etc.
- **Establish effective tracking and monitoring of overall transport activity, including ride services**. Licensing of operations for public transport and ride services, including taxis, should be contingent on licensees providing sufficient data or trusted insight so as to monitor the impact of these services on public policy objectives. This should extend to all registered and licensed transport operators, including public transport, taxis, ride services and freight delivery.

Mid-sized urban areas

Traffic pressure in the core may be less pronounced in mid-sized cities but the imperative to provide high quality mobility in a less-dense and spread-out urban area with a lower share of radial commuting patterns may be significant. Accordingly, the report suggests the following actions for mid-sized urban areas:

- Explore the scope for **ride service partnerships that extend first- and last-kilometre links to public transport** and see where they may be integrated into new, hybrid forms of shared transport provision.
- Exploit **co-marketing campaigns** to highlight and strengthen the synergies between all collective modes of transport, including ride services, and active travel modes.
- Facilitate the **integration of all transport modes into payment and trip planning and information systems**.
- Support the **integration of ride services into transportation demand management strategies**, especially those established for public institutions and large employers.

Smaller urban areas

The challenges facing small urban areas are structurally different than in the previous two categories of urban areas. Car use contributes to less overall traffic pressure and demand for street and curb space is often manageable. Nonetheless, a significant part of the population cannot use cars due to lack of availability or temporary or permanent disabilities. In these contexts there is a real opportunity to focus resources on core, trunk public transport services and fully integrate ride services and other shared modes into the other parts of the network. The report recommends:

- Public authorities and public transport operators should **pursue formal partnerships to provide feeder services and fill gaps** in current service provision
- Create partnerships with ride services to help provide a broad coverage of **on-demand and para-transit services** in low-demand zones and off-peak hours

Evidence on impacts of early-stage ride service deployment in the United States: Implications for policy and transferability

These studies outline some of the early impacts of the uptake of ride services in several US cities. They provide useful insights into how these services interact with other transport modes and may potentially impact cities more broadly if they become more popular. They provide some indication of regulatory and other actions that authorities should consider ensuring that their growth is consistent with broader transport goals and urban policies.

Are these lessons transferable to other cities and other countries? Not necessarily, though they do highlight potential points of conflicts that should be considered in other contexts? Do they indicate what the long-term impacts of ride services will be? Probably not because they represent the situation in the very early days of ride service markets. These will evolve as will the regulatory context framing them such that the ultimate impacts in mature and effectively regulated markets may be quite different from those emerging at present.

For instance, if ride services ultimately start to compete with single car use (and some share of public transport trips) and make living without a car easier than owning and driving cars, the ultimate impact may be quite positive. If, however, they make little inroad to reducing car dependency just as they erode public transport and active travel mode shares, the ultimate impact will be ill-aligned with many cities' policy objectives. Ultimately policy will have a role in shaping the regulatory environment and market in which ride services operate. Public authorities can also leverage the use of public infrastructure to help deliver wanted outcomes. In that context, what can be drawn from the US evidence to help guide the allocation of public space amongst different users and uses?

Should authorities make room for ride services at the curb, and if so where, when and how?

Overall, the evidence is inconclusive regarding if ride services contribute to or detract from public policy objectives such as those related to congestion mitigation, environmental policy and equity. There are four principal findings that help to understand the nuances surrounding this assessment.

The first finding is that there is evidence that ride services lead to more vehicle travel in certain contexts and there is also evidence that ride service trips replace public transport trips – but not always. In some contexts, public transport growth has occurred despite uptake of ride services. There are indications that ride service trips that replace public transport often replace poorer quality public transport trips and occur at times and in places where public transport use is either inconvenient or not possible. These are precisely when and where it is most expensive to provide frequent and convenient traditional public transport. Among the principal reasons given for using ride services instead of public transport in the US studies are because the former are often more convenient or faster than public transport.

The second finding is that ride service pressure on street and curb resources is not evenly spread across urban areas – it is greatest where cities are densest and where there are the greatest concentrations of trip origins and attractive destinations. Areas with the highest concentration of trip origins have lower overall car ownership rates and some (but not all) of the evidence indicates that early ride service adopters have lower overall car ownership and use rates. This suggests that cities should initially examine if it makes sense to reallocate street and curb space in those areas first – areas where demand for parking might be undergoing a structural shift in line with lower car ownership and use. It also suggests that airports are a good place to start thinking about how to give space to ride services as part of a mix of transport options made available to travellers (see Box 2).

Box 2: Airport pick-up drop-off: "Transportation Network Companies: Challenges and Opportunities for Airport Operators"

The pressure to rethink curb-space allocation naturally is greatest where curb space is in great demand from a number of competing uses and users. One such area is at airports and train stations where bus-based public transport, coaches, taxis, ride services and private cars all compete for limited space in front of terminals and near station access. In North America, the early introduction of ride services and their rapid adoption rates has led to particularly acute competition for curbspace at airports. This lead the Transportation Research Board of the US Academies of Sciences to commission a report on the state of play of ride service access to United States airports that was released in 2017 (Mandle and Box, 2017). The report – "Transportation Network Companies: Challenges and Opportunities for Airport Operators "summarises how airport operators:

- Permit and regulate Transportation Network Companies (TNCs – the common designation for platform-based ride services in the United States);
- Locate TNC passenger drop-off and pick-up areas and TNC vehicle staging/holding areas;
- Establish and enforce regulations concerning TNC drivers and vehicles, including penalties;
- Establish the fees charged to TNCs and collect and confirm payment of such fees;
- Monitor TNC vehicle trips, including the use of geofence boundaries and other tools to confirm and enforce TNC operations.

It found that at most airports (about 63% of the reporting airports), TNCs drop off customers at the same location as do private vehicles (e.g., the departures curbside adjacent to the ticketing lobby); the remaining airports require TNCs to drop off passengers at the commercial vehicle boarding area or at the passenger pick-up/boarding areas. About 64% of the reporting airports require TNCs to pick-up passengers at the commercial vehicle or private vehicle curbside boarding areas, whereas 34% require TNCs to pick-up passengers at the areas designated for passenger drop-off or in a nearby parking structure or lot.

Airports that require TNCs to pick-up passengers at the commercial vehicle curbside boarding area frequently reserve a specific curbside pick-up zone or curbside area for TNCs. At these airports, TNCs may pick-up passengers only while the vehicles are stopped in those zones. The lengths of the designated TNC pick-up zones vary, but typically they are large enough to accommodate one to five TNC vehicles.

Most airports (47 of 48 of the surveyed airports with TNC permits) require that TNCs pay one or more of the following fees:

- Annual permit fee. Of those airports, ten charge TNCs an annual permit fee—six charge each company less than USD 2 000 per year, and four charge more than USD 2 000 per year.
- Per-trip fee. Of the surveyed airports, 87% require that TNCs pay a per-trip fee either alone or in combination with another fee (Figure 1). Some airports charge a per-trip fee only for passenger pick-up (59%), but others charge for both passenger drop-off and pick-up (41%).
- Activation fee. Some airports require TNCs to pay activation fees at the time they sign a permit, in recognition that the companies were conducting business on the airport without paying fees prior to signing the permit. Eight airports reported charging TNCs activation fees. The amount of the activation fee charged varied considerably, from USD 1 000 to USD 100 000.
- Minimum annual guarantee amount. Three airports reported charging TNCs the higher of either a per-trip fee or a minimum annual guarantee (MAG) amount. At these airports, the per-trip fees received exceeded the MAG amount.

Increased curbside or roadway congestion was reported at 46% of the airports, particularly at airports with limited curb space and increasing volumes of TNC traffic (no indication of congestion severity).

Airports have seen a 5% to 30% decrease in taxicab trips and an 18% to 30% decrease in shared ride van customers. The decreases in the use of taxicabs and shared ride vans appear to increase over time. It has also resulted in airport staff having to renegotiate concession agreements with the operators of these transportation services.

Airport operators report a 10% to 20% decline in the use of private vehicles, with parking customers down by 5% to 10%. They also report a reduction in rental car transactions, estimated to be 13% or less.

Source: Adapted from (Mandle and Box, 2017)

The third finding is that ride service use peaks in the evening and for leisure trips. This would be consistent with much of the early press reporting on ride service conflicts in many US cities (San Fran DC and NYC reports). This suggests that there is scope to first start testing the re-allocation of curb space, either temporarily or permanently, in those areas.

Most emerging forms of single or shared ride services will prove to be faster, more convenient or have lower wait times and trip request latency than traditional public transport in low-density areas and when demand is low and after hours. But these are not areas or times where competition for street or curb space is most intense. In dense urban cores, at popular destinations (e.g. business districts, entertainment districts, airports) and at peak hours, high-capacity and high frequency shared transport will move the most people most effectively.

These services, irrespective of if they are operated by public or private operators or if they operate on fixed routes or on-demand, will require timely access to the curb. The findings from the US studies suggest that ride services may not erode high quality public transport shares if the latter is fast and convenient. This would suggest that giving (or expanding) space at the curb and on the street for these public transport and shared mobility services could help to ensure that low-occupancy ride services do not weaken core public transport networks.

In non-US contexts where high-capacity, high-frequency and high-quality public transport services prevail and are given priority, the US findings may therefore indicate that ride services would not significantly decrease core public transport trips, especially if the latter are given priority on the street and at the curb. In contexts where motorisation rates are low and public transport challenged by rising traffic, shared ride services may serve as an effective substitute to car ownership and solo driving. They may thus potentially reduce traffic pressure, but they (and public transport) will also likely require granting some priority access to the curb for these services.

Priority access to the curb is only one of several strategies that could help to balance traffic flows in favour of shared, high-capacity and low latency transport services. It is, however, a blunt instrument that does not necessarily allow for dynamic management of that space. Road or congestion pricing is a much more effective instrument that would allow large-scale traffic balancing. Nonetheless, despite solid theoretical backing and a few successful examples, these schemes have persistently failed to gain popular and political traction. Pricing parking has proven a more feasible and realistic option and its success suggests that, in addition to space allocation rules, access to the curb should be priced (as parking is) according to impacts and in line with public policy goals.

Should authorities make room for ride services at the curb? In most cities, yes. But they should do so as part of a strategic re-assessment of the priority they wish to give different modes to access and use shared public assets, including streets and curbs. There is much to be done to understand what this strategic re-allocation will look like – and it will be unique to local contexts.

Cities should start to anticipate a greater heterogeneity in mobility services. This greater heterogeneity will be accompanied by structural shifts in the way in which people travel – especially, but not only, with the onset of increased vehicle automation. This greater heterogeneity will compound some of the effects already observed for ride service-public transport interactions. For instance, modelling indicates that for every thousand bikeshare docks placed near bus routes in New York city, bus ridership decreases by nearly 2.5 % (Campbell and Brakewood, 2017). This is not necessarily a negative outcome if bus travel becomes less congested and more comfortable for those who remain, and it need not have financial repercussions if public transport and bike share passes are bundled together, but it does indicate that authorities must anticipate changes to the status quo that will occur with the deployment of new mobility services.

Faced with increasing and increasingly diverse demands for curb space, public authorities will need to plan for the formal re-allocation of curb space to the highest and most efficient uses (in terms of people or goods dropped off or picked up) in busy neighbourhoods and at peak times. This will entail thinking about how parking needs will evolve, the space to give to different forms of shared mobility and what pricing mechanisms will enable the city dynamically manage demand.

It will also require establishing principles that will guide future technology development and deployment on city streets – including for self-driving vehicles (see Box 3). They will have to be built on a clear vision of what cities, and transport in cities, should deliver. These principles will have to be robust to the changes brought about by new technologies and as-of-now infeasible or inexistent use cases.

Box 3: Shared mobility principles for liveable cities

These principles, produced by a working group of international NGOs, are designed to guide urban decision-makers and stakeholders toward the best outcomes for all. Outcomes that ensure that transport facilitates safe, efficient, and pollution-free flow of people and goods, while also providing affordable, healthy, and integrated mobility for all people. They were developed to help guide city action and assist public authorities in addressing the fast past of technological change, the proliferation of new use cases, the allocation of finite and scarce public space and future uncertainty.

1. We plan our cities and their mobility together.
The way our cities are built determines mobility needs and how they can be met. Development, urban design and public spaces, building and zoning regulations, parking requirements, and other land use policies shall incentivize compact, accessible, liveable, and sustainable cities.

2. We prioritize people over vehicles.
The mobility of people and not vehicles shall be in the center of transportation planning and decision-making. Cities shall prioritize walking, cycling, public transport and other efficient shared mobility, as well as their interconnectivity. Cities shall discourage the use of cars, single-passenger taxis, and other oversized vehicles transporting one person.

3. We support the shared and efficient use of vehicles, lanes, curbs, and land.
Transportation and land use planning and policies should minimize the street and parking space used per person and maximize the use of each vehicle. We discourage overbuilding and oversized vehicles and infrastructure, as well as the oversupply of parking.

4. We engage with stakeholders.
Residents, workers, businesses, and other stakeholders may feel direct impacts on their lives, their investments and their economic livelihoods by the unfolding transition to shared, zero-emission, and ultimately autonomous vehicles. We commit to actively engage these groups in the decision-making process and support them as we move through this transition.

5. We promote equity.
Physical, digital, and financial access to shared transport services are valuable public goods and need thoughtful design to ensure use is possible and affordable by all ages, genders, incomes, and abilities.

6. We lead the transition towards a zero-emission future and renewable energy.
Public transportation and shared-use fleets will accelerate the transition to zero-emission vehicles. Electric vehicles shall ultimately be powered by renewable energy to maximize climate and air quality benefits.

7. We support fair user fees across all modes.

Every vehicle and mode should pay their fair share for road use, congestion, pollution, and use of curb space. The fair share shall take the operating, maintenance and social costs into account.

8. We aim for public benefits via open data.

The data infrastructure underpinning shared transport services must enable interoperability, competition and innovation, while ensuring privacy, security, and accountability.

9. We work towards integration and seamless connectivity.
All transportation services should be integrated and thoughtfully planned across operators, geographies, and complementary modes. Seamless trips should be facilitated via physical connections, interoperable payments, and combined information. Every opportunity should be taken to enhance connectivity of people and vehicles to wireless networks.

10. We support that autonomous vehicles (avs) in dense urban areas should be operated only in shared fleets.

Due to the transformational potential of autonomous vehicle technology, it is critical that all AVs are part of shared fleets, well-regulated, and zero emission. Shared fleets can provide more affordable access to all, maximize public safety and emissions benefits, ensure that maintenance and software upgrades are managed by professionals, and actualize the promise of reductions in vehicles, parking, and congestion, in line with broader policy trends to reduce the use of personal cars in dense urban areas.

Experience with past technology development shows that the deployment of many "transformational" set of technologies is often motivated by a desire to solve an existing problem. And yet in many cases, the ultimate deployment and uptake of these technologies and the use cases they facilitate not only render the original problem statement largely moot, but radically different uses than were originally anticipated propagate rapidly. For example, city-scale electricity was motivated by replacing gas lighting, cars were partially seen as a public health response to the accumulation of horse carcasses and manure, computers to speed up large-scale mathematical calculations, portable telephones to enable ubiquitous calling and the internet as a way to rapidly and robustly ensure laboratory-to-laboratory messaging. In all cases, these technologies enabled use cases so far removed from their original intent that they were unimaginable at the time of their introduction and, therefore, largely unanticipated.

It seems clear that the nexus of digital, automated, sensing, thinking and decentralised technologies will lead to use cases that are only barely perceptible today. And it's likely that these use cases will have an impact on cities, public assets, streets and the curb in ways that will challenge their regulation. Beyond opening a discussion on the principles that should guide policy in this evolving space, cities can already start to experiment with different curb-space reallocation and pricing models. But they can only do so if they have themselves a good grasp of the principle asset of interest here – the curb. In many cities, this is far from being the case.

Knowing the curb, coding the curb

Many cities have a poor and disjointed knowledge of current levels and patterns of curb use, an incomplete overview of curb use rules and a limited understanding of how different stakeholders interact in that space. These are significant limitations that must be addressed as cities start to think about how they should imagine curb use rules for the future.

Knowledge of the curb is generally poor…

Inventories of curb space allocation are often kept in multiple departments responsible for different uses (parking, traffic, fire and emergency services, freight delivery and logistics, bicycle and car-share, street vendors and parklets, utility maintenance, etc.). These inventories may be digital but are often paper-based and are infrequently updated. Inter-department use is not always easy and their use by the public and other stakeholders, not possible, or only very difficultly so. Even for revenue-generating activities, such as parking or commercial use of that space, infrequent surveys of occupancy rates and usage lead to a poor understanding of curb-use efficiency. This limits the ability for public authorities to assess whether current allocation regimes are effective or how this space should be re-allocated to more efficient uses.

… and it is often shifting away from public authorities

Just as with other domains of digital mapping and remote sensing, much of the most up-to-date knowledge base is held by the private sector. Companies have mobilised significant resources and capabilities to develop high-definition and frequently updated virtual maps of the streets and their surroundings – including the signs that signify curb usage and parking rules. This capability will only grow as more and more vehicles, automated or not, become sensing platforms that feed central company-held databases. Access to part of this knowledge base may be granted for free in some circumstances, may be made commercially available in others or may not be shared or sold at all.

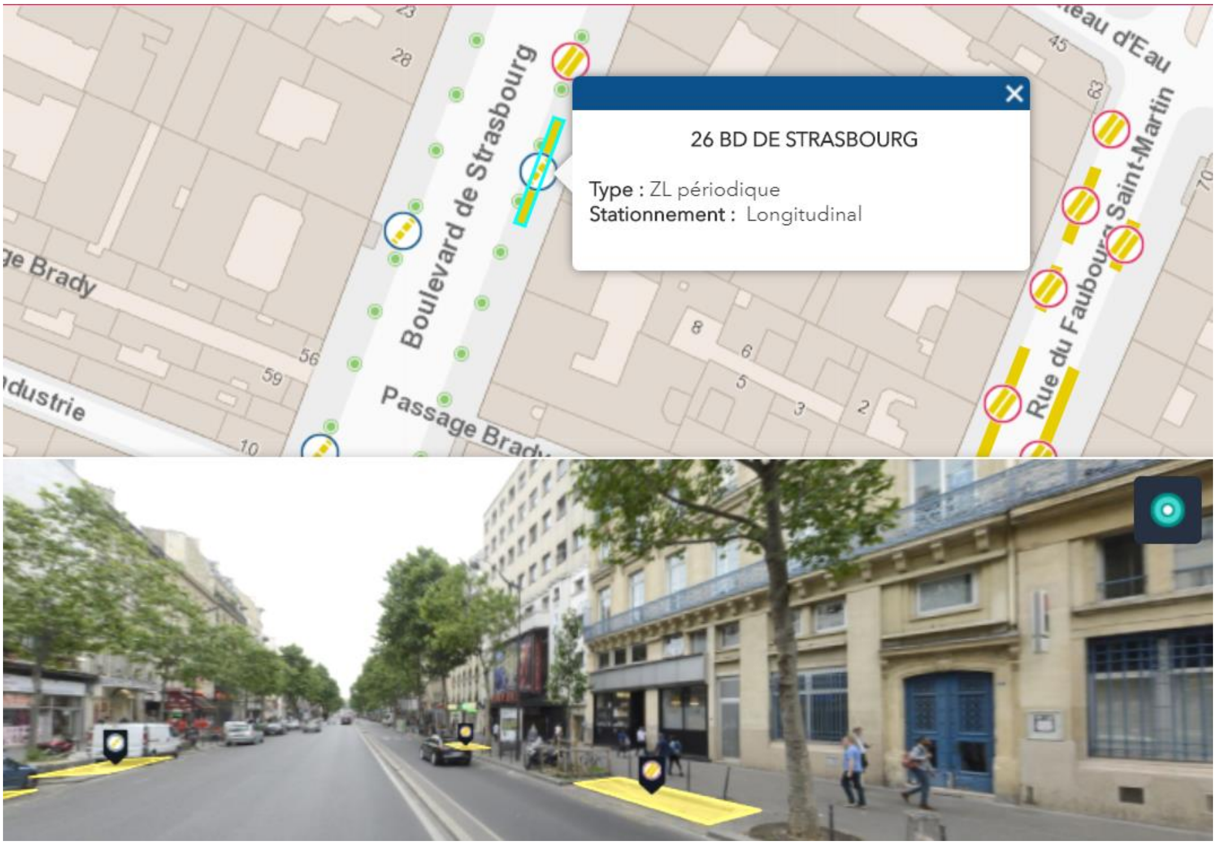
Appropriate metrics and data collection are lacking

The collection of curb use metrics, such as parking turnover, public transport and ride service pick-ups and drop offs, package and freight movements, originating or terminating bike share rides or the use of shared cars are rarely coordinated, nor their results compiled. Because of this, most public authorities have a limited understanding of the overall efficiency of current curb space allocation regimes. Real-time parking turnover data has been especially lacking in many cities but the growing use of automated payment via apps and more rigorous semi-automated control is starting to make data available in near real-time (as in the case of the Los Angeles Department of Transport – Xerox LA Express Park project). This data gives cities an understanding of how many vehicles are stored at the curb at any given time and enables dynamic management of that space via variable pricing.

Public authorities are seeking to remedy poor knowledge of the curb

Many public authorities are seeking to make more of their data interoperable and useable both internally and by a larger public. The move to open internal and siloed databases creates many synergies that were not possible before and enables new services that leverage public data. Open datasets published by cities sometimes include data related to the curb thought the quality and precision of this data is variable. Targeted open data can help improve curb use today. For example, faced with increased pressure for deliveries and pick-ups of goods, and noting that many delivery vans would double-park when a nearby delivery bay was free, the city of Paris created and shares an interactive dataset that gives the precise location, street view picture and rules of use (including hours of operation for flexible zones) for legal goods delivery zones. This data can be consulted online or built-in directly into third-party apps or other services to help alleviate pressure from increased goods delivery in the city (Figure 6).

Figure 6: **Interactive map and dataset for freight loading and delivery zones in Paris**



Source: Ville de Paris

Managing curb and street space benefits from a strategic vision

Some cities have established a broad strategic vision of how to manage urban space more generally and street space in particular. This vision, often the result of a consultative process and anchored in official planning guidance, is helpful to guide efforts to rethink curb space allocation regimes. They enable cities to fall back on vision-led principles even when new pressure for the curb manifests itself. Two examples, from London and Seattle respectively, help illustrate the such strategic visions for street and curb space.

Street Types for London

In order to create a common reference language for categorising streets by their functions for public authorities and others who must interact with the road network, London created a "Street Types" matrix in 2014. This matrix outlines 9 different street types as categorised alongside their "space" or "movement" functions (Figure 7). The former refers to the quality of the urban space with respect to urban liveability and civic life and the latter to the ability of the street to help people travel (Transport for London (TfL), 2017)

The Street Type matrix was the result of a 2-year consultation launched by Transport for London, the Greater London Authority and London borough authorities in 2012. Their expectation was that it would ensure consistent levels of service for people travelling on London roads irrespective of how they travel and enable other, non-transport uses of adjacent spaces in line with Londoners' wishes. The Street Types matrix serves as planning input for street interventions and could potentially prove useful for understanding where and how to re-prioritise curb access to different stakeholders in the future.

Figure 7: **London Street Types Matrix**

Source: TfL

Flex Zone/Curb use priorities in Seattle

Like London's starting point, the City of Seattle wanted to ensure that use of streets and curb space accounts for multiple functions and should be differentiated by context. The city's Comprehensive Plan, adopted in 2017, does so by establishing context-specific priorities for the use of curb space – which it broadly defines as "Flex Zones". Seattle's "Flex Zones" are the curbs areas where people get on and off from public transport, hail cabs, get in and out of ride service vehicles, make deliveries or pick-up goods, socialise in "parklets" or do business in "streeteries" (Shepard, 2018). In response to conflicting pressures to use these Flex zones, the city has set out a strategic vision for these spaces that sets priorities based on different functions it serves. These functions are set so that city streets can "safely and efficiently connect and move people and goods to their destinations while creating inviting spaces within the right-of-way" (Shepard, 2018). These functions and their priorities according to surrounding land uses are described below (Table 2 and Figure 8):

These and other categorization/prioritisation schemes create a shared understanding amongst different departments and with outside stakeholders on how street and curb functions shape design, interventions and access rules. They enable a consistent framework for designing or intervening in these spaces across the city and for similar types of streets. They also encourage stakeholder input into the ways in which street and curb space is allocated. As such, they represent a useful foundational basis on which to discuss the allocation of curb space.

Table 2: **City of Seattle Flex-use zone functions**

Function	Definition	Examples of Uses
Mobility	Moves people and goods	• Sidewalks • Bus or streetcar lanes • Bicycle infrastructure • General purpose travel lanes (passenger and freight) • Right- or left-turn only lanes
Access for People	People arrive at their destination, or transfer between different ways of getting around	• Bus or rail stops • Bicycle parking or bike share docks • Curb bulbs • Passenger loading zones • Short-term parking • Taxi stations
Access for Commerce	Goods and services reach their customers and their markets	• Commercial vehicle loading zone (incl postal and parcel delivery) • Truck loading zone
Activation	Offers vibrant social spaces	• Food trucks • Parklets and streeteries • Public art • Street festivals
Greening	Enhances aesthetics and environment health	• Plantings, including boulevards, street trees and planter boxes • Rain gardens and bio-swales
Storage	Provides storage for vehicles or equipment	• Bus layover • Long-term parking • Reserved spaces (e.g. for police or other government use) • Construction

Figure 8: **Seattle Flex zone functions prioritised based on surrounding land use**

	Residential	Commercial & Mixed Use	Industrial
1	Mobility (Modal Plan priorities)	Mobility (Modal Plan priorities)	Mobility (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: (Shepard, 2018)

Coding the curb will facilitate efforts to manage and efficiently allocate this space

A common data syntax for inventorying curb assets, signifying rules relating to these spaces and monitoring their use can improve understanding and efficiently allocate curb space. It can also help commercial operators and others who produce relevant data regarding the use of these spaces to share them in a common format with minimal risks related to leaking sensitive information. Much as popular harmonised data formats for public transport and bicycle sharing (General Transit Feed Specification – GTFS, and General Bicycle Share Feed Specification – GBFS, respectively) have enabled better monitoring and spurred innovation surrounding these modes, a common data syntax for describing curbs and their use could do the same for these assets.

SharedStreets

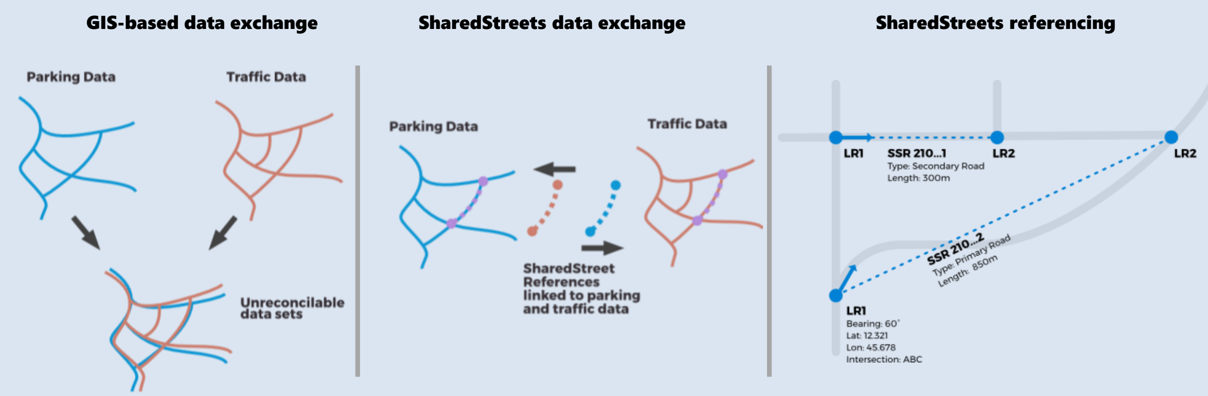
The Open Transport Partnership and the US National Association of City Transport Officials (NACTO) have created such a data standard with SharedStreets (www.sharedstreets.io). SharedStreets is a linear referencing system built on OpenLR – an open-source, compact and royalty-free software project launched by TomTom International B.V. (www.openlr.org). SharedStreets addresses a confounding issue that has limited the willingness of commercial operators to provide curb- and street-use data they collect –namely, the necessity to share proprietary base map information and commercially/privacy-sensitive un-anonymised data. SharedStreets creates a standardised syntax for street-level GIS-based data thus allowing the reliable exchange of information irrespective of the base map used by different departments, vendors or companies operating on streets and at the curb. It is an open data standard that is free to use and is governed by a non-profit body.

The lack of a standardised and anonymous method to inventory curb-use prevents effective cross-referencing and is a barrier to companies sharing data they collect and hold. By only focusing on linear referencing data (see Box 4) and only referencing key features of interest (and not on how the data was obtained or revealing personal identifiers), SharedStreets serves as a neutral anonymised clearinghouse for data. It provides a framework in which city departments can provide detailed, blockface level data on allowed curb uses, and operators can share essential information on curb access and use. For instance, several ride service operators can report anonymised pick-up/drop off data using the SharedStreet linear referencing system without having to reveal other more commercially sensitive or potentially privacy-invasive data (see Figure 9). This then provides city officials with an overview of ride service demand for curb space and, when combined with other uses like public transport, helps draw a comprehensive picture of overall curb use efficiency.

Box 4: SharedStreets Referencing System

Cities today depend on geographic information systems (GIS) to collect and share street data, but this process requires users to agree on a map, or to use predefined, and often proprietary IDs to describe streets. This limits the potential for collaboration and data sharing between government agencies, and with the private sector. And use of proprietary maps and identification systems can undermine cities' ability to use and share critical public information about streets.

SharedStreets provides a global, non-proprietary system for describing streets, designed to incorporate any source of street-linked data. This allows public and private entities to communicate with clarity and precision about streets while ensuring full compatibility with organizations' internal map data.



The SharedStreets Referencing system is built on four layers of data:

- **SharedStreets References:** basemap-independent references for intersection to intersection street segments built on Open Liner Referencing (OpenLR)
- **SharedStreets Intersection:** nodes connecting street segments references
- **SharedStreets Geometries:** geometries used to generate street segment references
- **OSM Metadata:** underlying OpenStreetMap (OSM) way and node references used to construct SharedStreets data

The OpenLR-style street segment references are the foundation of the SharedStreets Referencing System. SharedStreets References (SSR) are directional edges in a road network. Two-way streets have two SSRs, one for each direction of travel, while one-way streets only have one SSR. In the draft specification these are labelled "forward references" and "back references," with the forward reference following the direction of the map geometry used to generate the references.

Each SharedStreets Reference consists of two or more location references (LRs) that describe the latitude and longitude of the beginning or end of a street segment. SSRs also describe type of road (or the "form of way"), and length of the geometry connecting location reference points. In combination these attributes uniquely describe any road segment, and can be used to look up corresponding streets in users' internal maps.

These references allow users to uniquely describe any street segment in the world using just a few high-level characteristics. This allows users with different map geometries to describe the same street segments in identical or nearly identical terms. The references are used to find matching streets in users' existing internal maps. In cases where no matching street is found, users have the opportunity to update their map data to fill in missing or incorrectly mapped segments. Street segment references protect users' intellectual property, as data can be shared without disclosing a complete map. Segment references also enable rapid reconciliation of data derived from different maps.

SharedStreets is based on the idea that users will maintain their own internal basemaps. Any basemap--open or proprietary--can generate SharedStreets references for sharing with others using a different map. With open basemap data users are encouraged to share the full set of SharedStreets data layers (references, geometries and metadata). Users with proprietary basemap data can share only the segment references, allowing exchange of information while protecting map street geometries and other intellectual property.

Source: SharedStreets

Figure 9: **SharedStreets referencing system: Taxi and ride service pick-up and drop-off intensity in Washington DC**

Source: SharedStreets with data from Washington, DC Department of For-Hire Vehicles

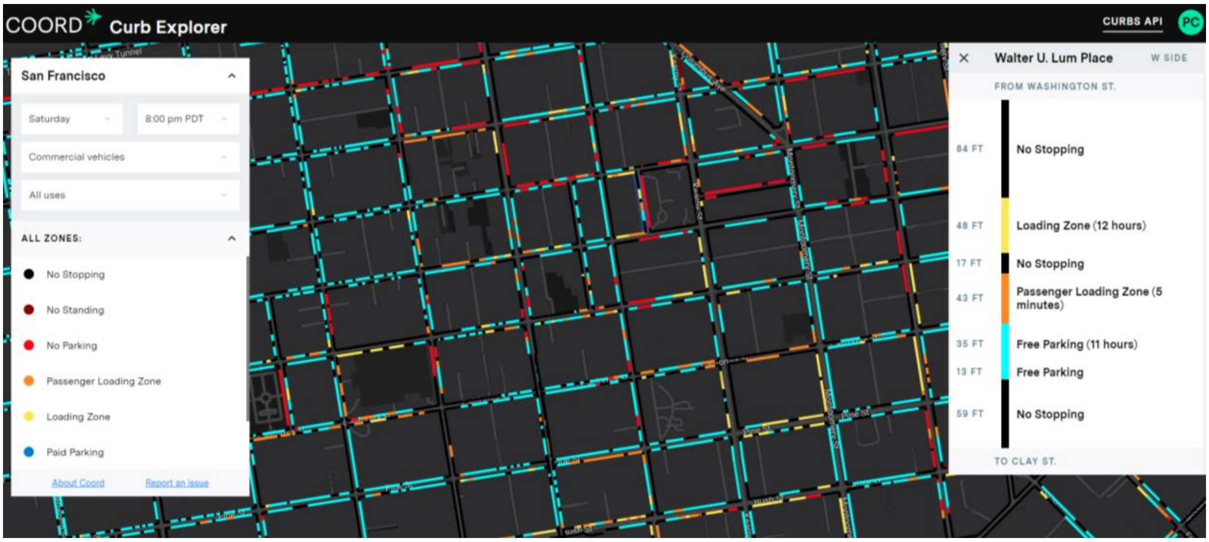
The SharedStreets model allows the city, its inhabitants and companies doing business at or around the curb to have a global vision of the use of those assets – combining, for example, the number of public transport pick-ups and drop-offs, the turnover at shared bicycle docks, the number of ride service passengers getting in and out of vehicles and the amount of time delivery vehicles occupy loading zones. From an operational perspective, operators needing to access the curb can build-curb-level use profiles directly into their back-office systems or customer-facing apps.

Early applications for the SharedStreets referencing system include measuring and monitoring congestion levels and identifying unsafe traffic behaviour, mapping curb regulations and monitoring curb use and as a basis for planning and re-allocating street and curb space.

Coord

The lack of a common data syntax for encoding street-level data has not gone unnoticed by the private sector – many companies are producing services linking high-definition maps with proprietary referencing schemes and ancillary, sometimes publicly-sourced data, such as and Inrix (On-Street Parking API) and HERE High Definition Map-based APIs and Software Development Kits – SDKs). Among these, for example, Sidewalk Labs (part of the Google Alphabet group of companies) has developed the Coord platform which collects information relating to new mobility services and curb infrastructure and use (Smyth, 2018). Coord provides API access to this data coded to its proprietary referencing model. Coord data can be used for navigation services, mobility service apps and interfaces or other novel products (e.g. real-time bidding and reservations for freight loading zones). Coord's APIs can be integrated into third-party apps and services or can be visualised on Coord's "Curb Explorer" (see Figure 10)

Figure 10: **Coord "Curb Explorer": curb use rules for San Francisco**



Source: Coord

Coord builds its inventory of curb uses by parsing a massive and continually updated dataset of digital photographs (collected by Coord's parent company) of parking signs and other curb-adjacent signs and objects. Integrating this real-time map of street and curb regulations into back-end code can help ensure that mobility services are fully and automatically compliant with these rules. At present, Coord provides API access to curb-related data regarding freight loading and passenger pick-up zones, street parking rules, bus stops, location of taxi stations and more. It currently has developed curb inventories for New York City, Seattle, San Francisco and Los Angeles. Future plans include integrating bicycle share referencing and automated access to tolling and parking prices (with an eye to also providing a back-end to support automatic transaction clearing for toll and parking payments).

Coding the curb: Implications for policy

Open-source data referencing and open data for the curb

As with other publicly-held assets, there is an imperative to digitise and share knowledge about streets and curbs. This inventory should ideally be useable by public and private actors and should be updated frequently. Because of the public nature of these assets, and the fact that public authorities are mandated to manage these, there is much to be said about providing this data in an open and broadly shared format. SharedStreets is one example of how this data can be referenced for easy and open use. Adopting an open data and open-source approach for coding and sharing data about the curb does not negate the business models of those developing high-definition maps and real-time inventories of all (public and private) curb assets. In many respects, it enhances these by reducing the amount of work necessary to build value-adding applications on this common base.

The self-communicating curb

These open and accessible inventories translate regulatory intent into machine-readable language and thus allow the rapid and automatic integration of curb and street use rules directly into third-part apps and algorithms. Public authorities can help by publishing their data in formats such as SharedStreets. They also have a role to play in leveraging the use of a common referencing syntax by, for example, requiring that licensed entities operating vehicles or services provide data in that format. With increased uptake, service providers, operators and app developers will code *for* this data directly and build this data stream directly into their products. Eventually, streets and curbs should digitally broadcast their own rules to vehicles and other users of that space much as signs currently visually signify usage rules to users. Digital curb use rules can be updated and adjusted as necessary and when vehicles and other systems are hard-wired to integrate this information into decision-support or decision-making systems, compliance becomes largely automatic. Authenticating the provenence and correctness of data regarding the rules of use for, and status of, public assets like the curb will require robust, verifiable and trusted mechanisms. Digital ledger technologies such as those being deployed in blockchain and other formats can provide the basis for this trust but will require some thinking about how to adapt them for regulatory purposes. Public authorities will also bear responsibility for providing stable, durable and predictable governance around street data standards and its content.

Digital identifiers for digital curb management

Common data referencing standards for curbs enable detailed knowledge of curb use rules and facilitate the monitoring of this use for regulatory compliance. However, truly effective monitoring and allocation of curb *user* permissions will require an analogous digital data standard for *users* of curb space. At a minimum, this data could simply be a digital representation of the physical license plate for vehicles. This digital identity could be secured with robust and secure identity management protocols, possibly based on digital ledger technology (see ITF, 2018 for a discussion of this). This identifier can then be cross-referenced with other data sets much as automated parking control systems do today with automatic license-plate recognition technology. Digital license plates would link vehicles occupying curb space to permissions, payments of fees and other information that would condition their use of that asset. The combination of digital identifiers, common data referencing formats and sensing technologies are especially important for managing *flexible use* of the curb as described in the next section.

The curb tomorrow: Pick-up drop-off city to flex use city

The contested curb, under pressure both from new demands and existing uses, is a focus of public authorities in many cities. Where and when these pressures are greatest, there is urgency for public authorities to act. However, if public authorities address these hotspots piecemeal they run the risk of underestimating, or perhaps not anticipating, longer-term changes that are underway. Changes which will require a more strategic approach towards the allocation of public space in cities, on their streets and at the curb. A strategic vision for the use of street space, as noted previously, should serve as the bedrock for future curb space management and re-allocation policies. Cities have numerous options to choose from regarding what uses they wish to prioritise and how these might be given space at the curb when they seek to build on this vision,

The street ahead

Cities designed for vehicles have often left little space for people, but cities designed for people will generally make room for vehicles. The move back to a people-centric focus for planning and policy is one that is gaining speed, not just for urban and transport planning, but for road safety as well as embodied in the Safe System approach and Vision Zero (ITF, 2016). These approaches recognise that cities derive economic, cultural and social strength and resilience from the diversity of people and functions they support. For transport, a growing set of mobility choices strengthens cities but space constraints in certain parts of the urban area mean that not all of these can be catered to equally. How to prioritise among street and curb functions is a matter of local context and inhabitants' preferences. One thing seems certain, however – the street (and curb) of tomorrow will be dissimilar to the street and curb of today in many fundamental ways as new technology, evolving regulations, emerging travel behaviour and patterns and other meta-trends co-mingle (Figure 11).

Figure 11: **The street of the future will be different in some fundamental ways from streets today – One potential scenario: Automated shared ride services (Renault EZ-GO concept car)**

Source: https://media.group.renault.com/global/en-gb/renault/media/pressreleases/21205140/renault-ez-go-premiere-mondiale-du-robot-vehicule-concu-pour-la-mobilite-urbaine-partagee

Julia Thayne of Siemens and Camilla Andersen of Gehl Architects lay out 5 guidelines in the think piece "Streets Ahead: Integrating Design and Technology in Future Streets" (Thayne and Andersen, 2017) that outlines the qualities that they feel should characterise streets of the future. These serve as a good starting point to frame the discussion regarding how street and curb space could be allocated.

Guideline 1: Maintenance and Operations - "The Self-Coordinating Street"

Congestion, conflicting uses, infrequent and un-coordinated maintenance activities and multiple siloed stakeholders within and outside of governments complicate effective street and curb management. In the future, the street (and the curb) should be self-aware and self-coordinating mixing sensing technologies and flexible, on-the-fly, adjustments enabled by design for multiple, rather than single, uses. Curb-space becomes a flex-use zone that adjusts over the course of the day based on demand and desired outcomes.

Guideline 2: Distribution of Space and Assets - "The Open Street"

Rigid allocation rules favour some uses, like through traffic for individually-driven cars, that in some parts of cities, crowd out other uses and other potential users of street and curb space. The cumulative impact of these micro-exclusions are cities and neighbourhoods that feel cramped for people although space is available for all. In the future, many urban streets, especially where demand for multiple uses are greatest, are open ecosystems that reflect the fluid nature of urban life. Rigid separations between different functional spaces are minimised, the street accommodates planned and spontaneous uses with real-time issuance of permissions and permits. Adjustments in space allocation account for past experience and citizen inputs.

Guideline 3: Social Inclusion and Access - "The Everyman's Street"

Streets serve to connect parts of the city to each other (for those in vehicles) but often serve as barriers to people interacting with each other. This is the result of prioritising vehicles over people, limited availability of transport options and poorly designed street environments. In the future, the street actively accommodates its daily users irrespective of whether they are passing through or if they spend time there. Multiple transport modes are given room with the highest priority given to the most efficient and those best aligned with the outcomes desired by people and the elected authorities that represent them. Seamless and rapid transfers are the rule, accessibility is guaranteed for all and rules of street and curb use are conveyed in human and machine-readable language.

Guideline 4: Sustainability and Resilience - "The Strong Street"

Today, streets can be noisy, polluted places where many of the negative side-effects of living in urban spaces are concentrated. They are also places that are subjected to major environmental stressors (stormbursts and other flooding risks, heat damage, etc) that can lead to disruptive failures and closures. In the future, the street is design and managed to deliver better overall health and resilience (for humans and for nature). The street environment is designed to support health-enhancing uses and to minimise the exposure of people to environmental and health risks. The sustainable street integrates elements of eco-system resilience to manage and mitigate flooding and heat risks. Sensor technology and predictive intelligence enables the street to anticipate risks and adjust its use – or warn users. The strong street also monitors its performance over time and uses this information to adapt to changing circumstances or better deliver health and resilience outcomes.

Guideline 5: Street Edges and Buildings - "The Supported Street"

With widespread motorisation, the "movement" aspect of streets has largely taken the upper hand over the "place" aspect, even in those contexts where this has reduced social, safety and liveability outcomes. Streets serve multiple purposes and support multiple outcomes across very different contexts and viewing them solely as conduits for traffic in all circumstances and all places is a reductive approach that some authorities have questioned as the examples of TfL and Seattle provided earlier illustrate. Further examples include: TfL, Paris, NYC, SF, Berlin, Barcelona, CPH). In the "street as pipe" paradigm, the built environment is seen as secondary and largely unrelated to the value that streets provide – except as destination for (vehicle trips). The street of the future is actively supported and integrated into its surrounding environment. Where density, attractivity and diversity of uses are greatest, this will mean that the built environment serves as an "active" edge to the street environment. Here, transparency, open ground floors, diverse services, frequent scale and texture changes amplify the opportunity for people to linger, shop, socialise and navigate. Technology helps the street accentuate the feeling of activity that improves safety and use of the built environment enables new, sometimes temporary, uses.

What to steer towards…

A sense of realism for the task at hand, a vision to guide action and adapted consultative processes

Discussions regarding the allocation of street space are typically very contentious – especially when they involve re-allocation of space from existing uses and incumbent users to new uses and users. Discussions around parking are particularly delicate in many contexts as any move to remove parking is seen as an erosion of car-drivers "rights" to occupy space and of the viability of commerces who feel that reduced on-street car-parking would lead to a drop in patronage. In cities, what is contentious often becomes highly political and this has often coloured debates around parking policy. This will likely be the case going forwards with broader curb space reallocation efforts.

Allocation of public street space is a broad issue that concerns all city users – not just those with cars and is a process that should be informed by evidence and wide consultation. Many cities have wrapped the issue of parking into a broader vision for how the city should deliver value for its inhabitants (e.g. Amsterdam, Barcelona, Copenhagen, London, Paris, Oslo, Stockholm, Tokyo…) (Barter 2016) (Kodransky and Hermann 2011) (Mingardo, van Wee and Rye 2015). These frameworks have enabled many cities to defuse some of the most contentious aspects of the parking and curb space debates. Paris has had a long policy of re-allocating public street space away from single occupancy car use towards public transport, pedestrians, cycling, shared cars and bicycles and motorised 2-wheeler parking. From 2001 to 2016, on-street parking and public off-street parking has dropped by 43% and motorised car and truck traffic has dropped by 33% over the same period (Mairie de Paris 2017). Oslo has embarked on an ambitious plan to render its centre as free of cars as possible not by banning cars outright, but rather by re-allocating all on-street parking to other uses – and in particular, to provide more space for walking, public transport and cycling. This plan has been developed in coordination with local businesses and city residents and concerns central parts of the city where car ownership is quite low (only 30-38% of households in the area own a car)((Cathcart-Keays 2017). The commercial impact of re-purposing some on-street parking has also been extensively studied with most results pointing to an abundance of under-used nearby parking and a significant overestimation on the part of shop owners as to how customers reach their shops (Jaffe 2015)

A broad re-assessment of curb space allocation will require the joined efforts of a wide range of stakeholders that have not typically been convened to plan, design or manage the street environment. These stakeholders will include technologists, designers, transport engineers, social scientists, public authorities and citizens. How this happens must be carefully considered as current approaches may not be sufficient, especially since many future uses cannot be clearly anticipated. Just as the street of the future is likely to change, the *consultative processes that give rise to a shared vision will also likely change*. One key aspect to consider is that the potential impacts from flexible curb use and its re-allocation away from a sole parking function may not be well understood by residents and businesses, nor measured by public authorities. Arrival mode and other forms of targeted travel surveys routinely reveal a disconnect between how much dedicated parking residents and shopowners believe is necessary and how much is actually required to handle those people travelling to local destinations by car (Roe and Toocheck, 2017). Many cities are addressing somewhat analogous discussions regarding the allocation of public space, especially in the context of parking policies. This experience and the consultative and planning processes cities employ (Sustainable Urban Mobility Plans in Europe, for example) should serve as the starting point for discussions regarding the future allocation of curb and street space.

Rethinking streets and curbs as flexible, self-adjusting spaces

Beyond enhanced stakeholder engagement, these guidelines imply a fundamental re-conceptualisation of public space – streets and curbs included – away from static and inflexible installations and more as highly flexible and self-solving puzzles (Thayne, J.; Andersen, 2017). The push to move from a parking city to a pick-up and drop-off city is only one part of a broader shift to *re-think and manage streets and curbs as flexible-use and as self-adjusting assets* and spaces.

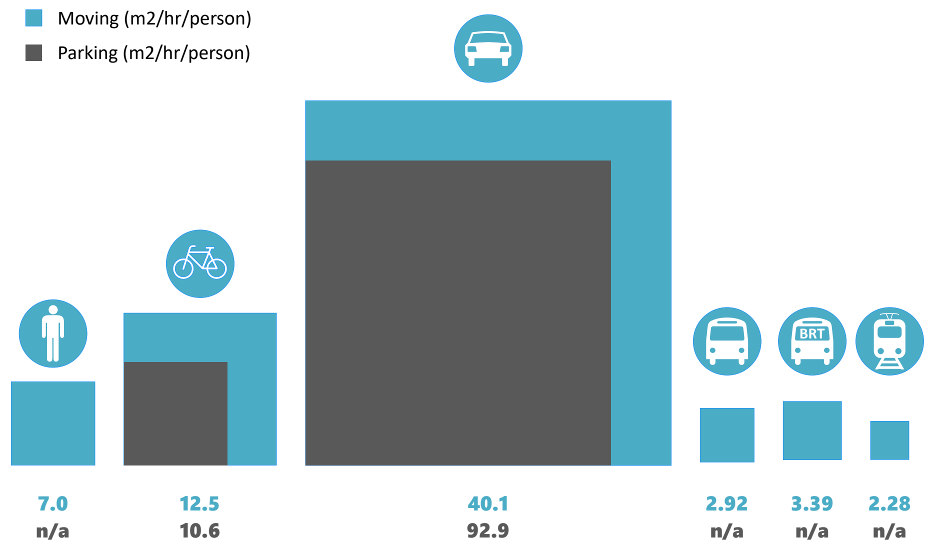
Alignment with broad policy goals

As cities begin to consider, and eventually plan and operationalise this shift, they will have to ensure that their street networks and the transport services that operate on, adjacent to and underneath deliver on a broad set of public policy goals. First among these is **safety**. Streets must be safe for all users and expressly designed to deliver high levels of safety despite errors that people or machines may make. This means integrating speed management, separation where necessary and safety-centric vehicle and technical system design. A second priority is that the transport system must deliver high levels of **access** for all, irrespective of income, sex, ability or age. **Efficiency**, in the use of space and in the movement of people and goods should be a central concern and re-balancing the use of streets and curbs should favour the most efficient uses – or those that contribute to **other policy goals**. In this respect, the street should make room for active mobility – cycling and walking – as these deliver significant health outcomes in addition to their transport function. **Real-time management** of street and curb space enable policy to be delivered more consistently and effectively – integrating technology into monitoring street use and space allocation should be a priority. All these goals should be expressly set out in a vision that enables authorities to ensure that **public benefit** guides engagement with, and the regulation of, private actors. In some cases, the result may be more flexible, lighter but more effective forms of regulation (NACTO, 2017).

Prioritising the highest time-area efficiency when space is constrained

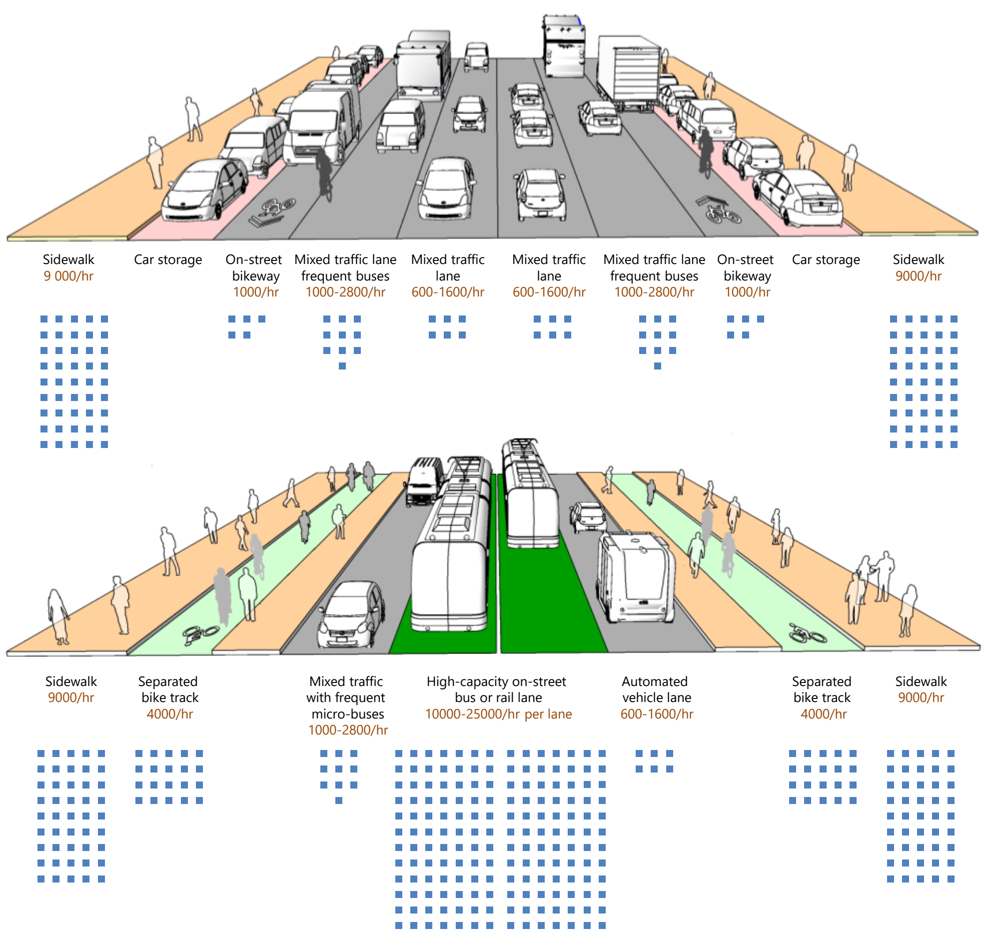
These strategic policy goals have concrete implications for rethinking curb management. One of the first is that a city that prioritises storing private vehicles at the curb in high-activity areas is likely missing out on more efficient use of that space – and of public space more generally. Where and when available space is constrained – as it is in many parts of cities and at peak hours – authorities have an imperative to ensure that the most efficient use of that space is prioritised.

Figure 12: **Time – area per person comparison of various transport modes considering street occupation only**



Source: Data from (Shin, 2008)

Figure 13: **Moving more people with fewer vehicles**



Source: Adapted from (NACTO, 2017).

Space occupation by vehicles (and people) has three components; an in-motion component, a stationary component and a temporal component (linked to speed of travel and duration of parking). The combination of all three into a single metric – the measurement of time-area (per person or per vehicle) – provides an indication of the real space consumption by different travel modes. Analyses of the time-area footprint of different travel modes indicates that single occupant cars use space the least efficiently – by several orders of magnitude worse than other modes (see Figure 12) (Bruun and Vuchic, 1995; Schmider, 1977; Shin, 2008). This is not necessarily a bad thing since car travel confers many benefits independent of their space consumption – but it is an issue on crowded streets and curbs.

Focus on moving more people with fewer vehicles

Cities may wish to prioritise travel modes that use scarce space more sparingly and more efficiently on a per-person basis. A practical outcome of the focus on the space efficiency of movement is that cities will be incentivised to allocate space to shared and active modes in many areas. The combination of active modes, public transport and other forms of shared mobility are the most space- and throughput-efficient space allocation methods when looking at a strict per person basis (Figure 13). Many cities are re-examining their allocation of street space accordingly (Figure 14). Since demand changes over the course of the day, by day of week and month of year, this allocation need not be fixed. Sensing technologies linked to variable message signs, signage, street markings and variable geo-fencing make it possible to "right-size" the allocation of space according to demand.

Figure 14: **Re-allocation of street space: Transformation of Plantage Middenlaan in Amsterdam**

Source: Photos by Google StreetView and Philippe Crist

Alleviating traffic congestion and other impacts from inefficient curb access

If cities feel the urgency to address curb management issues, it is usually because pressure at the curb is spilling out into the street. Curb spill over effects are triggered when people cannot park (or chose not to park further from their destination), when ride services cannot access the curb for safe pick-ups or drop-offs or when vans or trucks cannot find suitable delivery zones. In these cases, vehicles either cruise for the next available spot where they can access the curb or double-park in the first, and sometimes second lane of traffic. Cruising for parking and double-parking are two significant contributors to traffic congestion in dense urban cores.

At peak periods, upwards of 30% of vehicle-kilometres travelled in urban cores is comprised of vehicles searching for parking - and sometimes much more (Shoup, 2006). This number hides some important details. The first is that cruising for parking often occurs in areas with unpaid, or under-priced, parking. Metered parking, and especially time and demand variable performance pricing, like that instituted by SFPark in San Francisco is correlated with significantly lower cruising behaviour – in the order of 3% to 6% (Weinberger et al., 2016). The second is that public authorities have typically sought to alleviate cruising by encouraging or mandating the provision of off-street parking. This, counter-intuitively, has led to increased vehicle kilometres travelled (and more traffic conflicts getting into and out of off-street parking infrastructure) and unchanged or growing street parking pressure (Shoup, 2006; Weinberger et al., 2016). Though it is still too early to make a definitive statement on the traffic effects of increased ride and other new mobility services it would be reasonable to believe that their use leads to decreased parking pressure at peak times and popular locations given that part of their popularity stems from avoiding parking hassles and costs (R. Clewlow et al., 2017; Feigan and et C. Murphy, 2018). This hypothesis should be considered and monitored in curb space reallocation trials.

Double-parking is one of the most visible and vexatious outcomes of poor curbside management. It is also a significant source of backwards-propagating traffic stoppages in urban areas (Gao and Ozbay, 2016; Kladeftiras and Antoniou, 2013). This congestion stems both double-parked passenger and delivery vehicles, though the former has receded in many countries as a result of increased availability of parking and stricter enforcement. Double-parking by freight delivery vehicles is a persistent and growing feature of many cities and is fuelled by increased internet shopping-related parcel delivery (Conway, et al. 2016) (Jaller et Holguin-Veras 2013). The value of access near final destinations is such that freight operators and parcel delivery services are often willing to pay hefty cumulative fines rather than park further away (Conway, et al. 2016). At the same time, studies indicate that freight and parcel delivery service drivers typically commence their parking search as they approach their destination and are unaware of nearby available parking (Chaniotakis and Pel, 2015).

The traffic-disrupting impact of van and truck double-parking is acute. In Paris, for example, freight vehicles account for 16% of overall traffic and are involved in 161 000 freight operations per day. More than two-thirds (70%) of all parking choices are illegal and the average dwell time per parking incident is 17.5 minutes. This results in a daily loss of 2 777 hours due to freight vehicles double-parking (Beziat, A.; Koning, 2017). Eliminating double-parking in Athens, Greece (where the problem is particularly acute) could reduce traffic delays and stopped time by 33% and 47%, respectively (Kladeftiras and Antoniou, 2013).

Recently, some cities have observed an increase in double-parking by ride service vehicles picking up or dropping off passengers at peak hours in busy districts (Fitzgerald Rodriguez, 2017; Rudick, 2016). This pressure is likely to grow as these and other new mobility services simultaneously converge at the curb.

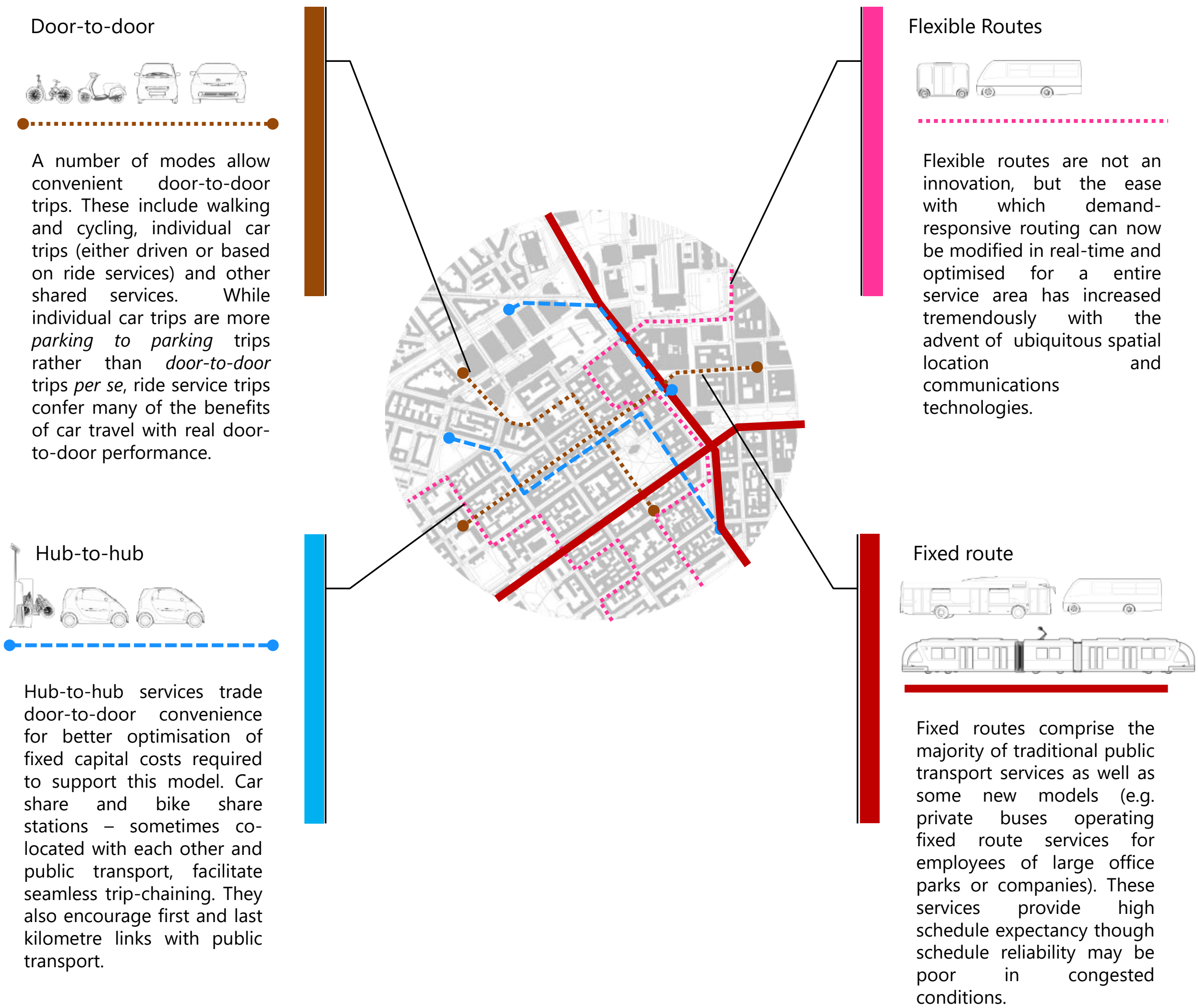
Freeing up curbside space for pick-up and drop-off activities for both passenger and freight movements can help diminish congestion linked to double-parking. Whether or not overall traffic congestion decreases (especially congestion linked to park searching) will depend on active parking management and pricing policies. In many areas under parking pressure, display a significant drop-off between the most congested parking corridors and nearby zones. Managing the effects of re-allocated and reduced parking supply on main corridors will require the provision of information regarding nearby parking availability. This information should preferably also be digital and machine-readable so that it can be directly integrated into navigation apps and automated driving systems.

Integrating multiple flexible service delivery models

The mobility ecosystem in many developed cities is becoming more diversified. Cities that for decades have accommodated cars and public transport on the streets are giving more space to pedestrians and cyclists and are seeing an increase in both single and shared ride services as well as in more flexible forms of public transport. At the same time, the already-diverse mobility ecosystems in many emerging contexts are becoming more formalised and there is convergence towards a few archetypal single and shared transport modes. This diversity should be accommodated on the street and at the curb in accordance with cities' goals for the management of those shared spaces (Figure 15).

Hub-to-hub services trade door-to-door convenience for better optimisation of fixed capital costs required to support this model. Car share and bike share stations – sometimes co-located with each other and public transport, facilitate seamless trip-chaining. They also encourage first and last-kilometre links with public transport. High-quality service delivery often requires some re-balancing of the fleet over the course of the day which has an impact on costs (and eventually for subsidies). Some ride service models direct riders to "virtual" hubs that help optimise dispatching efficiency and reduce vehicle kilometres travelled.

Figure 15: **Diversity and flexibility in transport service provision**



Source: Adapted from NACTO (2017)

Flexible routes are not an innovation, but the ease with which demand-responsive routing can now be modified in real-time and optimised for an entire service area has increased tremendously with the advent of ubiquitous spatial location and communications technologies. On-demand flexible route-based services – or services that can create (and broadcast) routes on the fly open new possibilities for thin markets and off-peak operation.

Fixed routes comprise the majority of traditional public transport services as well as some new emerging new models (e.g. private buses operating fixed route services for employees of large office parks or companies). These services provide high schedule expectancy though schedule reliability may be poor in congested conditions. When delivered by large-capacity vehicles, on protected or segregated facilities and when they connect major traffic generating zones, they prove very effective at moving large groups of people. This efficacy can drop significantly in thinner markets and off-peak hours. The emergence of all of the other options outlined above may facilitate a shift towards hybrid service provision models that capitalise on high-capacity trunk services that are integrated (or partially replaced at certain times of day) with more flexible and lower fixed-cost services.

These four types of service delivery models converge at the curb and this should prompt a strategic discussion amongst stakeholders on the rules of access and operation that are best able to deliver beneficial outcomes for people and are in line with broad policy objectives. Just as the discussion will include more diverse service delivery models than has been the case in the past for many cities, it will also include a more diverse set of stakeholders including public and private sector actors and incumbents and new market entrants. These discussions should take place in a governance structure that ensures fair and balanced treatment of all.

Fixing the curb: turning on-street parking into flex use zones

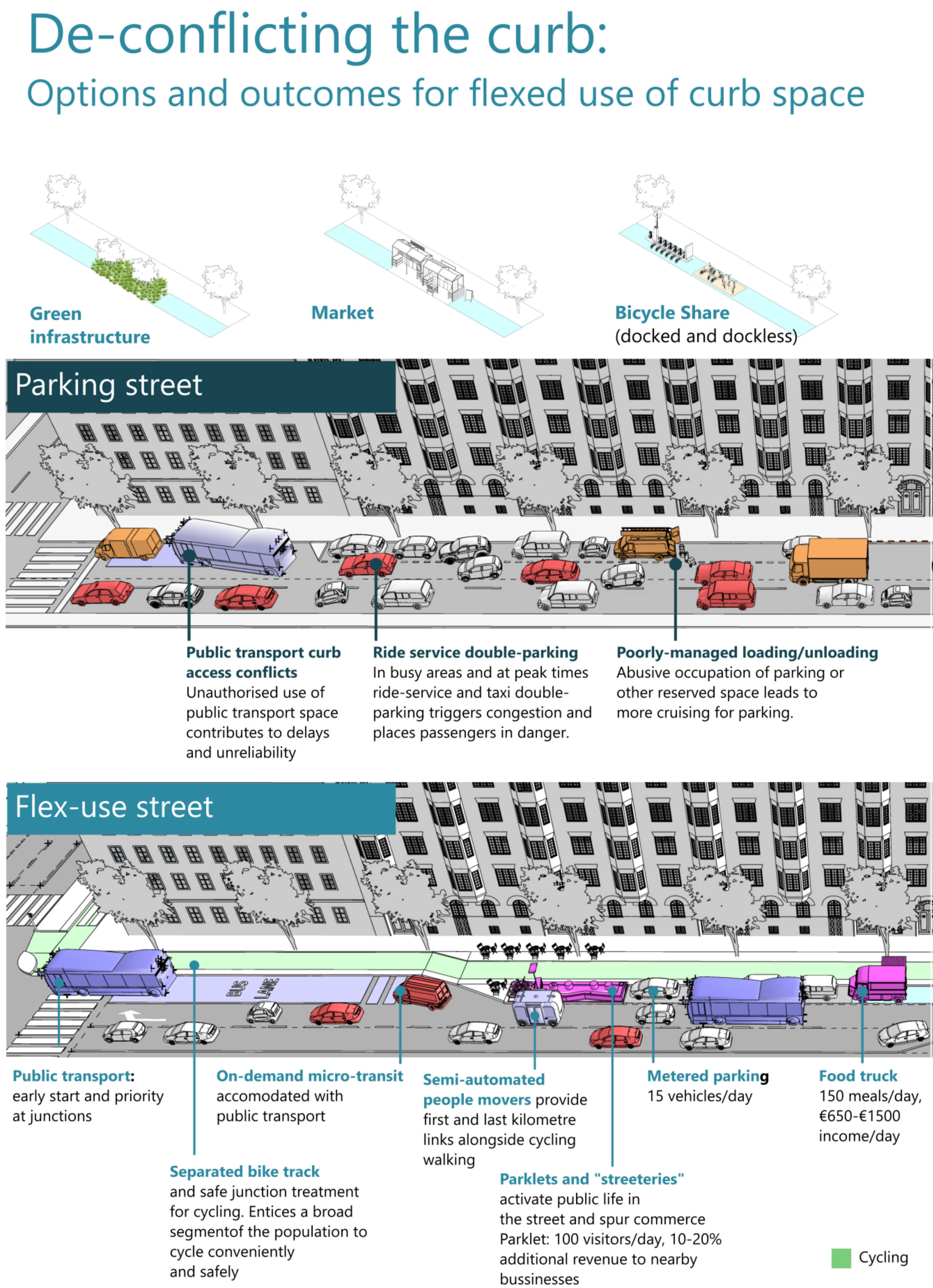
Moving to a more flexible use of curb space is not a trivial thing. It will imply design changes, engineering and construction costs (including knock-on congestion costs), revisiting the regulatory treatment of different transport modes and their access to public space (including anti-competition oversight), modifying or designing new revenue-collecting mechanisms, accounting for changes in peoples' travel behaviours and integrating a wide range of sometimes conflicting stakeholder concerns. One thing that seems clear is that the impacts of curb space reallocation on the location and availability of parking will likely be contentious and this must be carefully considered.

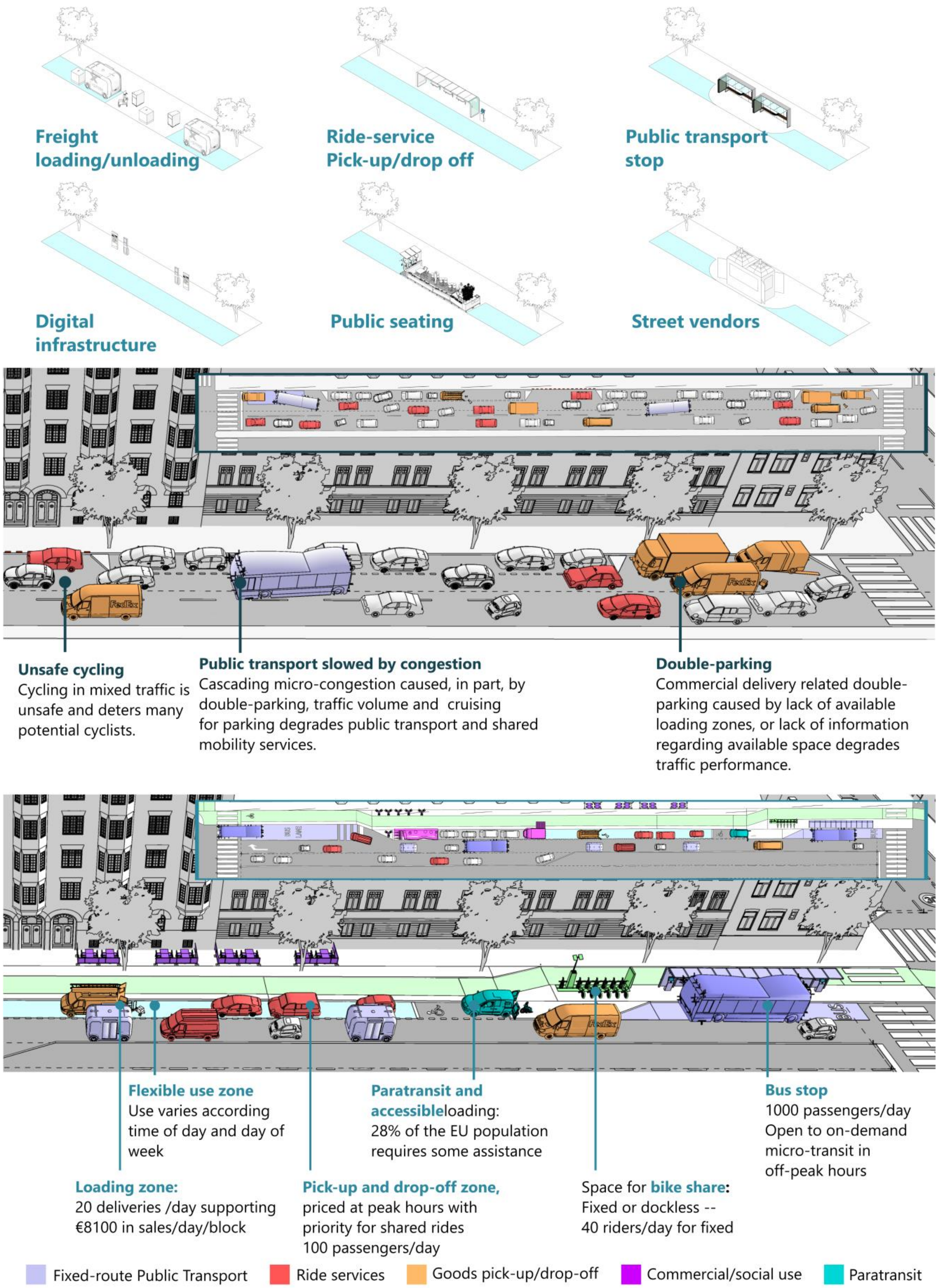
Curbed parking supply – and demand

As noted previously, there is a long history of, and theoretical background to, on-street parking management and pricing to optimally match supply and demand (Dowling et al., 2017; Marsden, 2006). The focus of this body of work has been on reducing cruising for parking, and, to a much lesser extent, on the impacts of double-parking. Some of this knowledge may apply to the supply and demand of curb space (e.g. with respect to queuing models) – but the economics of pick-up and drop-off zones is a nascent area of research. Parking demand may decrease as priority is granted to public transport and other shared modes if these effectively reduce single-occupancy car trips. There is already some indication that demand for parking is decreasing in areas with significant ride service use (Morris, 2018). Some cities, like Miami (Tenorio, 2018) are even co-located large developments with public transport and foregoing additional parking for ride service pick-up and drop-off zones.

More information about nearby parking availability (or about lower prices) may better shunt vehicles to areas under less parking pressure – evidence shows that people accept walking up to 2-3 blocks (~250 metres) in order to take advantage of cheaper parking (De Ruijter, 2015; Glasnapp et al., 2014). If policies actively seek to manage traffic levels, price curb access (including parking), facilitate greater transport service diversity, improve overall service quality and provide more actionable information on nearby parking availability, then the temporary or permanent re-allocation of curb space away from parking may be accompanied with better overall access and mobility outcomes.

Figure 16: **De-conflicting the Curb: options and design outcomes for re-allocating curb space.**





Source: Adapted from (NACTO, 2017; Roe and Toocheck, 2017).

Multiple options to choose and to trial

For many cities, this uncertainty about systemic impacts on parking will lead to a more incremental and trial-based approach. Changes in parking supply are often contentious for both residents and commerce, even if in the latter case, shopowners often overestimate the number of clients that come by car in central city settings (Roe and Toocheck, 2017). Some cities, on the contrary, may seek to implement a broad-scale strategy such as New York City's tactical urbanism approach to use temporary materials in multiple pilot demonstrations of bicycle infrastructure, bus lanes, pedestrian plazas and other adaptive re-uses of urban space (Sadiq-Kahn, 2016). In either case, cities have a menu of options available to them (Figure 16). Balancing uses and priorities should flow from the type of functional street typologies that cities such as London and Seattle have developed and should be strategic in nature. The US National Association of City Transport Officials (NACTO) has developed useful guidance on how cities in North America (and elsewhere) can ensure that the allocation of street and curb space best supports efficient shared mobility services – including high-capacity public transport, micro-transit, ride- and bike-sharing while minimising the impacts on private parking (Roe and Toocheck, 2017).

Flexing the curb: Dynamically adapting curb space to uses and users

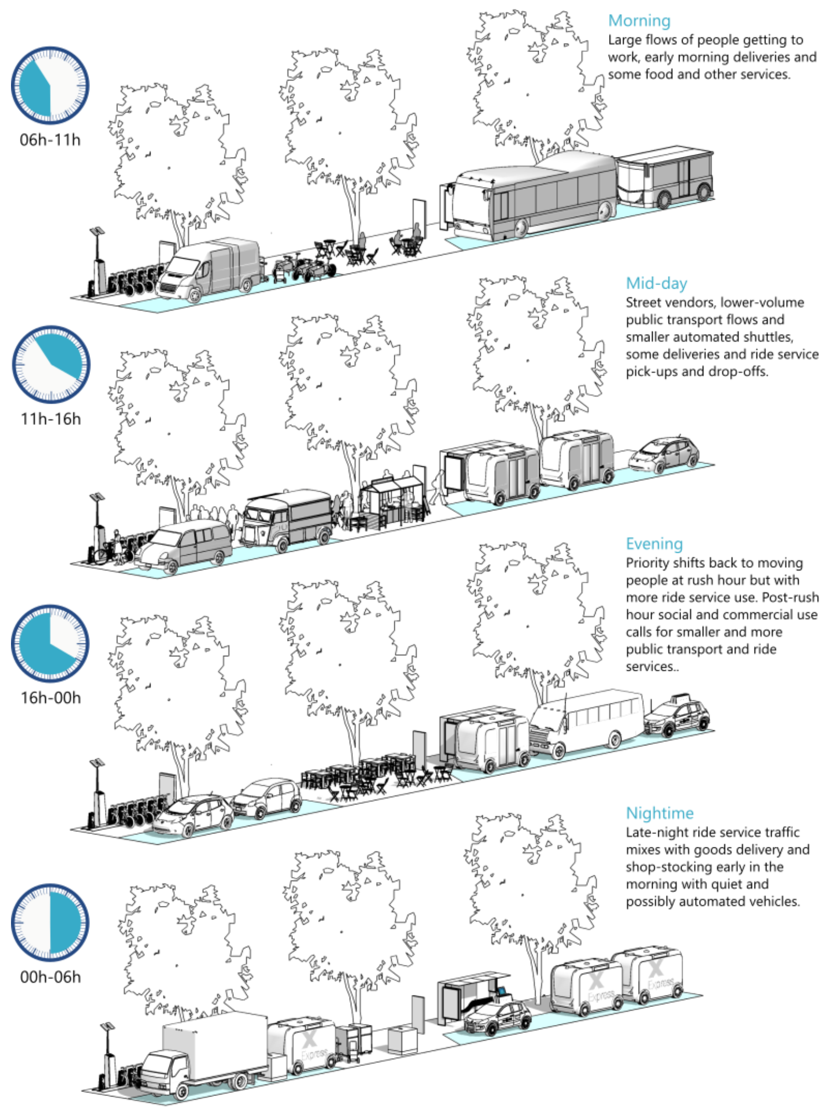
There is precedent in seeking to variabilise the use of scarce street (and road) space to accommodate different uses at different times of day. These include systems that dynamically open or close lanes for traffic on motorways or at toll stations. Cities like Barcelona have put in place active lane management systems that allocate street space to exclusive bus use, normal traffic, bicycle travel and night-time parking according to time of day and day of week (Cuevas et al., 2016).The city of Copenhagen has put in place several zones that allow bicycle parking during the day and night-time car parking or, alternatively, allow freight deliveries at some times of the day on otherwise dedicated bicycle parking bays (Cycling Embassy of Denmark, 2011).

Flexible curb space allocation specifically targeting new mobility services is much less common though, as current live trials and the results of the modelling exercise (discussed later) suggests, this is likely to change.

Technology will play a role in bringing flexible use of space to the curb and will be helpful in managing this use – but over the longer term, curbs and streets will have to be designed for dynamic and flexible use (Figure 17). The concept of the self-adjusting curb is one that is increasingly becoming possible within a fast-changing technological environment. The conjunction of "flat use" physical curb design and technologically-enabled curb space allocation renders new combinations of possible uses. "Flex-zones" as described by NACTO (Roe and Toocheck, 2017) or Shared-Use Mobility Zones (SUM zones) as defined by the Eno Transportation Foundation (Rogers, 2018) leverage adapted rules, light technologies and a coordinated vision to help guide cities to cater for multiple potential curb uses. Local authorities can use these concepts to guide priority setting for different temporary and permanent uses. Using, for example, the guidelines developed by Seattle, NACTO describes how a city planner might approach this exercise:

A project manager using this method first assigns critical uses like transit stops, transit lanes, and quality bikeways—the uses that often find themselves competing for space on streets otherwise designed for motor vehicle traffic. Next, transit-and business-supportive uses like bike share stations, commercial loading, and accessible passenger loading are assigned to the extent needed to prevent bus blockages by these uses. The remainder of the curb can be dedicated to valuable public space uses such as parklets and stormwater infrastructure, pick-up and drop-off areas for for-hire and private vehicles, and depending on local land uses, a cascading array of very short term, one-hour, multi-hour, and longer-term car storage (Roe and Toocheck, 2017).

Figure 17: **Dynamic use of curb space over the day**



Source: Adapted from NACTO (2017)

Parking to ride service pick-up and drop-off: Two early trials

Some cities are feeling the bite of competing demands at the curb at times of peak demand. In areas where ride services have first gained a foothold and are an important and growing part of the mobility mix, this pressure has been greatest at airports and train stations and in leisure and entertainment districts at night. At these times, the benefits of providing safe and efficient curbside access for taxis and ride services outweigh the benefits of providing on-street car storage for a few. Accordingly, cities are starting to experiment with a targeted and temporary reallocation of curbside space from parking to pick-up and drop-off zones. Below are some early examples from Washington DC and San Francisco:

Washington DC (Harris, 2017):

Like many other large urban areas in the United States, Washington DC has seen an increase in the diversity of ways in which inhabitants' travel – particularly as the city itself forms the core of the regional urban network and has an extensive public transport network (comprising 36% of trips). Nearly 40% of District residents do not own an automobile and the city has a relatively large share (for US cities) of walking (14% of trips) and cycling (5%). Pressure on its streets and curbs is accentuated by out-of-District traffic (2 out of every 3 vehicles at peak travel times) and significant maintenance backlogs for the metro system that have required prolonged shut-downs. Deliveries are also an issue and the city has digitised its curbside loading bay inventory and truck street restrictions in a routing API that oversize and overweight vehicles must use. The city has also seen an acute rise in curbside access pressure in some districts – especially at night.

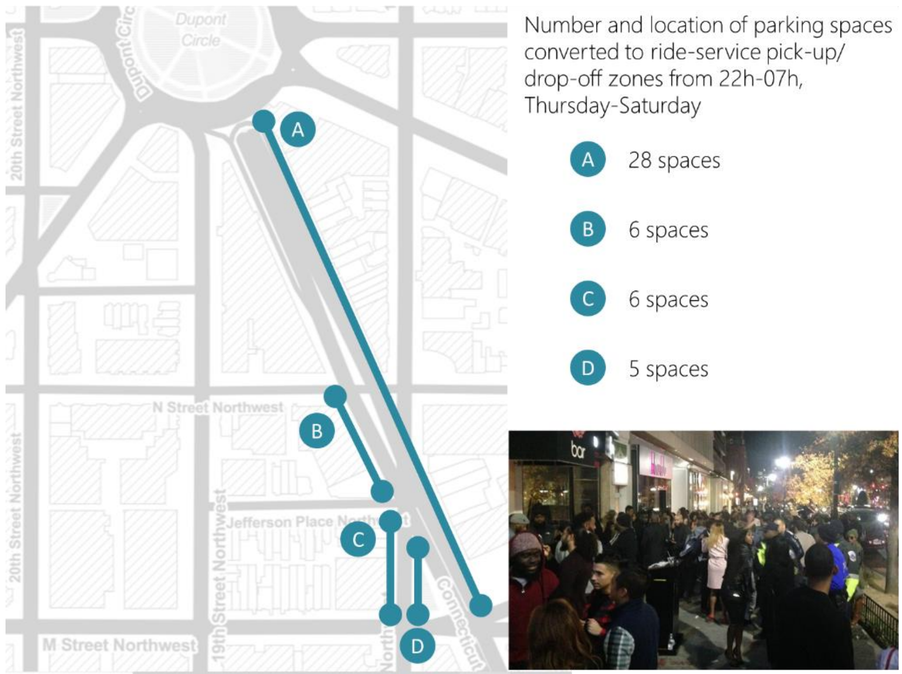
One such area, just south of Dupont Circle on Connecticut Avenue, has proven to be particularly challenging to manage. This area concentrates 100 restaurant and nightlife establishments in a 3-block area with a combined capacity of 17 528 people and sees peak flows of approximately 1 000 pedestrians per hour. Aggravated by the maintenance-related shut-downs of the metro and the influx of people driving or using ride services, a working group convened by local business interests to address growing traffic and safety concerns for their patrons in 2016. The influx of ride service traffic was a particular point of concern since there had been a noticeable uptick in the number of pedestrian-car conflicts, difficulties with bus and emergency vehicle access and blockages of travel lanes by double-parked vehicles.

This working group, facilitated by the Golden Triangle Business Improvement District (BID), included numerous other stakeholders including local nightlife venues and the District of Columbia:

- Department of Transportation
- Department of Consumer and Regulatory Affairs
- Alcohol Beverage Regulation Administration
- Metropolitan Police Department
- Office of Planning
- Department of Public Works: Parking Enforcement Management Administration
- Department of For Hire Vehicles

The working group monitored and observed nightime activity in the zone and surveyed business owners. It used time-lapse photography, manual counts and aggregated data from ride service operators (with the Golden Triangle BID serving as a third-party data-holder for sensitive ride service data). A detailed audit of spatio-temporal curb use allowed the working group to undertake a straightforward diagnosis. They observed a marked peak in traffic congestion and vehicular conflicts after 10pm from Thursday to Saturday. This peak was triggered by ride service vehicles blocking the travel lane. These drivers blocked the travel lane because no other stopping area at the curb was available nearby since these spaces were occupied by parked vehicles. Based on this, the working group suggested that the city test the re-allocation of 45 parking spaces in the most highly trafficked area to pick-up and drop-off lanes from 10pm to 7am on from Thursday to Saturday (see Figure 18).

Figure 18: **Washington DC parking to ride service pick-up/drop-off zone trial**



Source: Adapted from (Harris, 2017), photo from Golden Triangle BID

Re-purposing a complex space like the curb is not trivial from a regulatory point of view. The city had to modify 4 regulatory ordinances to make the trial possible. It also had to address the potential for shifting parking pressure from the re-purposed spaces to other nearby areas. This was a manageable risk since much of the neighbouring parking was metered and there was availability at those times further afield from the trial area.

The trial was launched in October 2017 and early returns have been generally positive. Neighbouring businesses have reported a decrease in curb access conflicts and anecdotal evidence points to reduced dwell times for ride service vehicles. Wayfinding for drivers remains an issue and the Police Department has resorted to placing cones in traffic to guide drivers. Enforcement is also an ongoing concern as some drivers still park in the pick-up/drop-off lanes. The City is evaluating the first 6 months of operation of the trial and will do so again after a year. They will look at a key set of performance indicators that include:

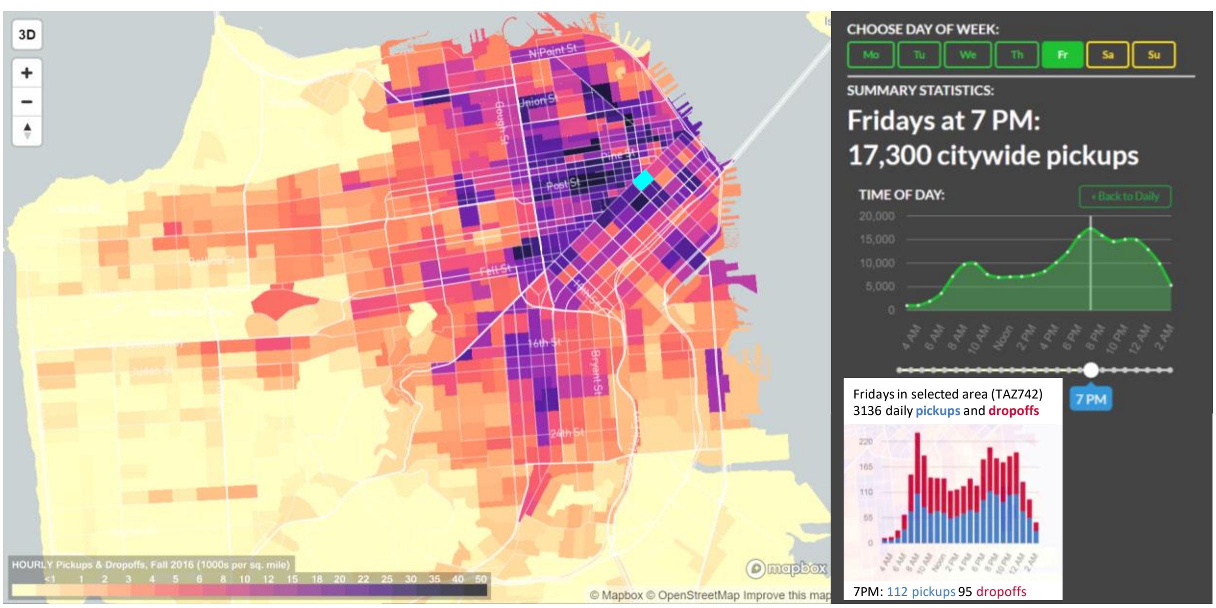
- safety (reduction in car-pedestrian crashes in particular)
- traffic flow
- ride service dwell time
- public transport and cycling trips
- bus travel speeds
- parking enforcement citation trends, and
- economic impact.

The city is also putting in place a working group to establish guidance for extending the pilot to other areas of the city. This guidance will consider criteria relating to land use, safety across all modes, curbside geometry, mode split and information on the availability of public transport. It will develop performance indicators based on these, specify enforcement strategies (which could include automated enforcement) and discuss how to structure a curbside access fee structure to reflect the scarcity of curb space and provide a tool for managing demand.

San Francisco (Harris, 2017):

The combination of population density, a fairly extensive public transport network and investments in cycling and walking make San Francisco a city where it is relatively easy, for North American cities, to live without a car. Only 48% of San Francisco trips involve solo driving. This is not the case for the wider San Francisco Bay area where much of the population lives; here 70% of all trips involve solo driving. Concerned with broader issues of equity and affordability, the city would like to make it even easier for households to lower their transport costs. According to the city, this would involve providing more varied options than solo car use which is a significant part of regional household budgets (approximately 19%). Emerging mobility service models including ride services, on-demand and flex-route micro-transit and both docked and dockless bike sharing all provide these options but at times put pressure on traffic and the curb. In a move from straightforward car-ownership patterns to one based on a menu of mobility options – and as part of a deal to get more granular data from ride service operators – the city announced in November, 2017 that it would pilot curb re-allocation from parking to pick-up and drop-off zones (Rodriguez, 2017).

Figure 19: **Modelled ride service pick-ups and drop-offs in San Francisco: Fridays at 7pm**



Source: http://tncstoday.sfcta.org/

Based on the TNCs Today3 modelling exercise (SFCTA 2017) the San Francisco Municipal Transportation Agency (SFMTA) was asked by Mayor Lee to begin to develop the pilot programme. The curb inventory of ride service pick-ups and drop-offs serves as a basis for picking targeted zones in conjunction with data from other mobility services (micro-transit, taxi, courier services, private shuttles, paratransit, goods delivery and pick-up and traffic/parking demand from the general public. The areas where the combined pressure is likely to be highest includes several commercial corridors, around public transport and train stations, event venues, business centres, hotels, schools and hospitals.

The data modelled by SFCTA indicate that ride service increases over the week with a peak from 6pm to 1am on Thursday through Saturday night as in Washington. Ride service pick-ups and drop-offs in crowded areas and at peak times trigger double-parking, the congestion-inducing effect of which is linked to general traffic flow at those times and the ride service dwell time which is greater for pick-ups (1 to 5 minutes) than for drop-offs (30 seconds).

Among the tools explored by SFMTA to include in the pilots is dynamic geofencing of excluded zones (e.g. Market Street in San Francisco) and pushing digital curb-use rules directly to ride service apps. The ability to “nudge” passenger pick-ups and drop-offs this way has proven promising when trialled by ride service providers around special events and specific zones (Figure 20). The major ride service providers in the United States offer such nudges as part of their standard offer of services in some markets.

Figure 20: **Geofence induced displacement of ride service pick-ups and drop-offs away from problematic zone: Case of CalTrans King Street Station**

Source: (Rodriguez, 2017)

The pilot programme has been under development as of Spring 2018. It involves the San Francisco Mayor’s Office, SFMTA and private stakeholders. Its focus will be on re-allocating parking spaces to reduce illegal stopping in travel lanes, reserved public transport lanes and stops, bicycle lanes and crosswalks. The pilot will build on ride service operator data, field observations (double-parking, dwell time, non-crash conflicts and near-misses), a curb-capacity inventory and surrounding traffic volume for all travel modes. Some key considerations to assess are whether the trial should be for one, or several, zones; if it should be only in operation at certain times based on demand, or all day, if the scope of the intervention should be incremental in nature, or broader, and how the curb use rules should be physically (and digitally) represented with signage and data. As with the Washington DC pilot, the city will establish a set of performance criteria on which to base appraisal. These will likely include traffic and safety outcomes, economic impacts, compliance rates and driver and rider experience.

Revenue implications of the future curb

The discussion around the curb of the future as outlined above pre-figures a potentially fundamental shift in the way in which city streets and their curbs are used. At the outset, these changes are likely to be localised but if they gain traction with, and in turn contribute to, more fundamental changes in travel behaviour, the knock-on impacts are likely to be significant. If and how the changing street will impact the city, travel patterns, agglomeration effects and peoples’ welfare may be hard to predict today, at least one impact seems certain. All else held equal, a shift in allocation of curb space from parking to pick-up and drop-off will have potentially significant impacts on public coffers.

The revenue stream from parking and parking-related citations is not insignificant. For example, in 2016, parking-related revenues comprised of parking fees/taxes and revenue from parking violations and fines accounted for USD 2.8 billion (roughly evenly split among the two) for the 25 largest US cities. This is likely to represent the lower bound of the potential revenue that could be expected with technology-driven enforcement since a significant share of paid parking is in fact unpaid and a significant share of that is un-detected (1000 Friends of Oregon et al., 2002). Should this source of revenue decrease if vehicles park less just as the technological capacity to better collect parking fees and taxes is on the rise, public budgets may come under pressure.

If cities intend to maintain curb-related revenue levels, the potential loss of parking revenues would have to be substituted by fees charged to other users of the curb – including shared ride service operators. Revenues from parking provides resources to promote other transport priorities such as improved public transport cost coverage or cycling infrastructure in many cities. Under a broader curb-use pricing model, payment of these fees could help pay for the provision of dedicated space throughout the city to perform safe boarding and alighting operations.

Beyond the revenue implications for cities is a second, perhaps more strategic consideration. Most urban regions have found it difficult to put in place road-pricing schemes that could otherwise effectively manage travel demand and contain congestion. Rather than price access to and use of roads, most large cities depend on pricing where and when cars can stop on the network e.g. by pricing parking – as a second-best approach. If cities become more and more parking "light" and more and more pick-up/drop-off "heavy", public authorities will find it increasingly difficult to manage traffic. For this reason, it is worth starting to think about what pricing instrument can be put in place that effectively represents external marginal costs and provides an effective demand management signal to those wishing to use streets and their curbs. Such a "curb-kiss" fee could be digitally triggered every time a vehicle operates a meaningful transaction at the curb (e.g. loading or unloading passengers or freight – or longer-term parking) but should be applied fairly to all curb users, including private car owners and shared mobility service providers (including public transport). To do otherwise would incentivise un-priced uses at the expense of others.

Effectively using curb-pricing models to manage demand for curb access and traffic will require an assessment of the behavioural response to the prices presented to users. Because curb access events are likely to much more numerous than parking events for the same space, a strict revenue replacement approach will likely lead to much lower per user fees. This change of scale of has a direct effect on the sensitiveness of the pricing measures adopted, as a much lower usage price may not be able to affect individual behaviour.

These "curb-kiss" fees could be gradated by type of services, by time of day and by location. If they are applied based on duration (for freight) or number of passengers, they would incentivise shared-uses over solo use. At present, levying such a fee pre-supposes the presence of digital infrastructure that is not deployed, regulatory language that must still be written, compliance regimes that are not yet developed and data standards that are not yet agreed. Pricing the future curb efficiently will require action by public authorities in all four areas. It will also require broad involvement of stakeholders around the technologies and rules that support efficient curb-pricing.

In the following section, we discuss some of these revenue-related issues as they relate to the modelling work undertaken in Lisbon to assess curb-space re-allocation away from parking.

Modelling new curb use scenarios

Experience with re-allocating curb-space from parking to other uses is limited. Whereas some cities have sought to test different re-allocation models concerning freight loading and unloading, very few have started to consider how to plan for growing demand for pick-up and drop-off access to the curb from multiple new mobility services and operators. In this context, some early insights and guidance from modelling exercises may prove useful to help orient public policy in this area. To contribute to the emerging knowledge base in this field, we modeled some curb-specific impacts that may stem from growing adoption of shared-use mobility services in cities. This work builds on previous ITF work looking at potential impacts from shared-use mobility services across several cities (Lisbon, Auckland, Helsinki and Dublin). For the purposes of this modelling exercise, we focus specifically on Lisbon.

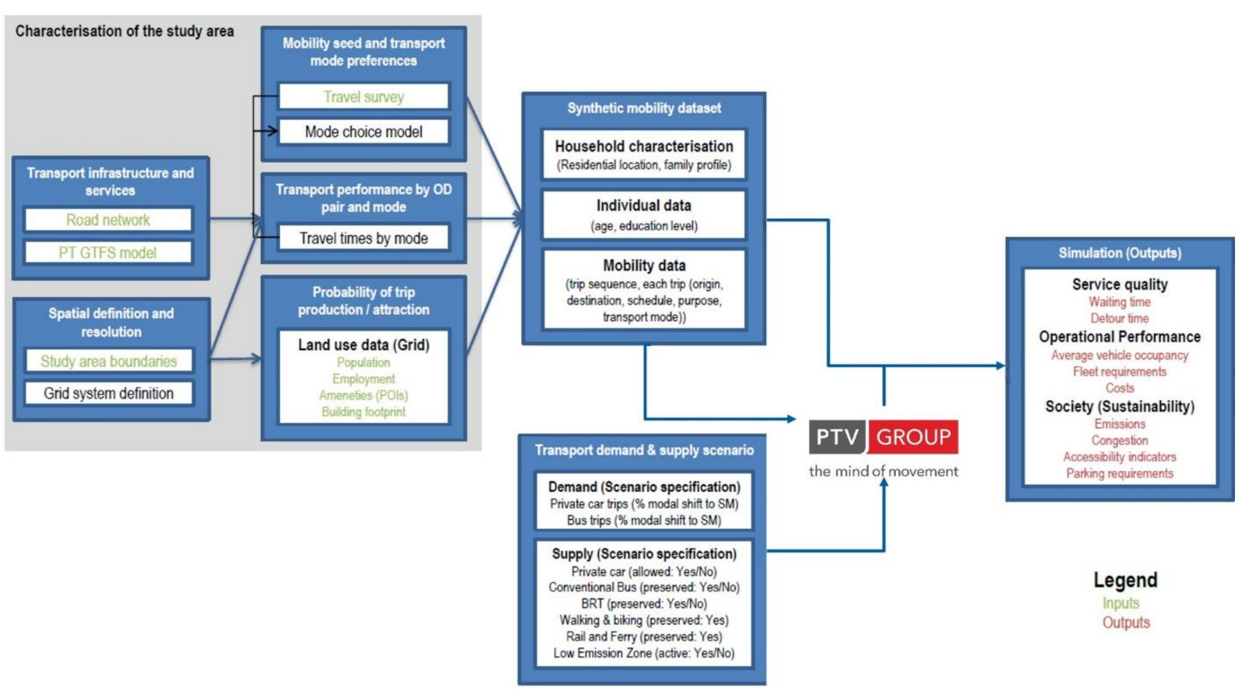
Our previous work relies on an agent-based model that simulates daily mobility throughout an urban area. The model is built around three main agents that interact in a common environment: users, vehicles and a dispatching entity. The model works with a synthetic population of trips that serves as a plausible proxy for every trip taken on a normal weekday. The current study uses demand generated by the synthetic population of trips developed for Lisbon, to understand how the diversion of current car users to shared modes may impact curb activity in the future.

This demand model allows estimating the global potential impact of such a system in the city at a meso scale. This demand is then fed into microsimulation software. This multi-resolution modelling exercise helps to realistically evaluate modified traffic flow and curb usage at the level of detailed vehicle movements.

Methodology

We used the Lisbon Metropolitan Area shared mobility simulation model as a base for the meso-scale demand generation analysis used in this exercise. We obtained traffic demand and requests for shared rides services for each tested scenario from the model's synthetic trip population and then imported these to PTV's traffic model for assignment and analysis.The methodology of the ITF shared mobility framework is summarised in Figure 21.

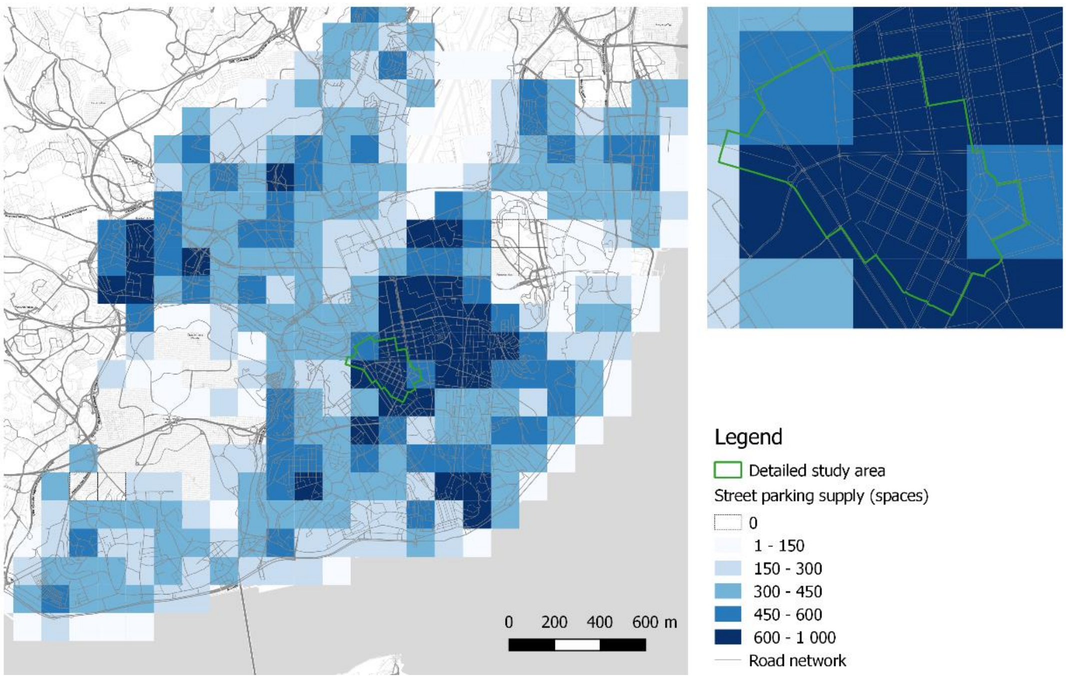
Figure 21: **Shared mobility modelling framework adapted for this study.**



Notes: PT- Public Transport; OD – Origin-Destination; SM – Shared Mobility.

Each synthetic trip record contains information about parking. This includes the parking duration and its location (on-street or off-street) and whether parking fees were paid. This information is then carried over as an input (among others) to feed a traffic flow and parking model focused on the city of Lisbon, and more specifically in a modelling area located within the Lisbon central business district (CBD). This area of the city is identified in the Lisbon mobility plan as the most dynamic area of the city (António Augusto Aguiar – AAA) with the convergence of high employment densities, upper-income residential zones and intense retail activity. This area is highly active and dynamic throughout whole day and contains a diverse mix of street typologies, from wide heavily-trafficked boulevards, to narrow one-way local streets. As such it is an interesting location for testing the convergence of traffic, dense public transport services, parking activity and growing pressure from shared ride service pick-up and drop-off activity in the model. The size of this study area is 0.83 sqkm, representing approximately 9% of the Lisbon municipality area.

Figure 22: **Lisbon's street parking supply**



The AAA area is characterised by a large supply of paid on-street parking. AAA on-street parking is generally located on either side of the street in line with the direction of traffic in bidirectional streets or, alternatively (and sometimes simultaneously), in a central median with oblique or parallel parking. On some streets this configuration has been updated and adapted to integrate bicycle lanes by replacing some parking (see Figure 23 B).

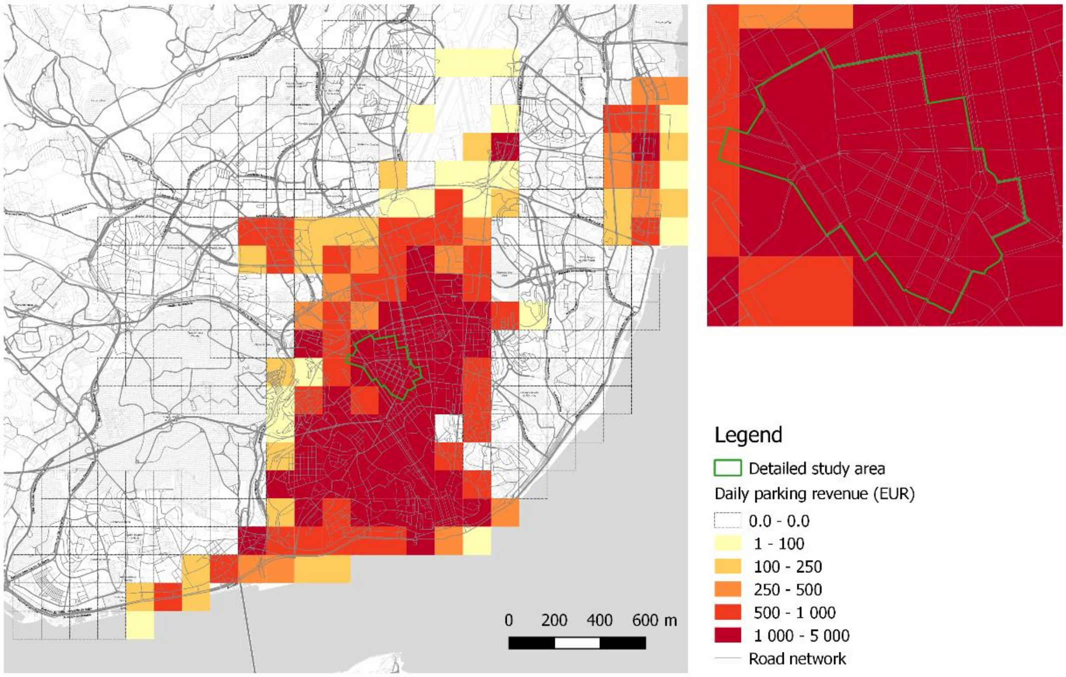
Figure 23: **Example of typical street layouts of the study area**

(a) Standard Layout

(b) Adapted to integrate central bicycle lane

The AAA area has higher-than-average parking fees and, due to privatised management and revenue collection, the area delivers the highest source of revenues for the parking municipal company Empresa Municipal de Mobilidade e Estacionamento (EMEL) (Figure 24). In parallel, the many off-street parking facilities in the area see high usage from visitors (retail or work meetings) and company owned fleets. Each 200 metre by 200 metre grid cell in the AAA study area generates between EUR 1 000 to EUR 5 000 of on-street parking revenue per average weekday, for a total revenue of between EUR 70 000 and EUR 100 000 per day for the zone (EMEL, 2014).

Figure 24: **Spatial distribution of parking municipal company (EMEL) street parking revenue**



We estimated the parking capacity in the study area Google Maps / Google Street View and validated our estimate with EMEL official statistics available on their website (www.emel.pt). There are primarily three types of parking in the study area – 45°, 90°, and parallel. We estimated that an average parallel parking space takes up about 5.4m of road length, an average 45° parking space takes up about 4m, and an average 90° parking space about 2.8m. The measurements and car counts were taken from Avenue Luis Bivar and Avenue Antonio Augusto de Aguiar. We calculated the total number of parking spaces by taking the length of the blockface as given by OpenStreetMap (OSM), and multiplying it by .95, since not all the blockface is used as parking after accounting for space for turns, crosswalks, fire hydramts, etc.

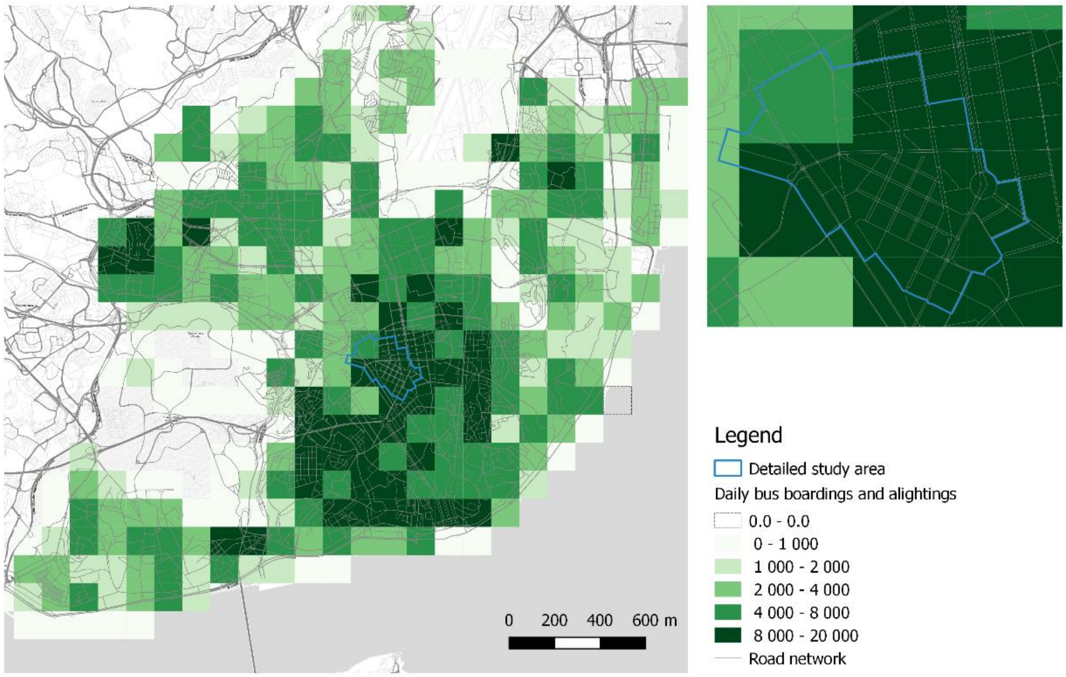
The estimated number of parking spaces in the study area is presented in Table 3. The 45 degree angled parking is normally found between the two traffic streams in two-ways streets (Figure 23 A). We did not consider this configuration for our curb use scenarios as their re-allocation to other uses beyond cycle paths could raise safety issues. For example, pick-up and drop-off operations would require customers to cross the street out of crosswalks which could pose safety issues.

Table 3: **Model area parking inventory**

Variable	*Type of parking*				*Total*
	Parallel	*45 degrees*	*90 degrees*	*Other*	
No. of spaces	6 753	3 611	188	21	10 572
Average length per bay (m)	5.4	4	2.8	4	
Equivalent distance used (m)	36 360	14 444	526	83	51 413

The study area is also one of the busiest bus boarding and alighting areas of the city along with the airport and some major transportation hubs (rail and metro stations). Most of the cells of the study area see between 8 000 and 20 000 people boarding and alighting a bus every day, with higher concentrations along the two to three principal axes of the study area (Figure 25).

Figure 25: **Spatial distribution of Lisbon Bus boarding and alightings**



On the basis of the ITF shared mobility modelling framework for the Lisbon metropolitan area, we assessed which synthetic trip takers currently driving would be most likely to first adopt new forms of shared ride services. This assessment was made on the basis a utility-based model (discrete choice model calibrated from stated preferences survey). We tested the adoption of shared ride services for three levels of current trip replacement with shared ride services: 10%, 20% and 50% (of former car trips).

The pattern of spatial intensity of pick-up and drop-off activities varies with different levels of adoption throughout the city. For lower levels of ride service penetration, first adopters are commuters that previously travelled to the CBD, some intermodal stations and the airport. As penetration rates for shared ride services increases, the shared ride trip patterns diversify and start to include leisure and other non-work-based trips (Figures 26 to 28).

Figure 26: **Spatial distribution of shared ride service pick-up and drop-off for a 10% penetration rate**

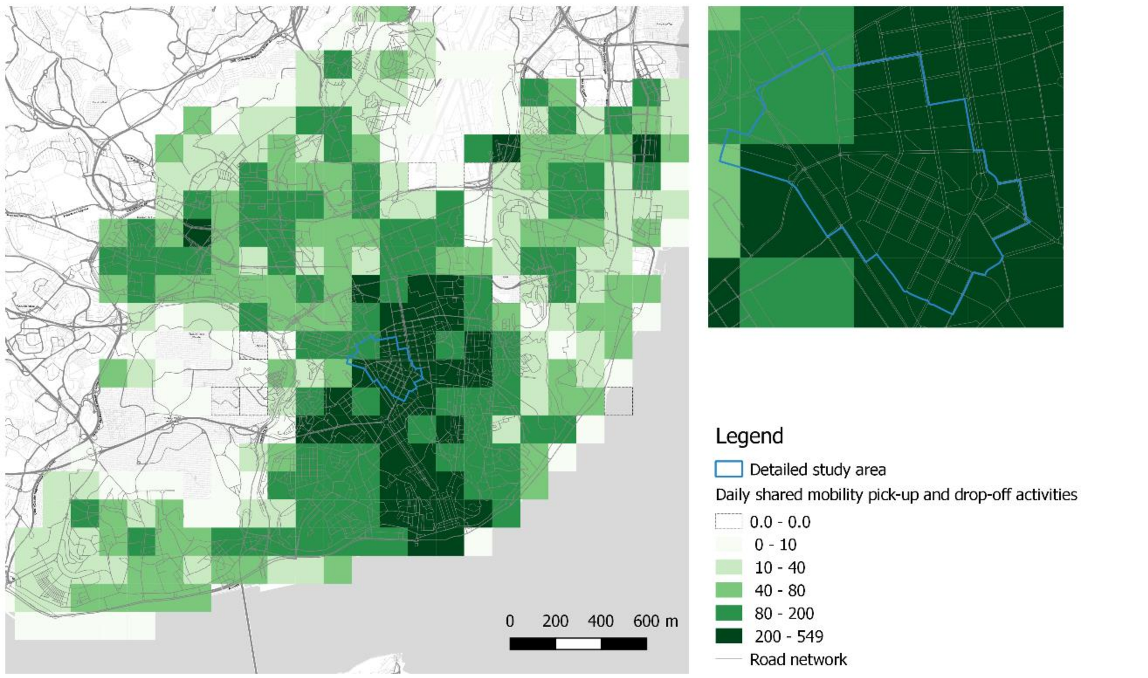


Figure 27: **Spatial distribution of shared ride service pick-up and drop-off for a 20% penetration rate**

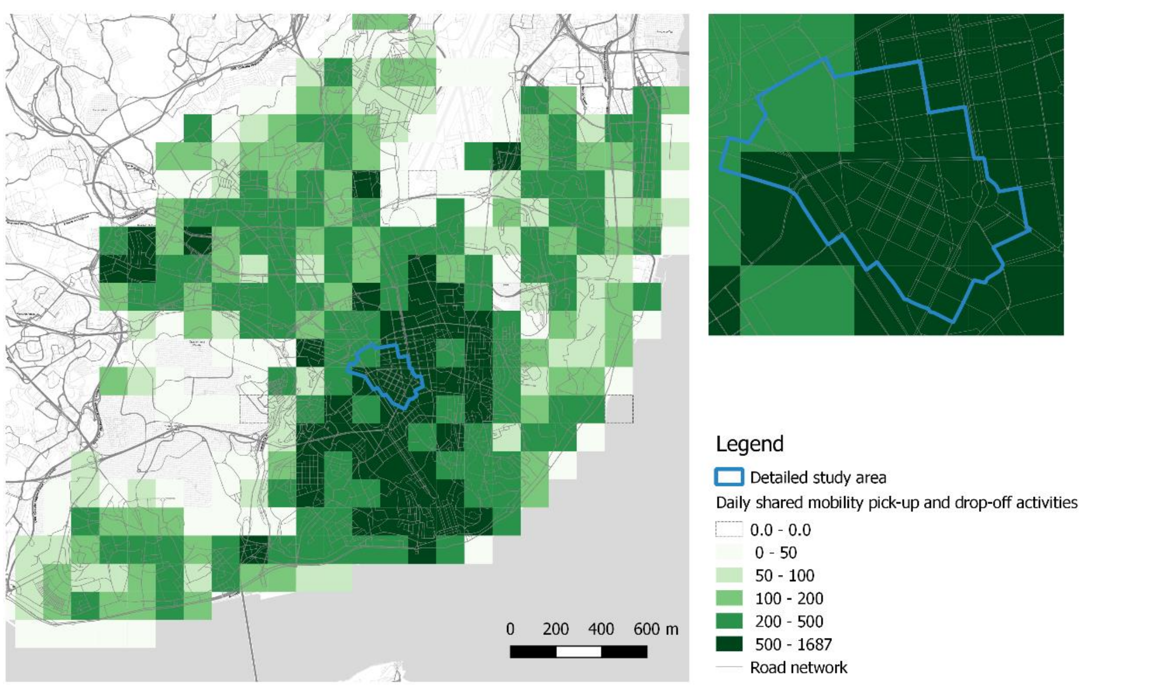


Figure 28: **Spatial distribution of shared ride service pick-up and drop-off for a 50% penetration rate**

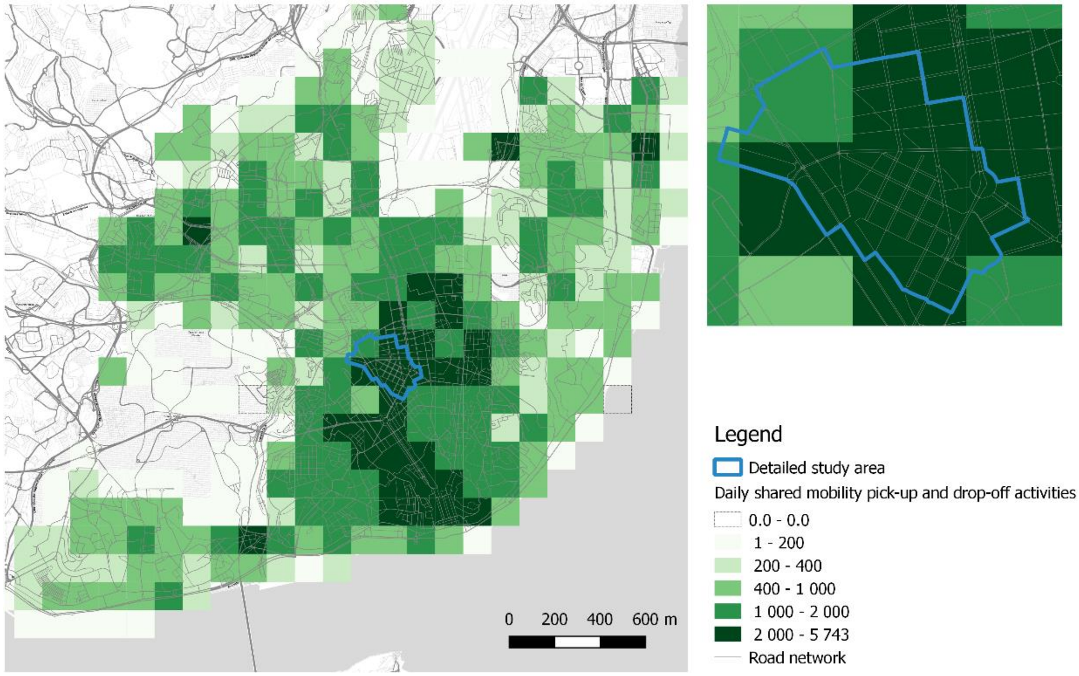


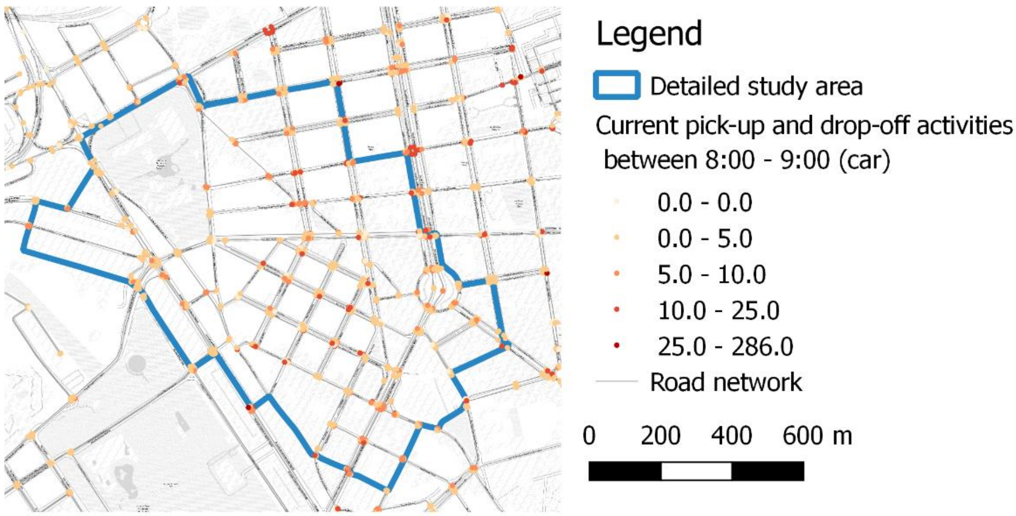
Table 4 details the number of potential pick-ups and drop-offs that would occur during the morning peak period between 8am and 9am inside the detailed study area.

Table 4: **Ride service demand pick-ups and drop-offs modelled within the study area**

Ride service adoption scenario	Number of ride service pick-ups/drop-offs
10%	375
20%	669
50%	1 193

A closer look at modelled pick-ups and drop-offs during the morning peak time (8am to 9am) in the study area reveals a relatively homogenous and well-distributed level of activity (Figure 29). This suggests that any curb re-allocation strategy should strive for relatively uniform provision of pick-up and drop-off zones – at least for the morning peak. Additional analysis would be necessary to test if this finding holds at other times of peak demand. This area of the city has a diverse land use mixture combining residential uses with multi-scale commercial activities and offices. During the morning peak, conflicts may emerge between ride service users and workers looking for longer-term parking whereas in the evening, conflicts may emerge between residents returning to park their vehicles and ride service users seeking access to commercial services or recreational activities.

Figure 29: **Spatial distribution of pick-up and drop-off activities at morning peak (8am to 9am) – 20% adoption rate of shared ride services from former private car users**

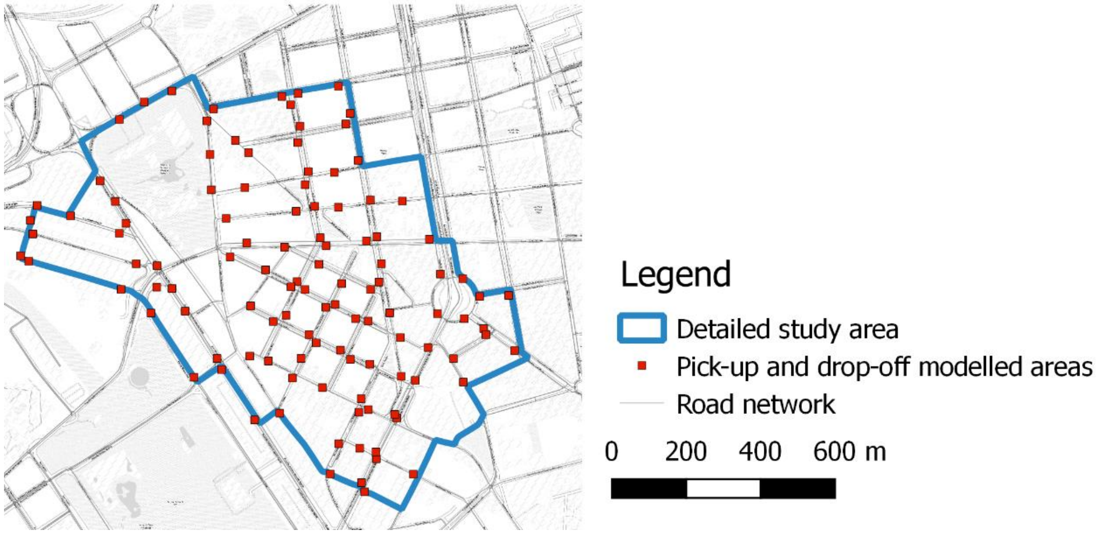


We defined a series of dedicated pick-up and drop-off zones in the model that would service demand for curb access by ride services. These zones were selected to maximise coverage for users to access points of interest while preserving a high productivity of the use of public space.

We set the locations for these zones at the beginning and end of blocks in bidirectional streets. For longer blocks, zones were placed mid-block to minimise traffic conflicts related to ingress and egress. Areas with high concentrations of demand, such as shopping centres or schools were also systematically assigned up to four parking spaces reserved for pick-up and drop-off, which could be permanent throughout the day or variable during periods of high demand.

In total 103 shared ride service pick-up/drop-off zones were evenly distributed throughout the study area (see Figure 30), comprising of the equivalent of 329 parking spaces. In the "curb-release" scenario we describe later, this entailed the re-allocation of 329 on-street parking places (3.1% of current parking supply). The designated pick-up and drop-off zones were adapted to the network geometry in the model. For example, when limited space near junctions constrained choices, we allocated less space to pick-up and drop-off zones. Taking into account all factors, pick-up and drop-off zones were about 15 metres long on average. It is important to highlight that not all parking spaces in the study area are located at the curb as this would require a detailed assessment of the parking locations compatible with this new use. Furthermore, the interaction of pick-up and drop-off activities should also be addressed as creating potential safety conflicts, for example with bicycle riders if the cycle traffic is located within the "dooring" zone.

Figure 30: **Location of reserved shared ride service pick-up and drop-off areas**



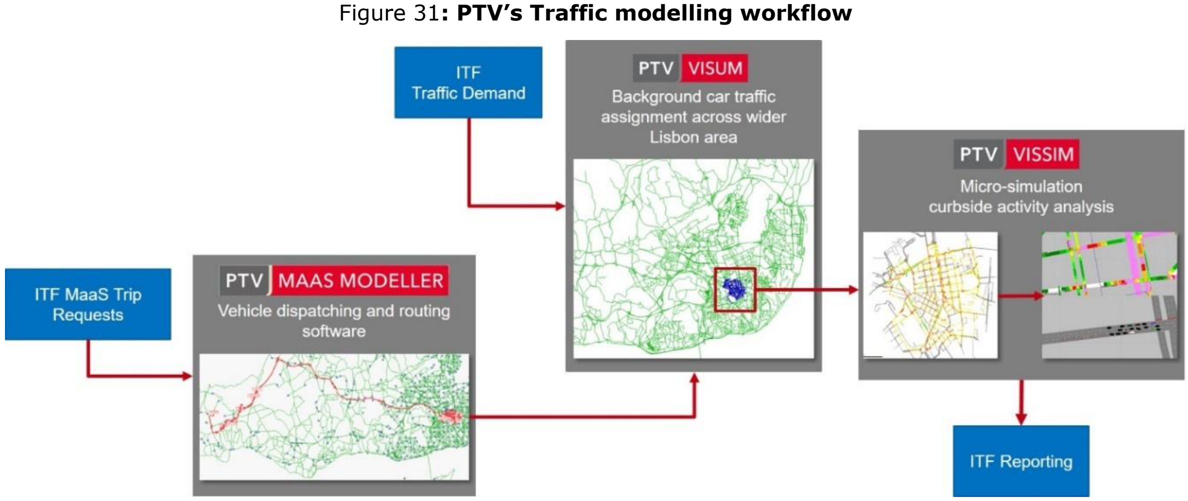
We then refined the demand outputs from the ITF shared mobility model in a PTV Visum model before we imported the result into a detailed traffic microsimulation model using PTV Vissim in order to analyse all the traffic implications of the curb management strategies for the AAA study area.

Description of traffic models for ride services

The primary purpose of the detailed modelling exercise was to determine the impacts of increased levels of ride service adoption on curbside activity and the knock-on impacts for traffic congestion in the surrounding area.

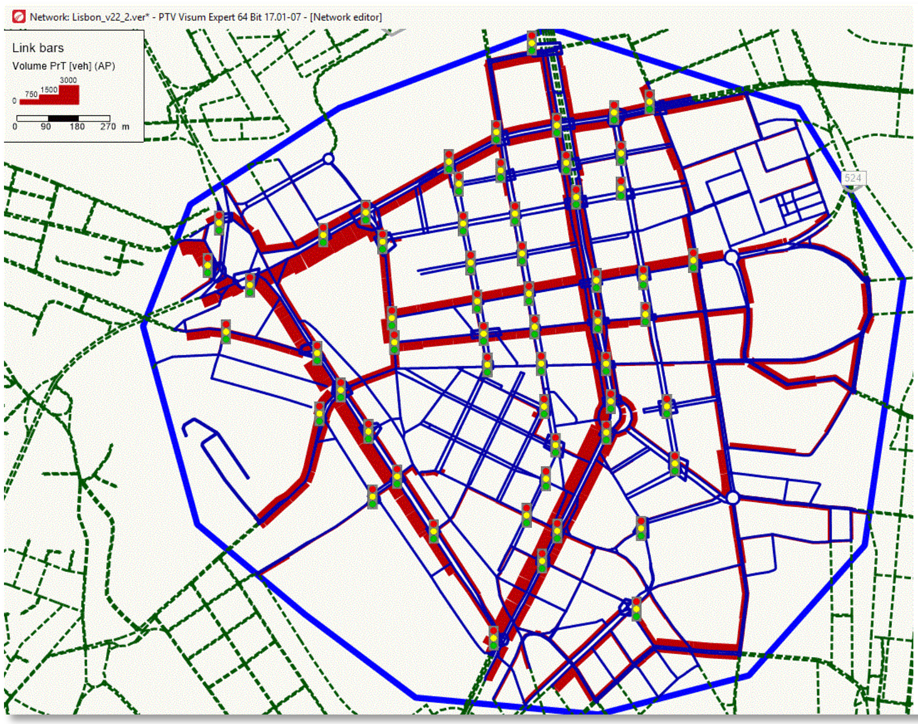
The modelling exercise was undertaken to provide quantitative analysis to help inform the discussion of a reduction in congestion through lessened car dependence. Or to both, in different measure. The three whether increased uptake of ride services leads to an increase in congestion due to curbside interactions, or modelling workflow phases are illustrated in Figure 31.

Figure 31**: PTV's Traffic modelling workflow**



In order to assess the potential congestion impact of different curbside management scenarios, we created a realistic representation of traffic conditions was for the base scenario. We construced this representation in PTV Visum using shapefile data from the ITF shared mobility model alongside OpenStreetMap (OSM) data for the model network. We then added background vehicle trips, i.e. non ride share services, to the network and undertook an iterative assignment process to ensure an accurate representation of traffic across the network - especially at junctions. The results of the initial assignment are presented in Figure 32:

Figure 32: **Background traffic assignment within study area**



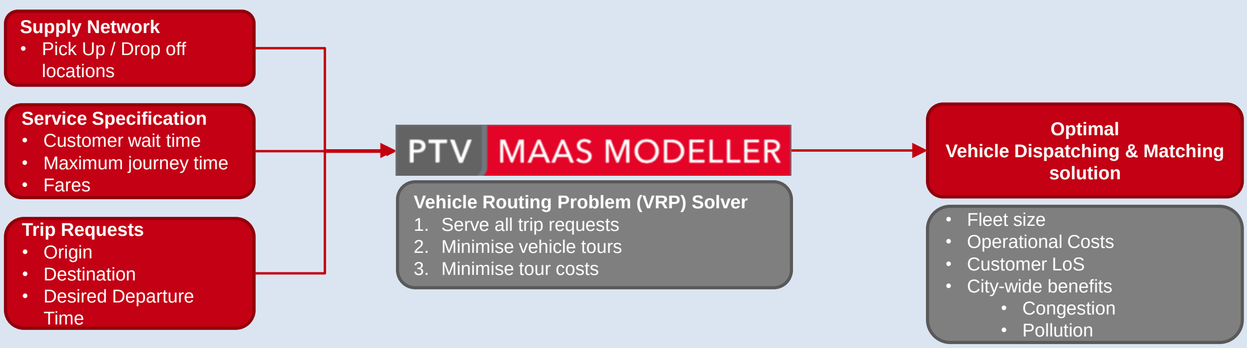
Following the initial traffic assignment, we then processed ride service trip requests from the ITF shared mobility model using PTV's MaaS modeller (see Box 5). This modelling framework matches trip requests to an optimised vehicle dispatching and routing solution. We repeated this process for each of the scenarios i.e. representing a 10%, 20% and 50% adoption rate of ride services, respectively.

Box 5: PTV MaaS Modeller

PTV MaaS (Mobility as a Service) Modeller is a software solution that measures the impact of shared mobility by calculating, simulating and optimising fleet dispatching and matching to traveller on-demand requests. It helps users to assess the potential for shared mobility services, to define an optimum service configuration and to help users to determine adapted business models.

MaaS Modeller assesses the potential for shared mobility services from the perspective of the city, the traveller and the operator. It uses as its primary inputs the definition of shared mobility (MaaS) supply (infrastructure), the trip requests (the traveller) and the service provided (the operator). It then calculates an optimal MaaS Shared Mobility solution such that all trip requests are served, the number and cost of vehicle tours is minimised. The software helps users to understand localised impacts at high demand locations, such as curbside pick-up / drop-off. The modelling framework also helps assess the economic tipping points of shared mobility services in order to help test the robustness of shared mobility business models.

Figure 33: **PTV MAAS Modeller workflow**



As the ride service trip requests were added to the traffic model, we adapted the background traffic state of the non-ride service vehicles so as to obtain a plausible traffic state reflecting the shift from car driving to shared ride services. Based on the experience on previous shared mobility studies by the ITF, we estimated a traffic flow elasticity as a function of vehicle kilometre travel reduction and applied this elasticity to non-ride service trips. As expected, this elasticity is highly variable from point to point, being quite rigid for small adoptions and close to one for higher adoption shares (Table 5).

Table 5: **Vkm elasticity to ride share adoption**

Ride share adoption scenario	Vkm elasticity
10%	-0.1
20%	-0.5
50%	-0.8

The results of this elasticity calculation for each scenario are (*all else held equal*):

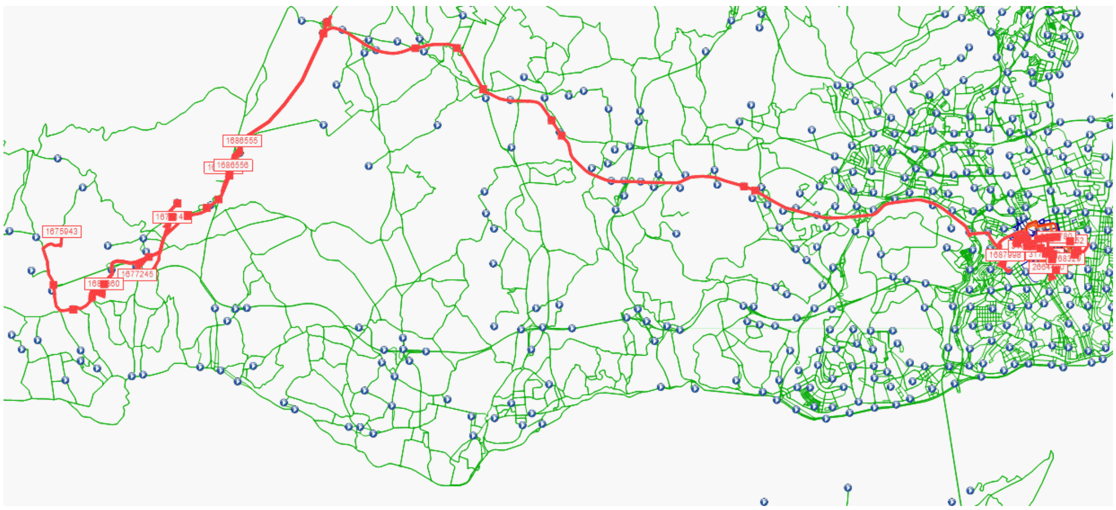
- 10% ride share reduces background demand to 99%
- 20% ride share reduces background demand to 90%
- 50% ride share reduces background demand to 66%.

The MaaS modeller linked trip requests with available ride service vehicles in the network. The ride service parameters included a vehicle capacity of up to 12 persons per vehicle and a tolerance by users of up to

15 minutes waiting time from the moment a ride was booked. The MaaS modeller then generated a series of ride service vehicle tours which serve the demand across the entire model area.

One example of a 62 kilometre long ride service vehicle tour is shown in Figure 34. The tour starts in Cascais Municipality just before 7am in the morning and takes passengers to Sintra Municipality before entering Lisbon City Centre and completing its tour around 10:00. The entire tour picks-up and drops-off passengers at 15 stops whilst reaching a maximum capacity of 12 passengers on board.

Figure 34: **MaaS modeller vehicle tour**



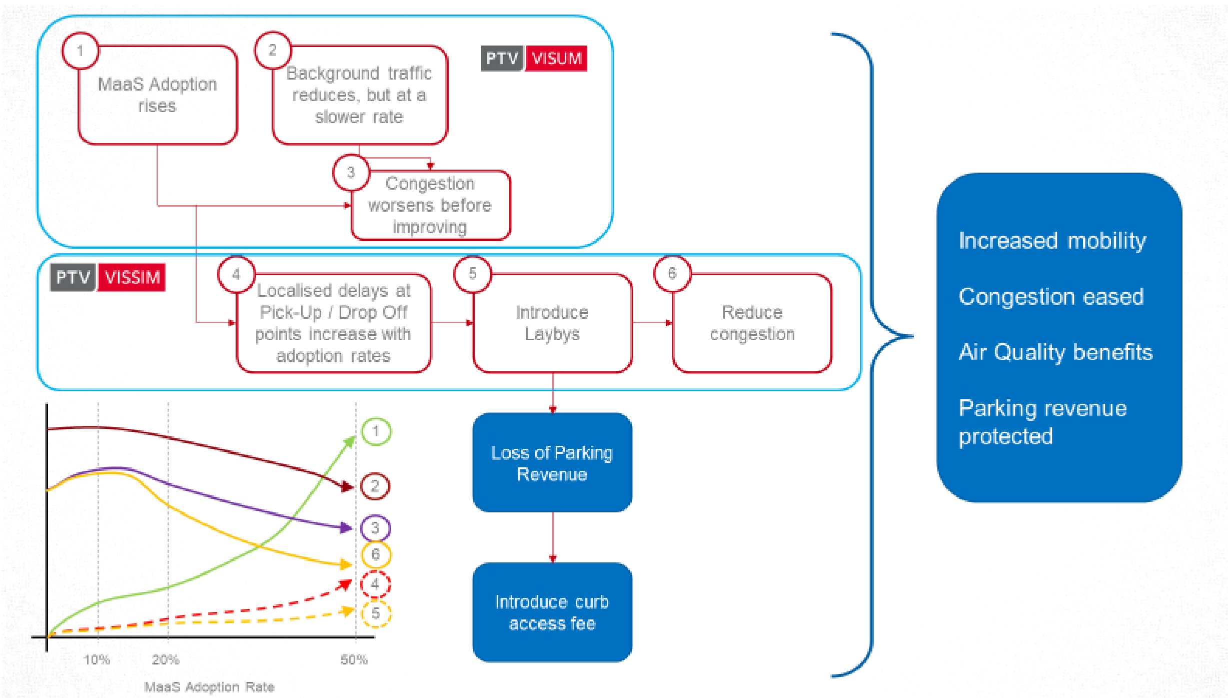
With the background traffic demand and ride share vehicle tours created for each of the three ride share scenarios and a base, the data was exported to a microsimulation model of the Lisbon inner city CBD study area.

Figure 35: **PTV Vissim Study Area**

Moving to a higher resolution of modelling allows all vehicles and their interactions to be individually simulated, including ride service and non-ride service vehicles. The nature of ride service operation means that the effects are seen at a very localised level; vehicles pick-up or drop-off in traffic or at the curbside outside individual buildings and occupy individual spaces. Therefore, as ride share adoption increases so do the localised impacts; i.e. more ride share vehicles creates higher demands for curbside pick-ups and drop-offs, and consequently, more vehicle and pedestrian interaction at a street level and more signficiant impacts on parking revenue.

The knock-on effects are illustrated in Figure 36 in the context of the modelling framework.

Figure 36: **Ride service adoption rates knock on impacts**



Microsimulation allows the intricacy of the network to be taken into account. The impacts that different geometric street layouts, pedestrian crossings and varying types of traffic junctions have on vehicles is captured in this approach. For example, locating a curbside pick-up and drop-off zone adjacent to a traffic junction or pedestrian crossing would mean that ride service vehicles may often face a queue when re-entering the traffic flow after picking up or dropping off passengers.

Following the import of the background traffic demand and ride service trips into the microsimulation model, detailed evaluations at the individual vehicle level are logged and extracted for both background traffic and ride share vehicles. This forms the basis for evaluating performance statistics across the Lisbon CBD study area.

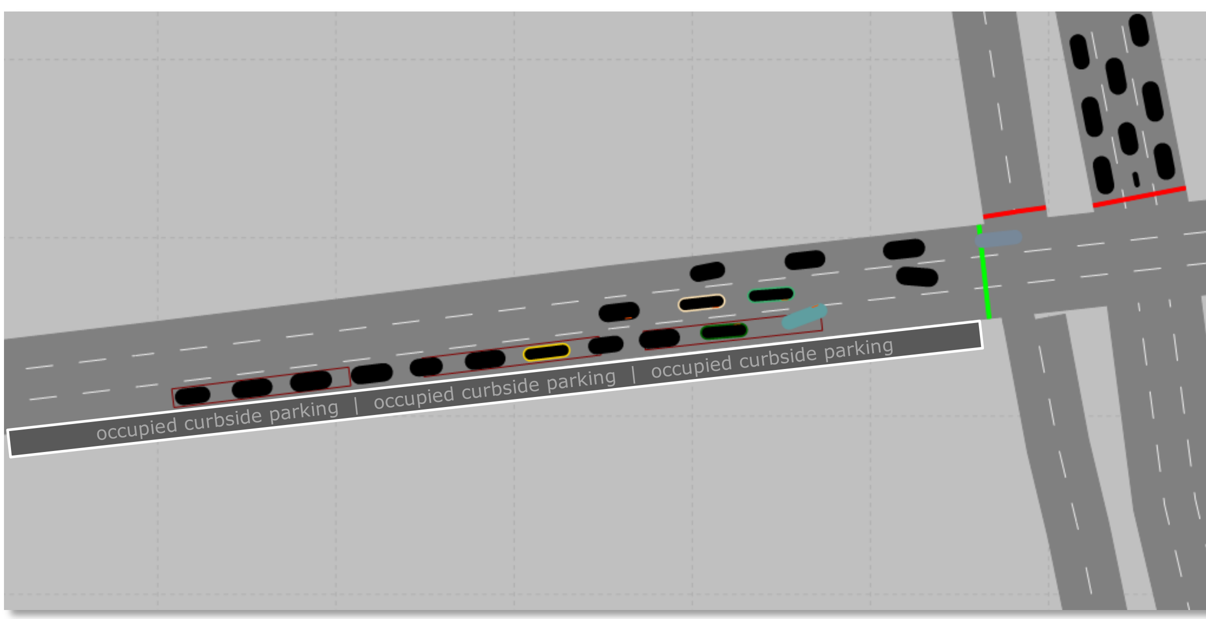
Simulation results and traffic impacts of a shift to increasing adoption of ride share services

As has been previously noted in this report, the positioning of pick-up and drop-off zones can have significant impacts on traffic flow. Instances of double-parking related to pick-up and drop-off's *in traffic* have a more significant impact on traffic flow than vehicles picking up and dropping off *at the curb*. With this in mind two scenarios were devised for each ride service penetration scenario (10%, 20% and 50%).

Scenarios

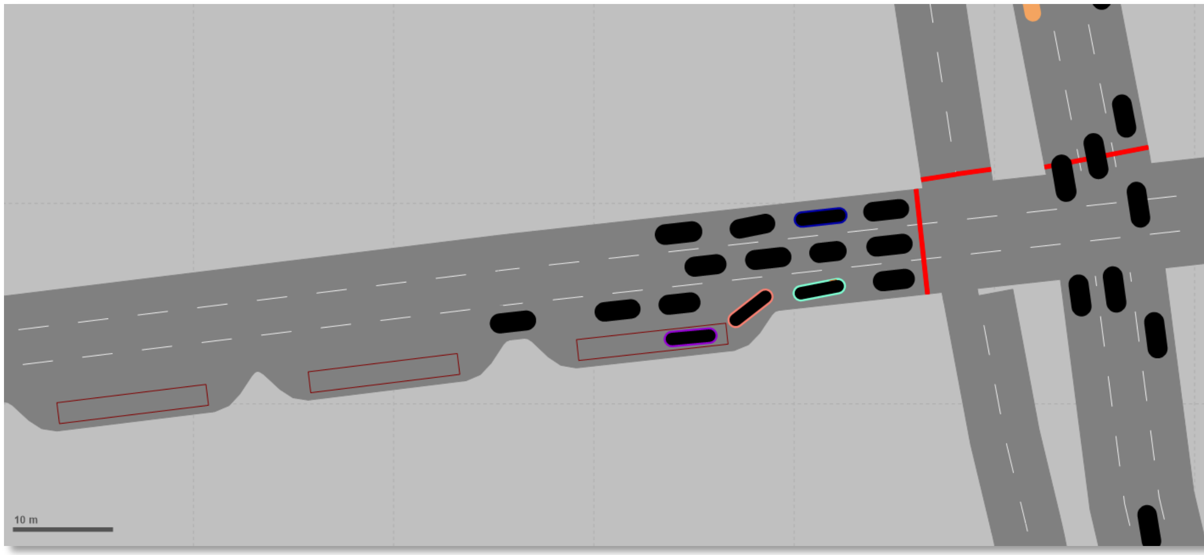
In the first scenario – "street release" – the ride service passengers are served at the pick-up/drop-off zone closest to their preferred destination. Passengers are picked-up and dropped-off in general traffic, i.e. the vehicle stops in the lane closest to the parking lane causing vehicles to go around or queue behind it. We modelled this scenario under the assumption that at peak times, on-street parking is fully occupied at the curb thus preventing ride service curb access. We also constrain the scenario so that no pick-up or drop-off occurs in crosswalks, in no-parking zones or at public transport stops. In reality, with little opportunity to pull up to the curb, ride service vehicles would probably seek to access the curb at all three of those locations – even if it were illegal to do so. We assume this isn't the case in the model under the assumption that ride service pick-up and drop-off should not depend on contravening existing curb access rules in order to minimise traffic flow impacts. If the intended stopping location of the vehicle is occupied, the vehicle double-parks in traffic outside of the zone propagating the congestion effects particularly on streets where there is high traffic flow. When the next spot becomes available in the preferred pick-up/drop-off zone, the vehicle advances and releases or picks up the passenger. This scenario does not require any parking suppression, although may produce traffic impacts at peak hours due to ride share vehicles occupying lane space, pulling into and out of spaces and affecting traffic flow as shown in Figure 37.

Figure 37: **On street pick-up drop-off zone**



In the second scenario – "curb release", the ride service passengers are also served at the pick-up/drop-off zone closest to their preferred destination but these are carved out of existing on-street parking and grant direct access to the curb. Passengers are picked-up and dropped-off in a reserved lay-by area at the curb, i.e. outside of the traffic lane. If the intended stopping location is full, the ride service vehicle queues in traffic waiting for the next avalible curb space to be free. This queing impacts traffic flow and safety much as in the previous scenario. The presence of dedicated pick-up and drop-off bays, and a good spatial distribution, contributes to less traffic impacts and safer pick-up and drop-off operations. This scenario reallocates space away from parked cars towards ride service access as shown in Figure 38.

Figure 38: **Lay-by pick-up drop-off zone**



At this stage the study has not considered the dynamic allocation of pick-up and drop off, i.e. vehicles diverting to surrounding pick-up/drop-off zones if their intended destination remains occupied beyond a certain acceptable threshold. The propensity for passengers to request ride share drivers to divert to an alternative space is a complex subjective choice which is influenced by a wide range of factors from environmental conditions to their own physical wellbeing.

Recalling that some evidence indicates that people are generally willing to walk approximately 250 metres to benefit from less expensive parking (Glasnapp et al., 2014), a similar acceptance may operate for short diversions if drivers cannot legally release in traffic and the only other option is to wait in the vehicle for a space at the curb to be freed-up. In those instances, the ride service vehicle would advance to the next available pick-up/drop-off bay and the passenger would then walk back to their destination. Those with permanent or temporary mobility impairments may suffer disproportionally under such a scenario. Special curb-access rules for this population, like being granted queue-cutting priority or exceptionally being able to access the curb at fire hydrants and other low-use but high-importance zones, could be considered.

Diversion scenarios may also form the basis for dynamic pricing of curb access to incentivise pick-ups and drop-offs where they would least disrupt traffic. In such configurations, pick-up/drop-off could be priced at a high rate where their disruptive impact on immediate or upstream traffic flow is greatest (or, alternatively, not allowed as in some high volume public transport corridors like it is for ride services, but not taxis, on Market Street in San Francisco). Pick-up/drop-off fees could be much lower, or even negative, for pick-up and drop-offs away from those streets.

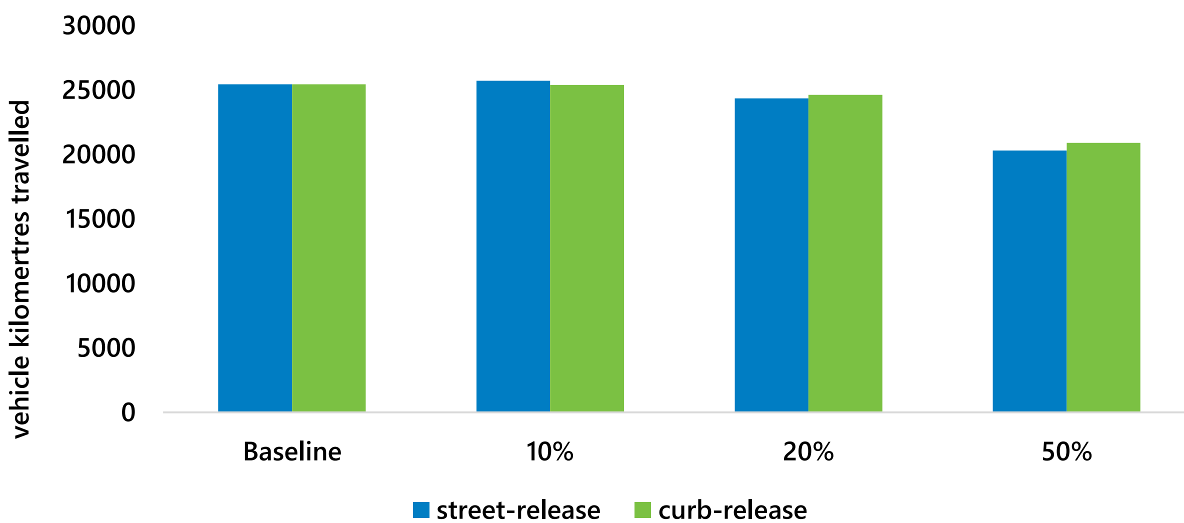
We make no judgement as to the immediate applicability of either scenario modelled but one of the main take-aways from this exercise is that the formation and duration of in-traffic queues serve as proxy indicators of where curb access pressure is greatest and when and where it makes sense to allocate more space to curbside pick-up and drop-off zones – including where this allocation of space could be variable over the course of the day.

Results

The results of the simulation reflect that increasing adoption rates of ride share service impact the traffic flow and performance of the network in the study area. The first thing to observe is that low rates of ride service adoption have very limited impacts on vehicular travel in the study area during the peak period

(08:00 to 09:00). Figure 39 presents the total vehicle kilometres travelled for all vehicles in the Lisbon CBD study area.

Figure 39: **Total vehicle kilometres travelled**

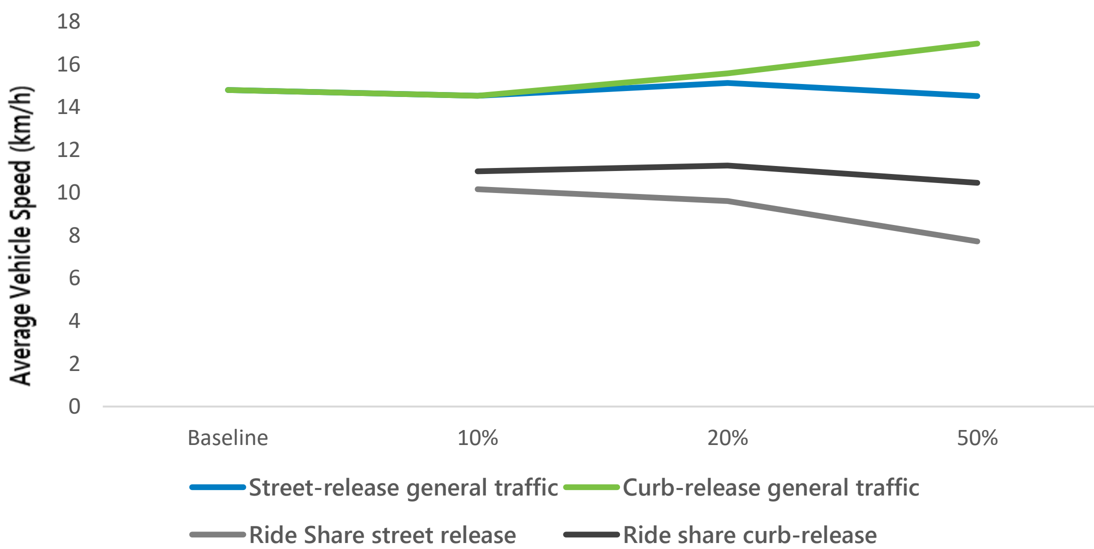


The data shows a marginal increase in total vehicle kilometres travelled in the 10% ride share adoption scenario which is a result of the small elasticity, meaning a minimal reduction in general traffic. As the ride service adoption rate increases, and more mode shift occurs replacing car trips with ride services, total vehicle kilometres travelled decrease up to 25% compared to the base in the 50% adoption scenario. A higher total vehicle kilometres travelled value for the curb-release scenario compared to the street-release scenarios for the 20% and 50% adoption rates demonstrate a more freely moving network with less delay allowing more trip requests to be served.

The current traffic model does not account for the so called “parasite” or “parking cruising” traffic in cities, where car users circulate at lower speed and travel longer while hunting for available parking spaces. Cruising for parking in Lisbon has been estimated to increase vehicle travel between 5% to 10% peak periods (Ferreira and de Abreue Silva, 2011), other estimates internationally point to a higher figure – up to 30% of urban traffic in busy areas (Shoup, 2005).

The uptake of ride services has an impact on traffic fluidity throughout the study area, as seen with traffic speeds in both street-release and curb-release scenarios. Figure 40 demonstrates peak hour average vehicle speeds across Lisbon CBD for both general traffic and ride services.

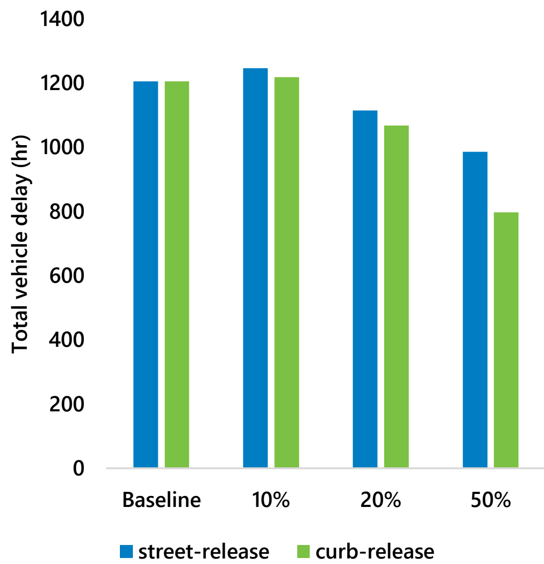
Figure 40: **Average Vehicle Speed**



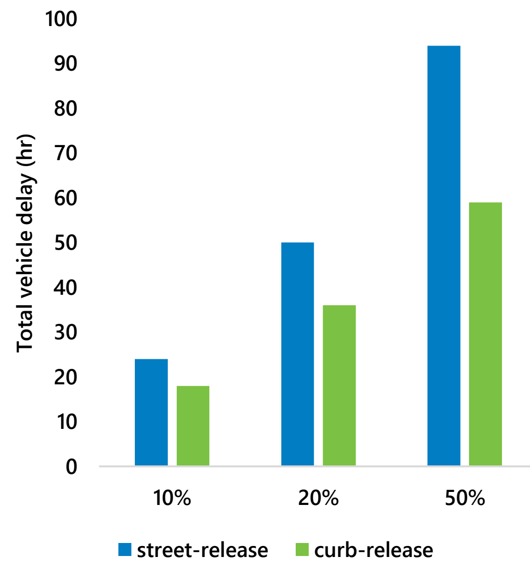
For background traffic it seems clear that as ride share adoption increases, curb-release operation has less impact on traffic fluidity than street release pick-up and drop-off. In the curb-release scenario, vehicle speeds actually increase for background traffic due to a combination of increasingly replacing car trips with fewer ride service vehicles, and curbside transactions being completed outside of traffic lanes. Whilst ride service vehicles generally have a lower average speed, due to the number of pick-up and drop-off stops completed, the curb-release operation again shows better performance than street-release operations due to the removal of traffic queue-related travel delays during pick-up and drop-off.

Total vehicle delay statistics reported from the simulation also suggest more fluid traffic movements in the curb-release scenario compared to the street-release scenario. Figure 41 presents total vehicle delay in the study area for all vehicles (a.) and then separately for ride service vehicles (b.). The general trend is that all vehicles experience a reduction in delay as ride service adoption increases, this is as a result of fewer vehicles travelling in the network due to mode shift towards ride services. Comparing street-release to curb-release scenarios shows that all vehicles benefit from less delay, up to 19% at the 50% ride share adoption for the curb-release scenario. When considering ride service vehicles only, delay increases as adoption of ride services goes up due to more vehicles being present in the network and more pick-up and drop-off requests. Curb release operation always deliver less delay than street-release operation and the increase in delay from 10% uptake to 50% uptake is lower for curb-release versus street-release. In effect, curb-release operation allows queues to be more easily mitigated whereas street-release queueing grows to unsustainable levels in the 50% adoption scenario.

Figure 41: **Total vehicle delay for general and ride service vehicles**



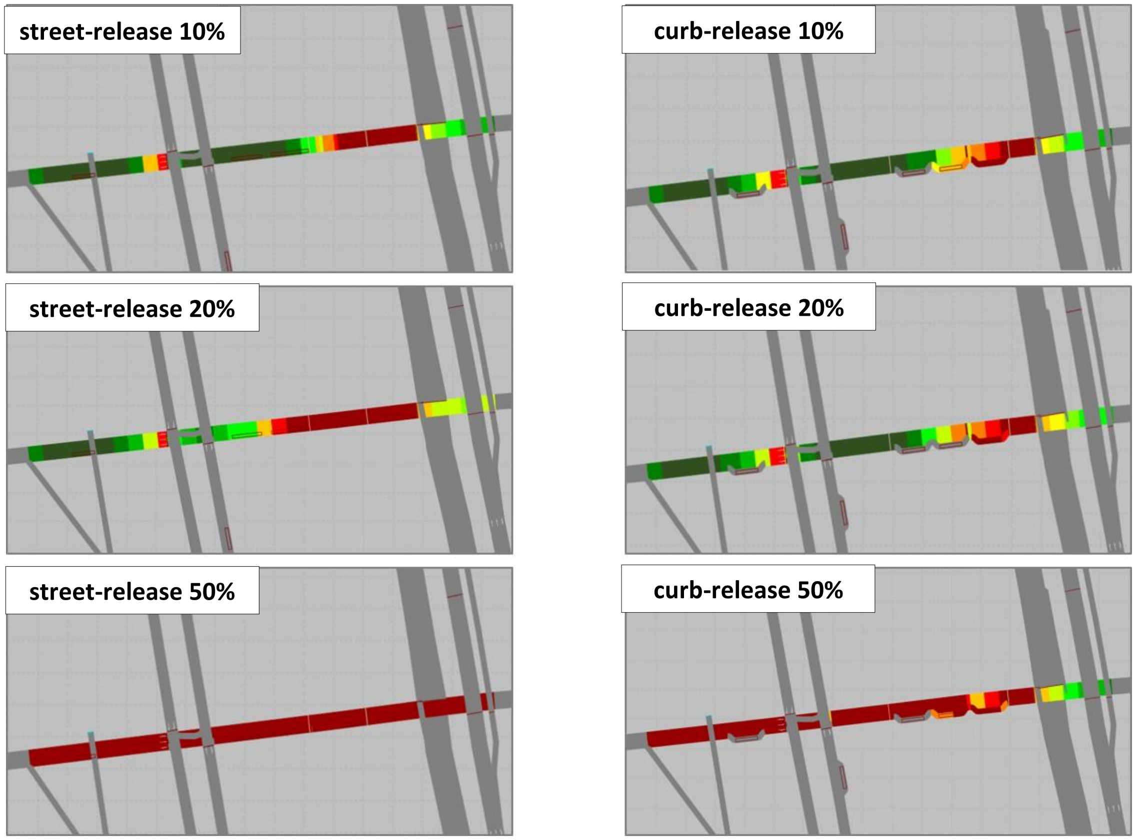
(a). General traffic



(b). Ride service vehicles only

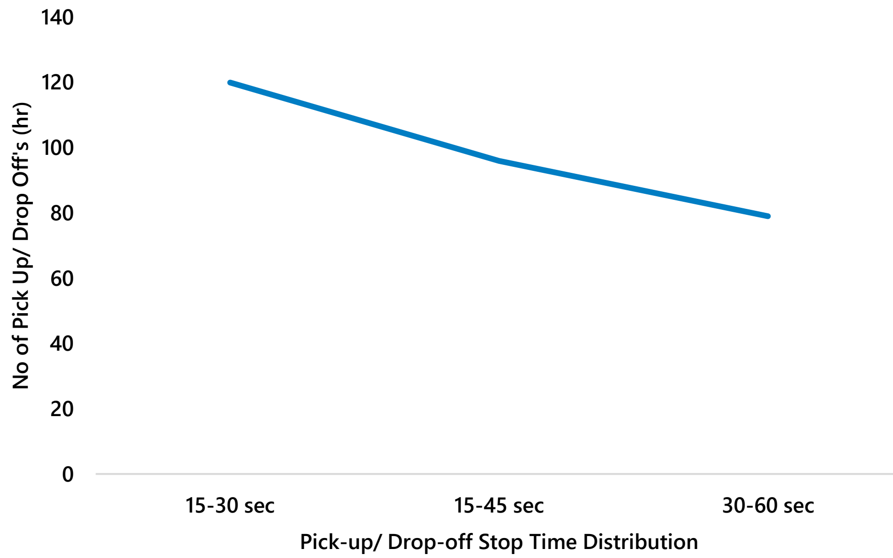
Focussing on certain streets within the study area reveals the more localised impacts on traffic fluidity from the increased adoption of ride share services and the designation of pick-up and drop-off zones. Figure 42 presents vehicle speed data from the simulation for a designated corridor within the study area. At the lower adoption rate of 10%, ride service vehicle speeds can be seen to be faster with relatively few slowdown hotspots as demonstrated by the red areas. At the 20% adoption rate, the benefit of curb-release versus street release is clear as traffic speeds for curb-release remain similar to the 10% scenario and are much better than those experienced in the street-release scenario. At the 50% ride service adoption rate, overall vehicle speed is similar in both the street-release and curb-release scenarios. Both show a reduction in speed relative to other scenarios. This suggests that for this location, the provision of pick-up and drop-of zones, either for street-release or for curb-release, is insufficient to accommodate demand.

Figure 42: **Average vehicle speed on local street for varying ride share adoption scenarios**



Further analysis of individual curbside pick-up and drop-off activities leads to interesting conclusions about the capacity of individual pick-up and drop-off spaces, as well as the impact on capacity of general traffic flow. In a simple theoretical experiment to test the capacity of an individual space, we added ride share demand to a simulation model with zero background traffic. We added a series of linear pick-up and drop-off time distributions between 15 seconds and 60 seconds to replicate the varying time passengers take to enter or exit a ride share vehicle, dependent for example on number of passengers or unloading of baggage. The resulting simulation runs identified that a single pick-up and drop-off space has a capacity of 95 transactions per hour. As there was no background or general traffic vehicle in the model the design of the pick-up and drop-off space, i.e. street-release or curb-release operational models have no bearing on capacity. Varying the time distribution to consider the impact of shorter or longer stops has a relatively linear impact on capacity as shown in Figure 43.

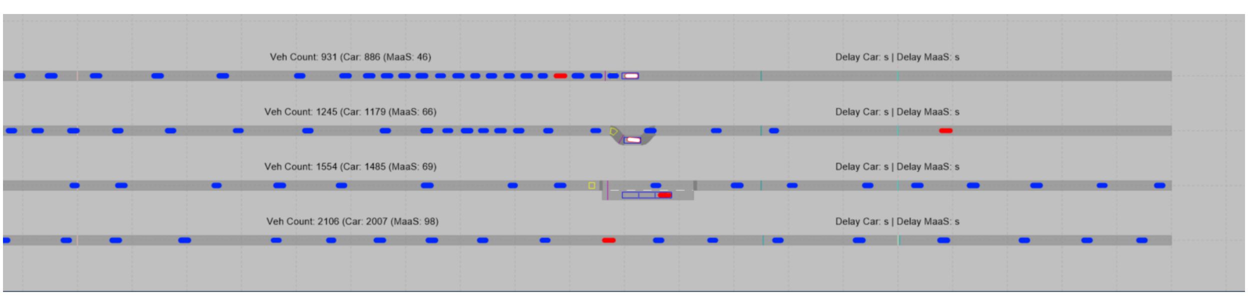
Figure 43: **Pick-Up and Drop-Off space capacity**



When this analysis is expanded into a simulation model that includes background traffic, interesting conclusions on the localised impact of ride share activites on capacity can be drawn. Four simulation models reflecting a single lane street were produced as follows:

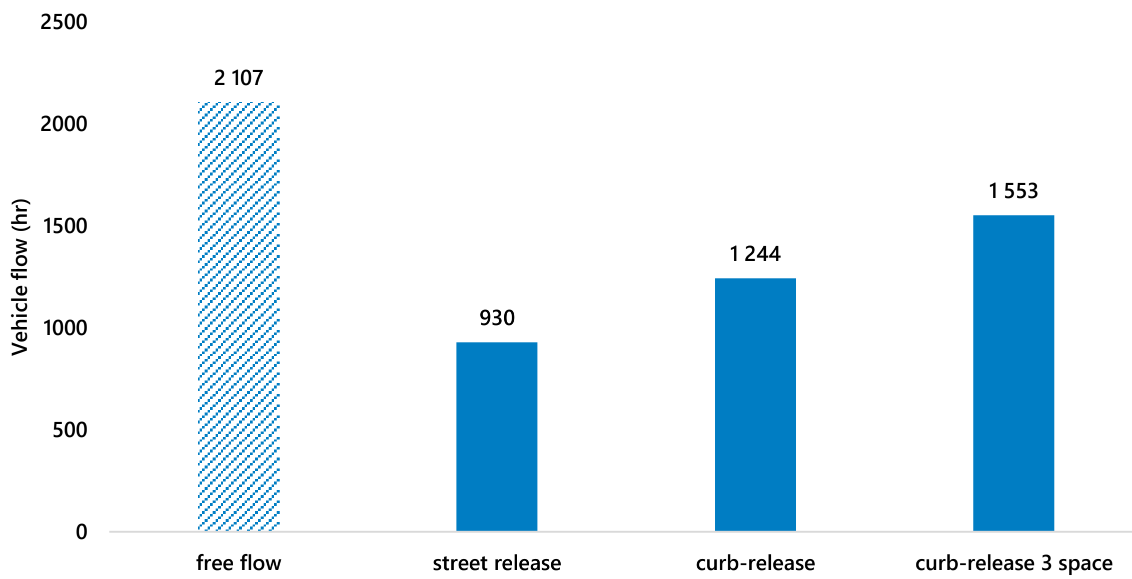
- Street-release single space ride service pick-up drop-off zone
- Curb-release single space ride service pick-up and drop-off zone
- Curb-release three space ride service pick-up and drop-off zone
- No pick-up and drop-off zone.

Figure 44: **PTV Vissim simulation models (one lane hourly throughput)**



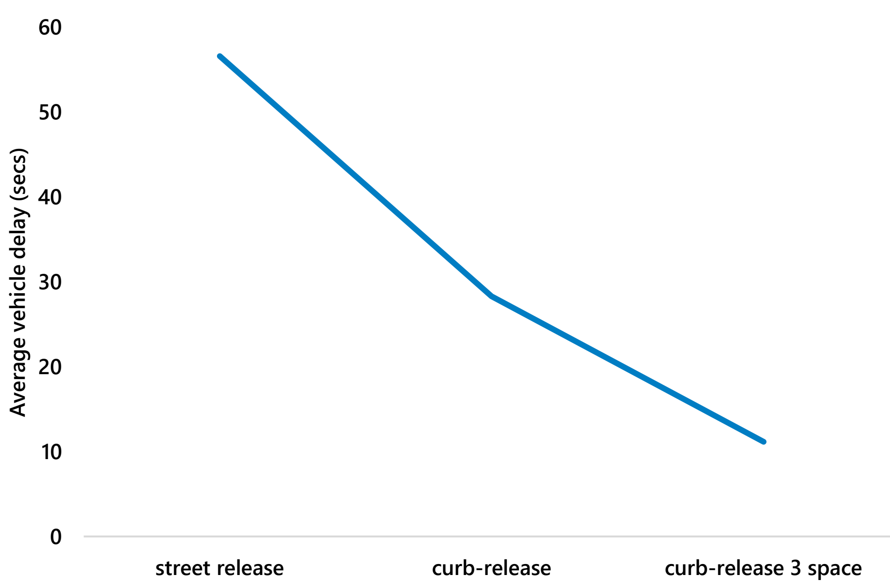
In simulated free flow conditions, represented by the fourth model where no pick-up and drop-off zones are present and vehicles have a desired speed of 50km/h, a single traffic lane can accommodate approximately 2 100 vehicles per hour, with no interferences in traffic (e.g. pedestrian crossings, intersection priorities, traffic lights or parking movements). These conditions are then theoretical and are normally not met in urban traffic and are impossible to be achieved in a steady car traffic movement just controlled by traffic density (vehicle proximity) and flow speed. When pick-up and drop-off zones are introduced the simulation results show there is a significant drop in capacity on the traffic lane as shown in Figure 44. The largest reduction in capacity results from the on-street pick-up zone where servicing 46 hourly ride share trips reduces lane capacity by 56% to 930 vehicles per lane per hour. Introducing a lay-by with space for a single ride share vehicle improves traffic flow compared to the on-street operation but still represents a significant reduction in capacity compared to free flow conditions. A larger lay-by pick-up and drop-off zone allows ride share vehicles to pull out of traffic flow further improving traffic flow. In this case, allowing a throughput 1 553 vehicles per hour. The simulation test demonstrates that even with curb-release operation the presence of ride share vehicles has the potential to effect network capacity.

Figure 45: **Hourly vehicle flow**



The impact of the reduction in capacity on vehicle delay is presented in Figure 46. With the introduction of on-street pick-up and drop-off zones, vehicles experience on average a minute of delay, this dramatically reduces with the introduction of lay-bys in the curb-release scenarios, falling to 11 seconds when a larger-capacity lay-by pick-up and drop-off zone is implemented.

Figure 46: **Average vehicle delay**



The results of the simple theoretical experiment draw parallels with the detailed simulation modelling results extracted for the Lisbon CBD, with on-street pick-up and drop-off zones having the biggest impact on traffic fluidity.

Management of pick-up and drop-off zones

The analysis from the PTV Vissim model shows from an operational perspective that curb-release lay-bys demonstrate a better fit between the supply and demand for pick-up/drop-off capacity. This results in a strong reduction of queuing and resulting delays. This finding suggests that as congestion moves increasingly from the street to the curb, cities will have to consider how to dynamically manage these spaces over the course of the day. This management should consider:

- Dynamic allocation of curb space allocated to pick-up and drop-off by time of day and day of week. Precedents that exist for the temporal variabilisation of curb use for freight loading and drop-off zones. Going forward, slot reservations for specific locations could become a possibility as with delivery slot reservation systems for congested freight facilities. This would require a complete re-evaluation of the physical and digital infrastructure supporting street and curb use today.
- Dynamic pricing of pick-up and drop-off spaces can help manage access to these. This approach would require good information on supply and demand – including away from crowded destinations, a way to communicate that availability to shared rides service dispatch and operating systems, and, eventually, coordination with other shared mobility services and back-office systems to allow multi-modal trip chaining using bicycle- or scooter-sharing to make up the last link in a diverted trip chain.
- To be effective, the level of price signals should be sufficient to enact a real change of behaviour within the bounds, otherwise public authorities may wish to explore other methods of managing demand for crowded zones and peak periods.

Revenue impacts

One key element of curb management is how to price this sometimes scarce resource effectively. If the city of Lisbon were to simply seek to replace lost parking revenue by pricing curb pick-ups and drop-off, the appraised per "curb-kiss" fee would vary betweenEUR 0.10 – EUR 0.28. In a strict revenue replacement scenario, lower shared ride service adoption rates lead to higher "curb-kiss" fees. At higher adoption levels, many pick-up and drop-off zones become congested at peak periods suggesting scope for a robust curb pricing mechanism to help manage demand. This mechanism could also be designed to divert trips from very congested locations to nearby locations with a lower "curb-kiss" fee.

An initial marginal cost pricing estimate for the study area in Lisbon indicates that "curb-kiss" fees could range from EUR 0.70 and EUR 1.25 at peak demand, EUR 0.11-0.20 mid-day and be almost be free the rest of the time.

In our scenarios, the revenue replacement options lead to a relatively low per pick-up and drop-off "curb-kiss". Even using a dynamic pricing method, resulting fees may not be sufficient to generate behavioural changes. This might suggest that curb-pricing mechanisms may not be strictly revenue neutral if they aim to be used in order to manage curbside demand at peak times and locations.

If we limit this assessment to the study area where parking spaces are on average more productive than the city average, the revenue that is needed to be compensated by parking revenue losses is EUR 4 112 (using an average daily revenue per parking space of EUR 12.5). The revenue loss would mean a "curb-kiss" between EUR 0.29 and EUR 0.91, representing approximately 3 times the average value estimated for the city.

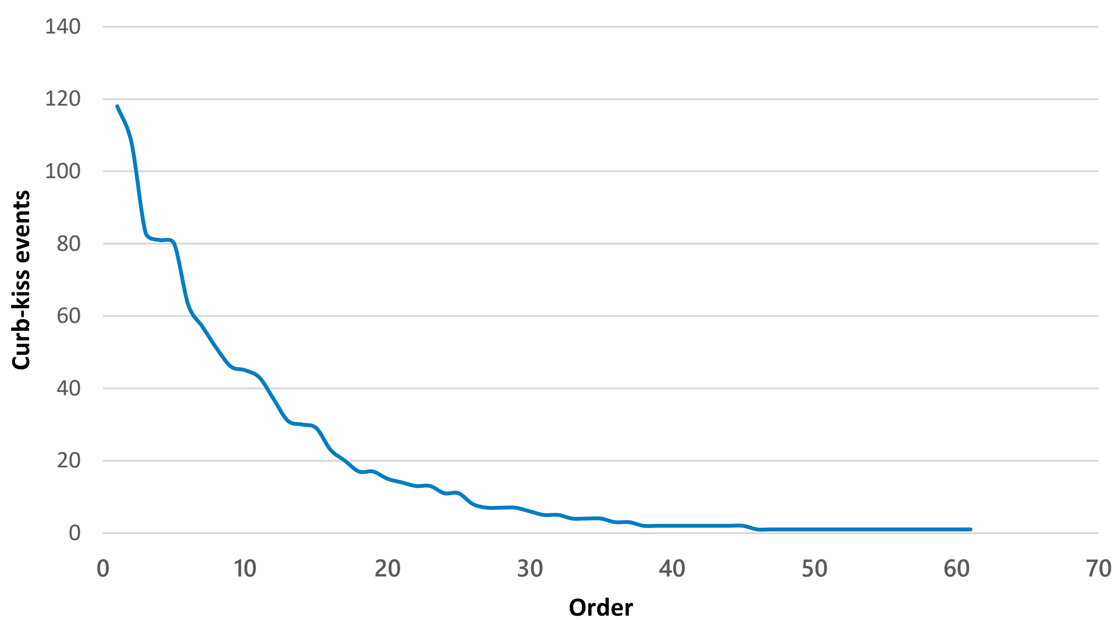
Use impacts (curb turnover)

The modelling also indicates wide scope to adapt curb usage for a more dynamic set of uses and away from the homogenous and static reservation of that space for a single use – currently for storing private vehicles in public space.

Flexible curb use regimes will require the capacity to dynamically adapt and predict demand and allocate space as necessary from one use to the other. Metrics on curb use productivity – especially in terms of the number of people and businesses served by different curb allocation regimes - will be necessary. This will likely highlight that curb use may be saturated in some areas and quite low in others.

Figure 47 presents the levels of spatial concentration of "curb-kiss" operations for the 50% adoption scenario. Each of the 61 pick-up and drop-off areas are presented in the chart and ordered by popularity. The obtained values show that less than 5% of the pick-up and drop-off zones accommodate approximately 50% of the pick-up and drop-off demand.

Figure 47: **Sorted number of "curb-kiss" events between 8:00 and 9:00 in the study area in the 50% adoption scenario**



Balancing this asymmetry via pricing, service delivery and technology are unexplored areas for many cities. Striving to reconcile efficient and safe pick-up and drop-off activities with the productive occupation of space will be a central challenge going forward. This will not always be easy, as some of the modelling work indicates that in certain areas, sufficiently convenient off-street parking is not sufficiently closely located to the modelled pick-up and drop-off areas. In these contexts, re-allocation of space away from parking may be seen by residents as unfair public policy.

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International Transport Forum

The Shared-Use City: Managing the Curb

This report discusses the street design and pricing implications of a large-scale introduction of ride-sharing services and other innovative mobility options in urban settings. It looks at the potential for a shift away from a model of the use of curb space focused on street parking to one that makes more flexible use of curb space for pick-up and drop-off zones for passengers and freight. The study presents the results of quantitative modelling of alternative curb-use scenarios and discusses their relative efficiency, contribution to wider policy objectives and implications on city revenues.

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