future transportation

Article

What Potential Do Light Electric Vehicles Have to Reduce Car Trips?

Laura Gebhardt [1,*], Mascha Brost [2] and Robert Seiffert [1]

[1] Institute of Transport Research, German Aerospace Center (DLR), Rudower Chaussee 7, 12489 Berlin, Germany
[2] Institute of Vehicle Concepts, German Aerospace Center (DLR), Pfaffenwaldring 38-40, 70569 Stuttgart, Germany
* Correspondence: laura.gebhardt@dlr.de

Abstract: Climate protection goals in transportation can only be achieved with a worldwide change in mobility behavior that is supported by technological progress and changes in vehicle concepts. One contribution to reducing greenhouse gas emissions may be using small and light electric vehicles (LEVs) instead of cars. LEVs have a favorable ratio of vehicle weight to payload and the efficiency of electric drives contributes to environmental sustainability. As with full-sized electrically powered cars, emissions from combustion processes are eliminated. Going beyond that, the traction batteries in LEVs can be considerably smaller, thereby reducing the consumption of critical raw materials and lowering production-related greenhouse gas emissions. Against this background, we present the results of a study which aimed to determine what proportion of current passenger car trips in Germany could, in theoretical terms, be covered by LEVs. Our estimation of the substitution potential of LEVs for car trips is based on the 2017 Mobility in Germany (MiD) survey, a national household travel survey (NHTS) containing the data of 960,619 trips. Many different types of vehicles, ranging from e-scooters, cargo bikes, and pedelecs to three- and four-wheeled light electric vehicles, are considered. The results show that up to 76% of car trips and 50% of car mileage could theoretically be substituted by LEVs. The results are further analyzed to determine for which trip purposes and age groups the greatest substitution potential exists. Based on the results, we discuss ways for supporting the realization of this potential as well as factors that determine whether the theoretically calculated potential can be realized.

Keywords: micro-mobility; LEV; potential analysis; car trip substitution; user acceptance

check for updates

Citation: Gebhardt, L.; Brost, M.; Seiffert, R. What Potential Do Light Electric Vehicles Have to Reduce Car Trips?. *Future Transp.* **2023**, *3*, 918–930. https://doi.org/10.3390/futuretransp3030051

Academic Editor: Armando Cartenì

Received: 19 April 2023
Revised: 19 May 2023
Accepted: 4 July 2023
Published: 12 July 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The desired climate protection goals and the transformation toward sustainable and livable cities cannot be achieved only through technical innovations or technological progress [1]. A worldwide change in mobility behavior is needed. Replacing large passenger cars with small and light electric vehicles (LEVs) can contribute to the reduction in greenhouse gas emissions and enhance quality of life, especially in cities. LEVs have a favorable ratio of vehicle weight to payload (passengers or goods), which contributes to a lower energy consumption compared to passenger cars [2] and, thus, a reduction in greenhouse gas emissions. As with electrically powered passenger cars, there are no local emissions from the combustion process. In contrast to large and heavy electric passenger cars, however, the traction batteries in LEVs could be significantly smaller so that the consumption of critical raw materials is also reduced, thus also reducing production-related greenhouse gas emissions. These small vehicles also take up far less space, a rare commodity especially in growing cities [3]. Mobility is, therefore, becoming more efficient and the use of resources to transport people and goods from A to B is being optimized.

Compared to passenger cars, LEVs are relatively under-researched; however, there are some studies and publications that address topics such as market potential, safety, or regulations (e.g., [4–7]). To the best of the authors' knowledge, there is no modeling of the substitution potential of passenger car trips by LEVs that includes associated CO2eq savings. There exists a previous analysis of substitutable passenger car trips without LCA modeling [8,9], which was used to prepare for this study. The study presented here goes beyond this and extends previous analyses by including other vehicle categories and analysis criteria for the substitution of car trips, as well as by including LCAs and the calculation of CO2eq that can be saved.

Against this background, this paper investigates what proportion of trips made by car in Germany today could, in purely theoretical terms, be covered by LEVs. While the study shows the potential of LEVs substituting for passenger cars, additional measures that may be necessary to achieve the desired climate targets, such as shifting road freight traffic to rail, are not included.

The analysis is based on representative, empirical data on mobility behavior in Germany (using the Germany-wide representative survey "Mobility in Germany" (MiD) 2017 [10]). By comparing defined vehicle characteristics (e.g., speed, possibilities to transport people, and range) and characteristics of trips, trips for which LEVs can be used are identified. This is used to calculate passenger car trips and kilometers that could be substituted with an LEV. Many different types of vehicles are considered, ranging from e-scooters, cargo bikes, and pedelecs to three- and four-wheeled LEVs. The data analysis makes it possible to show in which contexts LEVs could theoretically be used and car travel could be replaced.

Since these calculated potentials are theoretically possible potentials, we would like to discuss in a second step which measures and external conditions would have to be created in order to realize the potential, at least in part. The results presented are part of the study "LEV4Climate" [11], which also includes the calculation of life-cycle emissions and greenhouse gas saving potential. In this article, the focus is on the trip substitution potential and possible measures to promote LEVs.

In the following sections, a brief overview of the different LEVs considered in this study is given (see Section 2). Subsequently, the data basis as well as the methodological procedure for calculating the substitution potential is shown (Section 3). Following that, the results of the analyses are presented (Section 4) and discussed regarding the potential to substitute car trips (Section 5). The article ends with a conclusion (Section 6).

2. LEVs: Terminology and Considered Vehicles

In addition to the term LEV, there are several other terms such as micro-mobiles, personal electric vehicles (PEVs), or neighborhood electric vehicles (NEVs), which have a considerable different meaning with regard to the types of vehicles included and which are also not used uniformly [12]. Differences in the definition of terms, vehicle homologation, and usage exist internationally and with reference to the context (technical literature, press, politics, etc.) [6,13,14]. In this paper, the term LEV covers a wide range of different vehicles—from e-scooters to electric bicycles, cargo bikes, electric scooters, and motorbikes to three- and four-wheeled light electric vehicles, sometimes also called "microcars". LEVs include vehicle models with or without an enclosed passenger compartment; with no seat, one seat, or two or more seats; and with design speeds exceeding 100 km/h for some vehicles such as the Nobe car (https://nobecars.com, accessed on 15 April 2023). In the EU, apart from e-scooters and bicycles, LEVs are divided into seven categories from L1e to L7e according to Regulation (EU) No 168/2013 [15], each with different specifications regarding technical characteristics, such as dimensions, weight, drive power, or maximum design speed. For this study, nine LEV categories form the basis for estimating the potential of LEVs to replace car trips. Table 1 shows the chosen categories and a selection of parameters. An overview of all parameters used in this study is provided in the main study [11] and in Appendix A (Table A1).

Table 1. Characteristics of the considered LEVs.

Category	Icon	Max. Speed in km/h	Number of Seats	Relevant Range * in km (Roundtrip)
E-Scooter		20	0 (standing use)	8
E-bike		25	1	30
E-bike+		25	1 (+3 children)	30
Speed Pedelec		45	1	60
Moped		45	2	60
Motorcycle		120	2	90
Microcar 45		45	2	80
Microcar 90		90	2	140
Microcar 125		128	3	140

* The relevant travel distance defines a roundtrip length that is well rideable using a respective LEV based on the literature and expert assessments. It is shorter than the technical electric range.

For each category, an exemplary LEV model which is already available on the market (or will be available soon) was used to define technical parameters. Most parameters, such as weight, technical electrical range, and seating capacity, are used for the analyses without adjustments. With regard to the modeling of a future scenario, it is assumed that, due to technological progress, the lifetime mileage will increase. Even though other technical parameters are expected to develop positive as well, they are left at the current level to provide a rather conservative estimate. The exemplary models were selected as described below.

By conducting a market analysis, different LEV categories such as e-scooters and mopeds were examined, and the technical characteristics of selected models were compared for each category. For this purpose, we considered series models that are available on the market, models with announced sales launch for 2022, and models that have been tested in pilot projects. Based on the analysis, a selection of categories and one exemplary vehicle model for each category was made, which aimed to (a) cover a broad range of characteristics and capabilities, thereby addressing various use cases to identify maximum trip substitution potential; (b) make choices that overall capture the heterogeneity of LEV categories and models; (c) limit the number of possibilities and by thus the modelling effort but also creating comprehensive and memorable results; and (d) select models with low expected CO2eq emission, for example, models with a battery capacity sufficient for a required range, but not much higher.

3. Methodological Approach to Identify the Substitution Potential of LEVs

The estimation of the theoretical substitution potential of LEVs for car trips is based on a national household travel survey conducted in 2017 (MiD 2017) [10], containing data on 960,619 trips collected between May 2016 and September 2017 in Germany [16]. The dataset provides various kinds of information for each trip, such as trip length, trip purpose, number of passengers, and the respondent's age. Based on the MiD 2017 dataset, it is possible to calculate the absolute values that are representative of the mobility behavior of the residential population of Germany. The dataset, therefore, provides an extrapolation factor which is based on the socio-demographic characteristics of the respondents [17]. This factor is used in this study to calculate the absolute numbers of car trips and vehicle mileage.

When discussing personal motorized vehicle trips, notably, about 95% of these trips in Germany are made by cars, with the remainder being made by trucks and motorcycles.

For the sake of convenience, we use the term personal motorized vehicle trips or car trips synonymously in this paper. It refers to car, truck, and motorcycle trips.

In order to identify car trips that could theoretically be replaced by trips with an LEV, the car trips recorded in the MiD dataset were filtered based on selected criteria. The parameters of the vehicles regarding the criteria were defined based on a literature analysis and exchange with experts. Table 2 presents an overview of the selected criteria and illustrates the step-by-step filtering process using an E-Bike+ as an example. The term E-Bike+ describes a bike suitable for transport of goods or up to three children. The parameters for all considered vehicle categories can be found in Appendix A (Table A1).

Table 2. Criteria and procedure to identify the substitution potential of LEVs. Here, e-bike+ is used to explain the methodological approach. The same procedure is used with all selected vehicles.

Criteria	Exemplary Trip Reported in a Large-Scale National Mobility Survey in Germany (MiD 2017)	Scenario with E-Bike+	Check
Trip length	8 km (one way)	Up to 15 km (single trip), and up to 30 km for round trip	√
Trip purpose	Commuting	All trip purposes, excluding the following: • Accompaniment (except children under 7 years old) • Professional trips: transport of passengers or goods and "other" • Shopping trips: "other goods"	√
Age (driver)	59	18–70 years	√
Weather	Snowfall	Without heavy rain, snowfall, or icy roads	x
Impairments	None	Only people without any health or mobility impairments	√
Number of persons	1	1 + 3 (only children up to 7 years old)	√
Use of highways *	No highway use	Not suitable for highway use, as the maximum design speed is less than 60 km/h	√

* MiD 2017 does not provide any information about what type of street was used for a car trip. Therefore, the average speed on a trip was used as an approximation with speeds above 100 km/h assumed to be at least partially highway trips.

To decide whether a motorized trip could be undertaken using an LEV, trip characteristics were compared with LEV properties for each LEV model, for example, whether the considered LEV has enough seats for the number of persons making the trip or whether the LEV can cover the length of the trip. The example shows that the characteristics of the E-Bike+ meet all the characteristics of an exemplary car trip, and only weather is not suitable for the use of an E-Bike+. Therefore, this car trip cannot be considered for substitution by an E-Bike+.

In reality, a person's individual daily trips are usually not independent of each other and neither they are recorded in the MiD dataset. Most trips in the dataset can be assigned to trip chains, or round trips, since, in most cases, they start and end at home. This aspect should not be neglected when making a realistic estimation of substitutable car trips. Therefore, most of the criteria considered here were applied to the round-trip level, i.e., if only one trip of a round trip does not meet the criteria, then all other trips of that specific round trip are also assessed as not substitutable. This approach takes into account existing dependencies between individual trips that are part of a round trip, e.g., if a private car is needed on one trip during a round trip, it must be taken along on all other trips and cannot be left behind and picked up later.

What is also important to mention at this point is that this study does not examine possible changes of the vehicle stock and whether individuals would be willing to replace their car or whether an LEV would be suitable for all trips made by one person during a complete year. Car replacement does not require LEVs to be suitable for each trip of a person or household, as non-suitable trips could be traveled, e.g., by train or with a rented car. Moreover, we assume that a transport system that largely relies on shared vehicles (LEVs and cars) would be able to reduce the vehicle stock and thus help to optimize sustainable transport.

4. Results: Car Trip Substitution Potential

In Germany, almost 111 million trips are made by car every day (own calculation based on MiD 2017 [10]). Our data analysis (see Section 3) shows that around 84 million or 76% could be replaced by the LEV models considered in this study (see Figure 1). When converted to transport performance, daily car trips add up to almost 1.8 billion vehicle kilometers, of which around 881 million kilometers or 50% could be provided by these LEV models.

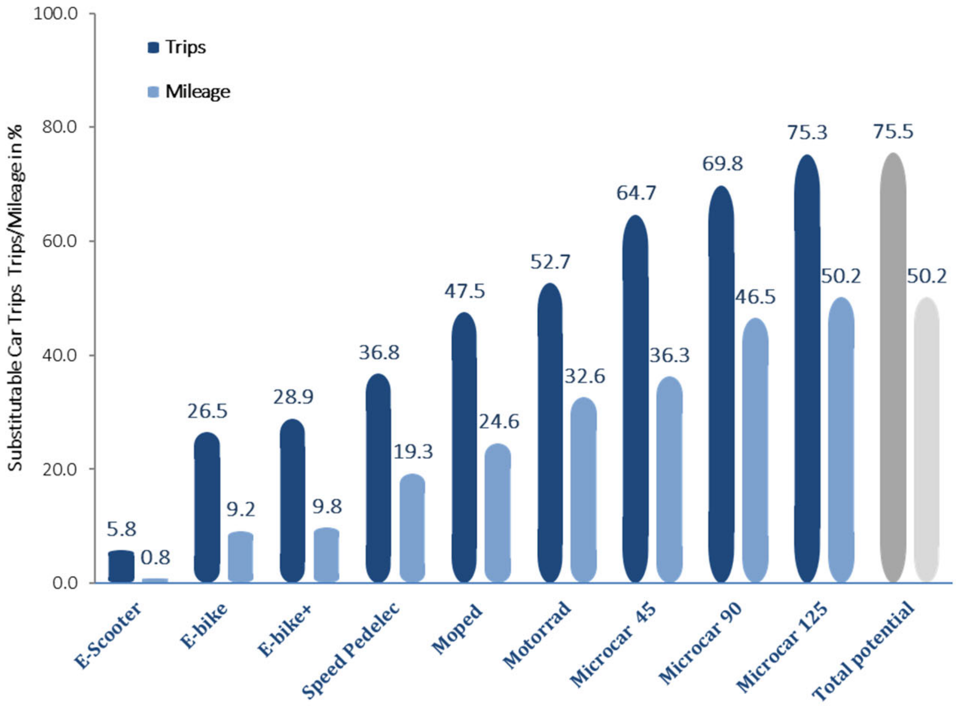

Figure 1. Substitution potential (trips and mileage).

Figure 1 shows, for each LEV category (blue columns), what proportion of car trips and kilometers could be substituted by the respective model and the total potential (grey columns) consisting of all trips that could be substituted by at least one model.

The substitution potentials differ considerably depending on the vehicle category: E-scooters are the simplest type of vehicles considered here and could substitute 6% of all car trips. E-bikes offer a considerable potential of 27%. Speed pedelecs could replace 37% of all car trips, and motorcycles could replace more than half of all trips (53%). Four-wheeled microcars offer characteristics that make them quite similar to a small conventional car. The microcar 125 offers the best characteristics in comparison to all models, so its substitution potential (75%) is close to the total substitution potential for all LEVs. Only the E-Bike+ surpasses the microcar 125 in one feature: it offers the possibility to carry up to three children.

Overall, with a substitution potential of 76% for all car trips and 50% of mileage, there is a significant potential for LEVs to substitute internal combustion engine vehicles for daily trips in Germany. Apart from certain characteristics of individual LEV models that are comparable to a conventional car, one reason for the high potential could be the short length of daily car trips and the comparatively low occupancy rate of cars in Germany: more than 80% of all car trips in Germany are shorter than 20 kilometers and more than half of the trips are made unaccompanied (own calculation based on MiD 2017 [10]).

The analyses of our overall study (see [11]) show that the calculated potential would mean a saving of around 44% in CO2eq emissions. This includes both production and use. This number should be mentioned briefly to give an order of magnitude of the CO2eq savings potential. The topic of emission savings will not be discussed in detail in this paper, but it can be found in [11,18] and related future papers.

4.1. Trip Purposes

In order to be able to estimate which trips can potentially be substituted by an LEV, Figure 2 shows the purposes of trips that can be considered substitutable. The figure makes it clear that LEVs theoretically cover the same purposes as conventional passenger cars. Thus, according to our criteria, they are not only suitable for tourist trips, as sometimes postulated in the media [19–21]. The substitution potential is somewhat higher for commuting/work and private errands trips than for the other categories. This can be explained by the fact that commuting/work trips are often made alone and trips for private errands are comparatively short, while, e.g., leisure trips are more often made with several people and are the longest car trips on average in Germany [16].

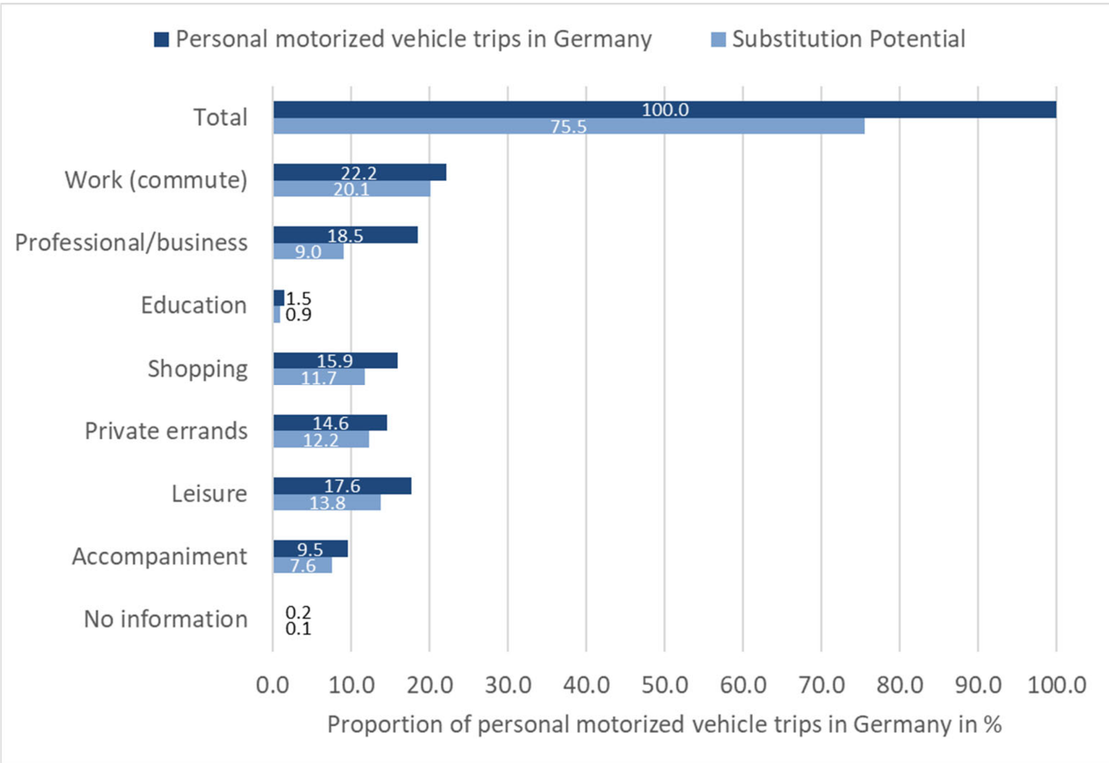

Figure 2. Personal motorized vehicle trips and substitution potential differentiated according to trip purpose.

4.2. Age

If we look at potentially substitutable car trips in terms of the age of the driver, we notice that there is a substitution potential for all age groups, but it is particularly high for the older age groups. The first column in Table 3 shows the share of the age groups for all car trips in Germany. It is noticeable that the group of 40 to 60 years old has the highest percentage of car trips. The second column shows the proportion of trips that could potentially be replaced by an LEV within the different age groups. Knowledge about age is an important information when, e.g., designing needs-based offers and measures and defining target groups for certain offers. In the current discussion, young people are often considered as early adopters and offers are tailored to these groups (the term early adopter originates from diffusion research and refers to people who buy and try out the latest products or technical innovations earlier than the majority of the population. They are usually relatively young and come from higher-education and/or higher-income milieus [22]). However, the analyses show that the potential also lies outside these groups.

Table 3. Substitution potential differentiated according to age groups.

Age	Proportion of Personal Motorized Vehicle Trips	Substitution Potential
0–9	0.5%	0%
10–19	2.4%	58%
20–29	11.6%	80%
30–39	16.7%	74%
40–49	22.0%	75%
50–59	23.0%	74%
60–69	13.3%	77%
70–79	8.2%	82%
80 and more	2.1%	81%
No information	0.2%	100%
Total	100.0%	-----

5. Discussion: What Adjustments Could Be Made to Raise the Calculated Car Trip Substitution Potential?

The analysis of the trip replacement potential shows a significant potential of 50% for substitutable car mileage, corresponding to 75% of substitute trips (see Section 4). However, in order to realize even part of this potential, comprehensive measures are required in many fields that go far beyond the development and market introduction of LEV models.

New technological innovations are driving the discussion about new mobility concepts. However, studies show that it is not (only) technology that is responsible for behavioral change but also how it is linked to certain practices of people and embedded in their everyday routines [23–25]. Accordingly, the evaluation and acceptance of technological mobility innovations are always linked to current everyday routines and mobility practices of users [25,26]. Following Lucke's theory on acceptance [27], three factors influence it: the acceptance subject, i.e., the user; the acceptance object, i.e., the LEV; and the acceptance context, i.e., the structural framework in which the object is placed. This can include, e.g., regulations or the granting of certain rights of use (parking and street space). These three aspects influence each other as a matter of course. In order to discuss the question of how the acceptance and, consequently, the use of new mobility offers can be increased, we would like to take a closer look at these three aspects in the following section. Based on the literature, our own studies [3,9,28,29], and discussions with experts, we provide below an overview of promising fields for action.

5.1. Subject

The subjects of acceptance, i.e., users and, in particular, different user groups and their requirements, must be considered. Understanding the usage requirements and barriers of different groups could improve the development of vehicles and operating conditions. Studies on users' potential acceptance of LEVs as well as specific requirements are currently still scarce and need to be extended. The following fields for action seem promising and should be evaluated in detail:

Changing mindset: This involves raising awareness of necessity to transform mobility and breaking up long-established routines and value systems. New role models and campaigns for a new mobility culture may support a transition in the current mobility culture.

Showing opportunities: This involves showing the potential for high quality of life in the city, but also in other spatial structures (participation in the countryside for people without a driving license), by converting areas that are freed up due to the little space needed by LEVs. An example of attractive urban design based on new transport concept is the Superblocks in Barcelona [30,31].

Creating low-cost offers: financial support for the use or purchase of LEVs could promote the spread of these vehicles until high numbers of use reduce the costs through economies of scale.

Providing information on LEVs and creating low-threshold access to LEVs: sharing offers or real-world labs provide an opportunity to simply try out LEVs. Transparent information on the safety of LEVs can clarify actual dangers for passengers and other road users, as well as mitigation measures, and, if necessary, allay exaggerated fears.

5.2. Object

The acceptance objects, i.e., the vehicles, could be qualitatively aligned even more with the requirements of users. The following list shows an excerpt of topics that could be improved on the vehicle side:

Increasing vehicle safety: Due to the small size and weight, small vehicles suffer disadvantages when colliding with heavy vehicles, especially at high speed [3]. Additionally, LEV safety equipment is often frugal and could be improved (active and passive safety systems). Challenges include the cost for safety equipment and technology in relation to the price of a complete vehicle, low production numbers, and requirements for a low total weight for most vehicles that fall under Regulation (EU) 168/2013 [15], as well as low legal requirements regarding vehicle homologation. Since there are physical limits to safety engineering for small vehicles, it is very important to align the operating conditions with safe operation (e.g., speed limits; see the section on context). Besides passenger protection, persons outside of these vehicles, such as pedestrians, cyclists, or passengers of other cars, must be safe. Regarding this, LEVs score with their small size and rather slow speeds, yet pedestrian protection could be further developed through technical measures.

Reducing costs: Due to low sales figures, LEVs are relatively expensive compared to passenger cars. In Germany, there are comprehensive subsidies for electric cars, but not for LEVs, which reinforces the discrepancy. To encourage market uptake, purchase premiums or financial support for sharing providers that offer LEV sharing could help.

Expanding the model range: As LEVs are still niche products, their model range is smaller than that for cars. There are already different models that vary, e.g., in terms of top speed, safety features, number of seats, and basic design up to premium equipment. Nevertheless, a diversification of the range offers the chance to better meet different user requirements. This may also include an improvement in ergonomics or convenience. However, some convenience features in LEVs will not meet "Mercedes" standards, as this would go against the lightweight design and, thus, jeopardize a core characteristic of LEVs and reduce the environmental benefits.

5.3. Context

Particular attention should be paid to the context of acceptance. This refers, e.g., to the urban and street space that is attributed to new means of transport. Currently, there are many conflicts with some kinds of LEVs, e.g., e-scooters lying around on pavements, and more and more different vehicles driving on narrow cycle paths. This affects the acceptance of these new transport modes in a negative way. Regarding the criticism that LEVs and, especially, e-scooters face, it should be noted that this is shaped by today's mindset: incorrect parking of vehicles, excessive speeds, and obstruction of other road users are also the major problems of cars. However, for these problems associated with cars, violations are highly accepted through long habits and the required space for stationary and moving traffic is set up.

To counter the criticism, the framework conditions for LEVs need to be improved, including elaborated curbside management to result in an improved perception and evaluation of such vehicles. Currently, measures such as setting up parking zones for micro-mobiles and wide cycle paths are being implemented in various cities in order to give space to these new modes of transport and to minimize conflicts [32,33]. By reducing conflicts, the public's assessment of these new means of transport may be better.

Reallocation of traffic space: Attractive and safe use of LEVs requires dedicated traffic infrastructure, same as the use of cars does. Current traffic infrastructure is mostly built for cars. If LEVs are to replace cars to a considerable extent, they need to be considered when transforming urban space and road networks in rural or suburban areas. Measures must match requirements of different types of LEVs. The necessity to improve operating conditions is especially important for micro-mobiles such as e-bikes, where vehicle safety technologies can only be expanded to a limited extent, but much can be done on the regulatory and infrastructure side. Redistribution of space that cuts the space for cars must affect both moving and parked traffic. Examples that are worth evaluating are structurally separated lanes for LEVs and push measures that make car use unattractive, such as abundant one-way streets or entry restrictions. Additionally, parking space dedicated to LEVs might be an effective measure supporting their introduction and acceptance, while minimizing the possibility and attractiveness of driving and parking a large car.

Adjusting the maximum design speed: Lower speed increases safety [34–37]. In urban areas, however, a speed limit of 50 km/h is still frequently found. This is not only a safety issue, but it is also unattractive for some LEVs: Regulation (EU) 168/2013 [15] limits the maximum design speed for classes L1e-B, L2e, and L6e to 45 km/h, creating a gap of 5 km/h. Speed limits should be reduced so that LEVs can integrate well. Another option would be to change the regulations to 50 km/h, but this is the worse option in terms of safety, energy consumption, and noise.

Sharing schemes and intermodal mobility—preventing unintended modal shift and increase in vehicle stock: LEVs are not a stand-alone approach but should be part of a holistic mobility concept. Walking; sharing of e-Scooters, bikes, LEVs, and cars; use of privately-owned vehicles, public transport, and long-distance trains; and more mobility options must work together. On the one hand, LEVs are not necessarily suitable for all of a person's trips, but on the other hand, they are supposed to replace passenger cars so that the vehicle stock does not increase. Therefore, a system must be created in which it is easy to use the right vehicle for different trips without having to own it. Digital systems can make sharing and the use of many different mobility options easy and attractive. An overview of user factors related to the acceptance of ride sharing can be found in [38]. Shared mobility might also be an option for people with disabilities. Accessibility of sharing services for this user group was evaluated by [39]. Profound changes in our mobility are necessary, which are very challenging to implement, but they also bring great opportunities for ecological, socially just, and attractive mobility and living space development.

Supporting intermodal transport: LEVs can best develop their potential if they are optimally networked with other means of transport. For example, in the case of very small LEVs such as e-scooters and e-bikes, people should also be able to take them on public transport.

Providing charging infrastructure: A broad application of sharing requires good solutions for charging vehicles. Since LEVs usually only require a household socket and low charging power, the charging infrastructure is much less complex than for passenger cars, but it must nonetheless be provided.

Push measures: Incentives must be supplemented with push measures that make the use of transport options with high energy consumption or high greenhouse gas emissions unattractive. Only a combination of push and pull measures will bring about the magnitude of change that is urgently needed for climate protection. Therefore, a bundle of measures must be taken that abolish car privileges, restrict the use of cars, and make them more expensive, thus promoting more ecological transport options such as LEVs. Prices for mobility today do not reflect the actual costs it causes. This mostly concerns costs borne by the general public, such as for public street spaces, but also for environmental impacts. Cause-related pricing would promote sustainable transport options, such as LEVs, make the use of environmentally harmful vehicles more expensive, and support a fairer distribution of costs.

Approaches for this are partly discussed in the above points, such as the reallocation of space, adjustment of costs, and regulatory measures such as entry bans. It is necessary to create a consistent set of measures and find a balance between what is effective, what is necessary, and what is tolerable for society and individuals. When assessing what is considered tolerable, some encrusted ways of thinking need to be broken down, as failing to meet climate protection targets also entails effects that are considered intolerable according to social criteria. Two things are important and should be pursued in parallel. On the one hand, further research must evaluate individual measures and the interactions of such measures. Existing approaches, e.g., as proposed by [29], must be supplemented with more comprehensive studies. On the other hand, fast and effective action in the transport sector is now necessary, as climate protection calls for fast action.

6. Conclusions

Given that more than 80% of all car trips in Germany are shorter than 20 kilometers and more than half of the trips are made unaccompanied, we asked ourselves whether car trips could also be made by smaller, lighter, and more efficient vehicles instead. Our study explores the substitution potential of LEVs for passenger cars in Germany based on real trip data and shows that the potential of LEVs to replace passenger car mileage and, thus, support climate change mitigation is significant. This demonstrates the urgent need for further investigation of their wider social, ecological, economic, safety, and planning implications. Important research topics include evaluation of specific changes that are necessary to realize a significant proportion of LEVs' emissions-reduction potential, investigation of LEVs' potential for logistics, and other sectors. In addition, the following factors should be discussed: possibilities to maximize LEV safety and options for urban planning through wide application of LEVs, but also ways to prevent unintended effects, such as reduced safety, or modal shift from more sustainable transport, such as walking and public transport. This should include detailed evaluation of sharing schemes that offer attractive solutions for using the right vehicle for each trip without increasing the number of privately owned vehicles. For effective climate protection measures in transport, many approaches must work together—the most effective option is to avoid motorized traffic. In addition, trips can be shifted from motorized individual transport to more sustainable modes such as public transport or LEVs. Optimizing vehicles supports the other two approaches so that fewer resources are consumed for production and operation. LEVs offer great opportunities to support the transformation of our mobility system. However, they should be seen as one component of many that can contribute to success - complementary to public transport, active modes and other options.

Author Contributions: Conceptualization, L.G. and M.B.; methodology, R.S. and L.G.; formal analysis, R.S.; writing—original draft preparation, L.G. and M.B.; writing—review and editing, L.G., M.B. and R.S.; visualization, R.S. and M.B.; supervision, L.G.; project administration, M.B.; funding acquisition, L.G. and M.B. All authors have read and agreed to the published version of the manuscript.

Funding: This work was commissioned by LEVA-EU, which was supported by Microlino AG, Superpedestrian HQ, Fairly Bike Manufacturing Co., Ltd., Podbike AS, and myStromer AG.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A LEV Parameters

Table A1. Parameters for trip substitution analysis.

Exemplary LEV Model	E-Scooter	E-Bike	E-Bike+	Speed Pedelec	Moped	Motorcycle	Microcar 45	Microcar 90	Microcar 125
Max. speed [km/h]	20	25	25	45	45	120	45	90	128
Relevant travel distance: one way [km]	4	15	15	30	30	45	40	70	70
Relevant travel distance: round trip [km]	8	30	30	60	60	90	80	140	140
Number of occupants [no. of persons]	1	1	1 + 3 kids (up to 7 years old)	1	2 *	2 *	2	2	3 **
Trip purposes [suitability]	All, with exceptions ***								
Street category	excl. highway					all	excl. highway	all	all
Max. age of driver [years]	70						99		
Weather conditions	all, without heavy rain, snowfall, or icy roads						all conditions		
Impairments [suitability]	none						walking impairment		

* Excluding children < 10 years; no accompanied shopping trips. ** for trips with the purpose of shopping limited to 2 persons. *** E-scooters: excluding social service, transport of passengers or goods; "other" E-bikes, e-bike+, speed pedelecs: excluding accompaniment (for E-bike+, accompaniment is restricted to children) and excluding some shopping and professional trips (transport of passengers or goods, "other"; and shopping: "other goods"). Mopeds, motorcycles, microcars: excluding some shopping and professional trips (transport of passengers or goods, "other"; and shopping: "other goods").

References

1. WBGU—Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen. *Der Umzug der Menschheit: Die Transformative Kraft der Städte*, 2nd ed.; WBGU: Berlin, Germany, 2016; ISBN 978-3-936191-44-8.
2. Husain, I.; Ozpineci, B.; Islam, M.S.; Gurpinar, E.; Su, G.-J.; Yu, W.; Chowdhury, S.; Xue, L.; Rahman, D.; Sahu, R. Electric Drive Technology Trends, Challenges, and Opportunities for Future Electric Vehicles. *Proc. IEEE* **2021**, *109*, 1039–1059. [CrossRef]
3. Ewert, A.; Brost, M.; Schmid, S. Small Electric Vehicles—Benefits and Drawbacks for Sustainable Urban Development. In *Small Electric Vehicles*; Ewert, A., Schmid, S., Brost, M., Davies, H., Vinckx, L., Eds.; Springer International Publishing: Cham, Switzerland, 2021; pp. 3–15. ISBN 978-3-030-65842-7.
4. Davies, H.; Bastien, C.; Nieuwenhuis, P.; Bailey, S. Challenges and Opportunities for Improving the Safety of Lightweight Vehicles. In Proceedings of the World Light Electric Vehicle Summit, Barcelona, Spain, 20–21 September 2016.
5. Pavlovic, A.; Fragassa, C. General considerations on regulations and safety requirements for quadricycles. *Int. J. Qual. Res.* **2015**, *9*, 657–674.
6. Ewert, A.; Schmid, S.; Brost, M.; Davies, H.; Vinckx, L. (Eds.) *Small Electric Vehicles*; Springer International Publishing: Cham, Switzerland, 2021; ISBN 978-3-030-65842-7.

7. Liu, T.; Bogdanski, R. Light Electric Vehicles for a Green Transport Transition: Regulatory Approaches, Managerial Challenges and Market Potentials in Germany and China. Beijing. 2021. Available online: https://transition-china.org/wp-content/uploads/2021/12/20211203_Mikromobilitat_Broschure.pdf (accessed on 5 May 2023).
8. Eisenmann, C.; Gruber, J.; Brost, M.; Ewert, A.; Stieler, S.; Gicklhorn, K. Fields of Applications and Transport-Related Potentials of Small Electric Vehicles in Germany. In *Small Electric Vehicles*; Ewert, A., Schmid, S., Brost, M., Davies, H., Vinckx, L., Eds.; Springer International Publishing: Cham, Switzerland, 2021; pp. 127–140. ISBN 978-3-030-65842-7.
9. Brost, M.; Ewert, A.; Schmid, S.; Eisenmann, C.; Gruber, J.; Klauenberg, J.; Stieler, S. Elektrische Klein—Und Leichtfahrzeuge: Chancen und Potenziale für Baden-Württemberg. e-mobil BW GmbH—Landesagentur für neue Mobilitätslösungen und Automotive Baden-Württemberg: Stuttgart. 2019. Available online: https://www.e-mobilbw.de/fileadmin/media/e-mobilbw/Publikationen/Studien/LEV_e-mobil_BW_Leichtfahrzeug_Studie.pdf (accessed on 14 April 2023).
10. BMVI. MiD 2017—Mobilität in Deutschland. Mikrodaten (Public Use File). Available online: https://daten.clearingstelle-verkehr.de/279/ (accessed on 17 April 2023).
11. Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R. The Potential of Light Electric Vehicles for Climate Protection through Substitution for Passenger Car Trips: Germany as a Case Study. Final Report, Berlin, Stuttgart. 2022. Available online: https://elib.dlr.de/186036/1/2022-03-24_LEV4Climate_DLR_LEVA-EU_report.pdf (accessed on 14 April 2023).
12. Behrendt, F.; Heinen, E.; Brand, C.; Cairns, S.; Anable, J.; Azzouz, L. Conceptualizing Micromobility. *Preprints.org* **2022**, 2022090386. [CrossRef]
13. Rashid, A.A.A.; Abdullah, M.H. The Impact of Power Source to the Outline Design of a Kei-Car Segment. *JEECIE* **2016**, *1*, 20–24.
14. Milakis, D.; Gebhardt, L.; Ehebrecht, D.; Lenz, B. Is micro-mobility sustainable? An overview of implications for accessibility, air pollution, safety, physical activity and subjective wellbeing. In *Handbook of Sustainable Transport*; Curtis, C., Ed.; Edward Elgar Publishing: Cheltenham, UK, 2020; pp. 180–189. ISBN 9781789900477.
15. Regulation (EU) No 168/2013. On the approval and market surveillance of two- or three-wheel vehicles and quadricycles. Text with EEA relevance. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:060:0052:0128:en:PDF#:~:text=This%20Regulation%20establishes%20the%20requirements,and%20equipment%20for%20such%20vehicles. (accessed on 14 April 2023).
16. Nobis, C.; Kuhnimhof, T. Mobilität in Deutschland—MiD Ergebnisbericht. In *Studie von Infas, DLR, IVT und Infas 360 im Auftrag des Bundesministeriums für Verkehr und Digitale Infrastruktur*; Bundesministerium für Verkehr und Digitale Infrastruktur: Bonn/Berlin, Germany, 2018; Available online: https://www.mobilitaet-in-deutschland.de/archive/pdf/MiD2017_Ergebnisbericht.pdf (accessed on 14 April 2023).
17. Nobis, C.; Köhler, K. Mobilität in Deutschland—MiD Nutzerhandbuch. In *Studie von Infas, DLR, IVT und Infas 360 im Auftrag des Bundesministeriums für Verkehr und Digitale Infrastruktur*; Bundesministerium für Verkehr und Digitale Infrastruktur: Berlin, Germany, 2018; Available online: https://www.mobilitaet-in-deutschland.de/archive/pdf/MiD2017_Nutzerhandbuch.pdf (accessed on 14 April 2023).
18. 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. [CrossRef]
19. Tack, A.; Klein, A.; Bock, B. E-Scooter in Deutschland. Ein Datenbasierter Debattenbeitrag. Available online: https://scooters.civity.de/ (accessed on 20 December 2022).
20. t3n. E-Scooter: Wer Nutzt die Elektrischen Tretroller Eigentlich Wofür? Available online: https://t3n.de/news/e-scooter-nutzung-elektrische-tretroller-1171584/ (accessed on 20 December 2022).
21. FOCUS online. Mobil für Touristen: Erste E-Scooter-Auswertung. Available online: https://www.focus.de/auto/news/erste-e-scooter-auswertung-mobil-fuer-touristen_id_10973682.html (accessed on 14 April 2023).
22. Schenk, M. *Medienwirkungsforschung*, 3rd ed.; Mohr Siebeck: Tübingen, Germany, 2007; ISBN 978-3-16-149240-2.
23. Zmud, J.P.; Sener, I.N. Towards an Understanding of the Travel Behavior Impact of Autonomous Vehicles. *Transp. Res. Procedia* **2017**, *25*, 2500–2519. [CrossRef]
24. Watson, M. How theories of practice can inform transition to a decarbonised transport system. *J. Transp. Geogr.* **2012**, *24*, 488–496. [CrossRef]
25. Fraedrich, E. How collective frames of orientation toward automobile practices provide hints for a future with autonomous vehicles. *Appl. Mobilities* **2018**, *6*, 253–272. [CrossRef]
26. Fraedrich, E.; Lenz, B. Automated Driving: Individual and Social Aspects. *Transp. Res. Rec.* **2014**, *2416*, 64–72. [CrossRef]
27. Lucke, D. *Akzeptanz: Legitimität in der "Abstimmungsgesellschaft"*; Leske + Budrich: Leverkusen, Germany, 1995; ISBN 978-3-663-09234-6.
28. König, A.; Gebhardt, L.; Stark, K.; Schuppan, J. A Multi-Perspective Assessment of the Introduction of E-Scooter Sharing in Germany. *Sustainability* **2022**, *14*, 2639. [CrossRef]
29. Ewert, A.; Brost, M.K.; Schmid, S.A. Framework Conditions and Potential Measures for Small Electric Vehicles on a Municipal Level. *World Electr. Veh. J.* **2020**, *11*, 1. [CrossRef]
30. Mueller, N.; Rojas-Rueda, D.; Khreis, H.; Cirach, M.; Andrés, D.; Ballester, J.; Bartoll, X.; Daher, C.; Deluca, A.; Echave, C.; et al. Changing the urban design of cities for health: The superblock model. *Environ. Int.* **2020**, *134*, 105132. [CrossRef] [PubMed]
31. CITIES Forum. Superblock (Superilla) Barcelona—A City Redefined. Available online: https://www.citiesforum.org/news/superblock-superilla-barcelona-a-city-redefined/ (accessed on 20 December 2022).

32. E-Roller.com. JETZT Kommen die E-Scooter Parkplätze. Available online: https://e-roller.com/news/jetzt-kommen-die-e-scooter-parkplaetze/#:~:text=E%2DScooter%20Sharing%20Anbieter%20fluten,sodass%20sie%20den%20Weg%20versperren (accessed on 14 April 2023).
33. 6t-Bureau de Recherche. Uses and Users of Free-floating Electric Scooters in France. 2019. Available online: https://www.mobilservice.ch/admin/data/files/news_section_file/file/4908/6t_trottinettes_synthese_eng.pdf?lm=1581430095 (accessed on 20 December 2022).
34. Taylor, M.C.; Lynam, D.C.; Baruya, A. *The Effect of Drivers' Speed on the Frequency of Accidents*; Transport Research Laboratory: Crowthome, UK, 2000.
35. Nilsson, G. Traffic Safety Dimensions and the Power Model to Describe the Effect of Speed on Safety. Ph.D. Thesis, Lund University, Lund, Sweden, 2004.
36. International Transport Forum. Speed and Crash Risk. Research Report. 2018. Available online: https://www.itf-oecd.org/sites/default/files/docs/speed-crash-risk.pdf (accessed on 21 April 2022).
37. Gitelman, V.; Doveh, E.; Bekhor, S. The Relationship between Free-Flow Travel Speeds, Infrastructure Characteristics and Accidents, on Single-Carriageway Roads. *Transp. Res. Procedia* **2017**, *25*, 2026–2043. [CrossRef]
38. Mitropoulos, L.; Kortsari, A.; Ayfantopoulou, G. A systematic literature review of ride-sharing platforms, user factors and barriers. *Eur. Transp. Res. Rev.* **2021**, *13*, 61. [CrossRef]
39. Goralzik, A.; König, A.; Alčiauskaitė, L.; Hatzakis, T. Shared mobility services: An accessibility assessment from the perspective of people with disabilities. *Eur. Transp. Res. Rev.* **2022**, *14*, 34. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.