



Cars and Space Consumption

Rethinking the Regulation of Urban Mobility

Discussion Paper



Yves Crozet
University of Lyon

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Introduction

Cities are the heart of economic growth and employment. In Europe, urban areas generate 85% of the GDP (European Commission, 2017a). At the same time, European cities are facing the challenge of reducing congestion, pollution and accidents (European Commission, 2017a). Private motorised modes tend to be the main reason for increasing congestion and greenhouse gas emissions across many urban areas. Motorisation rates across Europe remain high, despite some evidence suggesting the average annual distance travelled by car in most developed economies may have ceased to grow – a phenomenon called “peak car” (Goodwin and Van Dender 2013). The motorisation rate for the EU-28 in 2016 was 506 cars per 1 000 inhabitants, one car for every two persons (Eurostat, 2019).

CO₂ and air-pollutant emissions from road transport need to be drastically reduced to be in line with the United Nations Sustainable Development Goals adopted in September 2015 (United Nations 2019) and the Paris Agreement signed in December the same year (United Nations, 2015), which was ratified by all European countries.. Transport needs to be sustainable, in the sense that it needs to be “safe, affordable, accessible, efficient, and resilient, while minimizing carbon and other emissions and environmental impact” (United Nations Secretary-General's High-Level Advisory Group on Sustainable Transport, 2016, p. 10). In addition to the negative effects of pollution and CO₂ emissions, the congestion itself comes at a significant cost to the economy, estimated at around €130 billion per year, or just over 1% of the EU's GDP (European Commission, 2017b).

Within this context, the mobility objectives in most cities and urban regions are set to reduce these negative externalities, including air pollution, CO₂ emissions and congestion. Some cities have done this by promoting active travel (walking and cycling), and through public transport. The efficient use of the road space is also a key issue. As such, optimisation of road space has become a forefront challenge for public policies, confronted with a massive presence of the car, the dominant mode of transport, especially in the peripheries.

The question, therefore, is whether it is possible to reduce the role of the car in urban mobility while maintaining a satisfactory level of accessibility to urban amenities (employment, housing, shops, education, etc.), especially for residents located on the periphery. To address this, it is necessary to focus not only on the travel time of individuals, but also on the organisation of the urban space from two different perspectives. In other words, the "microscopic" approach to the consumption of road space by different transport modes on the one hand; and the "macroscopic" understanding of the impact of the car on the urban form, on the other.

The first part of this paper focuses on the consumption of street space by looking at it from the perspective of new mobility services. Proliferation of these services has made the question of congestion even more acute, making policy makers question two scarce resources: individuals' time and space for the community.

The second part will show that this tension between the scarcity of time and the scarcity of space has been addressed from a macroscopic point of view by increasing speed through providing additional road capacity and motorways for increasing numbers of cars. This has been the main solution to better link people and opportunities. However, the “solution” of speed has had negative impacts on land use and

urban sprawl. In order to shift policy priority in the transport sector from increasing speed to accessibility – a so-called “accessibility turn” – adjustments have been made in the regulation of urban mobility. The accessibility turn is a step-by-step process that started some decades ago with the concept of “transit oriented development” (TOD).

The third part will focus on the coming steps of the accessibility turn. In order to reduce the pressure of the car on public space, urban mobility regulations have to adopt coherent policy packages. The content of these packages are not the same in the central part and in the peripheries of the agglomerations. However, whatever the location, the new ambitions of Mobility and Transport Authorities (MTA) must address the issue of road pricing.

Car and space consumption: The rediscovery of an urban issue

From an economic point of view, the main interest of a city is the reduction of transaction costs. Historically, many cities grew around marketplaces due to their ability to bring sellers and potential buyers together in one place at the same time. The same rationale of facilitation, and increase of potential contacts and interactions, is at work in modern cities. Cities are still markets for goods and services, but they are also, among other things, labour and residential markets, as well as places that offer non-market public services. Nevertheless, these activities take place in different parts of a city: residents often have to move to take full advantage of urban opportunities. The city produces a mobility imperative.

Transport or trips are only one component of mobility. For individuals, mobility is an interface between three subsystems: activities, the locations of the activities and trips. Since the latter is the condition of obtaining a given location-activity pair, the adjustment variable is the duration of the trip. Reduced travel time increases the potential number of location-activity pairs. The individual point of view, therefore, favours shorter travel time and faster speeds. However, as more activities occur in the same place, moving at the same time as others leads to congestion. As a result, from the collective point of view, space becomes the scarcest resource.

Road congestion and the promises of shared mobility

Road congestion is very frequent in metropolitan areas. One of the most obvious effects is time loss due to long travel times. As shown in Table 1, in many cities, private car users lose about an hour per business day in traffic jams. The average speed of the last mile is often lower than that of the bicycle.

Time losses are not the only side effects of road congestion. Noise and air pollutants, as well as greenhouse gas emissions and particles, are among other negative impacts. To scale back these externalities, many public authorities are targeting road vehicles by limiting or prohibiting the most polluting ones, in particular

diesel engines. However, substitution of conventional vehicles by “clean” ones, even if they are autonomous, will not solve the problem of road congestion. To address congestion, authorities should reduce the pressure of car traffic on road networks. Is it possible to cut down traffic by leveraging new technologies and promoting shared mobility?

Table 1. Time losses per year in selected large cities

City	Annual time losses for car users (hours)	Road speed for the last mile (m/h)
Paris, France	237	8
Brussels, Belgium	195	7
London, United Kingdom	227	7
Rome, Italy	254	8
Milan, Ital	226	8
Dublin, Ireland	246	6
Bordeaux, France	223	7

Source: INRIX (2018).

Digitalisation is gradually transforming all sectors of economy, including public services, such as health and education, as well as banking, trade and energy. This is also the case for the transport sector, and urban mobility in particular. Nevertheless, the effects of digitisation on urban mobility may not always be evident. This is because today private modes of transport generate a large part of mobility (cars, motorbikes, bikes). Even in very large cities, public transport (PT) accounts for less than half of the mobility market. In urban areas, mobility is frequently based on a division of labour between public and private actors, but also between public and individual transport. Public authorities and private vehicle owners manage them independently. Clear boundaries exist, for example, between public transport vehicles and individual cars, and users are often opposed to the soft transport modes like cycling and walking, with the two-wheeled motorised vehicles occupying an intermediate position. With these well-defined categories, the roles of each actor are distinct: Public authorities deal with the organisation of public transport and the management of roads, whereas road users, including motorists and cyclists, use their own vehicle on the roads. Yet with the development of shared mobility, the boundaries between public and private transport are blurred. Is there a potential source of a new division of labour between public and private actors in the delivery of urban mobility services?

New mobility services have arisen because of the wave of digitisation within the transport sector. Multiple innovations are challenging public policies, which, sometimes, have existed for several decades and hence are not well adapted to changes in the sector. The proliferation of new app-based mobility services such as Uber, Lyft, Grab among others are changing the playing field for taxi industry. In fact, these mobility services are affecting all actors of urban mobility, including how bicycles and private vehicles are managed.

The main change comes from the development of new apps on smartphones, which could lead to a radical transformation: in other words the shared use of cars. Fleets of connected (and potentially autonomous) vehicles have a great potential within the new paradigm of shared mobility. As shown in studies conducted by the International Transport Forum (ITF, 2017, 2017b, 2018) in Lisbon, Helsinki or Dublin, a systematic

sharing of connected and autonomous vehicles could greatly reduce congestion, pollution and even travel time. However, this revolution is not easy to implement because it involves new and unexpected forms of public-private partnerships and regulations. It is also important to note that autonomous vehicles are not, until now, a real substitute for private cars or public transport.

New mobility providers have indeed disrupted the old organisation of public transport. With their apps, they not only question the traditional functioning of taxis, but also the way public authorities manage public transport. This is because shared mobility entails the sharing of an asset (i.e. a vehicle) that no one consumer owns, but instead multiple consumers use. This distinction between an asset and a service is at the origin of the concept of “Mobility as a Service” (MaaS).

A digital platform facilitates the use of shared vehicles. The vehicles can be bicycles, electric bicycles (commonly known as “e-bikes”), electric scooters, motorcycles or scooters, cars and vans. Strictly speaking, the original taxi/cab services and bus/train services are in fact also shared mobility services in a broad sense. However, they are not typically included in the definition of shared mobility in the sharing economy. Nonetheless, they should be included in the reasoning when addressing the issue of “zero car growth”.

New mobility services: What is their impact on congestion and pollution?

There are hundreds of examples of new mobility services throughout the world. Typically, either private or public entities own shared motorcycles or scooters, as well as shared bicycles and e-bikes. Sometimes, local governments contract out the private enterprises involved. Carpooling, car rental, and car clubs all existed before the internet age. The internet, however, along with smart phones and apps, has provided new opportunities to upgrade these models. As a result, app-based mobility services have become more practical and attractive, paving the way to new ideas and facilitating the use for citizens while creating new challenges for public authorities. Instead of focusing solely on public transport, public authorities have to understand how to accommodate new shared mobility services in the overall transport offer.

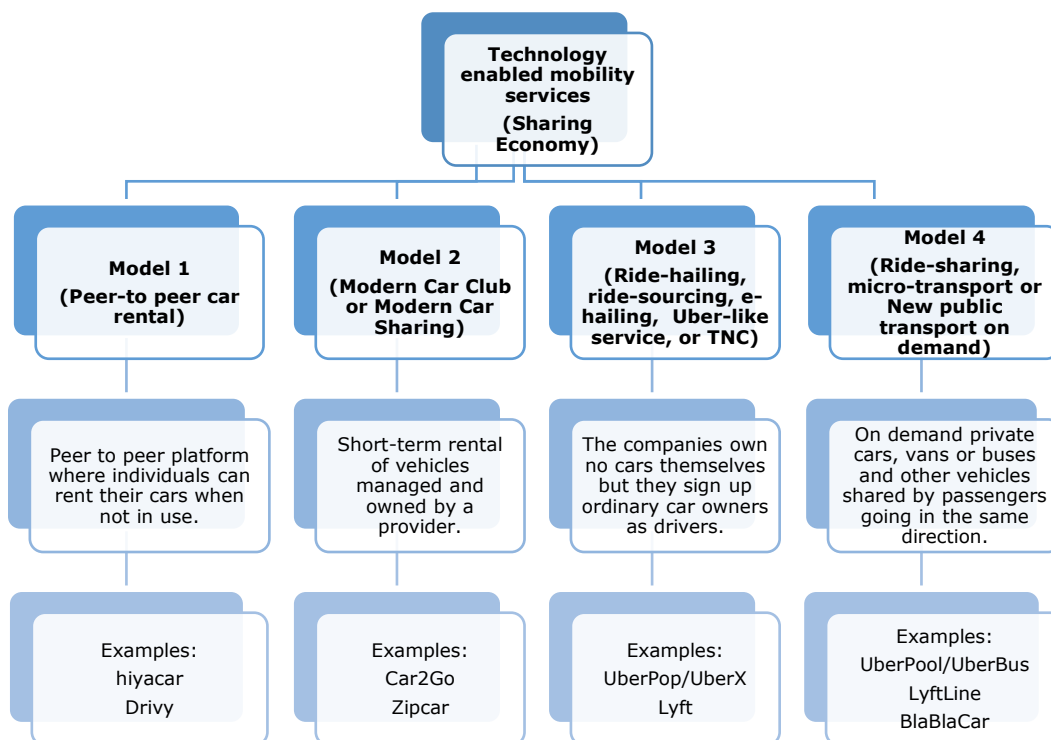
Shared cars and vans are typically private enterprises or peer-to-peer businesses. There is no reason, however, why a public company could not run a shared car business, other than that most market economies see commercial enterprises as endeavours that should ideally be undertaken by the private sector. When there are public services that can achieve public policy objectives, governments in most market economies will often consider stepping in. This has been the case with a number of shared bicycle schemes, as shared bicycles help achieve sustainable mobility. Bicycles do not cause pollution, do not emit CO₂ and usually do not cause congestion. In addition, they provide health benefits to those who use them. Can we draw the same conclusion for car sharing and ride sharing?

In Europe, transport is the only sector in which GHG emissions have grown since 1990 (Transport and the Environment, 2018). Road transport is responsible for 22% of total GHG emissions in Europe (European Environment Agency, 2019). Emissions of nitrogen oxides (NO_x) from road transport have not decreased enough to meet air quality standards in many urban areas (European Commission, 2017b). The emissions of air pollutants in cities are closely linked to traffic exhaust emissions. The transport sector is the largest contributor to NO_x emissions, accounting for 46% of total (urban and non-urban) EU-28 emissions in 2014.

Transport also contributed to 13% and 15% of total PM10 and PM2.5 emissions, respectively, in the EU-28 in 2014 (European Commission, 2017b). Therefore, one question that emerges is whether the new mobility services can have a positive, negative or neutral impact on not just pollution and CO₂ emissions, but also on congestion and traffic in general.

In order to assess the impacts of new mobility services, we have to distinguish four different models of shared mobility (Santos, 2018), as shown in Figure 1.

Figure 1. The four main models of shared cars and vans



Source: Crozet, Santos, Coldefy (2019).

Peer-to-peer car rental (Model 1) is booming in Europe and especially in France (Monitor Deloitte, 2017) due to lower cost compared to traditional car rentals. Peer-to-peer car rental offers decentralised solutions whereby customers have a wider set of options in terms of brands and models.

Modern Car Club or Modern Car Sharing (Model 2) is also growing in Europe. Model 2 users increased from 2.2 million in 2014 to 4.4 million in 2016 (Shaheen et al, 2018).

Ride-hailing (Model 3) has also grown substantially. The benefits of ride hailing to customers are widely recognised and well known: ride-hailing companies tend to provide fast, reliable and affordable services (Schaller, 2018). Uber, a company that only came into existence in 2009, is present in 63 countries and over 700 cities. Uber provides 14 million trips every day (Uber Newsroom, 2019). Model 3 companies have more than doubled the size of the for-hire ride services sector since 2012 in the United States. They served 2.6 billion customers in 2017, a 37% increase from 1.9 billion in 2016 (Schaller, 2018). In Europe, researchers forecast that they will serve 70.9 million passengers by 2023, up from 45.5 million in 2017 (Statista, 2019).

From a social welfare perspective, however, there is no difference when a person travels by car, be it a private vehicle, a taxi, a car rented from a peer (Model 1), a car from a car sharing scheme (Model 2), or a ride-hailing service (Model 3). A car is a car. It occupies the same amount of road space and produces the same level of air pollution and CO₂ emissions, regardless of who the owner is and who drives it. Therefore, there is no reason to think that wide adoption of any of the three first models could reduce congestion, pollution or CO₂ emissions. As indicated by some recently published papers, the development of Uber and Lyft has been a factor of a higher degree of congestion in some American cities (Schaller 2018). The overall effect for the United States case is that ride-hailing takes passengers away from public transport.

Rayle et al. (2016) survey users of model 3 in San Francisco. The authors find that, when asked what mode of transport users of model 3 would have used had ride-hailing not been available, 8% would have not made the trip (which is evidence of induced demand for travel), 39% would have used a taxi, 33% would have used public transport, and 6% would have driven their own car. In a detailed study for San Francisco, Erhardt et al (2019) find no changes in car ownership, despite the growth of ride-hailing in the city. They also find that the changes in travel time are worse than the background changes would predict and that travel times get worse on roads with more ride-hailing activity than on roads with less ride-hailing activity. Those authors conclude that in San Francisco ride-hailing increases congestion, and this increase is bigger than the combined effects of population growth, employment growth and network changes. They find that most ride-hailing trips are adding new cars to the roads, and that ride-hailing vehicles stopping at the curb to collect or drop customers off disrupt the traffic flow.

Could it be different with the Model 4? Model 4 can indeed reduce congestion, air pollution and CO₂ emissions when replacing solo trips made by car (ITF, 2016, 2017c; Furtado et al., 2017; Schaller, 2018). The key assumption here is that Model 4 replaces a substantial percentage of solo trips. In line with previous surveys (Henaio, 2017; Gehrke et al, 2017), Erhardt et al (2019) find that the small modal share of model 4 is, until now, not enough to offset the increase of congestion due to Model 3. The volume of ride-sharing (model 4) is too small to compensate the negative impacts of the development of ride-hailing (model 3). A reduction in congestion, pollution and CO₂ emissions is only shown by theoretical modelling efforts that assume a large switch from solo trips to ride-sharing (Model 4), something for which there is no empirical evidence anywhere as of 2019. Until now, the new mobility services did not deliver the proof of their efficiency in terms of road congestion. But we have to keep in mind that when Model 4 replaces solo trips and not public transport trips, the potential to reduce congestion, air pollution and CO₂ emissions should not be ignored. The question is therefore how to foster ride-sharing, that is to increase the rate of occupancy of cars? It is therefore necessary to come back to the issue of space consumption of different transport modes.

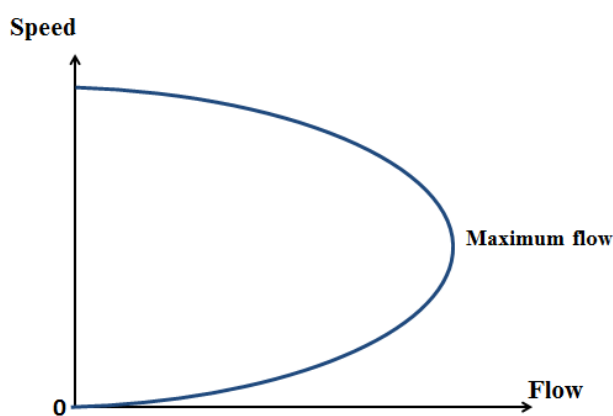
Compared space consumption of different transport modes

Economists have long known the “tragedy of the commons”. Arthur Young (1740-1830) had already presented it at the end of the 18th century. As W. Foster Lloyd (1794-1852) later pointed out, freedom of access to communal areas, where everyone could graze their cattle, led to a mechanism of “overgrazing” that seriously affected farm yields. In a way, the same principle applies to the road network in urban areas.

As access to, and use of, roads is mostly free; its performance is low due to resulting congestion during peak hours.

The principle of providing free access to road infrastructure is not unfounded from the economic point of view. Roads are a public good characterised by an indivisibility of use (with neither excludability nor rivalry) to which are added positive external effects for the community in the form of lowering the cost of mobility. For this reason, roads are generally free to access. However, roads are not a pure public good because they are congestible, justifying, from the economists viewpoint, the implementation of a toll. In 1920, when AC Pigou presented his famous example of internalising congestion costs by imposing a toll, his main objective was to maximise traffic flows by optimally distributing vehicles between two competing routes.

Figure 2. The speed-flow curve



Almost at the same time, in the United States, traffic engineers were also interested in the fluidity of traffic flows. They discovered a non-linear relation between speed and flow on the first motorways (Figure 2). When the number of cars that circulates is small, speed is high but flow is low (top-left point of the graph). With an increase in flow first comes a speed reduction. This is the upper part of the Figure, also known as the optimal flow. The more the number of cars is increasing; the lower is the road speed. From a certain level of traffic on, about 70 000 vehicles/day in the case of a 2x2 lanes, the flow starts decreasing with speed. This is the beginning of the forced regime, the lower part of the curve. In this case, the traffic flow and the speed decrease simultaneously if more cars use the motorway. The traffic jam is the road version of the tragedy of the commons: everyone is stalled (lower point on the bottom left of the curve).

The speed-flow curve clarifies the misconception of congestion by car drivers who do not take into account the concept of space consumption. More precisely, the car traffic is a demand for space-time of circulation, expressed in square meter perhour ($m^2\cdot h$). The consumption of space-time increases very rapidly with speed because both the inter-vehicular distance and the average width of the grip per lane of traffic increase mainly with the square of the velocity. Nevertheless, the consumption of space depends also on the size of the vehicle as indicated in Table 2 that compares different types of vehicles to the space consumption of a pedestrian.

Table 2. Compared space-time consumption

	m ² -h/vehicle km	Occupation rate	m ² .h/traveller km	Difference/pedestrian
Pedestrian	0.3	1	0.3	1
Cyclists	0.6	1	0.6	2
Two-wheeled motor vehicles	1.7	1.05	1.6	5
Cars	1.8	1.3	1.4	5
Bus (12m)	7	17	0.3	1.4
in peak hour	7	50	0.15	0.5
Articulated bus (18m)	10	23	0.3	1.4
in peak hour	10	70	0.15	0.5

Source: Héran and Ravalet (2008).

Table 2 shows the fundamental hiatus between individual and collective points of view. Motorists seek to minimise their time budget (or maximise their speed) as time is a scarce resource for them. From the collective point of view, space is the scarcest resource. To understand how individual scarcity of time and collective scarcity of space combine, it is necessary to introduce the concept of accessibility.

Car and urban mobility: The stages of the “accessibility turn”

J. Urry (2007) proposed the term "mobility turn" to describe the paradigm shift from a “static” approach to the one that recognises the importance of physical movements. This turn has been driven mostly by the widespread adoption of fast modes of transport, mainly car. Speed gains have enabled people in developed countries to cross distances of several tens of kilometres every day (Schäfer, 2009); however the transport time budget (TTB) has remained almost stable, at around one hour per day. This evidence can be surprising. Why did the increase in travel speeds not lead to a reduction in in the TTB? To answer this question, one needs to understand the ways in which the individual experiences the trade-off between the scarcity of time and the scarcity of space, compared to how the collective body perceives it. This will lead to the issue of accessibility and will clarify why public policies are shifting from a decision-making process, driven by the “mobility turn”, to a new range of choices based on an “accessibility turn”.

Travel time, road speed and land use

The economic analysis of mobility presents transportation as a cost that economic agents seek to reduce. For microeconomics, a shorter travel time corresponds to a surplus gain for the user. On this basis, the economic calculation has incorporated time-savings into the assessment of transport infrastructure projects, which often represent the bulk of non-market benefits. But what do individuals do with these time savings?

One of the lessons of the “mobility turn” is that the travel time is not always, as microeconomics implies, a cost that the travelers are trying to reduce. In fact, it is rather the case in a static approach: reducing the travel time for a given trip is a goal in itself. However, from a dynamic perspective, things are more complicated. In terms of the time when activities occur – daily, but also weekly or yearly – the main goal of individuals is not to reduce the travel time but to improve the ratio between carrying out a given activity and the related generalised cost of transport, i.e. the time cost plus the monetary cost.

Therefore, if an increase in speed results in having additional attractive opportunities (work, leisure, social relations, housing...), there is a “rebound effect”. This means that people will accept the same travel time, or even higher, if they can reach more and better opportunities. Being able to use a car often implies significantly increasing the number of opportunities and services reachable within a constant travel time and a constant or, even lower, monetary budget. As such, the development of “automobility” (Cervero, 1996) is the main factor contributing to the “mobility turn”.

Figures 3a and 3b illustrate the example of the Lyon agglomeration, where the average distance between home and work increased significantly between 1968 and 2011. Access to a car, combined with the construction of motorways and improvements to the road network, have incentivised residents to move further away to the periphery. This has inevitably resulted in vehicle km travelled, with the majority of the active population crossing several tens of km daily by car; although transport time budget remained close to one hour per day.

This hypothesis of a constant travel time, which suggests that travel time does not necessarily decrease due to higher average speed, was put forward in the 1980s by two World Bank researchers, Yacov Zahavi and Antti Talvitie. They relied on statistics collected in a large number of cities in developed and developing countries. They also underlined that, in addition to time budget, the share of household budgets allocated to travel was also almost constant, despite the decrease in relative transport costs.

If the travel speed increases, and/or if the monetary cost of mobility decreases, the result will be an increase in mobility, that is to say, longer trips. This is what has been observed with daily commuting in both urban and rural areas.

Evidently, the effects of increasing distances travelled vary between different urban and rural areas. As shown in Table 3, the distribution of daily commuting distances reveals, regardless of place of residence, a strong difference between those who move the most and those who move the least. The average travel time is lower in rural areas (50.7 minutes per day) than in city centres (61.5 minutes per day). The variation of speeds, 36.9 and 17.3 km/h respectively, explain this.

Figure 3a. Lyon urban area: Average distance from home to work in 1968

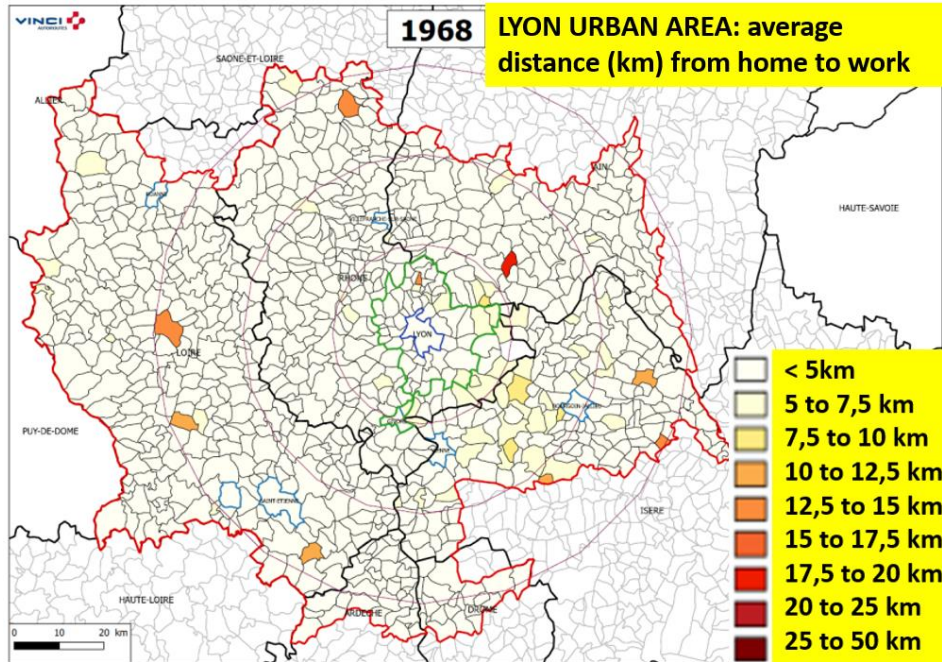
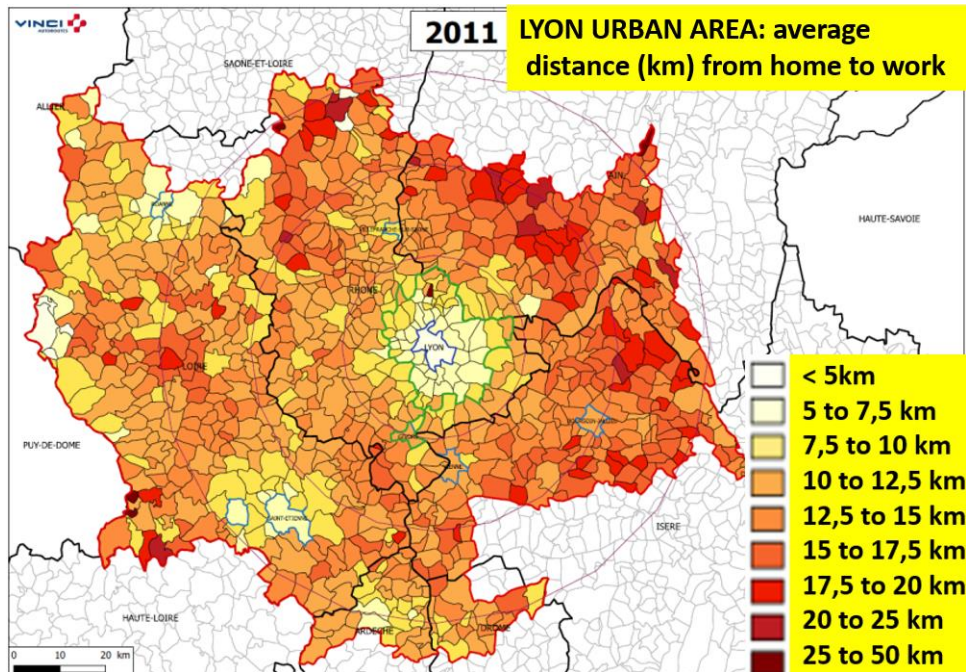


Figure 3b. Lyon urban area: Average distance from home to work in 2011



Source: André Broto, Vinci et Fabrique de la cité, presentation during the conference Assises de la mobilité (October, 2017).

Speed, however, does not explain everything: the amount and quality of opportunities available in different areas also play a role. Although inhabitants of dense areas spend more time in traffic, they also have more opportunities available in proximity. Longer distances and travel times give access to an even

wider range of choices, which is not the case in rural areas. It is therefore necessary to consider not only the cost of travel, but also the number of accessible amenities. This is what the concept of accessibility does.

Table 3. Daily distances and travel times for different locations in France (2008)

	City centres		Suburbs and peripheries		Small towns		Rural areas	
	Travel time (min.)	Distance (km)	Travel time (min.)	Distance (km)	Travel time (min.)	Distance (km)	Travel time (min.)	Distance (km)
Mean value	61.5	17.8	62	23.2	52	26.2	50.7	31.2
Median value	53.6	11.5	53.6	16.6	42.4	16.7	42.9	23
First quartile	28.1	4.6	28.1	6.5	21.4	5.5	20	7.9
Third quartile	85.7	22.6	85.7	32.7	72.9	37.5	71.1	45.3
Ratio 3 rd q./ 1 st q	3.04	4.91	3.04	5.03	3.40	6.81	3.55	5.73

Source: Y. Crozet, (2016).

Accessibility: From a positive to a normative approach

At a basic level, accessibility is the ease of reaching a location to perform an activity (Morris et al., 1978). In this sense, it already incorporates two different, yet complementary aspects: on the one hand, the opportunity or possibility of interaction between people and businesses; and, on the other, the distance people must cross in order to realise this interaction. Consequently, the concept of accessibility can also be seen as an interface between economics (transport cost) and geography (land use). Because of this double dimension, there are different approaches to the concept of accessibility: some of them putting more emphasis on the costs of transport, while the others emphasise the use of space. Both do not lead to the same result when it comes to moving from a positive approach to a normative approach to accessibility.

Hansen (1959) produced one of the most influential works on accessibility concepts and definitions 60 years ago. He defined “accessibility at point 1 to a particular type of activity at point 2 as directly proportional to the size of the activity at point 2 and inversely proportional to a function of the distance separating the two points. The total accessibility at point 1 to the activity is the summation of the accessibility to each of the points around point 1.”

Accessibility is therefore a function of accessible amenities, on one hand, and transport supply on the other.

$$A_i = \sum_j D_j f(c_{ij})$$

With,

A_i = Accessibility to destinations D from point i

D_j = Activity at points j

c_{ij} = Generalised costs (time, price, comfort... of the trip)

On this basis, work on different ways of measuring accessibility has increased in recent decades. In a paper presented at a recent ITF-OECD roundtable, Eric Miller (2019) indicated that from an academic perspective, an indicator of accessibility should consider four axioms that lead to four assumptions about how to measure accessibility:

- the travel “disutility” or “impedance”
- the location “attractiveness”
- the role of individual tastes, preferences and constraints in determining both travel impedance and location attractiveness
- the set of locations to be included in a given accessibility calculation.

A concrete example to illustrate the importance of these four assumptions is when a gravity-based metric of accessibility to urban jobs (E) is chosen, the function of Hansen's formula becomes a negative exponential. The measure of accessibility (A) from zone i to all opportunities (E) located in zone j is written:

$$A_i = \sum_{j=1}^n E_j \exp^{(-\beta C_{ij})}$$

This equation actually contains the four assumptions mentioned above. They deserve to be highlighted.

- The generalised cost measures the travel "disutility" or "impedance". The choice of a negative exponential function leads to accessibility decreasing rapidly if the generalised cost of transport increases.
- The generalised cost takes into account an objective value, the monetary cost, but also a subjective value, the time cost. It depends on the value of the time and, therefore, assumptions are made about the preferences and the individual constraints. These are also integrated in the value given to the parameter, β , reflecting the sensitivity to the cost of the trip.
- The location's “attractiveness” depends on the kind of chosen opportunities, for instance, in this case, the number of jobs.
- The set of locations depends on the size of the area considered as relevant for the measurement of accessibility.

The assumptions show that the choices made to define the accessibility index can be biased. The monetary measure of the value of time leads to a cardinal approach that strongly values the surplus gains resulting from an increased speed. Even when observed behaviour informs the value of the parameter, β , the parameter still may affect the results in a potentially biased way. In other words, even when accessibility is measured using a scientific, positive approach, the normative dimension of the results should still be questioned. In fact, Martens (2019) highlighted the risk of accessibility indicators becoming polarised in the transport system, without taking into account the impacts it may have on the functioning of the metropolitan area. He also mentioned the proposal of Robert Cervero (1996) in favour of a "shift from

automobility to accessibility planning": a paradigm shift is therefore needed to ensure that accessibility takes into account not only the individual benefits of improving the transport system, but also its negative, direct and indirect effects: namely pollution, urban sprawl and congestion. Those effects are largely related to the development of automobility. It is thus necessary to know if it is possible to replace the "mobility turn", which is based on the reign of the car, by an "accessibility turn" subject to the constraint of reducing the car flows (see Levine (2019) for the conditions of an "accessibility shift").

Accessibility turn: What does it mean?

We are thus starting to look at accessibility from a normative point of view: how to define a public policy of accessibility-based planning, if one of the objectives would be to reduce the modal share or car. Accessibility can be interpreted differently from the decision maker's view point. When the first stage of the accessibility turn appeared, the focus was more on public transport than on roads and car use (Crozet 2013).

If the focus of mobility policy is to increase travel and transport supply, potential speed gains brought by new transport infrastructure will appeal to decision makers (Crozet 2005). In this case, decision makers will add road capacity to increase accessibility. This will have the most visible positive accessibility effects during off-peak periods. However, even during peak periods, in many urban areas the accessible zone, and hence housing and job opportunities, grow significantly. Any speed improvement has a big effect on accessibility and explains the tremendous success of cars in industrialised and industrialising countries. Thanks to the individual car and policies that were accommodating for car travel, average distances covered each day per person have skyrocketed. But in urban areas, this omnipresence of cars has tended to turn the car "solution" into a problem. The more car accessibility increases during off-peak periods, the more road congestion during peak periods will also increase because of the induced traffic. As indicated in Table 1, the focus of mobility policies on dealing with accessibility by accommodating a faster mode (car travel) has resulted in urban sprawl and exacerbated congestion, which in turn have led to not only time losses, but also increasing greenhouse gas emissions and pollution.

These consequences have sparked awareness of the need of an accessibility turn. The first stage of this new deal leads to rethinking mobility policy and investment, focusing less on increasing speed and individual time gains, and more on improving accessibility by acting on land use and reducing urban sprawl.

It became obvious that the speed of travel is not the only factor making an urban area attractive. It also depends on the ability to offer a variety of opportunities and urban functions, which are key aspects of urban life. When the development of the road network encourages low-density dispersed patterns of development, comprised of single-use residential developments, then the city breaks up. On the contrary, mixed-use developments that put activities and people closer together at various scales and intensities can help keep the main characteristics of the city (i.e. a place of interaction) intact. However, accessibility is more than a simple trade-off between speed and density.

At this point of the reasoning a temptation arises. If a higher potential speed on roads is a factor that has contributed to urban sprawl and non-sustainable mobility, is it possible to reverse the process? Should authorities impose a lower speed on drivers in order to come back to denser cities, to cities where walking and cycling would be the best, and even the only way to go from point A to point B? Although promoting

higher speed indeed may lead to negative externalities, to what extent is it feasible to revert to pedestrian cities, or more generally speaking, to “low-speed” cities? Once again, this option is putting the focus on speed and, more generally, only on transport issues. But the “slowness” has a cost, especially for people living in the peripheries. A “people-centred approach” to accessibility must not disregard the car dependency of a majority of long-distance commuters. The main objective is not to slow the car, but rather to keep a high-level of accessibility for everyone, and thereby foster the urban attractiveness.

The development of public transport may be a way to keep a high-level of accessibility and to reduce the travel time budget of users. Speed remains, therefore, an important issue, for instance for train or subway lines, but reliability, frequency and comfort of PT are also among the essential factors of success. Even some slower PT is useful. By developing light rail (tramways) and bus rapid transit (BRT), authorities in charge of PT have, in many cities, reconsidered accessibility planning from a collective point of view. Rather than focusing mainly on speed, and the distance it provides, residents are invited to make choices that reflect the advantages of density and to some extent proximity. Accordingly, in many cities, there is a move towards transit-oriented development, that is to say, denser amenities denser in the areas served by the new BRT and tramway lines. When warranted by the size of the city, in terms of both the distance to be covered and the number of daily commuters, the chosen option will be forms of overground or underground trains that move people faster than tramways. This will involve underground and regional express trains, a field requiring substantial investment, and not always available in developing an even in developed countries.

By promoting walking, cycling and public transport, policy makers are setting up another objective. Policy makers no longer obtain accessibility improvements mainly by a speed increase, but rather by combining increases in density with investment in (slower), but high quality, alternative to car travel. Public authorities no longer focus on transport as a purely technical problem, but as a component of a system giving the priority to density and land use optimisation. They take into account the complex interactions between land use and transport, but also social conditions and the environmental challenges of sustainable development. The objective is no longer the satisfaction of a given travel demand via adding transport supply without caring about the related feedback mechanisms. As indicated by D. Banister (2008), accessibility has to cope with the three main challenges of sustainability:

- A social challenge: how to ensure that the residents of a metropolitan area, irrespective of social rank, continue to have access to all urban amenities. Karel Martens (2019) calls this a “people-centred approach to accessibility”.
- An environmental challenge: because of the external cost of mobility, especially car travel (space consumption, emissions of pollutants, noise, accidents...).
- An economic challenge: related to the increasing cost of passengers’ mobility for public finance and for commuters due to congestion.

Policy makers need to consider both the transport system and land use in order to address simultaneously these three challenges. Accessibility improvements can only be achieved if there is a common language for the integration of planning and decision making between transport and land-use development. This means that a new accessibility paradigm should now lead to a new approach that pursues the collective interest and assesses strategies and measures based on land-use priorities. Sustainability concerns have brought the need for better accessibility to the forefront of policy agenda. Aligning accessibility with

sustainability implies reducing catchment areas of trips via densification rather than enlarging catchment areas via increasing speed (be it by car or public transport).

Focusing on density and multifunctional attractiveness of urban spaces is important, but it is not enough. It concerns mainly the city centre, while the periphery continues to expand. For instance, in the city centre of many metropolitan areas, streets have been narrowed to benefit pedestrians, cyclists and public transport users. However, in the peripheries, car dependency remains strong and it is difficult to fight against it. How can policy makers implement the accessibility turn in the less dense parts of the agglomeration?

Zero car growth and accessibility: Towards coherent policy packages

The car remains unequally used in the different subparts of an agglomeration. As shown by tables 4.1 and 4.2, situations differ also from one city to another. The modal split in the city centre shows a reduction in the use of the individual car (except in Frankfurt). Walking and public transport already account for 55-82% of trips.

Table 4.1. Mobility and modal split in the city centre

	Walking	Public transport	Two wheelers	Cars
Barcelona, Spain	42%	34%	11%	13%
Frankfurt, Germany	30%	22%	13%	35%
Oslo, Norway	13%	68%	5%	14%
Paris, France	53%	29%	4%	14%

Source: Crozet et al. (2019).

Table 4.2. Mobility and modal split in the urban area

	Walking	Public transport	Two wheelers	Cars
Barcelona, Spain	39%	23%	6% (4 + 2)	32%
Frankfurt, Germany	27%	11%	11% (2 + 9)	51%
Oslo, Norway	32%	26%	5%	37%
Paris, France	34%	19%	2%	45%

Source: Crozet et al. (2019).

It is different at the scale of the urban agglomeration where the car is the most used mode, sometimes far ahead of public transport. It is a reality that imposes itself on the regulation of urban mobility. In order to

apply the accessibility turn in the peripheries, public policies should not hesitate to resort to the toll, but they should associate it with other tools, which take into account the pollution and the uses of the public space. But that does not mean the disappearance of the private car. Public authorities should differentiate in space future "urban mobility packages". This will require greater ambition from those authorities who organise transport and mobility; this may be the most challenging component of the accessibility turn.

Urban toll is not a panacea, but a useful component of the package

To address the risk of saturation of road infrastructure, economists have long proposed a solution called congestion toll. Yet, only a few cities in the world have adopted this solution. Congestion tolls are often based on the difference of value of time and aim at increasing fluidity on the roads. Equity concerns posed by the congestion charge have made other agglomerations to consider, even if implicitly, congestion itself is a means of discouraging the use of the car. Due to the limits of these two options, it is not clear which modes of regulation are the most effective.

Regulation by congestion is counterintuitive, but it is widely used, often with a rationale to achieve a modal shift objective by introducing, not a monetary charge (as is the case with congestion tolls) but a time-based toll (Crozet, 2005). Motorists do not pay more for rush-hour traffic, but they must expect longer travel times: the fewer roadways that are available to them at rush hour, the more they pay in terms of time spent in congestion. Mogridge's (1980) theory of induced demand – the phenomenon that increasing road capacity leads to an increase in traffic volumes – inspired this rationale, which many French cities practice. His theory was Mogridge's proposal is to achieve a reduction in car traffic and a modal shift to PT. For origin-destination pairs, for which there is efficient public transport, motorists must be dissuaded from using the car and this can be done by extending their travel time.

However, by deliberately causing traffic congestion, this method leads to increased air pollution, as the city of Paris showed. On 24 October 2019, France was the first country condemned by the European Court of Justice because of excessive pollution (NO_x and fine particles) in several large cities. For this reason, the government wants to introduce low-emission zones, by restricting motor traffic (as evidenced by the ban on diesel vehicles), and eventually all combustion engine vehicles. But this type of measure may have little effect if the area concerned is small and if it is not part of a package of different forms of incentives.

Regulation by the congestion toll alone has also encountered similar kinds of difficulties, and only a few cities have managed to overcome them and fully adopt this form of regulation. The British economist A.C. Pigou (1883-1960) proposed congestion pricing almost a century ago. Since then, it has been a very active research topic in transportation economics. Thousands of scientific articles have been published to show that congestion charging is the solution to congestion problems. But motorists, as well as most local politicians, are not in favour of congestion pricing. It might be for bad reasons (no willingness to pay), but also for good ones, for example, for its distributive effects (Crozet and Mercier, 2017). Pricing of congestion may not be beneficial for everyone. Implementing congestion charging also requires questioning its acceptability by the citizens. The issue of acceptability is one of the main reasons why so very few towns and cities have implemented congestion charging to date, with Singapore, London and Stockholm being the most cited examples.

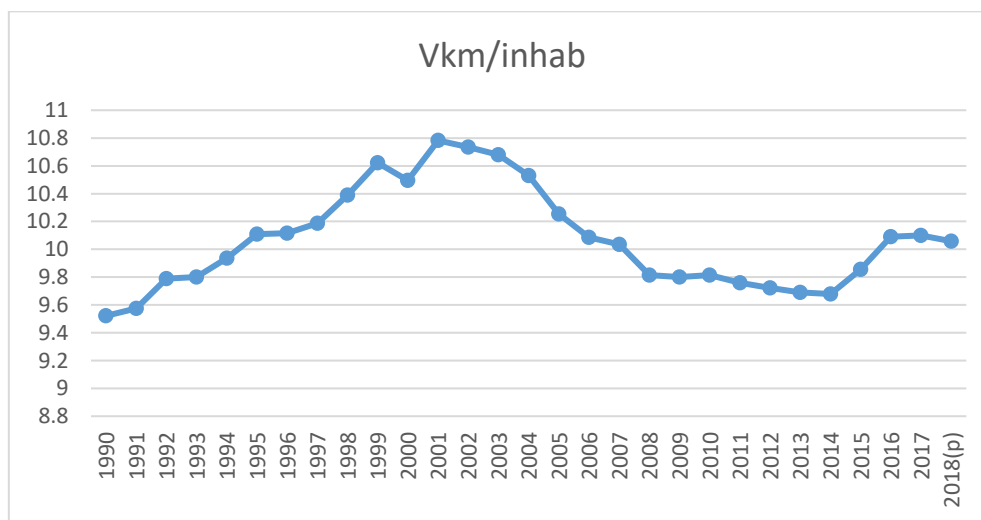
If so few cities have followed these examples, it is because a congestion charge is mainly justified by the time gains of travellers with a high value of time (VOT). With a congestion charge, the consumer surplus is

higher than without. But this result is obtained by an algebraic sum: utility gains of those with a high VOT minus disutility of those having a low VOT. This cardinal aggregation of utilities is questionable in the same way as is the distribution of income. On the contrary, it seems more acceptable for car drivers to pay for a car immobilised, using the space of a car park, than for a car in motion. Although it is an unrealistic view of things, it has the advantage of taking into account criteria other than time and speed of travel.

The concept of congestion pricing has to be adapted to the accessibility turn. The main goal of pricing is not to increase the road speed but to reduce pollution and the space that the car occupies. This way of justifying the toll plays an important role in the acceptability of the restrictions on car mobility. We are talking about several restrictions, as it is increasingly obvious that the use of a single regulatory tool (congestion, toll) is not enough. It is necessary to develop a package of solutions. This particularly means ensuring the availability of alternative mobility options of good quality, especially where travel demand management strategies aim at increasing the price of car travel in order to reflect negative externalities. This is what the cities of Stockholm and London have done by linking the implementation of the congestion charge with an improvement of the public transport supply.

Investment in public transport (especially buses) was a key element in the success of the London Congestion Charging Scheme, which the city introduced in February 2003. Many car drivers switched to the bus, and bus passenger numbers increased by 18% and 12%, respectively, during the first and second years after the city implemented the scheme. In addition, the city reformed bus fares, leading to a real decrease in the average fare the consumer paid per individual trip. At the same time, bus service reliability was improved on route in and around the charging zone, leading to reduced excess waiting time (Santos, 2008).

Figure 4. Car traffic per inhabitant in France (1 000 vehicle-km per inhabitant)



Source: Ministère De La Transition écologique et Solidaire (2019).

The concept of a package of measures also corresponds to what was done in Oslo, a city whose results in terms of managing car use are among the exemplary ones (see Table 3). Oslo has had tolls in place since 1990, but these are not congestion charges. In order to obtain acceptability from the inhabitants, the toll was designed to collect revenue to fund road and transport infrastructures. A congestion charge was

added in 2017, with different charges for electric, hybrid, petrol and diesel vehicles, and for Euro V or older, Euro VI and zero-emissions vans (Fjellinjen, 2019). This example shows that the key arguments that justify the toll are not only to better reflect the value of the time of motorists, but also to encourage them to take into account environmental constraints (pollution) and to finance the supply of public transport. In Oslo, toll revenues contribute to the financing of 20% of the public cost of public transport.

It is therefore obvious that an integrated and coherent policy package that simultaneously discourages the private car by a toll, and makes public transport, walking and cycling attractive alternatives, is much more likely to achieve the reduction of car use. Such a package is all the more accepted since the demand for car travel has been declining since the beginning of the 21st century in many industrialised countries, as the ITF-OECD roundtable “Peak Travel, Peak Car and the Future of Mobility” showed in 2012. Since that date, it is true that traffic has started to rise again, but if the evolution of the population weighs down traffic, traffic in 2018 remains below the levels reached at the very beginning of the century, as shown in Figure 4 for the case of France.

The challenge of car traffic in the peripheries

The "peak car" is, therefore, a reality in a country like France and it is even more visible in the central cities where the car traffic keeps decreasing. However, this observation needs to be nuanced in the case of the peripheries, as shown in the case of the Ile de France region (Table 5). The Ile de France region (12.1 million inhabitants, 5.7 million jobs) can be divided into three major rings: the city of Paris, the “Small Crown” (second ring) and the “Grand Crown” (third ring).

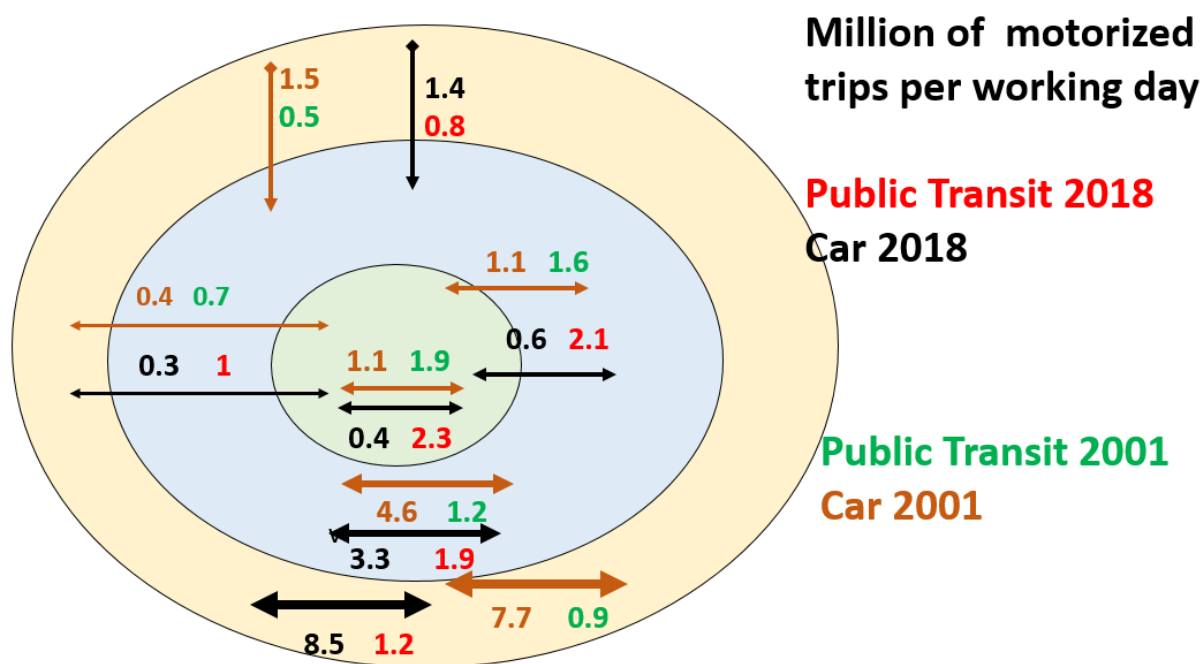
Table 5. Population and employment in Ile-de-France region

	Paris	First ring	Second ring
Population 2018	2 200 000	4 600 000	5 300 000
Change since 2008	-20 000	+ 220 000	+ 260 000
Employment 2018	1 800 000	2 000 000	1 900 000
Change since 2008	+ 26 000	+67 000	No change

Source: Île-de-France Mobilités and OMNIL (2019).

The majority of the population lives in the second and third rings. These areas experience the most population increase, whereas the population slightly decreased in Paris. On the contrary, the number of jobs continues to increase in the city of Paris and in the second ring, while the number has been stagnating for ten years in the third ring. This has resulted in a territorial mismatch between the place of residence of the majority of the population on the periphery, and the location of job opportunities in Paris and second ring. This situation is defining the current mobility landscape for the Ile-de-France region. Figure 5 clearly shows the differences in commuters’ mobility patterns according to their residence. Figure 5 also presents the change in mobility patterns between 2001 and 2018: a huge reduction of trips by car within the central part of Paris (first ring), within the second ring and between the city of Paris and the second ring. Nonetheless, the car remains the most important motorised mode of transport within the third ring.

Figure 5. Travel by car and public transport in the Ile-de-France region



Source: Île-de-France Mobilités and OMNIL (2019).

It is clear that public transport constitutes an increasingly large share of trips within Paris, as well as radial journeys with Paris as the origin or destination, due to the availability of a wide-ranging public transport offer, which includes train, metro, light rail, and buses. This is not the case for internal trips within and between the second and third ring. Notably, private vehicles makes the majority of trips within the third ring, with 8 times more trips made by car than by public transport. This is highly associated with a limited supply of public transport, which cannot adapt to the great diversity and dispersed patterns of origin-destination pairs.

In 2018, within the city of Paris, private car trips accounted for only 2.5% of the 13.2 million daily trips by private car in the whole Ile-de-France. This figure needs to be accompanied by the fact that 60% of Parisian households do not own a car. However, this “demotorisation” is not the case in the rest of Ile-de-France, despite the fact that since the beginning of the century, the number of car trips has tended to decrease slightly. Just as peak oil does not mean the end of fossil fuels, peak car does not mean the end of car travel. Nevertheless, it is possible to contain these flows by developing a public transport offer where it is financially viable. This is what the Ile-de-France region has been doing for a few years. Since 2010, the bus service in the large outskirts has increased by 33.7% to 193 million buses/km. The demand followed: in the same time period it grew by 39%. But the weakness of Ile-de-France policy is that the development of the public transport offer is done without the users (road or public transport) participating in its financing. The opposite is true: PT users pay only 28% of the operating costs of the system, which makes it necessary to increase the tax on companies, which now cover more than 50% of operating costs. The huge investments especially the Grand Paris Express project, are made by a massive recourse to debt. Road users do not pay anything, even if a small part of the fuel tax is now transferred to the mobility authority. However, the

responsibility of mobility authority is limited to only managing public transport. Strategic planning and organisation of all mobility services in the region is fragmented, undermining effective implementation and use of financial resources.

The necessary new ambitions of mobility and transport authorities

Taking into account all the territories that constitute an agglomeration, and not just the city centre, a coherent policy package for urban mobility, aimed at limiting car mobility, has the following dimensions:

- Traffic should be limited in dense areas where public transport, walking or cycling is a viable form of mobility. For this reason, it is necessary to consider charging automobility, not only for congestion, but also for the use of roads, whether it is parking space or traffic lanes. Policy makers may design the toll to reduce excessive congestion, but not to increase speed on the road network; the latter could be reduced to give more space to other modes of transport. The toll may be associated with regulations and restrictions that take into account the type of vehicle, the time of circulation etc (low emissions zones).
- Motor traffic must also be contained in the peripheries even if it will remain important. Policy makers can do this by limiting the development of the network but also by resorting to travel pricing (pay as you go). It is indeed important that financial resources are made available so that, gradually, mobility pays for mobility, via cross-subsidies from private cars to public transport. Especially if we want to develop public transport in the peripheries, as we saw in the case of Ile-de-France.

However, to establish a pricing system for the use of urban space while continuing to support the development of public transport, the Mobility and Transport Authorities (MTA) must encourage new ambitions. They should not only manage public transport; they should better control the uses of road networks and seize the opportunities offered by the digital revolution to help the commuters who face more constraints on car use.

If the ambition is to reduce congestion and pollution via putting in place constraints on the car, the regulation of urban mobility has to be more ambitious by integrating all the mobility vectors. Until now, the constraints on the use of cars are rarely implemented because in many metropolitan areas MTAs are only in charge of public transport, while road and traffic management is often under the responsibility of other administrations. This division of labour has created a fragmentation of the public authorities in charge of mobility. Co-operation does exist between these entities, particularly when it comes to setting up dedicated lanes for buses or light rail. Some cities, however, have managed to develop a fully integrated approach to mobility management. For instance, Oslo has an integrated approach where the same vice mayor oversees public transport and roads (even if, at a lower administrative level, PT and roads are managed by two separate administrative entities). Authorities prioritise the circulation of pedestrians, bicycles and public transport when managing the use of public space. The result is that car traffic is particularly reduced in Oslo compared to other European conurbations of the same size.

Following the example of Oslo, the accessibility turn requires an intensification of MTAs' action, notably through a monitoring of all the vectors of urban mobility. To take into account the complex interactions between land use and transport, and also social conditions and the environmental challenges of

sustainable development, MTAs must unify and integrate urban mobility regulation. They must intervene on the uses of roads, and even pavements and pedestrian zones. It is their role, and not that of commuters or mobility providers, to find the equilibrium between the different uses of roads. It is up to MTAs to take over the management of the main road networks. This is mainly a political discussion on how to integrate road traffic management and public transport organisation, but MTAs can have a certain influence on this discussion, even if they will not decide its outcomes alone.

Another extension of the role of MTAs is necessary in the management of databases, platforms and applications. This is a relatively new field of action for MTAs. They must invest by improving their skills in this area. MTAs must also value their own data as well as their brand name. They must not refrain from developing their own platform, even if, or more precisely because, they will face the opening of sales channels. For the same reasons, they have to enlarge the spectrum of mobility services in order to improve the variety of options offered to the inhabitants. If the objective is to increase the number of users of the various urban mobility services, platforms, information services and ticketing are crucial, even if digitisation is not a magic wand. The digitalisation of mobility is a field where co-operation between public stakeholders on the one hand, and between the public and private on the other, has to be developed. With the new mobility services, the spectrum of mobility offers is widening. The result is that there are more alternatives to solo car use.

For this to happen, authorities will need to more closely control the uses of the road network. Just as the development of public transport has necessitated the introduction of segregated lanes and right-of-way public transport, a large development of carpooling will mean limiting access to roads for vehicles with one person only. If, at the same time, lanes are reserved for carpool vehicles, carpooling may develop. The weakness of the business models of carpooling platforms has until now been largely due to the small number of users. For a critical mass to be reached, the main decision of public authorities must be related to roads. But for this, the current fragmentation of the regulation of urban mobility must be resolved.

Conclusion

The main problem related to excessive car use in urban areas is that of space consumption: a car occupies 2.5 times more space than a cyclist, five times more than a pedestrian and ten times more than public transport at peak hours. If there is only one person in a car, then there is an overconsumption of space. Consequently, recent decades have seen a step-by-step accessibility turn. Public policies are increasingly promoting the use of public transport and soft modes. They develop restrictions of the public space dedicated to private cars in order to liberate space for more sustainable modes. In order to make public transport more efficient, it is necessary to create exclusive dedicated lanes for public transport vehicles. It has thus become necessary to regulate more closely the use of roads, including pricing parking spaces and pricing congestion (London, Stockholm, etc.). To relieve cities from the pressure of the car, bike lanes have been installed. The street space previously dedicated to private cars has been reallocated to pedestrians, for instance via the introduction of fully pedestrian streets for shoppers.

But the car is necessary for mobility in the outskirts of the big agglomerations. Cars have not to be considered as the enemy of the city because of their impacts in terms of pollution, congestion or accidents. However, a kind of “automobility containment” is necessary even if a “zero car growth” is neither “zero car” nor “zero new car”. Hence, if the car remains an important mode of transport, it will be necessary to introduce a road pricing scheme that takes into account the external costs of road traffic, including the use of road infrastructure. The design of these pricing mechanisms needs to be well-informed from an equity perspective. According to the mobility needs of different user groups, the pricing mechanisms must be designed fairly. It is also important to notice that pricing alone is not enough. The objective is not only to reduce congestion. The road pricing scheme is just a component of an urban mobility package, including the development of public transport, more public space for two-wheelers and pedestrians and, in the coming years, shared mobility. The development of new mobility services is clearly intensifying the struggle for urban space in urban areas. The regulation of this fight is the next challenge of the accessibility turn.

The pressure of the car on road infrastructure could change with the development of shared mobility. If the number of passengers per car rises to 2.5 people, then the space consumption of a car is the same as that of a cyclist. The car is no longer a problem, it becomes a solution. However, in order to achieve this goal, shared mobility must not focus on incentives for time savings for commuters, but rather on a better use of public space. The development of connected vehicles, even autonomous, is of interest to the community only if the load factor of cars increases; that is to say, if cars become a part of the public transport supply. For this reason the mobility and transport authorities have to be more active in the domain of traffic management as well as in the new mobility services linked with the digitalisation of mobility (data, platforms, apps, etc.).

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Cars and Space Consumption

Rethinking the Regulation of Urban Mobility

This paper discusses the importance of reducing the space consumption of car traffic as opposed to simply reducing individuals' travel time. It highlights the role of app-based mobility services in reducing urban congestion from a spatial perspective and the importance of shifting the focus from mobility to accessibility as a way of reducing excessive traffic, meeting sustainability objectives and improving livability.

All resources from the Roundtable on Zero Car Growth? Managing Urban Traffic are available at: www.itf-oecd.org/zero-car-growth-managing-urban-traffic-roundtable.