LEVs in Urban Mobility

Research and Innovation Priorities

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Glossary

Acronym	Definition
Bodied Vehicle	According to the 'bodywork' definition provided in the Commission Delegated Regulation (EU) No 3/2014 supplementing Regulation (EU) No 168/2013, a 'bodied' vehicle is a motor vehicle equipped with a comprehensive external structure. This includes components such as fenders, doors, pillars, side walls, roof, floor, front bulkhead, rear bulkhead, and other external panels.
EV	Electric Vehicle
ICE	Internal Combustion Engine
LCA	Life Cycle Analysis
LEV	Light Electric Vehicle propelled by an electric motor only or a combination of muscular power and electric motor, which belongs to the vehicle categorisation of EU Regulation 168/2013 or which is excluded from this Regulation through article 2.2
LEVs excluded from Regulation 168/2013, subject to Directive 2006/42/EC on Machinery	- vehicles with a maximum design speed not exceeding 6 km/h; - vehicles exclusively intended for use by people with disabilities; - vehicles exclusively intended for pedestrian control; - vehicles exclusively intended for use in competition; - vehicles primarily intended for off-road use and designed to travel on unpaved surfaces; - pedal cycles with pedal assistance, which are equipped with an auxiliary electric motor having a maximum continuous rated power of less than or equal to 250 W, where the output of the motor is cut off when the cyclist stops pedalling and is otherwise progressively reduced and finally cut off before the vehicle speed reaches 25 km/h;

and Regulation 2023/123 on Machinery	- self-balancing vehicles; - vehicles not equipped with at least one seating position; - vehicles equipped with any seating position of the driver or rider having an R-point height ≤ 540 mm in case of categories L1e, L3e and L4e or ≤ 400 mm in case of categories L2e, L5e, L6e and L7e.
L-category vehicles	Includes powered cycles, mopeds, motorcycles, tricycles and quadricycles, as per Regulation EU 168/2013
L1e-A	Powered cycle
L1e-B	Two-wheel moped
L2e	Three-wheel moped
L3e	Two-wheel motorcycle
L5e	Powered tricycle
L6e	Light quadricycle
L7e	Heavy quadricycle
LMT	Light Means of Transport: term used in some EU-legislation without clear definition: e.g., new Regulation concerning batteries and waste batteries, draft European Critical Raw Materials Act
Micro-mobility	A commonly used term which is presently ambiguous and lacks an agreed upon definition / classification. Generally, refers to bicycles (pedal bikes), electric cycles, e-scooters, small self-balancing vehicles, and sometimes to all LEVs.[1]
PMD	Personal Mobility Devices: term used in "*Study on market development and related road safety risks for L-category vehicles and new personal mobility devices*", carried out in 2021 by TRL for Unit GROW C4 - Automotive and Mobility Industries. Term not defined in study
SUMP	Sustainable Urban Mobility Plan
Unbodied Vehicle	In contrast to the 'bodywork' as defined in the Commission Delegated Regulation (EU) No 3/2014 supplementing Regulation (EU) No 168/2013, an 'unbodied' vehicle is a motor vehicle that does not feature a comprehensive external structure such as fenders, doors, pillars, side walls, roof, floor, front bulkhead, rear bulkhead, and other external panels. This type of vehicle primarily includes the necessary operational components.
VRU	Vulnerable Road User

[1] https://www.eltis.org/resources/case-studies/rise-micromobility

1 Introduction

The goal of this paper is to inform on future research needs and innovation priorities. The primary topics covered in this paper provide an overview of where the discussion presently falls in the realm of the ERTRAC Integrated Urban Mobility Roadmap, which is presently being updated.

The ERTRAC Urban Mobility Working Group (UMWG) gathers experts and representatives of ERTRAC stakeholders to identify challenges and define priorities for future research. The process for this LEV paper began in early 2023 with outreach to gather expert contributors. This was followed by discussions of topics to cover and the distribution of writing tasks. The contributions were consolidated after two further rounds of input and feedback. A special thank you to LEVA-EU for their contributions and their support bringing in further expert contributors.

Light electric vehicles (LEVs) in Europe are booming. The assortment of vehicle solutions is becoming increasingly diverse, appealing to more target groups.

The use cases are also becoming more varied. In passenger transport, there is an explosion of sharing systems, not just e-scooters, but also electric cycles, electric cargo cycles, e-mopeds and light three- and four-wheeled vehicles. Shared micromobility is booming in many cities and has become part of the local mobility ecosystem.

Vehicle manufacturers are also taking steps in the shift from vehicle ownership to other forms of usage (sharing, renting, etc.), and LEVs play a role in this.

Sales of privately owned LEVs are also steadily growing in all segments. Many users are discovering LEVs to be more reliable, sustainable and enjoyable alternatives to the car for daily commutes, or as a complement to public transport.

Moreover, an increasing number of cities are taking measures to ban, restrict or charge a toll for the most polluting vehicles, often diesel and older petrol vehicles, and sometimes measures affecting both ICE and electric vehicles. Such measures generally result in growing numbers and use of EVs, and in particular LEVs. This trend is further driven by local governments giving lower priority to private car ownership and increasingly looking for a shift to alternative mobility solutions to meet transport needs.

Cities' sustainable mobility policies also lead to an increased focus on sustainable logistics. Here too, the share of LEVs is growing. For postal, small parcels and food delivery, petrol mopeds are being swapped for electric (cargo) cycles. Professionals in a wide variety of sectors are discovering that they move more efficiently with light, electric vehicles. These include doctors, caregivers, maintenance technicians, cleaning and DIY services, real estate agents, local authority staff, etc.

LEVs are also gradually playing a bigger role in public services, e.g., gardening services, rubbish collection, street cleaning, etc. Even emergency services such as police, ambulances and firefighters are discovering that they may operate faster with an LEV.

With the growth outlined above comes common growing pains. Infrastructure previously used only by cyclists is becoming saturated. Conflicts arise between road users, more and "different" road crashes occur, for example due to people not noticing an LEV due to its quietness. Speed limits, traffic codes and public space allocation/occupation both for moving vehicles and parking are questioned.

On the other hand, exciting and encouraging opportunities are also growing. What effects can LEVs have on the liveability and quality of life in cities, on public health, on social inclusion?

Increasing LEV deployment can prompt thinking and reflections on new distributions and use of public space, new and different safety technologies, new interactions/communication between different road users, new possibilities for collecting and using data and information.

In conclusion, the growth of light electric vehicles is unstoppable, and although they create some new challenges, they also create many promising new perspectives. This in turn opens new avenues for research that needs to be focused on solving these challenges and fulfilling the new perspectives. This paper is aimed at launching and feeding the discussion on that research.

Table 1 - EU LEV Market
(Source: LEVA-EU)

European LEV Market			
LEV-type	Year	Number	Remarks
Electric cycle, pedal assistance up to 25 km/h - 250 W	2022	Est. 5,5 million	Sales continuously growing since end nineties
Electric cargo cycles	2022	Est. at 165,000 in Germany	Market with strong growth due to increasing number of cities closing off for vans & trucks. E-cargo cycles ideal for last mile deliveries.
Speed pedelecs (45 km/h)	2022	Belgium: 24,325 Germany: 11,000 The Netherlands: 4,357	
E-scooters, e-monowheels, e-hoverboards, self-balancing vehicles, …	2021	±11,7 million	This number is based on incomplete and unclear Eurostat statistics HS codes 87116090 and 95030010
Electric mopeds	2022	85,846 registrations	e-mopeds have a 33,5% share in total moped market. More than half of the e-mopeds are speed pedelecs. The market grew thanks to e-mopeds.
Electric motorcycles	2022	43,484 registrations	e-motorcycles have a 4,6% share in total motorcycle market. Thanks to e-motorcycles, the market grew slightly last year.
All light, electric vehicles	**2021**	**Sales estimate: at least 17,5 million**	**For comparison, in 2021: 1,3 million battery electric car registrations in EU.**

Reliable statistical information on the European LEV market is hard to find, especially for those LEVs which are not registered. The above information has been gathered by LEVA-EU. The sources are industry associations and trade information/media platforms, including Bike Europe, ACEA, Eurostat, ACEM, CONEBI, DIV, RAI and other national trade associations.

2 What are LEVs?

2.1 Expanded definition, classification of vehicles

The term “light electric vehicles” (LEVs) is an umbrella term for a wide variety of electric-powered vehicles. In some cases, muscular power is added to the motor power.

The term LEV does not appear in the European classification for technical regulations, nor in any EU legislation. Nevertheless, they are in the scope of an ever-increasing number of European and national/regional regulations. Sometimes the abbreviations EL-V is also used, for Electric L-category Vehicle, with L-category indeed being an official EU and UNECE classification.

As for technical legislation, some LEVs come under Regulation 168/2013, which is the case for electric (cargo) cycles >250W–25 km/h, speed pedelecs, electric mopeds and scooters, electric motorcycles and electric 3- and 4-wheelers. Other LEVs are excluded from Regulation 168/2013 and come under the Machinery Directive and Machinery Regulation. This is the case for electric (cargo)cycles <250 W-25 km/h, self-balancing vehicles and vehicles without a seating position.

The different types of LEVs have developed separately from each other, so legislators do not consider and treat them as a single entity in legislation and regulations. As a result, legislators use a variety of terms such as micro-mobility, personal mobility devices (PMD), light means of transport (LMT), and others. Thus, this potentially encompasses a very wide range of products.

The lack of a clear and uniform definition sustains the absence of harmonised and adequate policies on LEVs, which in turn hinders the development of the LEV-market. A uniform definition of LEVs would enable legislators to draft adequate and future-proof rules for these vehicles, which could encourage their adoption and use. A uniform definition of LEVs would also considerably facilitate the development of the usage of common terminology with national/regional authorities.

A common denominator for most of these vehicles is reduced vehicle weight, which results in greater energy efficiency and sustainability. Consequently, they could be defined as “*electric-powered vehicles with a reduced weight which can contribute to a diverse range of sustainable mobility solutions*”.

The current status of LEVs in regulatory frameworks clearly shows the need for a consistent and aligned definition. From a regulatory perspective, LEVs are not explicitly named in the EU harmonised technical legislation, i.e., Regulation 168/2013 and the Machinery Directive, but they are nevertheless defined by these legal texts.

TRL published a study[2] in 2021 on market developments and safety for LEVs. The study presents different scenarios in terms of LEV regulation, rather than reaching a particular conclusion on what would work best. According to TRL’s view, the most apt solution would be to develop a technical regulation outside the Machinery Directive and Regulation 168/2013. The system could include a variety of assessment methods, ranging from self-certification to independent testing. “*In our view this new system for the*

[2] TRL (2021): A Study on market development and related road safety risks for L-category vehicles and new personal mobility devices. Report.

regulation and approval of PMDs[3] *would provide the flexibility necessary to support innovation in this rapidly evolving sector, while maintaining technical standards and road safety.*"

On the other hand, a substantial amount of research should be carried out before lifting regulations that are in place for consumer safety, as the results are potentially unsafe, or even deadly.

The simplest definition for LEVs, which could serve as the basis for future harmonisation of the terminology used, could read as follows: "*a powered vehicle equipped with a motor that does not produce tailpipe emissions and a maximum mass in running order* ≤ *1,000 kg*". (The maximum mass stated here, is what is currently in Regulation 168/2013.).

Figure 1 - LEVs
(Source: Uni Kassel)

[3] TRL used the term personal mobility devices (PMD) instead of LEV.

3 LEV issues setting the frame for future R&I

The following chapter looks at different key areas linked to the roll-out and usage of LEVs and provides background context towards indicators of where further research is required. This includes information on infrastructure, safety, environmental and social impacts, accessibility and exchange of best practices. Details are provided which, along with the classification needs from the previous chapter, and information from previous roadmaps, will be used towards presenting research priorities for LEVs.

3.1 Infrastructure

In order to accommodate growing numbers of LEVs into urban environments, sufficient infrastructure, charging capacity, allocations of space, and adaptation of existing space should be made available. The use of public space involves integrating LEVs such that they are convenient for intermodal transport and safe for both the user and others in traffic (primarily pedestrians, cyclists, and other LEV users). Infrastructure is an integral part of the overall concept of mobility management. User behaviour is determined by the built-up environment. The following sub-sections cover some of the primary elements to consider and topics to highlight for future research in regard to infrastructure and public space.

3.1.1 Use and design of public and private space

LEVs require space to move, to be parked, to be charged and to be maintained. Where movement is in principle happening in public space, parking, charging and maintenance can happen in public, semi-public and private spaces (open air as well as in buildings). The introduction of LEVs can be seen as 'right-sizing', i.e., the use of the best size of vehicle for the purpose of a trip or delivery, bringing potential for more efficient use of space. Furthermore, there are other aspects to be considered in the deployment of LEVs, such as the location of recharging and battery-swapping stations, road design (including junctions), road space allocation in view a growing variety of vehicles with different speeds and kinetic energy, and the provision of secure parking spaces, etc.

To support the usage of smaller LEVs, comprehensive changes and re-allocations of space are needed to provide adequate space to support all modes of road transport fairly. This involves counteracting decades of car-centric planning in road and parking allocations, as well as the dynamic management of public space (function, time of day usage, space allocated to parking vs. other uses, etc.) towards a better balance. Consideration should also be made in the placement of supporting infrastructure (charging, signage, bins, shop advertising, etc.), and enforcement of vehicles illegally stopping and parking, to avoid obstructing or subtracting from the limited space presently allocated, and in the planning of future space for LEVs and active mobility. Where there are existing bicycle paths, LEVs add further traffic. When vehicles block this road space for deliveries, or infrastructure such as charging points take away from this space, safety is reduced and there is potential for more friction between modes.

Research could be valuable that explores identifying potential differences in needs and behaviour between private ownership and shared services. Shared services generally require stricter allocations of space for parking and speed limitations. With personal vehicles such as e-scooters, a certain level of quality, safety, and speed limitation standards should be institutionalised and monitored, to ensure that off the shelf products are sufficiently robust and operated with the legally required speed limiting software. These vehicles also require proper parking allocations to be safely secured and to avoid the obstruction of sidewalks.

In view of future research needs, the following priorities can be listed:

- **Safe and balanced redesign of public space** in view of road safety and modal shift in the context of scaled uptake of innovative LEV solutions
- **Review of traffic codes and traffic rules** in view of a growing diversification of vehicles on the road
- Elements related to **road space use and allocation of new mobility services**, as presented in the ERTRAC Roadmap on New Mobility Services, in case the LEVs are used in shared mobility services
- **LEV parking, charging/battery swapping facilities and maintenance** in public and semi-public settings (e.g., office parking, shopping centre parking, railway stations/transport interchanges, etc.), design and business models

3.1.2 Infrastructure safety

The safety and quality of infrastructure are integral to the successful integration and adoption of LEVs. The condition of roads, in particular, has a direct correlation with the performance, safety, and longevity of these vehicles. Well-maintained, smooth road surfaces mitigate wear and tear on the vehicles, thereby enhancing their operational lifespan and reliability.

For two-wheeled LEVs, the quality of roads assumes an even greater significance. Given their smaller size and lighter weight, these vehicles are more vulnerable to road conditions. Hazards such as potholes, debris, and uneven surfaces can pose substantial safety risks, potentially leading to crashes and causing undue strain on the vehicle's components.

In addition to the overall quality of roads, specific infrastructure elements tailored to LEVs can significantly enhance their operational safety and efficiency. These include dedicated road space, dedicated traffic rules and related traffic signs, speed limits considering LEVs, parking space and charging facilities. Traffic calming can help in the safety of larger LEVs like microcars or two-wheeled LEVs sharing space with other vehicles without dedicated space allocation. For two-wheeled LEVs, dedicated lanes can provide an additional layer of safety by minimising interactions with larger, faster vehicles. Separating LEVs from other vehicles and pedestrians can enhance the overall flow of traffic and minimise potential conflicts. Such infrastructure adaptations not only facilitate the seamless integration of LEVs into the existing transportation system but also incentivise their adoption by enhancing user safety and convenience. **Research is lacking in regard to the interaction between >25 km/h LEVs (e.g., speed pedelecs) and other <25 km/h vehicles (e.g., cycles) in dedicated lanes.**

Moreover, the presence of safe and reliable infrastructure and adapted traffic rules can bolster public confidence in LEVs, creating an environment conducive to their widespread adoption. Consequently, investment in infrastructure safety, with a particular emphasis on road space allocation, and the review of traffic codes emerge as a critical determinant in promoting the use of light electric vehicles. This underscores the need for further research and policy focus in those areas.

3.1.3 Mobility hubs and secure parking facilities

Mobility hubs serve to support journeys from a holistic perspective. In order to support sustainable first/last/ as well as mid-journey solutions, parking should be secure, charging should be an option, transfers should be convenient, and barriers should be minimised, such as parking costs and rental of LEVs through a common platform which allows a simplified approach to pick up and return to various locations.

The characteristics of LEVs create specific parking concerns, which requires well-considered and integrated solutions. Parking can be combined with charging. The cost of the vehicles and the fragility of the technology raises concerns about open air and unprotected parking and increases the need for secure parking facilities. These will have to be fit into the urban fabric and have a sound business model for operation. Integration with services (MaaS) and existing parking offers (for bicycles and cars) is another factor, as well as the storage of LEVs that are used for urban deliveries.

LEVs such as electric cycles and scooters which are increasingly common, represent a significant personal investment which require personal safety coming to and from facilities as well as vehicle security. Research is still needed in regard to LEV parking security, as smaller electric vehicles remain the target of thieves, despite various security measures which are often in place. The level of theft monitoring and follow-up is generally neglected by public authorities, despite the increased costs of the vehicles, which many depend upon for their day-to-day lives.

Further research is needed in leveraging data to support MaaS solutions, space management, and security in multimodal hubs to enhance intermodality. This would support the integration of LEVs as a convenient and viable part of longer journeys.

3.1.4 Charging infrastructure / Swappable battery technology

With the increases uptake of vehicles requiring charging, rather than using fossil fuels, the charging infrastructure and capacity to meet these demands will require adaptations and innovative solutions for the future. This includes public and private parking facilities, mobility hubs, and homes. The load on the energy grid is also likely to increase, which is a pending issue in regard to electric vehicles but may be relevant with a large uptake of LEVs.

Swappable batteries present a transformative potential for the development of LEVs in the European Union. This innovative technology can address two of the most significant barriers to the widespread adoption of LEVs: range anxiety and long charging times. By enabling users to quickly exchange depleted batteries for fully charged ones, downtime could be significantly reduced, and the range of these vehicles could be extended. Furthermore, the adoption of a membership or rental scheme for these batteries introduces an economical advantage for consumers. Since the battery is typically the most expensive component of an LEV, not having to bear its full cost upfront can make LEVs more accessible to a broader range of people. Moreover, this scheme ensures that the battery is always in good shape, leaving only the vehicle subjected to wear and tear, which can significantly increase the lifespan and performance of LEVs.

Battery swapping infrastructure could be more energy-efficient and cost-effective to implement than traditional charging stations in certain settings, particularly in urban areas where space is at a premium. However, to fully realise this potential, **it is crucial for the EU to establish a harmonised standard for swappable batteries, ensuring interoperability across different manufacturers and regions**. This will not only foster innovation and competition but also facilitate the creation of a robust, pan-European battery swapping network. With the right policy framework in place, swappable batteries could be a game-changer for LEVs, accelerating a transition to a more sustainable and resilient transport system. **The value of swappable battery technology is a topic for further study**.

3.2 Safety

Safety-related aspects of LEVs affect vehicle occupants as well as other road users and they involve many different fields, such as vehicle properties, regulations on use, infrastructure aspects and user behaviour. In the following sections, aspects of equipment, battery and user behaviour are highlighted, while aspects of infrastructure are covered in section 3.1.2.

LEV-safety is currently based on the requirements of Regulation 168/2013 plus supplementing regulations, or on the Machinery Directive. The latter has been supplemented with a number of EN safety standards for specific LEV-categories.

- EN 15194:2017+A1:2023 “Cycles. Electrically power assisted cycles. EPAC Bicycles”.
- EN17128:2020 “Light motorized vehicles for the transportation of persons and goods and related facilities and not subject to type-approval for on-road use. Personal light electric vehicles (PLEV) – Requirements and test methods”.
- EN 17404:2022 “Cycles. Electrically power assisted cycles. EPAC Mountain bikes. – Part 2: Specific requirements applicable to electric mountain bikes.”
- ISO/TS 4210-10:2020 “Cycles — Safety requirements for bicycles — Part 10: Safety requirements for electrically power assisted cycles (EPACs)”.
- IEC 63281-1:2023: E-Transporters - Part 1: Terminology and classification
- EN50604-1:2016+A1:2021 ‘Secondary lithium batteries for light EV (electric vehicle) applications. General safety requirements and test methods”.
- IEC 62133-2:2017+A1:2021 “Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications. Part 2: Lithium systems”.
- IEC 60335-2-114:2022 “Household and similar electrical appliances - Safety - Part 2-114: Particular requirements for Personal-e-Transporters".

Furthermore, several other relevant standards are under development:

- prEN 17860:
  - Part 1 – Terms and definitions
  - Part 2 – Lightweight single track carrier cycles – mechanical aspects
  - Part 3 – Lightweight multi track carrier cycles – mechanical aspects
  - Part 4 – Heavyweight multi track carrier cycles – mechanical aspects
  - Part 5 – Electrical aspects carrier cycles
  - Part 6 – Passenger transport carrier cycles
  - Part 7 – Carrier cycles – Trailers
- IEC 63281-2-1 ED1: E-Transporters - Part 2-1: Safety requirements and test methods for personal e-Transporters

- IEC 63281-2-2 ED1: E-Transporters – Part 2-2: Safety requirements and test methods for autonomous cargo e-Transporters
- IEC 63281-3-1 ED1: E-Transporters – Part 3-1: Performance test method for total run time of e-scooters with consideration to environmental conditions of actual use
- IEC 63281-3-2 ED1: E-Transporters - Part 3-2: Performance test methods for mobility of cargo e-Transporters

Regulation 168/2013 plus supplementing regulations need to be scrutinised to **find out whether requirements and tests are optimised for light electric vehicles**. As for LEVs subject to the Machinery Directive, a risk assessment for LEVs would allow detection of gaps and anomalies for LEVs in the current legislation and standards.

Even where standards exist for comparable products, there may be inconsistencies in the requirements within those standards. This may be due to a legacy issue or lack of liaison between different technical committees responsible for drafting and developing interrelated standards.[4]

3.2.1 Equipment safety

User equipment should be perceived as an integral factor in facilitating the evolution of LEVs. It is important to recognise that protective gear is not a hindrance to LEV development, but rather a mechanism for instituting a comprehensive safety strategy.

Considering the inherent vulnerability of users in the case of unbodied LEVs that can achieve high speeds, the use of protective equipment (e.g., helmets, gloves) and enhanced visibility elements (e.g., reflective clothing and non-glaring lighting devices) provides safety benefits.

It is crucial for national regulatory systems to adjust to the evolving challenges posed by new modes of transport, taking their kinetic energy into account in the potential need for adjustment of existing guidelines. Kinetic energy will depend on the mass of the given vehicle, plus the user(s), plus any cargo. LEVs capable of exceeding speeds of 25 km/h are a good example in this framework. Safety equipment guidelines developed for mopeds have been successful in reducing injuries and fatalities over recent years. However, today the moped category does not only cover traditional mopeds anymore. Speed pedelecs and e-scooters with seats are also categorised as mopeds. **Further research should focus on understanding how to adapt the existing guidelines for these new vehicles.** Conversely, for LEVs with speeds equal to or below 25 km/h, the guidelines designed for cycles should be deemed applicable, given that most of the LEVs have a comparable or even lower kinetic energy.

Generally, regardless of whether the use of safety equipment remains voluntary, its application could potentially enhance the protection of both users and pedestrians, representing a catalyst for a universal safety strategy.

Several aspects related to LEV vehicles and their use can possibly involve safety issues.

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[4] Electrical Safety First, July 2023, "Battery Breakdown: Why are e-scooter and e-bike batteries exploding in people's homes and what can be done about it?"

- **User aspects**: familiarity with the vehicle and riding / manoeuvring it, personal capabilities, as e.g., no driving licence or some training is required; personal choices on e.g., wearing protective equipment;
- **Vehicle aspects**: technical aspects, maximum speed (including anti-tampering measures), visibility, recognisability, weight etc.;
- **Interaction in traffic** with other road users/traffic participants; aspects on the environment/ surroundings (presence of infrastructure, traffic codes, road conditions, even weather and time of the day can have an impact)
- Impacts of various **regulations and legislation** on different levels: local, regional, national, European; lack of clear regulations; operating bans, where these vehicles are allowed etc., shared / rented vs. private ownership.

Important issue: **Data on accidents with these vehicles is either missing or (under)reported under different vehicle categories, therefore safety and potential safety issues are difficult to assess.**

Focus is needed on (required) mitigating measures, to address all the safety aspects mentioned above, as well as the remaining risks.

3.2.2 Battery Safety

The risks associated with batteries, as well as home charging of these batteries, with the influx of vehicular batteries, presents various safety aspects to be considered and further researched. Ideally this leads to improved safety standardisation and procedures within the supply chain and marketplace.

Currently, there is a lack of knowledge about the safety aspects of various batteries when charging, and this is valid for both policymakers and LEV users. Awareness raising for users is needed, to ensure proper knowledge about the charging of LEV batteries and fire safety risks. This is particularly important for specific use cases like delivery platform workers who are often not aware of the potential dangers of charging their batteries at home and need safe charging stations. Although not yet significant, there is a growing number of fires occurring from LEV batteries which made policymakers and public authorities increasingly weary of these vehicles. The vast majority of these occurrences result from charging damaged or batteries of inferior quality, and some resulted in fatal consequences.

Data on fire incidents with LEV batteries is still scarce, but in the period from 2020 to 2022, a total of 327 fires with LEVs occurred in the Netherlands, involving a total of 690 LEVs. The majority of these fires were in e-scooters, or e-bicycles. In 35% of the cases, the fire was caused by a technical defect. The figures indicate that quite a few fires involving LEVs have already occurred in the Netherlands. That will not diminish: LEVs are on the rise. This development requires **extra attention to the (fire) safety of LEVs by manufacturers and further research on the development of innovative battery management systems, not only for passenger cars, but also for LEVs, and in particular for non-type-approved products.**[5]

The growing perception of fire risks with LEVs can lead to undesirable actions such as blanket bans on e-bikes and other LEVs in residential buildings. Besides reducing the attractiveness of these forms of

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[5] Netherlands Institute for Public Safety (NIPV) "Analysis of media reports of fires with Light Electric Vehicles 2020-2022", 15. March 2023. https://nipv.nl/wp-content/uploads/2023/03/20230315-NIPV-Analyse-mediaberichten-branden-met-LEVs.pdf

micromobility, taking such actions is not the solution – the majority of batteries comply with safety standards, and such moves will simply prevent people switching from their cars to more sustainable forms of mobility.

3.2.3 User Behaviour

Inexperienced users of LEVs, for example, first-time users of shared e-scooters, are often not aware of the speed and the acceleration that these vehicles are capable of, putting these users at higher risk. Inadequate user behaviour increases the risk of road accidents and collisions with pedestrians and other vulnerable road users,

Since 2020, electric scooters can be identified in official Belgian accident data. There were 408 accidents involving an electric scooter in 2020 in Belgium. There was one fatality and 432 injured. The majority of injured are e-scooter users themselves (368 injured, 85%). In addition, 27 cyclists and 23 pedestrians were injured in an accident involving at least one electric scooter. Most of the electric scooter users affected were between 25 and 49 years old, 15% of them were 17 or younger.[6]

There is also the risk of battery fires, as a puncture or an impact from a crash may result in the batteries igniting and lead to "thermal runaway" of the chemicals inside the battery. Thermal runaway cannot be stopped once it starts without specialist fire suppression and containment equipment. This has resulted in many injuries where people have tried to stop the fire using standard fire extinguishers.

Manufacturers, operators and public authorities need to **raise awareness for proper user behaviour** and inform/train users. All of these stakeholders should contribute to fire-safe behaviour of consumers with information about fire-safe use (maintenance, loading, storage).

3.3 Environmental impacts

LEVs provide the potential to reduce greenhouse gas (GHG) emissions and local pollutants by replacing large and heavy vehicles, as well as light ICE vehicles such as petrol-powered scooters/mopeds. The high potential reduction in GHG per driven kilometre is a result of, among other factors, the low vehicle weight of LEVs and the resulting low energy consumption, combined with lower production related CO_{2eq} emissions compared to passenger cars[7]. Additionally, fewer material resources are required to produce LEVs compared to battery electric cars. This is particularly relevant with regard to traction batteries, which are a major factor in the consumption of critical raw materials and production-related emissions, and which are generally much smaller in LEVs. The weighted average battery capacity of battery electric passenger cars registered in 2021 in Germany is 50 kWh (analysis based on KBA [1,2] and ADAC [3] data) [8]. LEVs, on the contrary, are typically equipped with batteries of around 5-15 kWh for larger vehicles (e.g., L5e, L6e, L7e) and battery capacities of smaller LEVs are significantly lower (based on manufacturer's information). Emissions decrease for trips made with LEVs compared to cars with any type of propulsion, albeit to varying degrees[7]

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[6] Les trottinettes électriques & la sécurité routière. BRIEFING. 2021. VIAS | E-scooters in the rain: what to keep in mind
[7] Ehrenberger, S.; Dasgupta, I.; Brost, M.; Gebhardt, L.; Seiffert, R. Potentials of Light Electric Vehicles for Climate Protection by Substituting Passenger Car Trips. World Electr. Veh. J. 2022, 13, 183. https://doi.org/10.3390/wevj13100183
[8] Kraftfahrt-Bundesamt, Neuzulassungen von Kraftfahrzeugen und Kraftfahrzeuganhängern nach Herstellern und Handelsnamen (FZ 4), Jahr 2021 [2] Kraftfahrt-Bundesamt, Neuzulassungen von Personenkraftwagen nach Marken und Modellreihen (FZ 10), Monatsergebnisse, Dezember 2022 [3] ADAC Fahrzeugdatenbank 2022

In order to quantify the theoretical potential for emission reductions, a scenario was modelled for a case study in Germany as part of the LEV4Climate study[9]. An analysis of substitutable car trips formed the basis for the analysis of potential emissions reductions.

Using data of the representative national mobility survey "Mobility in Germany 2017"[10], characteristics of trips and vehicles were matched to identify substitution potential for different exemplary LEVs. Criteria such as the age of car users, trip purpose, number of passengers, and other relevant factors were considered. Analysis of the data shows that, depending on the LEV category, up to 75% of all car trips in Germany could be replaced, corresponding to a 50% share of mileage. These figures more or less correspond to the combined potential of all LEV categories, since the potentials of the individual categories show quite high overlaps (Figure 4).

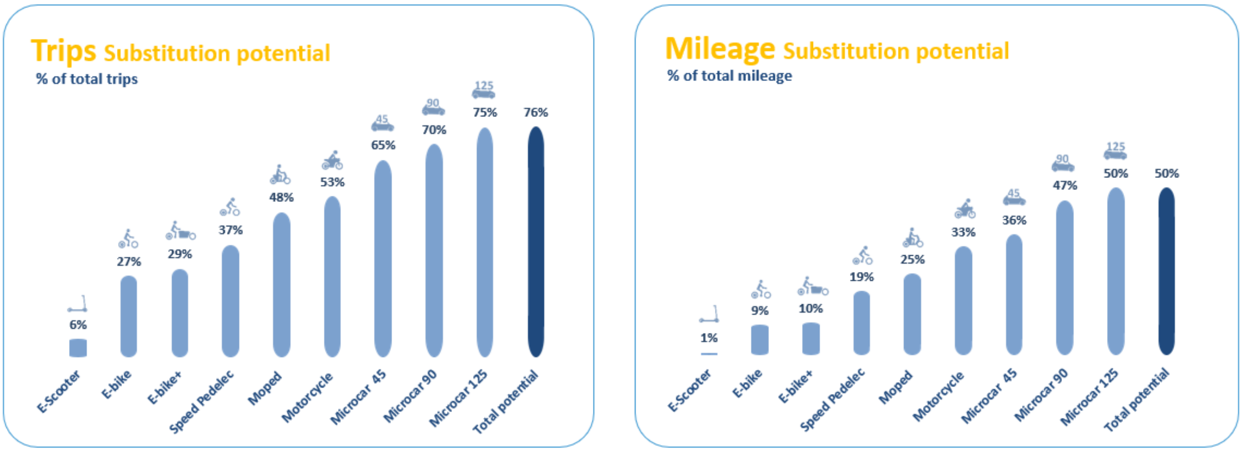

Figure 2 - Substitution potential of LEVs as share of passenger car trips (left) and mileage (right) in Germany
(Source: DLR, LEV4Climate[11])

Conducting a life cycle analysis (LCA) for the nine different LEV categories from e-scooters to four-wheeled LEVs of the category L7e formed another building block for modelling possible emissions savings in Germany. The LCAs consider emissions from manufacturing and operations, including production of the required electricity. GHG emissions of the assumed energy mix are about 230 g CO_{2eq} per kWh as a base scenario for 2030. Based on assumptions about the total mileage for the different LEV categories, CO_{2eq} emissions per kilometre were calculated. The results of the LCAs clearly show the lower total emissions per km of LEVs compared to passenger cars (Figure 3).

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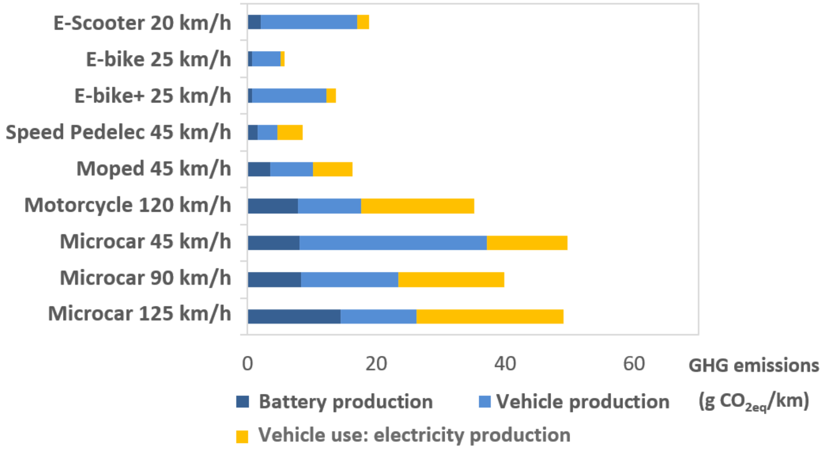
[9] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.
[10] BMVI (no date): MiD 2017 – Mobilität in Deutschland. Mikrodaten (Public Use File). Available online: www.clearingstelle-verkehr.de [20 November 2021]
[11] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.



By **comparison**, **the average passenger car** emits **203 g CO_{2eq}/km.**

Based on a 2030 scenario from the Kopernikus project Ariadne 2021[12], production and use considered, stock with:

56% gasoline vehicles, 19% diesel vehicles, 14% battery electric vehicles, 9% plug-in hybrid electric vehicles and 2% hybrid electric vehicles

Figure 3 - Lifecycle emissions of various LEVs and cars per kilometre
(Source: DLR, LEV4Climate[13])

Using the results of the life cycle assessments for the different LEV categories and the data of the substitution potential for car trips, savings in greenhouse gas (GHG) emissions were calculated for Germany for one year. For the baseline scenario considered in the LEV4Climate study, it was found that car-related emissions (production and operation) in Germany could be reduced by 44% if 50% of car mileage were replaced by LEVs. The magnitude of this potential indicates that intensified research on LEVs is required to avoid discounting the potential of this type of vehicle. On the one hand, this research should deal with the question of which strategies and measures can support the exploitation of the potential in a timely manner and, on the other hand, whether and what negative effects a wider use of LEVs could bring with it and how these could be minimised.

Similarly, the ELVITEN project[14] concluded significant potential savings in GHG and pollutant emissions, based on scaled up results from its six demonstration cities: three in Italy (Genoa, Rome and Bari) and one each in Germany, Greece and Spain (Berlin, Trikala and Malaga).It studied the environmental impact of using more EL-Vs (L-category LEVs) by creating two scenarios up to the year 2050: a baseline scenario ("business as usual" with moderate LEV growth) and a "-30% shift" scenario in which 30% of the activity of conventional ICE vehicles is shifted to EL-Vs in these six demonstration cities.[15] The latter scenario showed **significant environmental benefits from the emissions reductions in urban areas, as well as economic benefits**. The environmental benefits from reduced air pollution are greater for those cities which now have lower air quality (i.e., Bari, Genoa, Rome, Malaga) and the benefit from sound emissions (noise) reductions will be higher in cities which have a high urban population density (i.e., Rome, Berlin) and a lot of conventional motorcycles already circulating as part of their fleet (i.e., Rome). Regarding the upstream (Well-to-Tank) CO_2, it is known that these emissions are usually higher for electricity production (to charge the EL-Vs) compared to the production of conventional fuels (i.e., petrol and diesel). A typical example is Trikala due to the many coal-fired power stations in Greece. As a result, some of the monetised

[12] Kopernikus project Ariadne (2021): Ariadne-Report: Deutschland auf dem Weg zur Klimaneutralität 2045 - Szenarien und Pfade im Modellvergleich. https://doi.org/10.48485/pik.2021.006
[13] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.
[14] ELVITEN – Electrified L-category Vehicles Integrated into Transport and Electricity Networks, EU Horizon 2020 project, 2017-2020, https://cordis.europa.eu/project/id/769926
[15] Papadimitriou, G. et al (2020): Cost-benefit analysis and potential market uptake of EL-Vs. ELVITEN D6.2. Available at https://cordis.europa.eu/project/id/769926/results

benefits from the air pollutant and GHG emission savings are ‘lost’ due to higher Well-to-Tank/Wheel CO_2 emissions for electricity production in countries where this still relies mostly on fossil fuels.

ELVITEN[16], also scaled up traffic effects of a shift to LEVs in the above six demonstration cities. Microscopic traffic modelling of different scenarios concluded that although a reduction in traffic density can have positive impacts with respect to emissions and fuel consumption, there is no clear benefit on the traffic travel time, in contrast with the initial expectations.

While there are numerous positive impacts, the life cycle analysis of LEVs should also consider the impacts of the sourcing and disposal of materials, especially in regard to the batteries - including **end of life collection, recycling systems and the recovery/re-use of materials**.[17] Further research is needed to assess systems in place and best practices. Research would also be beneficial which examined manufacturing, marketplace, consumer, operations (shared services), municipal and national practices - to resolve the results of no plans in place, and further explore best practices.

3.4 Accessibility and usage beyond urban areas

In addition to urban mobility, LEVs can significantly contribute to sustainable mobility in other areas such as suburban, regional and rural areas, and islands by offering accessibility options beyond traditional ICE vehicles to visitors and to those who prefer active transport but need to cover longer distances. This depends on the trip characteristics of inhabitants (or visitors e.g., in areas with a strong tourism economy) as well as the spatial context and characteristics of these areas. The figure below shows the distribution of substitutable passenger car mileage in Germany based on analyses conducted as part of the "LEV4Climate" study[18]. Of the total car mileage that could also be driven with LEVs in Germany, 30% is in small towns and 26% is in urban areas which represent the areas on the outskirts of cities. Of the total mileage driven by cars in metropolitan areas, 38% is substitutable with LEVs, while in other regions an average of 46% is substitutable. The maximum emission reduction potential computed in Germany varies from 58% for metropolis regions to 48% in rural or village regions. The potential described is theoretical and based on analyses of technical parameters of vehicles and travel characteristics, without considering acceptance issues. Further research is required to determine the exact hurdles in converting this potential.

[16] Georgakaki, M. et al (2020): Scaled up impacts on mobility and traffic from the usage of EL-Vs in a city-level. ELVITEN D6.1. Available at https://cordis.europa.eu/project/id/769926/results
[17] Melin, Hans Eric for the Global Battery Alliance (2018): The lithium-ion battery end-of-life market – A baseline study. Available at https://www3.weforum.org/docs/GBA_EOL_baseline_Circular_Energy_Storage.pdf
[18] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.

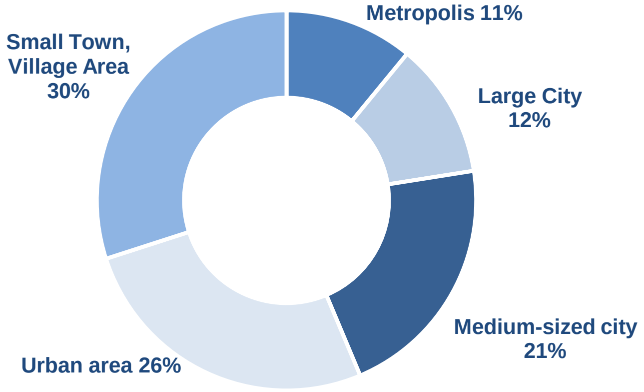


Figure 4 - Distribution of substitutable mileage by suitable LEV in Germany
(Source: DLR, LEV4Climate[19])

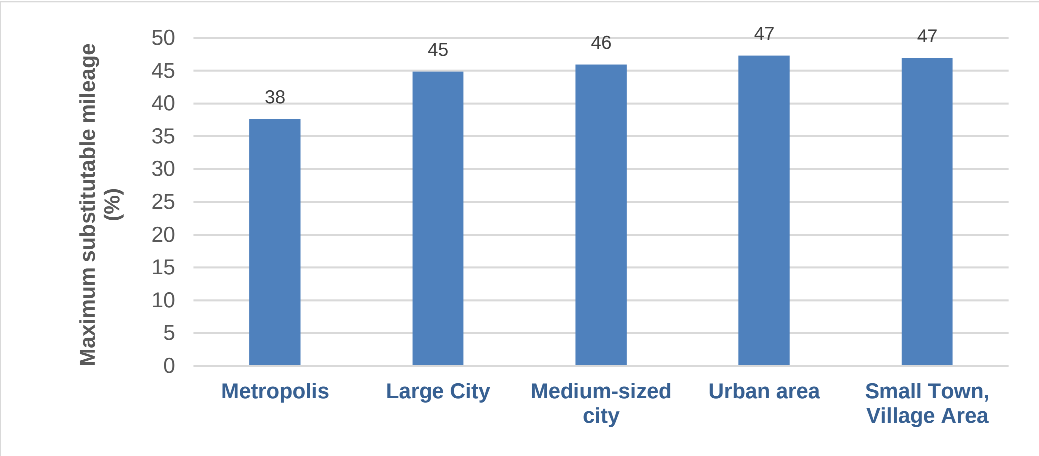


Figure 5 - Region wise maximum mileage substitution potential in Germany
(Source: DLR, based on LEV4Climate[20])

This can be explained by the high car usage in non-metropolitan areas for shorter distances. Highly dense areas have more public transport and shared mobility options due to proximity and usage, in comparison to less dense and therefore more car-dependant regions. Further research needs to be carried out on LEV use cases beyond major city centres, to **establish viable business models for low density areas, and identify specific opportunities and constraints which may be tackled by push and pull measures**,

[19] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.
[20] Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study. Project report.

e.g., the use of the e-bike for longer commuting distances, coupled with long-distance cycling infrastructure, so-called super cycle highways.

An example for successful implementation of LEVs as a means of transport is Japan. There, small Kei cars (smallest highway legal passenger car category) are a popular mode of transport, due to high cost of car ownership and to space restrictions, accounting for 28% of all vehicle registrations in 2021[21]. 14% of all Kei cars are in high density areas with 4000 inhabitants per km^2, compared to 45% in low-density areas with 500 inhabitants per km^2. 80% of low-density light car users use it for their daily needs, in comparison to 42% of high-density users[22]. **Transferability to European suburban and rural areas needs to be further researched and studied**.

3.5 Exchange of best practice

The way towards successful integration and adoption of LEVs can differ substantially between the various types of LEVs. Research on the perception of and awareness about new solutions could look at the different stakeholders (authorities granting type-approval and road-worthiness certification, road authorities, planning authorities, vehicle manufacturers, mobility service providers, and end users). Successful deployment and scaled market uptake can be compared with less successful cases, **learning the framework conditions and processes needed for success, as well as approaches, use cases or business models that did not succeed**.

As most of this activity will be based on real-life experiences, a methodology to understand and share successful cases, facilitate the exchange of best practices and share lessons learnt could be developed.

Efforts to enhance perception, awareness, information, and the exchange of best practices can be accomplished through a variety of means, including public awareness campaigns, educational programmes, industry conferences, workshops, online platforms, and collaborations between different stakeholders.

[21] Japan Automobile Manufacturers Association, Inc. The Motor Industry of Japan 2022; 2022. Available from: URL: MIoJ2022_e.pdf (jama.or.jp)
[22] Japan Automobile Manufacturers Association, Inc. FY2021 Mini Vehicle Usage Survey; 2021. Available from: URL: https://www.jama.or.jp/library/invest_analysis/s_car.html

4 Priorities for future research

This chapter presents relevant sections from previous roadmaps as well as the priorities for future research from the key topics presented in this paper. We reiterate and endorse these priorities from previous roadmaps in addition to the ones specified by this paper. Numbering of the source documents is maintained to allow for referencing.

4.1 LEV research topics from recently published roadmaps

The 2017 joint ERTRAC-ERRAC-ALICE *'Integrated Urban Mobility Roadmap'*[23] (UM Roadmap) contains a number of interesting research topics which apply to LEV issues in urban mobility and which require further attention. Below are extracts of relevant research topics from the document:

- "Understand people's needs and expectations, including those of specific groups such as young and aged citizens, as well as recently immigrated and low-income citizens, for assuring social equity – in order to understand mode choice behaviour – reasons for using active and light modes instead of the car (especially if there is a car in the household) and possibilities to promote their use;"
- "Integrate active and light travel modes in the long-term planning processes of communities, also considering a better integration of safety aspects into SUMPs and horizontal integration of health, transport and environment at the local level;"
- "Determine the possibilities for adapting urban infrastructure to promote active and light travel modes;"
- "Recognise active and light travel modes in transport surveys and transport modelling, including transport demand and emissions modelling;"
- "Study mobility management measures that can foster active and light travel modes;"
- "Analyse the relationship between built infrastructure, encouragement and modal choices";
- "Investigate intermodal transport options in a systematic manner;"
- "Research the potential of new technologies for instance for electric cycles, e-cargo cycles and electric L-category vehicles, for passenger and logistics transport; analyse the development and use of LEVs for specific target groups such as younger or older people, especially since their risk estimation capabilities are different in an ever faster moving society.";
- "Study the interaction between new LEVs and vulnerable road users (VRU);"
- "Identify new regulations required to reallocate public space dedicated to different modes of transport, notably sustainable and light modes of transport;"
- "Study the potential of active and light travel modes in sharing schemes."[24]

ERTRAC's '*Safe Road Transport Research Roadmap: Towards Vision Zero: Following the Safe System Approach'*[25]

4.10 Safety of bicyclists and users of other micro-mobility devices

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[23] ERTRAC Working Group: Joint ERTRAC-ERRAC-ALICE Working Group on Urban Mobility (2017): Integrated Urban Mobility Roadmap. Report.

[24] ERTRAC Working Group: Joint ERTRAC-ERRAC-ALICE Working Group on Urban Mobility (2017): Integrated Urban Mobility Roadmap. Report. p.70

[25] ERTRAC Working Group: Road Transport Safety & Security, 'Safe Road Transport Research Roadmap: Towards Vision Zero: Following the Safe System Approach', November 04, 2021.

"For the interaction between motor vehicles and users of any micro-mobility devices, it will be important to focus on the one hand on detection by motor vehicle-based sensor systems, and on the other hand on V2X based detection of these types of road users, in line with e.g., the MeBeSafe and the SAFE-UP projects. The inclusion of behavioural aspects is also essential and an aspect that needs further research, including the area of safety coaching features (nudging). This research should also lead to dedicated measures for automatic conflict resolution and protective safety measures for crash mitigation and a forgiving infrastructure. It shall result in new and advanced safety measures both from a technological and a behavioural perspective, while limiting the costs."[26]

Use case of LEVs if often part of shared modes or new mobility services, hence reflection of items from the New Mobility Services roadmap.

ERTRAC's '*New Mobility Services Roadmap*'[27] (NMS Roadmap)

6. Urban space and physical infrastructure

"The breakthrough of NMS in cities has resulted in the occupation of urban space and the use of infrastructure by new types of vehicles. Micro-mobility vehicles compete with traditional bikes, mopeds, and sometimes with pedestrians for public space, while cars from all types of services – rented, shared, taxi – generate congestion on lanes sometimes also taken by public transport and freight vehicles[28]. The scarcity of urban public space requires smart space management and prioritisation. From reallocation of available space to more sustainable forms of transport, intermodal hubs and interchanges enabling more seamless combinations of sustainable modes, to dynamic management of kerbside and infrastructure, and the integration of suburban areas in strategic planning, future research must set up the needed enablers for the development and expansion of sustainable, accessible, fair, and efficient services through urban space interventions. The "15-minute city" concept also is gaining ground and has an enormous potential in shaping urban planning and mobility services, with extremely positive impacts on urban quality of life."[29]

6.1. Reallocation of space and infrastructure

"The disproportionate allocation of public space in favour of motorised traffic[30], a legacy of decades of car-centred urban planning, poses a challenge to achieving sustainable mobility policy objectives. At the same time, public space is a very powerful tool at the disposal of public authorities to bring about change, and over the past years, a trend towards 'giving the streets back to the people' has been observed in many cities. By taking away space from certain modes and giving more to others, the use of unsustainable transport means can be discouraged and that of sustainable ones incentivised."[31]

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[26] ERTRAC Working Group: Road Transport Safety & Security, 'Safe Road Transport Research Roadmap: Towards Vision Zero: Following the Safe System Approach', November 04, 2021. p.28

[27] ERTRAC Working Group: Urban Mobility, '*New Mobility Services Roadmap*' v4, August 04, 2021.

[28] ReVeAL international workshop: Barriers to implementing Dynamic Kerbside Management, Per Solér, WSP Sweden, October 2020.

[29] ERTRAC Working Group: Urban Mobility, '*New Mobility Services Roadmap*' v4, August 04, 2021. p.25

[30] CIVITAS SATELLITE CSA. COVID-19 SUMP Practitioner Briefing. July 2020.

[31] ERTRAC Working Group: Urban Mobility, '*New Mobility Services Roadmap*' v4, August 04, 2021. p.25

4.2 LEV research and innovation priority topics from this paper

Activities in the area of LEVs have increased in recent years, in terms of research, vehicle development, and to some extent regulation (e.g., adequate harmonised technical legislation). Research shows that the potential of LEVs to contribute to sustainable mobility and reduce emissions and resource use is considerable. The implementation of the potential in practice needs to be accelerated, and for this it is important to gain more comprehensive knowledge that identifies deployment pathways, addresses barriers, and provides solutions to unresolved challenges. Intensification of research is required for this in the areas described below.

The adaptation of transport systems to growing numbers of LEVs has to be well thought through. Often policies focus on simple measures, e.g., maximum speed and parking, ignoring the interaction of LEVs with other road users, safety considerations, and their integration into the transport system in general.

How the future adoption of these vehicles and the resulting modal shift will look is largely unknown due to the lack of comprehensive data, including on reasons for users choosing to use (or not use) LEVs and what their alternative modes would be. We need to be clear that not all LEV users would transfer from ICE cars; some would shift from soft/active modes or public transport, but statistics do not give clear patterns. LEV user profiles are equally unknown (journey purpose, length, age, what other modes were available or were considered, etc.).

The impacts on traffic safety should also be assessed in various situations, including integration with other modes, and space allocated for usage, storage, and charging - in order to avoid conflicts, injuries and negative perceptions of LEVs.

The potential contribution of LEVs to sustainable transport is such that their market uptake and deployment should be accompanied by adequate research, innovation, and policies at EU, national, regional, and local levels. With that, policymakers should also consider that both unclear rules and overregulation may discourage use. This in turn may affect planning for car-free, climate-neutral, zero-emission cities, where light mobility can be a strong asset. The introduction of projects focused on researching the potentials, the unknowns, and best practices with LEVs, which support data-based decision making would contribute to the evolution of everyday usage of LEVs and help to integrate them into multimodal trips as well.

Examining past trends in transport emissions and the increasing success of large and heavy vehicles, whether electric or with combustion engines, it seems evident that exclusively relying on incentives will be inadequate for fully harnessing emission reduction potential related to LEVs. To envision a future where a substantial portion of large and heavy vehicles transitions to LEVs, a holistic approach, encompassing "push measures" aimed at discouraging the use of heavy vehicles, will be necessary. Research can offer valuable insights to support this challenging task.

The following summarises guiding topics, questions and context of LEVs in urban mobility and leads into the research and innovation priorities from this paper.

Defining LEVs

Clarification of terminology and classification

The current status of LEVs in regulatory frameworks clearly shows the need for a consistent and aligned definition. Uniform classifications and terminology would facilitate future proofing the drafting of legislation and policy, as well as serve to align terminology used on the EU level, nationally and locally. Research which supports an examination of present terminology, simplification of classifications and related guidelines would benefit this cause. However, a substantial amount of research should be carried out before lifting existing consumer safety regulations, in order to avoid potentially unsafe results.

Infrastructure

How can the infrastructure be adapted for safer accommodation of these vehicles?

Use and design of public and private space

Traffic codes and rules should be reviewed from a holistic perspective of the growing diversification of vehicles on the road. To support the usage of smaller LEVs, research should be conducted on effectively implementing incremental changes and re-allocations of space that can begin to counteract decades of car-centric planning towards a better balance. Research is also recommended on the dynamic management of space (function, time of day usage, space allocated to parking vs. other uses, etc.) and the placement and future planning of supporting infrastructure (charging, signage, etc.), which does not obstruct or subtract from the space allocated to LEVs and active mobility.

Infrastructure safety

Research is lacking in regard to the interaction between >25 km/h LEVs (e.g., speed pedelecs) and other <25 km/h vehicles (e.g., cycles) in dedicated lanes. Consequently, investment in infrastructure safety, with a particular emphasis on road space allocation, and the review of traffic codes emerge as critical determinants in promoting the use of light electric vehicles. This underscores the need for further research and policy focus in those areas.

Mobility hubs and secure parking facilities

Mobility hubs serve to support journeys using a combination of modes. In order to support sustainable first/last/ as well as mid-journey solutions, parking should be secure, charging should be an option, transfers should be convenient, and barriers should be minimised, such as parking costs and rental of LEVs through a common platform which allows a simplified approach to pick up and return to various locations.

The characteristics of LEVs creates specific parking concerns. The cost of the vehicles and the fragility of the technology raises concerns about open air and unprotected parking and increases the need for secure parking facilities. Further research is needed in integrating charging into secure parking facilities.

Research is still needed in relation to optimising LEV parking security, as smaller electric vehicles represent significant personal investment supporting a shift to sustainable mobility and remain the target of thieves, despite various security measures which are often in place.

Further research is needed in leveraging data to support MaaS solutions, and space management, and security in multimodal hubs to enhance intermodality. This would support the integration of LEVs as a convenient and viable part of longer journeys.

Charging infrastructure / Swappable battery technology

Battery swapping infrastructure could be more energy-efficient and cost-effective to implement than traditional charging stations in certain settings, particularly in urban areas where space is at a premium. However, to fully realise this potential, it is crucial for the EU to establish a harmonised standard for swappable batteries, ensuring interoperability across different manufacturers and regions. This will not only foster innovation and competition but also facilitate the creation of a robust, pan-European battery swapping network. The value of swappable battery technology is a topic for further study.

Safety

How can the vehicles be designed to be safer?

The existing legal framework and safety standards should be assessed for the production and testing of LEV vehicles, related batteries, and electronics to enhance consumer safety.

Regulations, standards and tests should be scrutinised to find out whether these are optimised for electric vehicles. Even where standards exist for comparable products, there may be inconsistencies in the requirements within those standards. This may be due to a legacy issue or lack of liaison between different technical committees responsible for drafting and developing interrelated standards.[32] Further research should be carried out to align safety standards, including legacy issues and considering future innovation on the radar, in order to address and avoid such inconsistencies. This effort should involve the cooperation of key technical committees and related stakeholders in order to bring various areas of expertise to the table.

Technological systems in the field of active and passive safety, especially for larger LEVs such as microcars, must be further researched to assess potential improvements to occupant safety, but also the safety of other road users.

Equipment safety

Speed pedelecs and e-scooters with seats are categorised as mopeds. Further research should focus on understanding how to improve technical legislation, road infrastructure and existing guidelines for these new vehicles.

LEVs with speeds equal to or below 25 km/h, the guidelines designed for cycles should be deemed applicable, given that most of the LEVs have a comparable or even lower kinetic energy. Data on accidents with these vehicles is either missing or (under)reported under different vehicle categories, therefore safety and potential safety issues are difficult to assess. Research focused on standardising the collection of this

[32] Electrical Safety First, July 2023, "Battery Breakdown: Why are e-scooter and e-bike batteries exploding in people’s homes and what can be done about it?"

data as well as on assessing the impact on existing cycle lanes and at what point the increased usage requires expanded space to ensure user safety.

Focus is needed to address safety aspects, such as training to ensure familiarity with new types of vehicles, the need and required adaption of licensing training for LEVs, and determination of the best space for various new modes. Safety risks exist for LEV users on the roads and potentially for slower users in the cycle lanes. Regardless, clearly designating and optimising these spaces would help reduce friction with other modes and reduce negative perceptions of LEVs.

Battery Safety

LEVs are on the rise. This development requires extra attention to the (fire) safety of LEVs by manufacturers and further research on the development of innovative battery management systems, not only for passenger cars, but also for LEVs.[33]

Fire safety is a topic that has been mentioned several times during the SRIA update of the 2Zero Partnership, but the main topic of interest was related to the safety of charging in (underground) garages, and there has been no particular focus on fire safety of LEV and e-scooters yet.

A recommendation might be to push for R&I, as well as collaboration, between public authorities, OEMs and other stakeholders with Batteries Europe[34] (the technology platform of batteries). They also have a safety task force[35] which might have already identified some activities.

User Behaviour

Research would be valuable in regard to the determination of LEV user groups and development of LEVs for specific target groups, e.g., older/younger, people with disabilities.

Data on crashes with LEVs is either missing or (under)reported under different vehicle categories so safety is difficult to assess. LEVs need to be identified and introduced in accident statistics.

Research is lacking in regard to the interaction between >25 km/h LEVs (e.g., speed pedelecs) and other <25 km/h vehicles (e.g., cycles) in dedicated lanes.

How the future adoption of these vehicles and the resulting modal shift will look is largely unknown due to the lack of comprehensive data, including on reasons for users choosing to use (or not use) LEVs and what their alternative modes would be.

How can regulatory measures support safety?

Inexperienced users of LEVs, for example, first-time users of shared e-scooters, are often not aware of the speed and the acceleration that these vehicles are capable of, putting these users at higher risk.

[33] Netherlands Institute for Public Safety (NIPV) "Analysis of media reports of fires with Light Electric Vehicles 2020-2022", 15. March 2023. 20230315-NIPV-Analyse-mediaberichten-branden-met-LEVs.pdf
[34] Batteries Europe. 2023. https://batterieseurope.eu/workstream-bodies/integrated-working-groups/
[35] Batteries Europe. 2023. https://batterieseurope.eu/workstream-bodies/cross-cutting-task-forces/

Inadequate user behaviour increases the risk of road accidents and collisions with pedestrians and other vulnerable road users,

There is also the risk of battery fires, as a puncture or an impact from a crash may result in the batteries igniting and lead to “thermal runaway” of the chemicals inside the battery. Thermal runaway cannot be stopped once it starts without specialist fire suppression and containment equipment. This has resulted in many injuries where people have tried to stop the fire using standard fire extinguishers.

Manufacturers, operators and public authorities need to raise awareness for proper user behaviour and inform/train users. All of these stakeholders should contribute to fire-safe behaviour of consumers with information about fire-safe use (maintenance, loading, storage).

Research is needed on assessing mitigating measures which may be necessary to address user aspects (competence, training, personal choices on e.g., wearing protective equipment), vehicle aspects (technical aspects, maximum speed, etc.), interaction in traffic with other road users/traffic participants, aspects in the environment/surroundings (infrastructure, road type use, road conditions, etc.), and impacts of various regulations and legislation on different levels (where these vehicles are allowed, shared/rented vs. private, etc.).

Environmental impacts

While there are numerous positive impacts of LEVs, the impacts of the sourcing and disposal of materials, especially in regard to the batteries – including end of life collection, recycling systems and the recovery/re-use of materials should be further researched. Research is needed to assess systems in place and best practices. Research would also be beneficial which examined manufacturing, marketplace, consumer, operations (shared services), municipal and national practices - to resolve the results of no plans in place, and further explore best practices.

A significant environmental impact can only be achieved if LEVs are used in considerably higher numbers than today, replacing less sustainable vehicles. In all likelihood, communicative measures and incentives (financial, regulatory, etc.) alone will not be sufficient to bring about such a change within the timeframe set by climate protection targets. Rather, a holistic approach is needed that addresses many fields and combines incentives with "push" measures aimed at discouraging the use of heavy vehicles. Research can provide valuable insights to support this challenging task, as acceptance of push measures is usually harder to achieve than pull measures. So, in addition to research on life cycle assessment, increasing lifetime performance and similar issues, research on environmental impacts must also focus on implementation issues.

Accessibility and usage beyond urban areas

Further research is needed on the effects of different sets of measures that include regulation of different areas and push and pull measures.

In view of the high urgency and relevance for GHG emission reduction, reliance on incentives is probably insufficient. Further research is needed to investigate possible effects of different sets of measures in order to support climate mitigation effectively, efficiently, reliably, and rapidly. Sets of measures could affect regulation, infrastructure, (external) costs and more. Push and pull measures for behavioural changes need to be accompanied by safe, affordable and convenient transport alternatives. Further research should be conducted on the situations, infrastructure, and factors which 'allow' and 'support' this shift to LEVs and sustainable transport - within homes, organisations, and by public authorities.

Further research needs to be carried out on LEV use cases beyond major city centres, and in rural areas to establish viable business models for low density areas, and identify specific opportunities and constraints which may be tackled by push and pull measures, e.g., the use of the e-bike for longer commuting distances, coupled with long-distance cycling infrastructure, so-called super cycle highways.

Additionally, international LEV solutions, take up and usage should be researched and studied more to explore the potential for transferability to European suburban and rural areas.

Exchange of best practice

Research and innovation topics should be inclusive of the following elements and considerations in order to explore and share best practices for a range of scenarios. These include:

- Social, ecological, and planning implications of scaled roll-outs
- User acceptance factors and user requirements, including gender perspective
- Understanding and reducing obstacles for uptake
- Incentives - factors for maximising uptake
- Collecting and analysing evidence of successes and failures, the reasons for them, necessary framework conditions, good practice and lessons learnt

The way towards successful integration and adoption of LEVs can differ substantially between the various types of LEVs. Successful deployment and scaled market-uptake can be compared with less successful cases, learning the framework conditions and processes needed for success, as well as approaches, use cases or business models that did not succeed. As most of this activity will be based on real-life experiences, a methodology to understand and share successful cases, facilitate the exchange of best practices and share lessons learnt could be developed.

5 List of tables and figures

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6 References

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Annex 1 - Recent projects in this field

European LEV projects funded by the European Commission:

BATTERY PLUS
High performing batteries for accelerated uptake of hybrid and electric vehicles.
From: 1 December 2019
To: 31 May 2022
https://cordis.europa.eu/project/id/881472

BB6S
Active Anti-lock braking system for e-bikes able to avoid the front wheel locking and the rear wheel lifting increasing cyclist safety during braking
From: 1 June 2018
To: 31 May 2020
https://cordis.europa.eu/project/id/823116

BEHICLE
BEst in class veHICLE: Safe urban mobility in a sustainable transport value-chain
From: 1 November 2013
To: 30 April 2017
https://cordis.europa.eu/project/id/605292

BICAR
The definitive 100% energy autonomous, CO2-free and recyclable last mile solution
From: 1 May 2018
To: 30 September 2018
https://cordis.europa.eu/project/id/815899

CityChangerCargoBike
From: 1 September 2018
To: 31 July 2022
https://cordis.europa.eu/project/id/769086

CLEVER
Compact low emission vehicle for urban transport
From: 1 December 2002
To: 31 March 2006
https://cordis.europa.eu/project/id/G3RD-CT-2002-00815

ECOSHELL
Development of new light high-performance environmentally benign composites made of bio-materials and bio-resins for electric car application

From: 1 January 2011
To: 31 December 2013
https://cordis.europa.eu/project/id/265838

ELVITEN
Electrified L-category Vehicles Integrated into Transport and Electricity Networks
From: 1 November 2017
To: 31 October 2020
https://cordis.europa.eu/project/id/769926

ESPRIT
Easily diStributed Personal RapId Transit
From: 1 May 2015
To: 31 October 2018
https://cordis.europa.eu/project/id/653395

EU-LIVE
Efficient Urban LIght VEhicles
From: 1 June 2015
To: 31 May 2018
https://cordis.europa.eu/project/id/653203

FREVUE
VALIDATING FREIGHT ELECTRIC VEHICLES IN URBAN EUROPE
From: 15 March 2013
To: 14 September 2017
https://cordis.europa.eu/project/id/321622

FREEWAY
FREEWAY: safely and effortless commute in an urban environment
From: 1 June 2015
To: 30 November 2017
https://cordis.europa.eu/project/id/672389

FURBOT
Freight Urban RoBOTic vehicle
From: 1 November 2011
To: 31 December 2015
https://cordis.europa.eu/project/id/285055

GEM
GEM in-wheel motor
From: 1 December 2015
To: 31 December 2017
https://cordis.europa.eu/project/id/691371

ISABELLE
Integrated SAfety Benefit Estimation tooL for 2-wheeLErs
From: 1 June 2012
To: 11 November 2017
https://cordis.europa.eu/project/id/294264

LockAndCharge
Ground-breaking and convenient electronic bicycle fleet management system available for the mass adoption.
From: 1 February 2016
To: 31 May 2016
https://cordis.europa.eu/project/id/711607

ONO
A Whole New Category of Vehicle: The ONO Pedal Assisted Transporter
From: 1 August 2020
To: 31 July 2022
https://cordis.europa.eu/project/id/960713

PowerShare
Charging network optimized for Light Electric Vehicles (LEVs)
From: 1 October 2018
To: 28 February 2019
https://cordis.europa.eu/project/id/837353

PROSFET
Promoting Sustainable Freight Transport in Urban Contexts: Policy and Decision-Making Approaches
From: 1 January 2017
To: 31 December 2019
https://cordis.europa.eu/project/id/734909

RESOLVE
Range of Electric SOlutions for L-category VEhicles
From: 1 May 2015
To: 30 April 2018
https://cordis.europa.eu/project/id/653511

Silver Stream
Social innovation and light electric vehicle revolution on streets and ambient
From: 1 June 2015
To: 31 May 2018
Sustainable and affordable personal mobility for the growing and ageing population in congested European cities
https://cordis.europa.eu/project/id/653861

SMART BIKING
Safe parking system for bicycles
From: 1 March 2016
To: 31 August 2016
https://cordis.europa.eu/project/id/729640

STEVE
Smart-Taylored L-category Electric Vehicle demonstration in hEtherogeneous urban use-cases
From: 1 November 2017
To: 28 February 2021
https://cordis.europa.eu/project/id/769944

Torqway
Hybrid Safe personal transportation that makes you healthier.
From: 1 October 2017
To: 31 January 2020
https://cordis.europa.eu/project/id/778154

UDO
The ultimate commuting solution for a car-free city
From: 1 August 2017
To: 30 November 2017
https://cordis.europa.eu/project/id/781145

WEEVIL
Ultralight and ultrasafe adaptable 3-wheeler
From: 1 June 2015
To: 31 May 2019
https://cordis.europa.eu/project/id/653926

ZED
Innovative electric traction Module for Zero Emission downsized urban vehicle
From: 1 January 1998
To: 29 February 2000
https://cordis.europa.eu/project/id/JOE3970067

Annex 2 - Ongoing projects in this field

European LEV projects funded by the European Commission:

eCharge4Drivers

Electric Vehicle Charging Infrastructure for improved User Experience

From: 1 June 2020

To: 31 May2024

As the popularity of electric vehicles (EV) grows, users' needs and expectations on charging solutions and services are increasing. The EU-funded eCharge4Drivers project will improve the user experience as regards available charging options and services. Specifically, it will develop and demonstrate user-friendly charging stations, smart services and charging solutions, including mobile charging and battery swapping stations. User-centric services such as route planning, booking, and charging location planning will be developed to further improve users' experience and foster e-mobility growth. The project's user-friendly charging systems and interoperable services will be demonstrated in 10 areas, covering cities and regions (Barcelona, Berlin, Bari, Zellik, Grenoble-Alpes and Luxembourg), the Trans-European Transport Network and cross-border routes (Austria, Northern Italy, Greece, Istanbul & Western Turkey). The project will conclude with recommendations for legislative and regulatory amendments, as well as guidelines for the sustainability of charging infrastructure investments.

https://cordis.europa.eu/project/id/875131

www.echarge4drivers.eu

Green-Log
Cooperative and Interconnected Green delivery solutions towards an era of optimized zero emission last-mile Logistics
From: 1 January 2023
To: 30 June 2026

GreenLog accelerates systemic changes in last mile delivery ecosystems for economically, environmentally and socially sustainable city logistics. The project establishes city platforms comprising of inclusive stakeholder Urban Living Labs for nurturing social innovation, designing and deploying innovative delivery solutions while allowing the most effective exchange of ideas, the development of robust, harmonized regulatory and policy frameworks, and cooperative business models that build upon effective public/private-sector collaboration and joint investments. The GreenLog approach provides an innovative simulation environment for scenario building combining different solutions that allow the integration of last-mile delivery interventions with the highest possible impact on environmental sustainability and traffic reduction, while considering their financial viability. On the operational level, GreenLog provides cargo-bike based innovations for sustainable micro-consolidation design and deployments, multimodal parcel

deliveries integrating public transportation, Logistic as a Service platforms for interconnected city logistics and automated delivery concepts with the use of autonomous vehicles and delivery droids.
https://cordis.europa.eu/project/id/101069892
https://greenlog-project.eu/

LENS
L-vehicles Emissions and Noise mitigation Solutions
From: 1 September 2022
To: 31 August 2025

Cities, regulators, and enforcement officials need support in finding ways to reduce noise and air pollution generated by motorcycles and mopeds, i.e., L-category vehicles (LVs). The EU-funded LENS project will apply techniques to monitor LVs' noise and emissions, provide recommendations on how to control the contribution of current and future LVs, examine emissions and noise performance under real driving conditions and deploy methods to identify tampered vehicles. LENS will conduct detailed pollutant and noise characterization to more than 150 vehicles in the lab and on the road and will demonstrate the impacts of LENS recommendations in 3 case studies at different spatial and temporal resolutions. LENS output will be tools and methods for less noise and better air in cities.
https://cordis.europa.eu/project/id/101056777

LEVIS
Advanced Light materials for sustainable Electrical Vehicles by Integration of eco-design and circular economy Strategies
From: 1 February 2021
To: 31 January 2024

New materials light up the path for electric cars
Lightweight materials are required to drive the electric car market in the coming years. The reason is simple: it takes less energy to accelerate a lighter object than a heavier one. In this context, the EU-funded LEVIS project will develop multi-material structural parts using thermoplastic-based carbon fibre reinforced plastics/metal hybrid materials integrated with a structural health monitoring system. The aim is to achieve a significant weight reduction while keeping the mechanical in-service performance of the targeted parts. As such, new sustainable materials and suitable manufacturing and assembly procedures as well as advanced simulation methodologies/workflows and innovative sensing/monitoring technologies will be developed.
https://cordis.europa.eu/project/id/101006888
https://greenvehicles-levis.eu/

REFLECTIVE
RECONFIGURABLE LIGHT ELECTRIC VEHICLE
From: 1 February 2021
To: 31 January 2024

A less polluting means of moving. Emissions from the transport sector are a major contributor to climate change. Transport represents almost a quarter of Europe's greenhouse gas emissions. It is also the main

cause of air pollution in the cities. To address this situation, the EU-funded REFLECTIVE project will develop and test an innovative, modular vehicle concept tailored for urban usage needs. This new vehicle will be zero-emission, compact and safe. More specifically, this new vehicle will be electric, modular and scalable with reconfigurable interiors. Not only will this new vehicle meet the highest quality standards, it will also be affordable (making it irresistible for any urban environment).
https://cordis.europa.eu/project/id/101006747
https://www.reflective-h2020.eu/

SOLUTIONS-PLUS
Integrated Urban Electric Mobility Solutions in the Context of the Paris Agreement, the Sustainable Development Goals and the New Urban Agenda
From: 1 January 2020
To: 31 December 2023

Innovative and integrated e-mobility solutions represent a key step in the transition towards low-carbon urban mobility and are compliant with the Paris Agreement goals. The EU-funded SOLUTIONSplus project proposes the development of an innovative and highly effective approach to urban e-mobility that will lead mobility systems to meet sustainable development goals and address the New Urban Agenda. The project will conduct city level displays to test diverse innovative e-mobility solutions and engage a wide range of highly committed actors such as cities, industries, research and implementing institutions and finance partners. SOLUTIONSplus has secured direct co-funding contributions from cities involved in the project and cooperates with the UN Environment Programme (UNEP) and the International Energy Agency (IEA) on a common global urban e-mobility programme.
https://cordis.europa.eu/project/id/875041
https://www.solutionsplus.eu/

ULaaDS
Urban Logistics as an on Demand Service
From: 1 September 2020
To: 29 February 2024

The EU-funded ULaaDS project sets out to offer a new approach to system innovation in urban logistics. Its vision is to develop sustainable and liveable cities through re-localisation of logistics activities and re-configuration of freight flows at different scales. Specifically, ULaaDS will use a combination of innovative technology solutions (vehicles, equipment and infrastructure), new schemes for horizontal collaboration (driven by the sharing economy) and policy measures and interventions as catalysers of a systemic change in urban and peri-urban service infrastructure. This aims to support cities in the path of integrating sustainable and cooperative logistics systems into their sustainable urban mobility plans (SUMPs). ULaaDS will deliver a novel framework to support urban logistics planning aligning industry, market and government needs, following an intensive multi-stakeholder collaboration process. This will create favourable conditions for the private sector to adopt sustainable principles for urban logistics, while enhancing cities' adaptive capacity to respond to rapidly changing needs. The project findings will be translated into open decision support tools and guidelines.
https://cordis.europa.eu/project/id/861833
https://ulaads.eu/

USER-CHI
innovative solutions for USER centric CHarging Infrastructure
From: 1 February 2020
To: 31 January 2024

Improving user experience of EVs. Europe's electric vehicle (EV) sector has significantly evolved over the past years. Accelerating electromobility is a priority and requires a series of innovative measures. The EU-funded USER-CHI project will promote large-scale electromobility market take up in Europe through smart solutions, novel business models and new regulatory framework conditions. The aim will be to integrate innovative charging technologies and put the user at the centre of the entire transition. The project will also exploit the synergies between electromobility and the process of greening and smartification of the grid. To pave the way for more EVs, the project will integrate the technological tools, business models and regulatory measures to be tested and validated in five EU cities (Barcelona, Rome, Berlin, Budapest and Turku).
https://cordis.europa.eu/project/id/875187
https://www.userchi.eu/