White paper: The Role of e-scooters and Light Electric Vehicles in Decarbonizing Cities

Study report by Carbone 4 for Bird
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BIRD

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Executive Summary

This white paper examines the **role that shared light electric vehicles (LEVs) such as e-scooters can play in decarbonizing cities** and presents a **framework for the roles and responsibilities of operators and cities in bringing about a low-carbon urban transport future.** It finds the following:

1. **Dockless e-scooters show popularity as a lightweight and energy-efficient transport mode for quick urban trips, along with biking.** Bicycle ridership has been increasing in cities across Europe, but dockless e-scooters are being adopted at a pace that has never been seen before: for instance, after less than one year in operation, e-scooters have reached a modal share of between 0.8 to 2.2% in Paris according to a recent study by the research consultancy 6t, that is twice as fast as the growth of the Velib' system in the first year of operations.

2. **Light electric vehicles can help cities meet decarbonization goals.** Based on the current mode split in Paris, Carbone 4 examined three exploratory scenarios to determine the potential for dockless LEVs, and e-scooters especially, to meet future mobility needs and mitigate carbon emissions in the long-term, around 2030. By this time, there would be significant energy efficiency gains for all transport modes that would lead to reduction of emissions from energy consumption of 40%, all other things being equal. However, higher mitigation potential could be reached with structural changes in the mobility system to reduce the use of cars, along with fostering alternate mobility solutions. The analysis found that biking and LEVs could feasibly account for around 21% of all trips in Paris, supporting an overall reduction of emissions from energy consumption of 68%.

3. **Long vehicle lifespan is critical to ensuring LEVs are sustainable on a lifecycle basis.** Durability, maintenance, and vehicle retention in the fleet are the most important factors for long lifespan. Based on the data from the fleet Bird operates, the company has assessed that the consumer models lasted 3-4 months, while Bird's current custom designed scooters would last 18 months.

4. **Trip replacement or "modeshift" away from cars is another essential condition for sustainability.** Electric scooters are currently attracting riders from cars, public transport, walking, and biking, as well as providing mobility for trips that would not have otherwise been taken. To be compatible with the climate goals, LEVs must help to reduce car trips in an overall shift of urban mobility. For this to happen at scale, the vehicle must be attractive for former car users, and the streets they operate on must have bikelanes that offer safe and convenient places to ride.

5. **Cities focused on sustainability should select companies with vehicles that last at least one year and provide quality service to riders.** We provide several recommendations for operators and cities to ensure vehicle longevity of at least one year, and maximal modeshift from cars. For example, on longevity, companies should monitor carbon emissions throughout a vehicle's lifecycle and adopt plans to reduce impacts, and cities should implement anti-vandalism policies. To maximize modeshift, companies should continue improving convenience and user experience, and pricing should be competitive with other modes.

6. **Cities should also invest in infrastructure and adopt policies that support the modeshift from cars to light mobility.** Cities and companies must work hand in hand to organize and optimize new forms of micro-mobility, for example, working together to allow for connection to transit. Cities must also invest in bike lanes, which support greater transition to micromodes and thus, a reduction in carbon emissions.

Decarbonizing urban transport

1. Facing climate change, air quality, and urban congestion challenges, urban mobility must shift toward more efficient forms of transport

To address climate change, air quality, and urban congestion, cities and states around the world are advancing initiatives to reduce car usage. This has been pursued through committing to a target year for banning fossil-fuel vehicles. In Europe, several national bans have been announced including in Norway (by 2025); Ireland, Denmark, the Netherlands and Sweden (by 2030); and France (by 2040). In addition, municipalities such as Amsterdam, London, Milan, and Paris have adopted plans to prohibit or limit the use of fossil-fuel cars in parts of their cities. For example, London is implementing its Ultra Low Emission Zone (ULEZ) program, which results in drivers paying an extra charge to drive in certain neighborhoods throughout the city, if the car does not meet the emissions standards of this scheme.

Paris has taken several steps to reduce car dominance and move people to more sustainable modes. The Paris Climate Plan sets a goal of prohibiting the use of diesel and gasoline fueled cars in city limits by 2024 and 2030, respectively. To compensate and support this reduction in car traffic, Paris intends to promote active and low carbon mobility by extending the bikeway network to make Paris 100% cyclable by 2020 and limiting traffic speed to 30 km/h on all roads (except for major arterials). In addition, the city is taking steps to support multimodal trips, including establishing an all-in-one mobility card that merges buses, metros, tramways, RER (commuter train), Velib' and Autolib' (shared station-based bikes and cars). Further, the City is implementing "Paris Respire" (Paris is breathing), enforcing car free zones in every district, each Sunday and on Public Holidays.

Public space used for cars can be put to better use. Surface space is highly valuable in dense cities, yet roughly ¾ of public streets are dedicated to car movement and personal car storage when car trips only represent 14% of trips. This prioritizes the needs of the least efficient mode and leaves other mobility solutions to fight for slivers of remaining public spaces. This issue is particularly acute in Paris, the densest European capital, with around 20,000 inhabitants per square kilometer.

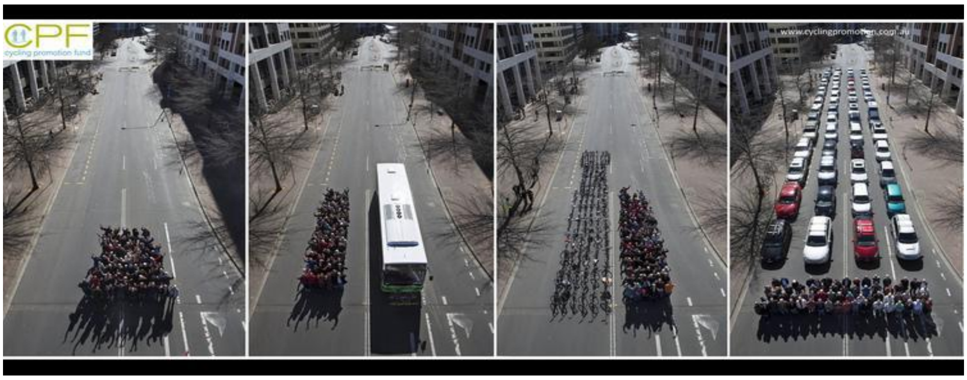
Mass and space per person for cars, buses, e-scooters and bikes[1]

1,000 kg & 8 m^2 per person	**430 kg & 1.4 m^2 per person**	**15 kg & 0.8 m^2 per person**	**10 kg & 1 m^2 per person**

Indeed, cars are highly inefficient and unnecessary for most urban trips. Cars are best designed for long-range trips, at high speed, or where it is necessary to carry heavy loads or multiple people. Cars have an optimum energy yield at 70 to 90 km/hour and are not appropriately sized for most of urban mobility needs: the engine capacity needed to propel a 2-ton vehicle carrying only one passenger weighing 80 kg and travelling at a speed of less than 30 km/hour is extremely wasteful.

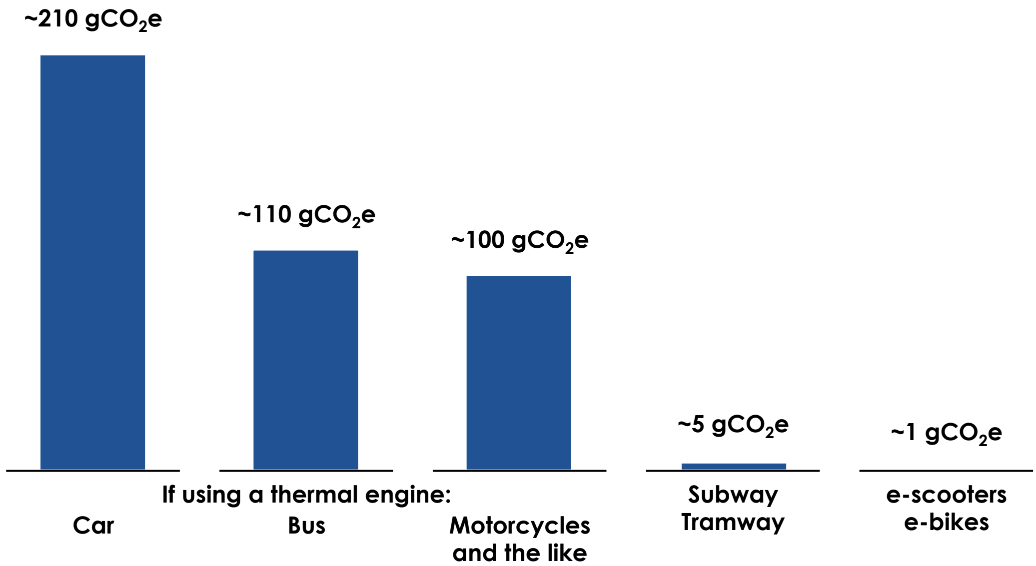
[1] Source, for car, bus and bike: based on data collected and analyzed by Nicolas Meilhan, energy and transport expert.

Space needed to move 69 people using public transports, bicycles and cars[2]



As shown in the figure below, cars produce twice as much CO_2e as buses or motorcycles. In Paris, road traffic (including cars, vans and heavy-duty vehicles) is responsible for 60% of NOx emissions, 50% of particulate matter, and 30% of greenhouse gases emissions. In addition, road traffic, and especially the internal combustion engines, is a main source of noise pollution.

Greenhouse gases emissions from energy consumption for different transport modes in French cities
gCO_2e per passenger and per km



Sources: Carbone 4 analysis based on data from ADEME, IFPEN, and energy consumption estimations for e-scooters and e-bikes.

On a per passenger basis, **lightweight electric vehicles** allow to **drastically reduce greenhouse gases emissions from energy consumption**.

Caveat: only emissions from energy consumption are shown on this chart. Emissions on a lifecycle basis might differ, due to the manufacturing of the vehicle itself, and of its battery in the case of electric vehicles.

Electric and light vehicle solutions such as e-scooters and e-bikes are well aligned with the political ambition to provide mobility without harmful emissions. These modes are extremely lightweight, requiring less energy to move, and highly efficient, since the yields of electric motors are much better than internal

[2] Source: https://www.cyclingpromotion.org/

combustion engines. There are no tailpipe emissions, and France's low carbon grid supplies the energy. As with electric vehicles, there may be some emissions from wear of tires, road friction, and brakes, but these too are minimal. Thus, **shared light electric vehicles offer an ideal solution for supporting cities to decarbonize.**

2. *Investment in bike infrastructure has increased cycling in European cities, and helped set the stage for LEVs*

Over the past decade, biking has become a more popular mobility option in Europe, spurred by effective policies and infrastructure investments. Amsterdam and Copenhagen in particular have steadily increased cycling rates across all ages and demographics and in all seasons. Copenhagen achieved a bicycle mode share of 29% through investment in high quality bikeway networks, the pillar of the development of any sustainable transport policy. For the case of Amsterdam, which has bicycle mode share of 27%, investment in traffic calming and cycling infrastructure was driven through political protest over road safety that began in the early 1970s, with particular concerns over children.

More recently, cities have shown how to rapidly increase cycling with investment in connected and protected cycle networks. The case of Seville, Spain is particularly impressive, where 80 kilometers of bikeways were built in only 18 months, resulting in biking mode share increasing from 5% in 2007 to 9% in 2011[3]. In France, the number of bike trips doubled between 2001 and 2010 according to the National Study on Transport (EGT) and French cities are among the most bicycle-friendly in Europe, with Strasbourg, Bordeaux and Paris being ranked 5th, 6th and 8th in the "Copenhagenize Index 2019"[4].

Because of their popularity, bicycles factor heavily in European decarbonization strategies. For instance, Copenhagen's ambition is to increase the mode share of bikes to 38% by 2025 and the Paris Climate Plan aims to triple mode share up to 15% by 2030. **Electric scooters and e-bikes have fit seamlessly into this movement, while diversifying mobility options.** The speed and weight of the e-scooters allows them to ride in the same lanes as bikes, and the ride experience is quite similar to cycling.

3. *Shared, dockless LEVs expand mobility options, and attract even more riders to two wheels*

Urban mobility has diversified in recent years with the arrival of new shared mobility services, such as e-scooters. First appearing in the United States, these self-service, dockless modes (commonly known as free-floating) have multiplied across France since the arrival of the first operators in Paris in the summer of 2018.

E-scooters and other shared LEV solutions are popular, and enjoyed for their convenience. Users of free-floating e-scooter and non-electric bike services in France are depicted in two recent studies by the research consultancy 6t[5]. The studies found average user age is 36 years old, and the users chose e-scooters because of the enjoyment of this mode, the time savings they allow, and the convenience provided by a door-to-door trip. Convenience is increased thanks to the ubiquity of the smartphone, and increased familiarity of accessing services with it. Further, the flexibility provided by dockless seems to contribute to uptake: for instance dock-based bikeshare has largely been replaced by dockless forms in North American cities.

Shared e-scooters and other LEVs could play an important role in the future low-carbon mobility landscape in Europe. E-scooters have been rapidly adopted in the mobility landscape: with cautious assumptions, 6t

[3] Available at https://www.witpress.com/Secure/elibrary/papers/SC14/SC14065FU1.pdf.

[4] The "Copenhagenize Index" is, according to the company that releases it, "the most comprehensive and holistic ranking of bicycle-friendly cities on planet earth". It is produced by Copenhagenize Design Co., an urban design consultancy based in Copenhagen, Brussels and Montréal.

[5] Available at https://6-t.co/trottinettes-freefloating/ and https://6-t.co/etude-ademe-vff/

found that **e-scooters have reached a modal share of between 0.8 to 2.2% in Paris after less than one year in operation, twice as fast as the Velib' system**[6].

After 9 months of service, weekly trips from e-scooters are 1.3 to 3 times larger than for Velib' after the same period, based on assumptions and data derived from the 6t study. Possible reasons for the rapid growth might include that users prefer the mode (preference for electric motor and/or prefer the comfort of a scooter), increased comfort with mobility-as-a-service solutions, improvements in user experience, and preference for the flexibility of dockless since users can use a smartphone to locate available scooters and leave them in a convenient location after use, without having to search for an empty Velib' dock.

A continuation of uptake of e-scooters and light electric vehicles is expected due to several factors:

- **Improvements to the service:** technology advancements including GPS and in-app features will continue to improve the rider experience.
- **Improvements to the vehicles:** as vehicle design improves, the ride becomes more comfortable and enjoyable. Introduction of new vehicle types is also expected; it will make them accessible to a wider range of ages and abilities.
- **Investments in safe infrastructure:** as the case of bicycle modeshift has shown, investment in connected and protected cycle infrastructure will increase ridership.
- **Increasing intermodality:** e-scooters can be further integrated in the mobility landscape since small electric modes could allow designing highly efficient feeder traffic to connect to mass transit. It is worth noting that at the moment in Paris 23% of e-scooter trips are already intermodal (of these, 66% are connecting to mass transit, and 19 % to walking).
- **Changes in weather brought by climate change**: On a somewhat different note, one can observe that heat waves, which are expected to be more and more frequent in Paris, can also contribute to the development of these new mobility forms, as they are more adapted than public transport. Travelling in the open air directly from point to point can provide a more comfortable experience for riders than other modes in such circumstances.

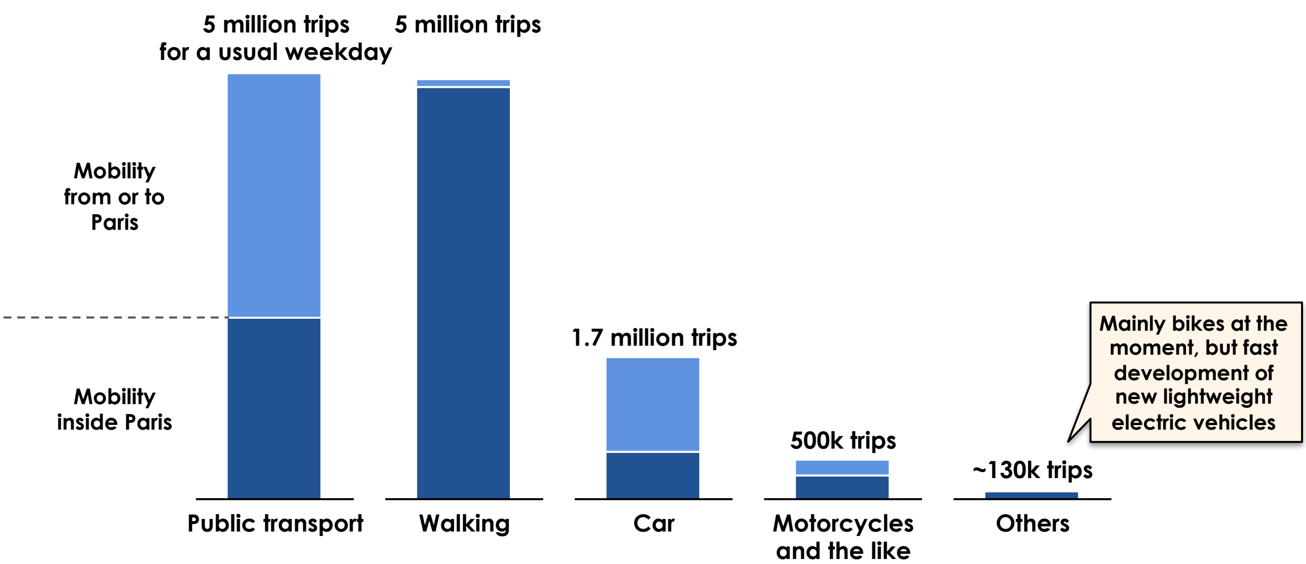
[6] It is worth noting that for this mode share only residents are considered. Shared light electric vehicles are also being commonly enjoyed by tourists to the city: there are 58% residents, and then 42% tourists, among which 33% from abroad and 9% from France.

Long-term scenarios for sustainable mobility: what is the role of shared dockless micro-modes, and what are the climate impacts?

It is likely that an increasing portion of car trips will be replaced by dockless LEV mobility, since they provide a convenient option for riders and align with emerging environmental regulations to address air quality, greenhouse gases, noise pollution, and congestion. But what proportion of car and other existing modes are likely to be replaced by dockless LEV mobility, and what will be the environmental impact?

Let us have a look first at **current mobility in Paris**. For the purpose of this scenario analysis, the scope is limited to trips that occur within the borders of the city (i.e., going from a location in Paris to another one within the city limits) and trips that connect to Paris (i.e., trips that begin or end in Paris). Transit trips are not taken into account in the scope of this study: crossing Paris in a single trip to go from a suburban area to another by car or heavy rail is not addressable by light mobility solutions. In addition, data for non-resident transport is lacking, so the focus will be on daily trips for residents of the Paris area (Île-de-France region).

Current modesplit in Paris
For a customary weekday, and only for mobility of residents in the Paris area



Sources: Carbone 4 analysis based on data from "Plan Climat" 2018 of Paris, "Observatoire des déplacements à Paris" 2016 and 2017, and "Enquête globale transport en Île-de-France", 2010.

There are **~8 million trips daily in Paris**, and **4.3 from or to Paris**, mainly made by **public transport and walking that constitute nearly 80% of all trips**. Car represent ~14% of all trips.

Presently, the modal share of walking is 40% of all trips within the bounds of the study. This modal share is similar to that of public transport, with the combination of incoming / outgoing trips and internal trips. Cars have a modal share of around 14%, but if transit trips were to be taken into account, there would be at least two times more trips: for each car trip within the bounds of the study, there are two other car trips inside Paris, but these trips cross Paris to go from suburb to suburb. The proportion of biking and shared dockless micro-modes are currently very small, representing around 1% of daily trips, or around 130,000 trips daily. But this portion is rapidly increasing and shows promise for development.

To determine the climate potential for dockless mobility, and especially e-scooters, it is valuable to **examine what mobility needs it is currently addressing**. In the 6t study, we find that the primary trip type is commuting to and from work, other professional errands, and leisure-related trips. Trips last on average 19 minutes, and travel a distance of 4.6 km. This average hides a wide heterogeneity since the median duration is 11 min for a distance of 2.75 km. To date, e-scooters substitute public transport, walking, and car trips, but also include trips that would have not otherwise been taken.

Given the pace of uptake, in the long-term, as service and availability improve, restrictions are placed on car use, and investment is made in bike lane infrastructure, we should expect that e-scooters will increasingly link to transit modes, and that they will substitute for additional car trips. Current studies cannot be seen as indicative of what would happen in the long term since the sector is rapidly evolving. Individual transport decisions are made based on convenience and price, and the changes described above will create an environment that is increasingly supportive to shared LEV.

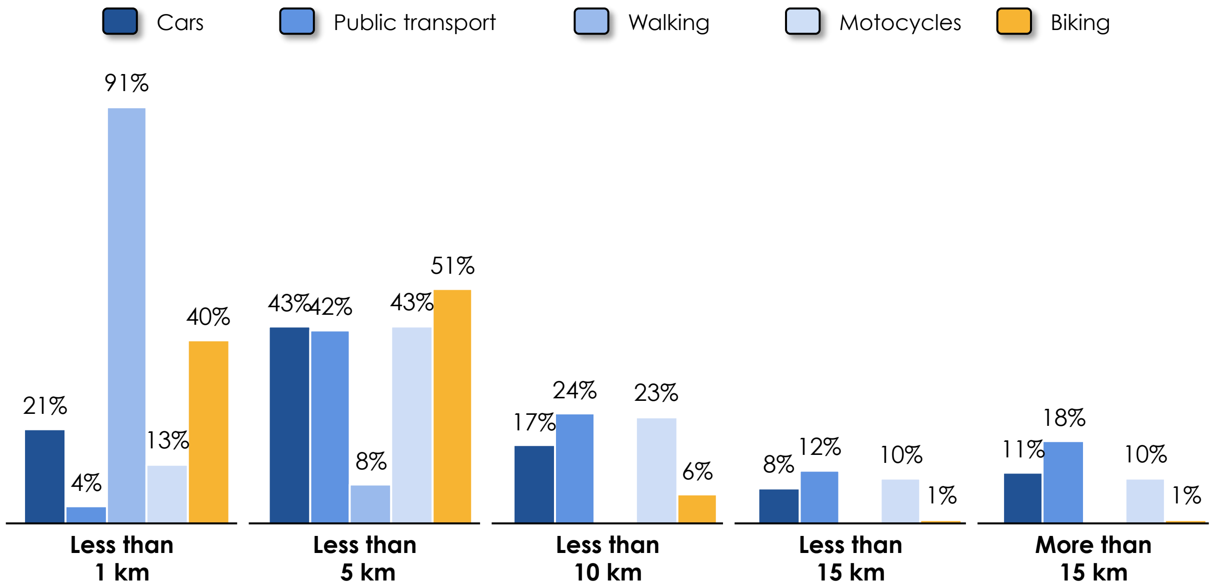
The table below summarizes the trend, and influential factors of existing mobility in Paris, and considers the potential for modeshift towards dockless mobility (either e-scooters or e-bikes), on the basis of the demand it can address.

	Current modal share	Average trip length	Main growth outlook	Influential factors	Modeshift potentials towards dockless mobility
Car	14%	6 km	↙	Restrictive policies aligned with political ambition to reduce car modal share	/ Large modeshift: passengers might turn to light electric vehicles for short trips, and public transport for longer trips
Public transport	41%	9 km	~	Alternate options may replace some public transport for short trips	/ Medium modeshift: public transport, especially the subway, will remain an efficient and cost-effective way to travel fast
Walking	40%	400 m	~	Incentives and better urban conditions for walking	/ Small modeshift: e-scooters and e-bikes might substitute to long walking trips
e-scooters e-bikes	< 1%	2 - 5 km	↖	Growing demand and favorable regulatory framework	n.a.

Sources: Carbone 4 analysis based on data from "Plan Climat" 2018 of Paris, "Observatoire des déplacements à Paris" 2016 and 2017, and "Enquête globale transport en Île-de-France", 2010.

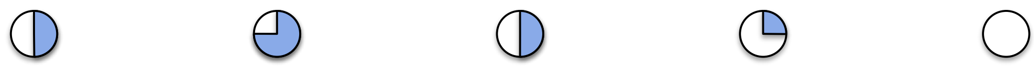
To assess modeshift potential, this analysis considered the range of current trips that e-scooters and e-bikes are likely to capture, setting a feasible range of trips that are longer than 1 km but shorter than 15 km. For each transport mode the distribution is calculated in five different range segments as shown in the chart below. Each one of these segments corresponds to a maximum technical potential for LEVs in terms of modeshift. The average maximum technical potential is calculated by the combination between range distribution and maximum technical potentials per range segment.

Distribution of ranges per transport mode in the current mobility in the Paris region
For a customary weekday, and only for mobility of residents in the Paris area



Sources: Carbone 4 analysis based on data from "Enquête globale transport en Île-de-France", 2010.

Corresponding maximum technical potential for light electric vehicles:



Sources: assumptions by Carbone 4.

Light electric vehicles are likely to attract short range trips, until a range of 15 km. **Technical modeshift capacity is set for each different range intervals, in order to assess the overall modeshift potential based on distance**. For instance the technical modeshift potential is 75% for trips that range from 1 to 5 km.

The methodology takes into account that not all trips for a given mode could be converted to e-scooters or e-bikes due to trip type factors affecting modal choice. These factors include cost of the transport mode, reason for the trip, need to carry heavy goods or transport children to school or other activities, as well as the personal preference for a given mode. For all these reasons, modeshift potential shown in the table above are derived from maximum technical potential after applying a discount factor capturing socio-economic effects in a simplistic way: a discount of 20% when there is a high likeliness to meet the technical potential (for instance for the modeshift from cars), a discount of 50% for a medium effect (for public transport), and a discount of 80% when there are important socio-economic barriers (for instance for walking when the time savings are not worth the price from the perspective of the walker).

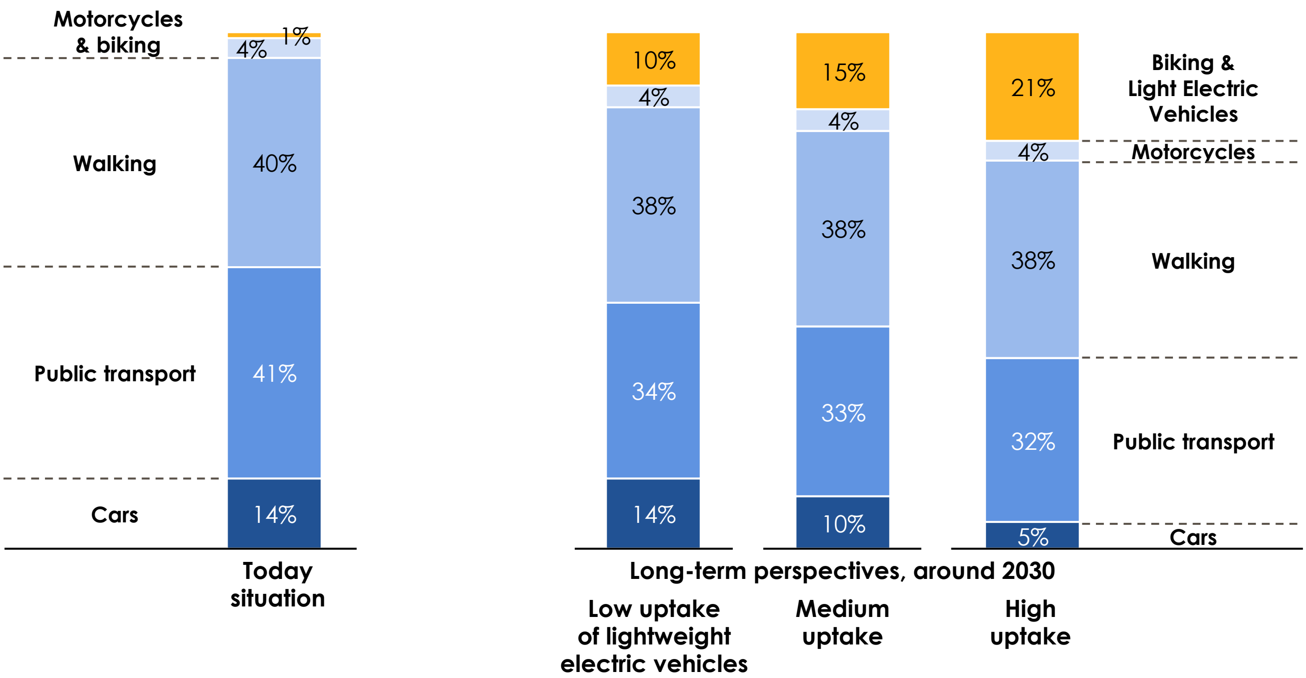
With no surprise, **walking is concentrated on very short trips**, with around 70% of trips under the range of 500 m, and 90% under 1 km. On trips of less than 500 m, e-scooters or e-bikes have a low technical potential since the trips might be more convenient and faster on foot. But for longer trips that are walked today, the potential is more substantial, especially for trips around 1 km. Therefore, the maximum technical potential for modeshift is around 50% of total walking trips. But since the willingness to pay might not be enough for the low time savings, the **actual potential taken into account is a modeshift of 7 to 10% of total walking trips**.

Public transport trips have a higher average trip length, and therefore potential modeshift is limited. In addition, the fare for buses or subways are inexpensive (for the end-user since public transport is subsidized by local authorities and employers' contribution), and a lot of people already have the annual or monthly subscription. The actual modeshift taken into account vary from **20% to 25%**.

Cars trips are surprisingly short, and potential modeshift is therefore higher, from **30% to 40% in the long term**. This corresponds to a large portion of car trips that are less than 5 km.

This information informed modeling of three long-term scenarios to explore plausible futures for Paris mobility in 2030.

Current and projected modal share of mobility in Paris or in connection with Paris



Sources: Carbone 4 analysis and assumptions based on data from "Plan Climat" 2018 of Paris, "Observatoire des déplacements à Paris" 2016 and 2017, and "Enquête globale transport en Île-de-France", 2010.

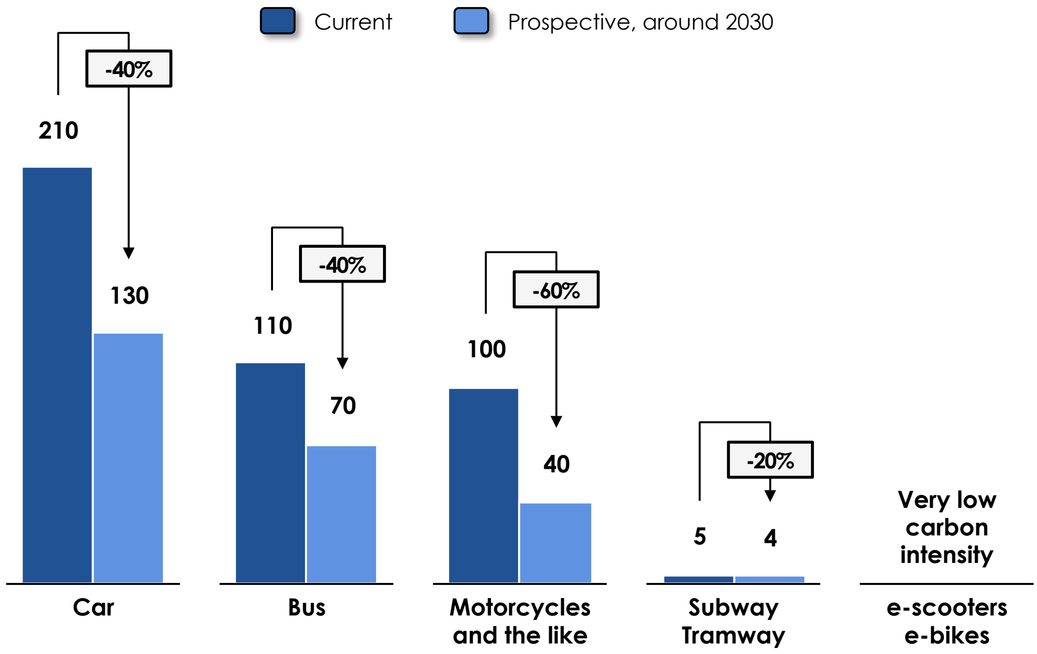
The low, medium, and high scenarios vary based on quality of light electric vehicle service, successful implementation of policies that restrict cars, and quality of bike lane infrastructure.

- **Low uptake** assumes a rather constant share of cars, with **no additional efforts in limiting the environmental impacts of road traffic**. In this scenario, **the uptake of electrified light vehicles is driven by the growing demand** for these emerging mobility solutions that substitute partially with public transport and walking, with the lower end of the potential modeshift: almost 20% for public transport, and 5% for walking;
- **Medium uptake** assumes **high quality of service** and **policies and infrastructure investments take place to promote lightweight and electrified forms of mobility while restricting use of cars**. In this scenario, car trips are primarily replaced by LEVs;
- **High uptake** assumes **high quality of service** and **highest ambition** among the three scenarios for limiting car traffic, with **coordinated policies and investments to fundamentally change the mobility landscape of the city**. The higher end of potential modeshift is used, combined with waterfall effects from the reduction of the car modal share. For example, public transport replaces long car trips, but connectivity is improved with LEVs and modeshift towards light vehicles is stronger. As a whole the modal share of public transport decreases from 41% currently to 32% in the high uptake scenario.

To assess the potential greenhouse gases emissions under each scenario, Carbone 4 derived the **carbon intensity of mobility in the present situation and for future mobility among the scenarios**. As stated above in this report, the scope for greenhouse gases emissions covers emissions from energy production and use (and not greenhouse gases emissions on a lifecycle basis), and additionally the mobility in scope only covers daily trips from residents of the Paris region, for trips within Paris or trips ingoing / outgoing Paris. Transit trips, trips on weekends or trips of tourists are not taken into account under this approach. There is a rather high confidence, however, that the results (proportion of reduction of carbon emission per km) would be similar if the scope in terms of mobility were broader.

Current and prospective greenhouse gases emissions from energy consumption for different transport modes in French cities

gCO_2e per passenger and per km



Sources, for prospective values: Carbone 4 analysis and assumptions based on the French "Stratégie Nationale Bas Carbone".

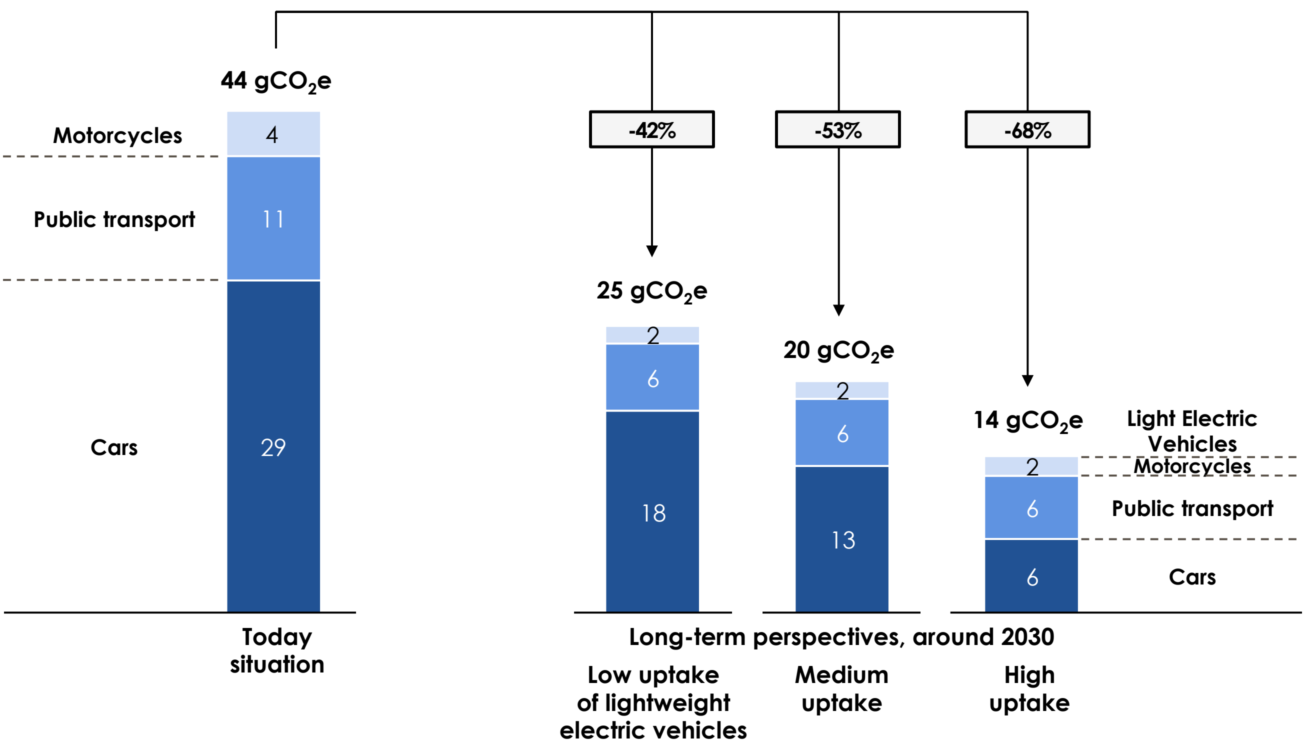
> In the long run, **carbon intensity of all modes** are likely to **significantly decrease** in scenarios with high climate ambition, **especially for vehicles that are not currently electrified** and that can therefore **benefit from the low-carbon electricity in France**.

Prospective emission factors for each transport mode were estimated based on policy targets for the transport sector and electricity sectors in France. Due to increasingly stringent requirements, carbon intensity of energy consumption is likely to decrease for all vehicle types due to energy efficiency improvements, reduced carbon content per energy vector (e.g., renewable vs. fossil fuel electricity), and conversion of road vehicles towards alternate energies such as electricity, biogas, or hydrogen.

By combining emission factors for transport modes with the modal mix of mobility, and with the assumption of a stable volume of trips, Carbone 4 estimated the carbon intensity both for the status quo and the prospective scenarios, as shown below.

Current and prospective greenhouse gases emissions from energy consumption of mobility for different uptakes of lightweight electric vehicles in the future

gCO_2e per passenger and per km | For mobility in Paris or in connection with Paris



Sources: Carbone 4 analysis and assumptions.

In all scenarios the emissions from energy consumption are significantly lower than today, with a decrease in a range of 40% to 70%. The scenario with low uptake of LEVs reflects the mitigation potential derived from energy efficiency gains in all transport modes, with little structural change in the mobility mix. Structural effects allow higher emission reductions. The lower the modal share of cars, the lower the greenhouse gases emissions of the scenario. Even though it has not been assessed in quantitative terms, **air quality in the long-term scenarios would also be much better, especially in the case with a high share of electrified light vehicles**: the decrease of greenhouse gases emissions is likely to be at the lower end of the reduction in local pollutants emissions. There is also the potential for light electric vehicles to substitute from motorcycles, though this has not been explicitly modeled.

The key message here is valid for sustainable mobility projections in any high-density city: a range of low-carbon intensity modes can collectively displace cars while maintaining access to mobility. Car trips within the cities and ingoing or outgoing cities must be transferred to lighter forms of mobility. The case of transit trips by cars must be handled with caution, since the modeshift potentials are much smaller due to the longer trips and the high-speed necessity for this type of mobility.

The results of the scenarios are well aligned with the political ambition of Paris in terms of CO_2 emissions, especially the scenarios with medium or high uptake of LEVs. Paris has pledged to reduce Intramuros emissions (inside Paris) by a factor of two for all sectors from 2004 to 2030 in its climate neutrality roadmap[7]. Since transport accounts for a quarter of Intramuros emissions of Paris, it is critical to have more than a 50% decrease of emissions from this sector. In particular, in the original study[8] that the climate neutrality roadmap of Paris is based on, the greenhouse gases emissions from short-distance mobility decrease by 2/3 from 2015 to 2030. This reduction agrees with the level of reduction that is achieved in the high LEV uptake scenario modeled here.

[7] "Plan climat de Paris", Mairie de Paris, May 2018.

[8] "Paris change d'ère | Vers la neutralité carbone en 2050", study by Elioth, Egis Conseil Bâtiments, Quattrolibri and Mana, Nov. 2016.

Pre-conditions of sustainability for shared mobility solutions

As seen in the previous section, ensuring a high level of shared LEV uptake by shifting people out of cars supports Paris' climate neutrality goal, while also improving air quality, reducing noise pollution and alleviating congestion. Beyond tailpipe emissions, peripheral questions have been raised about lifecycle impact, vehicle durability, and the importance of street design in supporting convenience and safety that will support car trip replacement. In order to maximize modeshift and ensure sustainability of LEV options, these vehicles must:

1. **Shared mobility solutions must have a low carbon footprint**
2. **Shared mobility must replace car trips**

Both cities and mobility companies have a role to play in realizing a low-carbon transport future. This section outlines the characteristics, roles, and responsibilities for achieving it.

What must be achieved for shared mobility solutions to be sustainable?

They must have **a low carbon footprint** in a lifecycle perspective

i.e. vehicles need to last

They must be convenient, safe, and comfortable for consumers to use

in order to **replace car trips**

Companies are responsible for **retention** of the vehicles in the fleet and **durability** of vehicles and parts

Both the cities and companies are responsible for better **integration in the mobility landscape**, with enhanced multimodality for instance

Cities are primarily responsible for **availability**: allowing scooters to be in the city, with appropriate regulations and infrastructure investments

1. *Shared mobility solutions must have a low carbon footprint, when considering a lifecycle perspective*

In order to decarbonize the transport sector, shared LEVs must have low lifecycle emissions. Full accounting of sustainability impact requires comparing modes based on environmental impact throughout the lifecycle of the vehicle, including manufacture, shipping, use, and end-of-life. In the transportation sector, emissions associated with manufacturing and use of a vehicle are the most important factors for comparison. End-of-life of the vehicle is less important for assessing the carbon footprint, but should be considered for other environmental reasons.

According to initial analyses, for shared e-scooters and e-bikes, the largest emissions are in the manufacturing phase. In the use phase, emissions come from energy consumption, charging, and maintenance processes. The carbon footprint of the use phase is low given the energy efficiency of the vehicles and the low-carbon content of electricity in France. There may be some impact associated with charging and rebalancing, but this can be mitigated through the use of low-to-zero emission vehicles and other improvements in operational efficiency.

This means that the most important factor for ensuring a low-emissions profile is to achieve a long lifespan of the vehicle. The importance of lifespan has been stressed recently in the media, based on research of early model vehicles, which estimates lifespan of one to three months, a figure that has been disputed by e-scooter providers.

The "28 day study":
An article on free-floating e-scooters published in Quartz in February 2019 reported an average vehicle lifespan of 28 days, which would lead to profitability challenges and a high environmental impact. According to Bird, this information is erroneous: the analysis was based on data that tracked average number of days scooters are in service in a given location, not the number of days that a scooter is operational. The analysis did not account for scooters that may be moved to different markets, hibernated to meet fleet cap requirements set by cities, or otherwise taken off the streets due to weather, ride demand, and vehicle maintenance needs. Bird's analysis suggests that lifespan for consumer models in the field on those dates was closer to 3-4 months, and that lifespan for proprietary models such as the Bird Zero is significantly higher than that.

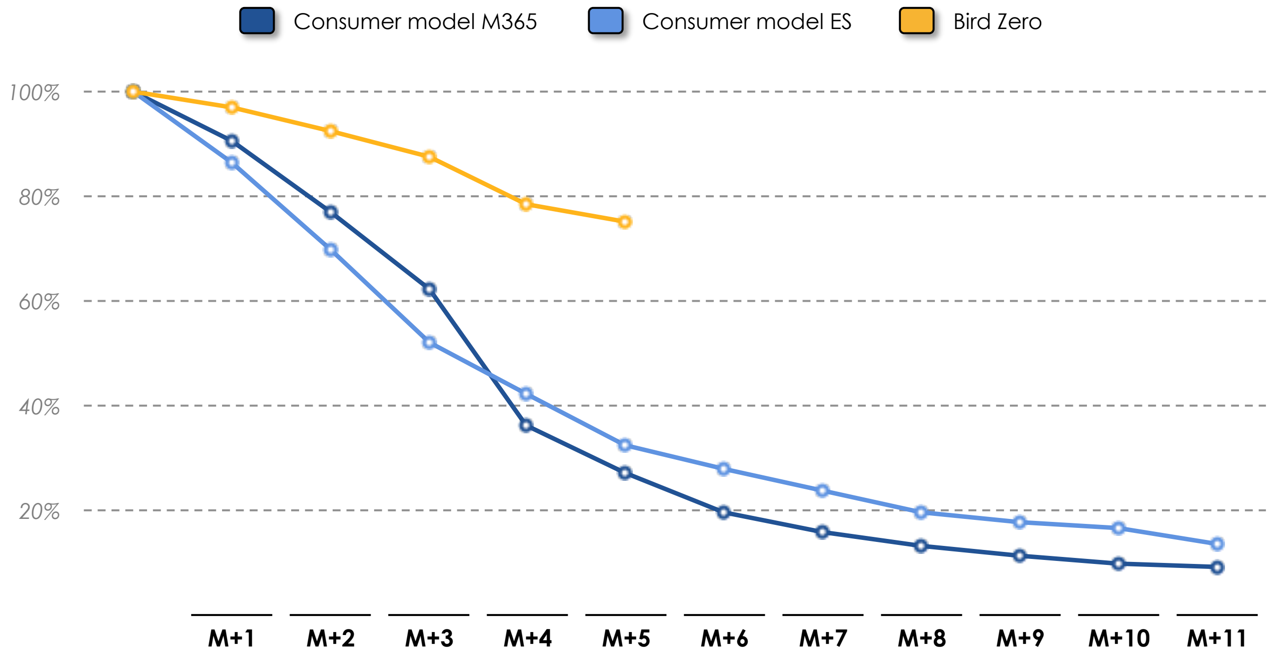
The environmental impacts related to the production of a vehicle are amortized through its utilization lifespan. The longevity of a shared mobility solution is thus especially important, since the pooling of utilization, with less vehicles needed for a given use, allows for a major amortization of the production. But there is an opposite effect due to the harsh operating conditions that can accelerate vehicle attrition and thus fleet turnover. Shared micro-modes face pressures of frequent use, exposure to the external elements, theft, and occasional tampering. **To ensure a long lifespan, e-scooter operators must have sufficient sophistication to achieve two things:**

- **Retain the vehicles** in the fleet, and protect them from theft, tampering, and other losses
- **Ensure durability and maintenance** of the vehicle, and that it is designed to withstand frequent use

We estimate that vehicles must last at least 12 months to achieve a substantially low carbon intensity of the manufacturing phase. Indeed, the carbon footprint of manufacturing is likely to be around a hundred kilograms of CO_2e, and the annual mileage is likely to be 3,000 to 5,000 kilometers. Based on Carbone4's expert judgement, scooter manufacturing emissions must be an order of magnitude lower than a typical car's carbon footprint (around 200 gCO_2e / km for the use phase only) to be a low carbon intensity in the manufacturing phase. Thus, scooters must last at least 12 months to have manufacturing emissions around 20 to 30 gCO_2e / km.

Proprietary designs fare much better than consumer models in terms of retention and durability. Consumer models are unfit for frequent use, and companies who have invested in R&D are seeing significantly longer lifespans than these early models. For instance, the very first vehicles Bird put in service, consumer models such as the M365, were targets for theft as they were capable of being hacked or sold for parts: as a result 50% of the fleet would be lost in less than 4 months as shown in the figure below. Internally developed vehicles, such as the Bird Zero, have been designed to prevent theft and have a much higher retention rate: after 5 months, more than 75% of the fleet is retained. **This retention, if trends were to last, would lead to an average lifespan of approximately 1.5 years according to Bird, which would be adequate in terms of longevity for e-scooters, in order to provide a low carbon intensity of the manufacturing phase**.

Fleet retention: internally developed vehicles vs. consumer models
% of fleet retained after deployment | 2019 cohort



Sources: data from Bird.

Global **Bird Zero fleet retention is greatly higher than retention for consumer models**:
after 5 months for instance, ~75% of the Bird Zero fleet is retained, against ~30% for consumer models.

New models, such as Bird One, are expected to last even longer.

Thus, innovation around custom designs and regular maintenance, along with appropriate retention processes, increase lifespan and significantly lower the climate impact of this mobility solution. To that extent, the Bird Two model has just unveiled in August 2019, featuring hardware innovations for a better durability and retention of vehicles, such as a longer-lasting battery, self-reporting damage sensors, anti-tipping kickstand, anti-theft encryption, puncture-proof tires, absence of exposed screws. Practical examples of these best practices are detailed in the Bird case study below.

Consumer model M365 (left) compared to Bird Two model (right)

Cities also have a role to play in supporting long lifespan and sustainability of shared LEVs. Cities should require operators to have durable vehicles and a sustainability strategy to reduce lifecycle emissions. Cities should also allocate appropriate street space, including parking spaces and bike lanes, as well as implement anti-vandalism policies.

To summarize, the following actions can be undertaken to improve lifecycle sustainability:

Stakeholder	Sustainability recommendations
Companies	**Monitor** the carbon footprint in a lifecycle perspective: ❑ Manufacturing of vehicles ❑ Manufacturing of spare parts ❑ Processes of maintenance and operational logistic (deployments, picking for charging or servicing, on-site maintenance) **Improve** the products and processes: ❑ Continue design progresses on longevity of vehicles and components ❑ Keep on optimizing processes for even longer lifespan and higher retention ❑ Optimize reuse and recycling programs
Cities	❑ Require sustainability plans from operators ❑ Coordinate deployments with operators to avoid vandalism due to particular events (strikes, sport events) ❑ Create dedicated parking spots to avoid friction with pedestrians and other mobility solutions ❑ Implement anti-vandal policies ❑ Require fleet average lifespan of 1 year

Extending vehicle and fleet lifespan: Bird case study

Scooters need to withstand frequent use, occasionally harsh weather conditions, and prevent tampering. Bird, the first company to offer shared electric scooters, has taken a number of steps to improve fleet durability and retention.

DURABILITY: CUSTOM DESIGN AND REGULAR MAINTENANCE

Bird invested in R&D to internally design its own e-scooters (Bird Zero, Bird One, and Bird Two) to improve on the consumer models used in earlier operations. The improvements included:

- Custom battery with battery management system;
- A frame more adapted to a shared used, with reinforced parts;
- Long-lasting tires with flat protection;
- Tamper-resistant components (i.e., no exposed cables);
- A regenerative front brake and a rear drum brake with no electronic failure vulnerability.

Regular maintenance also contributes to a longer usable life. Investment in local service centers and streamlined maintenance processes allowed for a reduction in the proportion of Bird Zero fleet damaged from 40% to 12%. Key features that contributed to this improvement include:

- Staff presence on street, in-app reporting, and sensors that alert to maintenance needs;
- Regular maintenance performed by in-house mechanics;
- A stock of spare parts in service centers, with part reuse from retired vehicles;
- Weather analytics to remove scooters in case of extreme weather.

VEHICLE RETENTION

The proprietary design in itself prevents risks from hacking and resale for parts. In addition, specific design developments are made to enhance retention: for instance installation of a superior GPS system, sensors, and algorithms that detect suspicious movement have improved retention of the Bird fleet to close to 90% retention after 6 months.

In the future, retention is expected to increase even more as the Bird proprietary models are becoming more numerous in the fleet: between September 2018 and July 2019, the proportion of consumer models went from 98% to 25% of the worldwide fleet, the fleet being now composed of 57% of Bird Zero, 19% of Bird One, and Bird Twos beginning to be deployed in Summer 2019.

There is wide variation among providers. Establishing an e-scooter business that is sustainable requires investment in vehicle R&D, technology, and personnel. It can be assumed that providers who have not made these investments have an environmental impact that is moderately to significantly higher than those companies who have.

2. Shared mobility solutions must replace car trips

In order to fulfill their positive environmental potential, LEVs must replace emission intensive modes. This requires action on the part of companies as well as local officials. Some recommendations at different levels are presented here. Combined with the actions on durability of vehicles and retention of the fleet, they would allow fostering the full sustainability benefits of LEVs, in the perspective of climate neutrality roadmaps of mobility.

For micro-mobility companies, the main challenge is to pursue the growth of mode share: pushing up the use of scooters while enhancing substitution of car trips. This can be done by attracting new customers for the present service, by convincing customers to use their services more often and by proposing new solutions that answer another demand, such as transports with loads. Advancements that ensure frictionless service, including accurate location and ease of unlock, is also important. It is thus recommended to continuously improve the hardware (comfort) as well as the operational intelligence ensuring the optimum convenience of the service, while making sure that the price will be competitive to the other modes.

But efforts from scooters operating companies alone are not sufficient. They must be combined with appropriate support from cities to develop better integration of LEVs in the mobility landscape. Supportive policies to encourage modeshift are essential, with first and foremost an appropriate infrastructure investment: a connected and protected bikeway network. This would benefit all light modes and it is the most mentioned factor that would influence the use of light vehicles, as widely shown in studies on urban mobility. However, these supportive policies have to be implemented along with regulation to users and operators to ensure the safety of all light vehicles users and pedestrians, and the order of public spaces. Inside the given regulatory framework that discourages the use of cars (e.g., speed limits, zero-emission zones), the local authorities should ensure the development of multiple alternate options to cars, in order to reduce transport insecurity of inhabitants (the fear of not finding a transport mode).

A street in Paris 12 for cars only (left) retrofitted with greenlanes (right). Cities investment in infrastructure supports modeshift toward more sustainable options.

Cities and companies must work hand in hand to organize and optimize these new forms of micro-mobility. First to allow for an enhanced multimodality (easy connection with other modes) and to solve the nuisance problems related to incivilities (badly parked on sidewalk, accidents with pedestrians, etc.), but also to plan a smart deployment of vehicles (especially for large events and touristic places) through the limitation of the number of companies allowed to operate.

Finally, over the long-term, it is critical to re-design public spaces to prioritize efficient modes. Public infrastructure is currently organized around the use of personal cars. To meet climate neutrality goals, there must be a transition from car-based designs towards streets that allocate connected and protected greenlanes, which would be more adapted to LEVs, pedestrians, bikes and public transport.

To summarize, the following actions can be undertaken to ensure a maximal modeshift from cars:

Stakeholder	Main recommandations
Companies	❑ Enhance ride comfort: safe/reliable/robust vehicles ❑ Ensure competitiveness: explore subscription model and affordability ❑ Expand range of vehicles: availability, frictionless experience, geographical scope ❑ Extend services to answer other demands, such as transport with loads (cargo bikes)
Cities	❑ Invest in infrastructure: connected and protected greenlanes and designated parking ❑ Adopt supportive policies: zero-emission zones, speed limited to 30 km/h to all modes
Companies & Cities together	❑ Match supply and demand to enhance multimodality: ensure vehicles are reliably available at key hubs of the mobility network, in order to foster efficient transit connections ❑ Maximize economies of scale: limit the number of operators

Conclusion

Dramatic changes in policy and urban form are needed to transition from the current mobility system in which a majority of street space is given to cars, toward a more sustainable transport network wherein walking and more efficient transport modes such as transit, bikes, and light electric vehicles (LEVs) are prioritized.

Over the past decade, bicycle modeshare has dramatically increased thanks to changes in lifestyles, supportive policies, and infrastructure investment. Many cities have expanded bikelanes and integrated bikes in their mobility strategy, which has helped to set the stage for growth across new micro-mobility forms, especially shared free-floating LEVs, including e-scooters and e-bikes.

These lighter forms of mobility are popular and show promise for helping cities achieve carbon neutrality, provided they are fully integrated in a sustainable mobility landscape. At the moment e-scooters are attracting riders from all types of modes, including some that would have walked or used public transport. They are also replacing car trips, and to be compatible with the climate goals, this modeshift should be high enough. In scenarios modeled for this report, LEVs play a role in the mobility package needed to achieve reduction in greenhouse gases: LEVs are part of the solution that can help Paris to reduce total transport related greenhouse gas emissions by up to 70% in an exploratory scenario with significant reduction in the use of cars, which is aligned with the political ambition of the climate neutrality roadmap of Paris.

In order to achieve the sustainability benefits of LEVs, there are two conditions to be met, and they require collaboration between mobility companies and local authorities: to ensure low lifecycle footprint of vehicles though design and operational sustainability, and a coordinated approach to encourage modeshift from cars. Vehicle longevity (through design and maintenance) is most important for lifecycle sustainability, and the presence of safe and convenient infrastructure is important for supporting modeshift.

But not all operators are equipped to provide long-lasting vehicles and operate sustainably, and cities should consider their track record and capacity on that aspect. It is a key focus area for Bird as seen in the case study presented. Custom design and regular maintenance, along with appropriate retention processes, are among the best practices to make vehicles last longer.

More broadly, cities and companies must work hand in hand to organize and optimize new forms of micro-mobility. We note there may be transition costs as operators learn-by-doing, but these new forms of mobility already show an impressive adoption by city inhabitants and tourists, a trend that is expected to continue and should be considered by anyone committed to a low-carbon urban future.