Analysis of the potential of a new concept for urban last-mile delivery: Ducktrain

Schomakers, Eva-Maria; Klatte, Marcus; Lotz, Vivian; Biermann, Hannah; Kober, Fabian; Ziefle, Martina

Transportation Research Interdisciplinary Perspectives 14 (2022) 100579

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: www.elsevier.com/locate/trip

Analysis of the potential of a new concept for urban last-mile delivery: Ducktrain

Eva-Maria Schomakers [a], Marcus Klatte [b], Vivian Lotz [a,*], Hannah Biermann [a], Fabian Kober [c], Martina Ziefle [a]

[a] Human-Computer Interaction Center, Chair of Communication Science, RWTH Aachen University, Campus-Boulevard 57, 52074 Aachen, Germany
[b] Chair and Institute of Urban and Transport Planning, RWTH Aachen University, Mies-van-der-Rohe-Str. 1, 52074 Aachen, Germany
[c] DroidDrive GmbH, Bohr 12, 52072 Aachen, Germany

ARTICLE INFO

Keywords:
Urban mobility
Micro mobility
Last-mile delivery
Light electric vehicle
Acceptance
Ducktrain

ABSTRACT

As cities continue to grow and the online retailing business continues to boom, last-mile logistics is becoming more and more of a challenge. This paper introduces Ducktrains, a new electric, automated, and compact light vehicle logistic solution for dense urban areas. Moreover, we present first insights on the potential of such a concept from a transport planning and social science perspective. Using a comparative transport analysis focusing on the factors speed, payload, and range, we validated the vehicles' suitability for urban delivery. To explore social acceptance, we used an empirical mixed-method approach, conducting both a qualitative interview study ($N = 70$) and an online survey ($N = 1007$). Results of both analyses reveal the general suitability of the introduced concept for urban deliveries. The Ducktrains showed to be competitive for standard delivery tours, and acceptance was generally high, with the main associated advantages being environmental friendliness and quality of life improvements. However, some concerns, including negative impacts on the overall traffic situation and safety, remain from the public's perspective.

1. Introduction

To reduce carbon emissions and environmental pollution for public health and climate crises, new mobility concepts are needed. As the traffic infrastructure especially in urban area reaches its space limits, not only traffic jams, noise and air pollution increase but due to the enormous growth of e-commerce also the inner-city delivery traffic grows — competing with individual and public transport for the scarce infrastructure space. Current delivery solutions for the crucial last mile with conventional delivery vehicles do not only lead to high emissions. They also impede the flow of inner-city road traffic, e.g., through second-row parking, and are currently used with overcapacity, problems that are not resolved by electrifying the delivery fleet. Instead, new mobility concepts are needed that are focused on urban last-mile delivery with zero local emissions, which are better adapted to the existing urban infrastructure. Here, automated and electrified light vehicles offer promising potential.

In this paper, a mobility concept for the urban last-mile delivery is presented, which is comparable to other concepts in the sector of automated micro-vehicles but also shows distinct advantages over comparable solutions. In more detail, these are light electric vehicles that can be coupled with various lead objects (e.g., pedestrians or cyclists) or drive autonomously. They offer usage advantages over traditional delivery vehicles (e.g., electrified vans and cargo bikes) due to their compact vehicle size and high payload. After detailing their characteristics, the potential of this new mobility concept is analyzed from two perspectives: A transport potential analysis compares the automated light vehicles to conventional delivery concepts (by foot, cargo bike, and delivery vans) and interviews and a survey provide empirical results on the public acceptance of the concept by road users and delivery customers. This research is a first step to analyze the potential of these automated micro-vehicle solutions as an example for this new type of vehicle.

2. Urban logistics and autonomous light vehicles

The need for new mobility concepts for urban logistics is related to two global trends: Increasing urban population, online retailing as a booming business, and, consequently, increasing (urban) freight traffic. This results in, on the one hand, major traffic burdens, e.g., high

* Corresponding author.
E-mail addresses: schomakers@comm.rwth-aachen.de (E.-M. Schomakers), klatte@isb.rwth-aachen.de (M. Klatte), lotz@comm.rwth-aachen.de (V. Lotz), biermann@comm.rwth-aachen.de (H. Biermann), fabian.kober@ducktrain.io (F. Kober), ziefle@comm.rwth-aachen.de (M. Ziefle).

https://doi.org/10.1016/j.trip.2022.100579
Received 22 November 2021; Received in revised form 21 February 2022; Accepted 27 February 2022
Available online 2 April 2022
2590-1982/

traffic volumes, congestion, accident risks, and possible delays in delivery (Allen et al., 2017). On the other hand, using conventional delivery vehicles, e.g., trucks and vans with internal combustion engines, leads to increased environmental and noise pollution and, therefore, accelerates climate change and poses threats to the public health and well-being (Digiesi et al., 2017).

One promising approach to relieve burdens of urban and last mile logistics is the use of electrified and automated delivery vehicles with small size and light weight (Patella et al., 2021). While electric (conventional) vehicles, i.e., electric cars or vans, have been discussed in research for years, are successfully deployed in traffic (Patella et al., 2021; de Oliveira et al., 2017; Melo et al., 2014), and their automation has been discussed and tested (Cregger et al., 2020), novel vehicle designs with smaller sizes may offer even more flexibility and benefits for urban delivery solutions. Electric but not automated solutions often come in the form of bicycles and tricycles (de Oliveira et al., 2017). Also, various kinds of small or light automated delivery vehicles have been proposed, with a rapid increase in recent years, however, to our knowledge there is no agreed-on label or taxonomy yet (Cregger et al., 2020; Baum et al., 2019).

For example, Baum et al. (2019) define automated micro-vehicles as vehicles with 2 to 4 wheels, which reach a speed of up to 45 kph and weigh up to 400 kg. They differentiate micro-vehicles based on the required infrastructure (non-road vs. road), the vehicle type (automated bikes vs. delivery robots), and whether a human reference is used, and conclude that most proposed automated micro-vehicle solutions are sidewalk delivery robots. Cregger et al. (2020) report on autonomous delivery vehicles for the U.S. Department of Transportation. They differentiate between wheeled and legged sidewalk delivery robots, novel design automated delivery vehicles, as well as conventional design automated delivery vehicle and combination automated delivery vehicles models, with the latter two not fitting into the category of *light* vehicles. Often, these light autonomous delivery vehicles operate with a human reference that the vehicles follow or are remote-controlled due to the early stage of the development and legal obligations (Baum et al., 2019; Cregger et al., 2020).

Relevant usage benefits of electrification are the reduction of air pollutants and traffic-related noise levels. Smaller sizes improve the integration of the vehicles into the urban space and the traffic infrastructure, as, for instance, smaller vehicles create fewer parking obstacles and can navigate on non-road infrastructure (including bike lanes, sidewalks, and pedestrian zones). The automation of light vehicles can even increase the opportunities for optimization, with ideas ranging from moving micro-depots or moving pick-up stations to the use of flexible platooning of autonomous delivery vehicles (Baum et al., 2019; Arvidsson and Pazirandeh, 2017; de Oliveira et al., 2017).

In the following chapter, an innovative concept for such automated electric light vehicles is presented, fitting the needs of urban last-mile delivery.

3. Ducktrain: Electric and automated vehicles for urban logistics

Ducktrain is an electric and automated logistics solution for dense urban areas (DroidDrive GmbH, 2022; Gringer, 2021). A Ducktrain is a train or platoon consisting of automated light electric vehicles (“Ducks”) following a leading reference person or vehicle (cf. Fig. 1). The vehicle fits into the diverse category of “novel design automated delivery vehicles” by Cregger et al. (2020) and could be described as delivery robots with human reference that are able to operate on non-road as well as road infrastructure according to Baum et al. (2019). However, several characteristics distinguish Ducktrain from other automated light vehicle concepts, whereby the flexibility of the concept is one of the key advantages, especially in last-mile delivery. (See Fig. 2).

The Ducks can either be operated with a pedestrian or a cyclist, as the Duck drives at a maximum speed of 25 kph (15.53 miles per hour), fitting to electrically assisted bicycles where the electrical

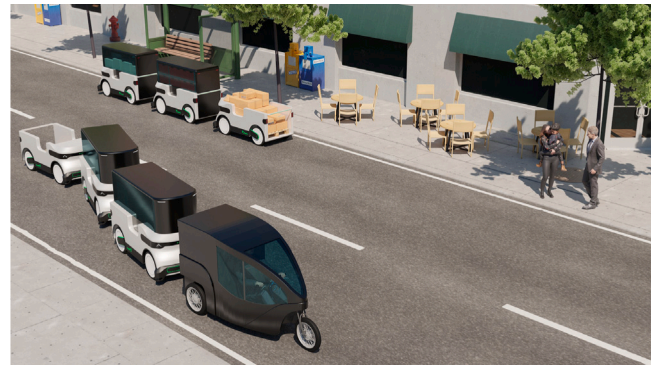

Fig. 1. A Ducktrain of three Follow-Me Ducks following a passenger micro vehicle (front) and another Ducktrain of three parked at the side of the road (back).

support is limited to a maximum of 25 kph in Europe. The footprint of the none-passenger vehicle is 1 m in width and 2.2 m in length, allowing Ducks to use non-road infrastructure like bike lanes as well as sidewalks, and with its steering angle of more than 70 degrees, the Duck is very maneuverable. A single Duck has a payload of 300 kg and a loading volume of 2 m^3. When Ducks are operated in convoy, a Ducktrain of five Ducks can transport up to 1.500 kg and 10 m^3. Thus, the Duck enables bike or pedestrian based transportation of goods that, today, need to be transported in a transporter. Compared to sidewalk delivery robots, the payload and loading volume and the maximum delivery speed are considerably increased. However, as the concept also offers operation via a pedestrian, more flexible delivery concepts are possible in comparison to electric cargo bikes such as the ono (Onomotion GmbH, 2022). Moreover, pedestrian zones can be reached with the same comfort as with follow-me sidewalk robots such as the postbot (Anna, 2018).

Thereby, three vehicle generations are distinguished regarding their automation degree for a flexible use and a fast approval for the use in traffic.

- The Trailer Duck
- The Follow-Me Duck
- The Auto Duck

The Trailer Duck, which is the enabling technology to prepare the on-road drive approval for the more automated Duck generations, is already tested in traffic and is anticipated to be approved for general use in 2022. The Trailer Duck is connected to its leading object with a physical, force-free drawbar, which can be pulled by a pedestrian or connected to a bicycle or other light electric vehicle. The Follow-Me Duck automatically follows the leading object with a digital connection based on sensor technology and is expected to be approved for test rides at the beginning of 2022 and thereafter to road traffic in general. The Auto Duck, finally, can drive fully autonomously, allowing Ducktrains or single Ducks to drive without any human involvement. The Auto Duck has the ability to take its own driving decisions. However, as an intermediate step, it might be remotely operated to comply with legislation.

In order to demonstrate the potential of the Ducktrains, we consider those concepts listed by Bogdanski (2019) to reduce urban delivery traffic as well as the smart logistics framework by Bundesvereinigung Logistik (2014).

Like all automated light vehicle concepts, Ducktrains can increase the multimodality of existing logistic structures and may be used to improve consolidation and pairing. A recent study has shown that consolidation using conventional delivery vehicles alone will not sufficiently reduce the number of transport vehicles needed to impact urban traffic positively. The minimal positive logistical effects of consolidation in the urban area are offset by the additional heavy-load traffic

Fig. 2. A Trailer-Duck during a test ride in Aachen following a cargo bike.

generated between the depots. In addition, the parcel transit time is extended, and transport costs rise. Furthermore, the tour duration, due to the legally prescribed maximum working hours of the parcel delivery company, has proved to be a restriction on consolidation (Bogdanski, 2019). Alternative concepts for traffic relief and emission reduction include the use of loading zones to reduce traffic disruptions, micro depots, and cargo bikes to replace classic delivery traffic and inter-provider parcel stations (ibd.). Here, the flexibility of the Ducks can offer several solutions. Ducks can either serve as a micro-depot for cargo bikes or even follow the cargo bikes in their function as a micro-depot to optimize urban delivery with cargo bikes. Ducks can also serve as inter-provider micro-depots.

Through the automation and real-time connection to the vehicles, autonomous delivery vehicles have the potential to increase the first delivery rate via interaction with the recipients as well as to optimize routes due to the integration of real-time traffic data. Increased convenience for the delivery person can be achieved through optimized location selection depending on the delivery addresses of the loaded shipments. Also, Ducks in particular can serve as mobile or fixed pick-up stations, i.e., micro parcel stores, which is feasible due to their rather large transport volume. Especially the automated Duck generation can provide much convenience for the customers as the parcel stations can move close to the location of the customer.

In comparison to other conventional or novel electric vehicle solutions, one of the greatest advantages of the Ducks is the reduction of space consumption during unloading times and thereby traffic disruptions due to their small and narrow size with at the same time a large increase in volumes and weight that can be transported in comparison to only by foot or (cargo) bike transport. Delivery areas with high delivery volumes can be approached on foot or by bicycle, which minimizes dwell times because the Duck only stops when a delivery is performed. In comparison to a conventional delivery vehicle, the number of stops may increase as one stop is made for each delivery, but this has the advantage for the delivery person of not having to transport multiple deliveries at once. Furthermore, it is conceivable to reduce the runtime of the delivery agent. Additionally, with the option to flexibly use the number of Ducks needed, especially the Follow-Me and Auto Ducks can effectively bundle delivery routes, further reducing the space consumption in the urban area. Various interchangeable bodies are conceivable with regard to the loading option. These can be designed according to the respective requirements in order to ensure more ergonomic working and to positively influence loading and unloading times.

4. Transport potential analysis

As seen before, various use cases are possible with automated light delivery vehicles and especially with Ducktrains. To analyze the potential of the Ducks, this chapter aims at comparing the Ducks to different means of transport. For this comparison, we focus on the use case of the Ducks serving as delivery vehicles for CEP services and the Follow-Me Duck generation, as this case can be implemented in the near future. The comparison is based on a systematic comparison of various transport-specific characteristics of CEP services. At this point, it is a theoretical and purely value-based comparison of the characteristics. The following means of transport are juxtaposed:

- Duck
- Ducktrain (3 Ducks)
- by foot
- electrical assisted cargo bike
- station wagon
- transporter (VW Caddy/MB Vito)
- transporter (sprinter $\leq$ 3.5t)
- electric transporter (StreetScooter XL)

The following transport-specific characteristics are compared between the different modes of transport:

- speed [kph]
- payload [kg; m^3]
- range [km]

4.1. Speed

The maximum speed of the compared vehicles differs clearly (cf. Fig. 3), with the conventional delivery vehicles limited to 130 kph by the recommended speed on German highways and (electric) cargo bikes limited to 25 kph which is the maximum speed for electric bicycles in Germany (StVZO, 2021). Nevertheless, the cargo bike can go faster (e.g., downhill or through muscle power). This situation is

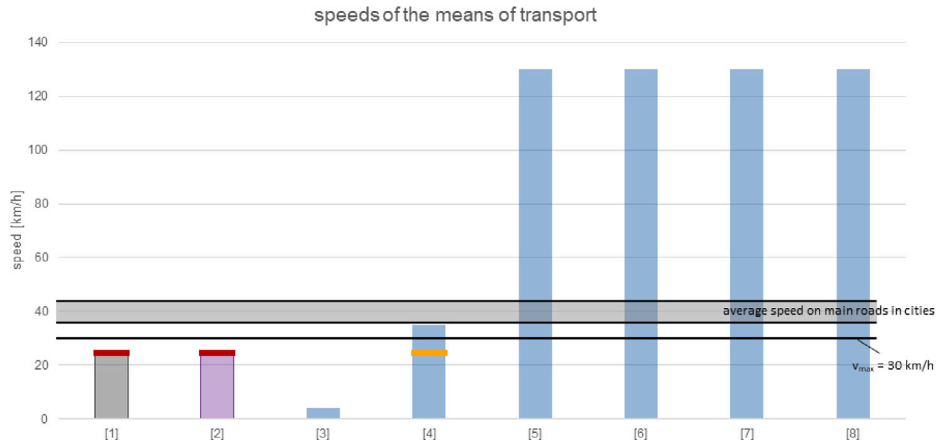

Fig. 3. Maximum speed of the means of transport ([1] Duck, [2] Ducktrain of 3 Ducks, [3] pedestrian, [4] electric cargo bike, [5] station wagon, [6] transporter, [7] electric transporter).

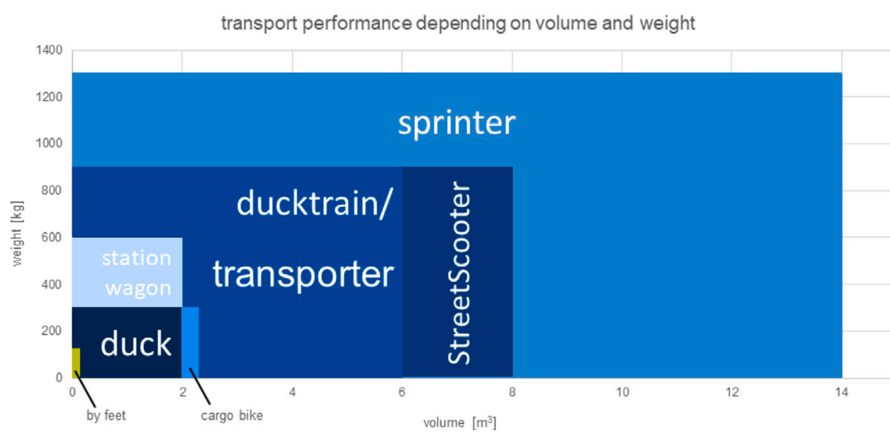

Fig. 4. Transport performance of the means of transport.

different for the considered Ducks. Their speed is strictly limited to 25 kph.

However, with the focus on urban logistics, the average speed in cities becomes relevant, which varies in selected German cities between 36 kph and 43 kph (on main road maximum 27 kph) (BVL.digital, 2019). In addition, several cities (e.g., Paris, all Spanish cities) have currently decided to introduce a 30 kph speed limit, which applies to almost the entire city. Considering this context, the possible higher speed of delivery vehicles becomes negligible, and the speed of (electric) cargo bikes and Ducks seems to be sufficient to be part of the flowing traffic.

4.2. Payload

Two factors are relevant with regard to the payload: The maximum weight and the maximum volume. Fig. 4 shows the transportable weight on the y-axis and the available volume on the x-axis. With approx. 300 kg the payload of a Duck is comparable to that of the largest cargo bicycles and considerably more than sidewalk robots. With 900 kg and 6 m^3 volume, a Ducktrain of three Ducks has the same payload possibilities as a conventional van. An advantage at this point is the flexible possibility to extend the load by Ducks driving in sequence. In this way, different transport volumes can be served.

The use of a Duck for delivery by foot is also conceivable similar to follow-me sidewalk robot solutions like the PostBOT (Deutsche Post AG, 2017). The advantage is the electrical support and the rapid increase in payload, which means that more end customers can be reached by foot per delivery tour. Compared with the station wagon, two Ducks traveling in succession can replace it in terms of transportable weight, doubling the transportable volume and thus representing a substitute for the station wagon or other automated conventional vehicle concepts.

4.3. Range

A comparison of the ranges must be made while taking into account the different engine types. Conventional delivery vehicles with combustion engines often have ranges of 500 to 600 km and can refuel within a few minutes. Delivery vehicles with purely electric drive have ranges of up to 330 km and, depending on the charging infrastructure and charging capacity, require different amounts of time to fully charge the batteries. However, according to a survey by the ADAC, the majority of vehicles have a range of less than 250 km, and the StreetScooter Work XL requires between 3 and 16 h for a full charge (StreetScooter GmbH, 2019; ADAC, 2020) (cf. Fig. 5). Thereby, conventional electric delivery vehicles have a range approximately five times higher than that of Ducks or electric cargo bicycles, which have a range of about 50 km (which represents a hard limit in the case of the Ducks and may be increased for cargo bicycles with muscle power, however only to a limited extent, e.g., without a load or without an incline).

However, looking at typical distances for the (inner) urban logistics, it can be seen that many use cases can be covered with a range of 50 km (cf. Fig. 6). First, in combination with a micro hub, a delivery radius of max. 2 km can be specified. Since delivery is already successful with cargo bikes, the Ducks' range of 50 km should be sufficient.

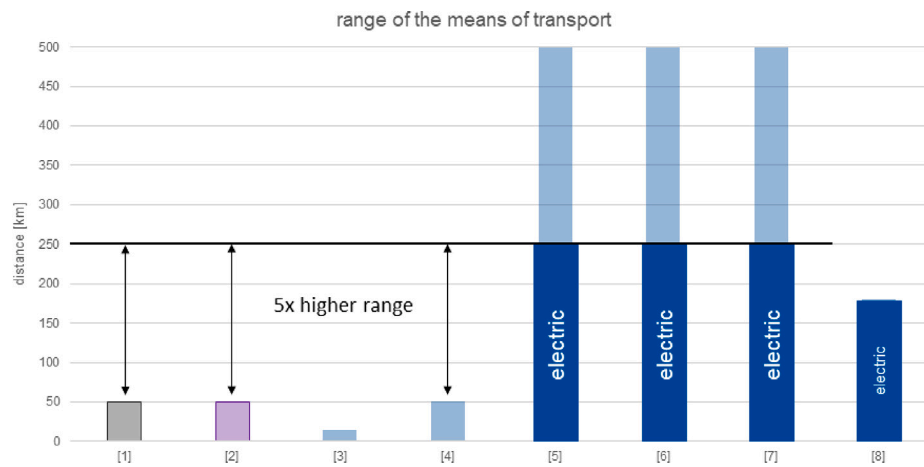

Fig. 5. Range of the means of transport ([1] Duck, [2] Ducktrain of 3 Ducks, [3] pedestrian, [4] electric cargo bike, [5] station wagon, [6] transporter, [7] electric transporter).

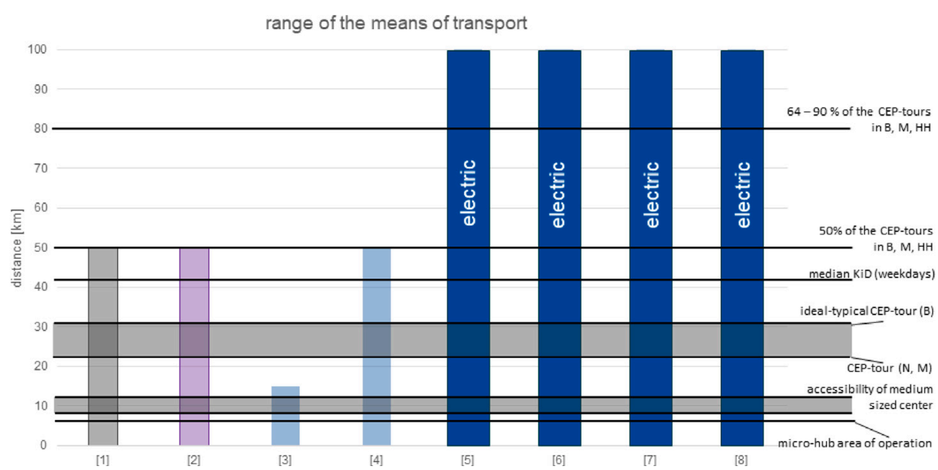

Fig. 6. Range of the means of transport with different use cases ([1] Duck, [2] Ducktrain of 3 Ducks, [3] pedestrian, [4] electric cargo bike, [5] station wagon, [6] transporter, [7] electric transporter).

Next, we look at the accessibility of medium-sized centers, meaning cities that serve the supply of upscale needs beyond the basic supply (Greiving and Flex, 2016). The average time required to reach a middle or upper center was 9.4 min (with a median of 9 min) as indicated in the Indicators and Maps of Spatial and Urban Development (INKAR, 2021). Assuming speeds of 50 and 70 kph, this results in 7.5 km as the minimum and 11 km as the maximum average distance to a middle or upper center in Germany (INKAR, 2021). These distances can be interesting for delivery from an out-of-town warehouse to the city or further use cases, where the Ducks can be used as shared vehicles in order to be able to transport larger loads by bicycle.

The ideal, typical tour lengths of two of the five largest CEP service providers in Germany are 22 to 24 km in Nuremberg and Munich and 31 km in Berlin (Bogdanski, 2019). Correspondingly, in Berlin, Munich, and Hamburg, 50% of CEP tours are max. 50 km and 75% of the tours are max. 80 km long. Therefore, in terms of their distance, half of the conventional sprinter tours can be carried out by Ducks. Another quarter of the tours can be covered with partial recharging or replacement of the batteries. Also, the median distance traveled across all days of the week, and motor vehicle types (cars and trucks $\leq$ 3.5t) is approximately 43 km for commercial transport in Germany according to the KiD (Kraftfahrzeuge in Deutschland). It suggests that the Ducks could be used for other purposes with regard to their range. However, it should be noted at this point that the KiD data originates from 2010 and can therefore only be assumed to be (still) correct to a limited extent (Wermuth et al., 2012).

5. Road users' perceptions and willingness to use

The introduction of new technologies, such as autonomous light vehicles, is often accompanied by social skepticism. This is, among other things, due to the novelty of the technology, for which users cannot yet draw upon previous experiences. In particular, in the case of socially controversial technology developments such as autonomous driving, which has undeniable advantages but simultaneously raises concerns among users about a loss of control and unclear liabilities (Brell et al., 2019). At the same time, the public's opinion on and acceptance of mobility concepts is a crucial factor for successful implementation. Thus, the users (i.e., operators & delivery customers) and the perspective of other affected road users who encounter the light vehicles incidentally should be included in the technology development from the very beginning (Roberts, 2004).

Autonomous electric light delivery vehicles for delivery purposes are a comparably recent concept. As such, the public's perception of it is relatively under-explored compared to the vast body of literature available on the acceptance of autonomous vehicle concepts in other contexts (i.e., shared passenger shuttles, personally owned vehicles) (Kapser and Abdelrahman, 2020). Moreover, most acceptance research in the context of light vehicles and sustainable urban delivery concepts focuses either on the user (Antonakopoulou et al., 2021; Hyvönen et al., 2016; Javaid et al., 2020; Kapser and Abdelrahman, 2020), or involved stakeholders (de Oliveira et al., 2017; Amaya et al., 2020; Matusiewicz et al., 2019). Antonakopoulou et al. (2021) found

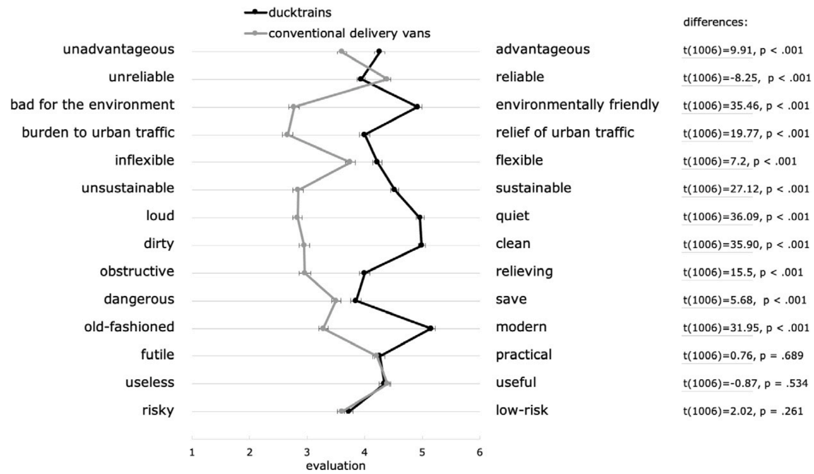

Fig. 7. Evaluation of the Ducks juxtaposed by evaluation of conventional delivery vans (error bars depict 95% BCA Confidence Intervals based on 1000 bootstrap samples; n = 1007).

that prospective users of light electric vehicles are concerned about the need to use dedicated lanes as well as the charging and parking infrastructure. Associated benefits were comfort, transportation speed, affordability, and environmental friendliness.

In first U.S. American surveys, the general public acceptance for follow-me and autonomous mail delivery robots is relatively high (US Postal Service, 2018) and the use of autonomous vehicles for deliveries is more accepted than for passenger transport (Edmonds, 2019). However, especially the opinion of other road users – people who come into contact with the vehicles only by chance – matters as the vehicles are meant to drive on sidewalks and bike lanes and, thus, share the limited traffic space with the more vulnerable road users. Additionally, for delivery services, the attitudes of their customers are important, especially in the competitive carrier domain. Therefore, we surveyed citizens about their perception of autonomous electric light vehicles, concerns, and associated benefits in their role as road users sharing the traffic space with the Ducks, as potential customers of delivery services using Ducks, as well as potential users of the Ducks for personal transports.

5.1. Empirical approach

In order to get insights on the social acceptance of the Ducktrains, a two-tier multi-method approach was chosen. Opinions of citizens who have experienced the Ducktrains in real traffic situations were collected in interviews during test rides. Additionally, a questionnaire was used to collect information from a census-representative sample of German citizens living in urban areas who evaluated the Ducktrains after a detailed description of the concept. The combination of these two methods ensures better validity of the results as the respective advantages and disadvantages of both methods complement each other. In the following, first, the interview study's methodology, sample, and key findings are presented before the survey is focused.

5.2. Procedure of the qualitative study

Because of the novelty of the mobility concept, many fundamental aspects of the public's opinion have not yet been analyzed. Therefore, we started by conducting a short exploratory qualitative study with a semi-standardized interview guideline.

In the interviews, the Duck Trains and their applications were explained, while the participants were encouraged to study the vehicle's prototype up close. Participants were asked about their first impressions of the vehicle, the benefits and barriers they perceive, and they were asked to grade the Duck Trains (using a six-point scale with max = 6 = insufficient). The interviewees' demographics were collected at the end of the interview.

5.3. Interview participants

Interviews were held in July 2021 in public places in Aachen, Germany. In total, 70 laypeople, 40 men (57%) and 27 women (39%; $n = 3$,4% not specified) between 11 and 79 years old ($M = 38.8$ yo, $SD = 15.61$), voluntarily participated in the interviews.

5.4. Interview results

Overall, the participants' opinion concerning autonomous light vehicle-based delivery services was positive. Only seven (10%) stated to have a negative first impression of the concept, and another six (9%) were still undecided. The average assigned grade – on a scale from 1 to 6 with six being the worst – for the concept was $M = 2.1$ ($SD = 0.88$, $n = 63$).

The participants **perceived benefits** of the Duck Trains especially involved improvements of environment and quality of life in cities (air quality, reduced noise, car free city centers). They also assumed positive effects on road traffic and comfort benefits for the users compared to bicycles. Additional, safety benefits because of the small size and lighter weight of the Duck Trains were mentioned as well as economic advantages compared to car ownership.

However, the participants also remarked on several **barriers** that militate against the introduction of light vehicles in densely populated urban areas. A large proportion of the problems discussed were related to sharing space-constrained urban infrastructure with other road users (cars and vulnerable road users), resulting in safety concerns and concerns about negative impacts on traffic conditions. Moreover, there was concern about the use, production, and recycling of batteries, which were considered as not environmentally friendly and potentially hazardous. Other barriers regarded doubts of the general and economic usefulness of the Ducktrains and the legal regulations and liabilities in case of accidents.

5.5. The questionnaire

As a second step, an online survey was developed to gain insights on perceptions and acceptance by a representative German sample. In the questionnaire, the Follow-Me Ducks were introduced with a detailed description and several pictures focusing on cyclists as the reference object. The participants evaluated their first impression of the Ducks as well as their impression of a conventional delivery van on a semantic differential scale (items cf. Fig. 7). Thereafter, different use cases ranging from delivery services over private use to passenger transport were evaluated regarding their acceptance ("In your opinion,

Table 1
Percentage of the participants who have used electrified and micro-vehicles at all and use them regularly (n = 1007).

Vehicle	Have used it at all	Thereof regular users
e-bike	28.0%	8.7%
e-cargo bike	5.7%	0.6%
e-scooter	15.7%	2.6%
e-skateboard	3.9%	0.8%
hoverboard, ninebot, and similar	5.4%	0.9%

what should Ducks be used for?") and regarding the willingness to use ("Personally, what would you use the Ducks for?"). These two measures were used to acquire not only the *passive* acceptability as citizens and road users but also the *active* intention to use as customers, or private users, respectively. Potential use cases were identified beforehand in workshops.

To describe the sample, the questionnaire included questions about demographics (including age, gender, education level, income), the residential area (including quality of the area Schulz et al., 2002), mobility behavior (including experiences with micro-mobility), and attitudes like the perception of the environmental impact of car traffic (Hunecke et al., 1999) and the internal environmental responsibility attribution (Hunecke et al., 2014).

For consistency and comprehensibility for the participants, all items were assessed on a 6-point Likert scale ranging from 1 "I do not agree at all" to 6 "I fully agree".

5.6. Survey participants

The participants were recruited in spring 2021 via an independent market research company with quotas of age and gender to reach a census-representative sample, including only German citizens from urban areas. For a quality check, the questionnaire included questions like "Please choose the option 'I fully agree'" and participants were directly excluded when failing to answer any of the three quality questions. Additionally, speeders were excluded.

1007 participants were included into the analysis aged between 18 and 86 years ($M = 48.6, SD = 17$). 50.4% were women, and the education level was rather well distributed (for details, see Table 2 in Appendix).

Most participants live in the inner city (64.9%). The quality of the individual residential area was evaluated to be rather positive with $M = 3.9$ ($SD = 0.89$). 42.0% of the sample are mainly pedestrians, 39.3% car drivers, and 14.0% cyclists. The participants agree on average to the environmental impact of car traffic ($M = 4.2, SD = 1.13$) and to the self-attribution of environmental responsibility ($M = 4.3, SD = 1.02$). Regarding micro-mobility and electrified vehicles, most participants are inexperienced (cf. Table 1).

5.7. Survey results

Overall, the **evaluation** of the Ducks was quite positive and also mostly more positive than the evaluation of conventional delivery vans (cf. Fig. 7). Among other attributes, Ducks are perceived as more environmentally friendly, quiet, clean, and modern as well as relieving for urban traffic. No differences to conventional delivery vans could be observed regarding perceptions of practicality, usefulness, and risk. The only attribute that is seen as more positive in conventional delivery vans is the reliability which is not surprising given the novelty of the Ducks.

The **general acceptance** of various use cases for the Ducks is also high (cf. Fig. 8). Parcel deliveries (low value of goods) and delivery of medicines are most accepted. Ducks as an emergency vehicle and for passenger and animal transport are seen as rather neutral with a tendency to not be acceptable. In the same vein, the **willingness to use** delivery services is rather high, especially for parcel deliveries with a low value of goods. The sample is ambiguous regarding the willingness to use parcel deliveries with high value of goods. Using the Ducks as mobile parcel pick-up stations is also quite accepted. Private use is not as well accepted as most delivery services. However, Ducks for transport of bulky items, on short ways, and for smaller errands are also seen rather positive. Rather no acceptance and willingness to use exists for the use of Ducks for leisure day trips and transportation of pets and children.

6. Discussion and future research

This paper introduced the Ducktrains as a new mobility concept for urban last-mile delivery. This concept from the emerging field of electric and autonomous light vehicles caters to the needs in the CEP sector due to increasing delivery traffic, on the one hand, and increasing urban traffic in general while being free of local emissions. A preliminary traffic potential analysis as well as empirical studies of social acceptance were carried out to gain first insights on the potential of these new vehicle concept.

6.1. Results: The potential of the Ducktrains

Both analyses pointed out that the Ducks are suitable for urban delivery and that the social acceptance and use intention is generally positive and particularly positive for parcel deliveries.

In detail, the traffic potential analysis looked at speed, payload, and range. The Ducks are limited in terms of speed by their hard limit of 25 kph. However, this does not make them uncompetitive. The speed seems sufficient to be part of the flowing traffic against the background of the speeds achieved in inner cities — especially as there are more and more initiatives in Germany and Europe to reduce the speed limit in city centers to 30 kph (Appunn, 2021). With regard to the payload, the flexibility of payload, weight, and volume is worth mentioning, as it allows different transport volumes to be served. Bicycles can be used to transport much larger volumes than would be the case with a conventional cargo bicycle. The comparison also showed that a Ducktrain consisting of three Ducks can replace a van in terms of payload. Compared to other autonomous light delivery vehicles, the payload and speed seem exceptional — while the narrow size and corresponding ability to operate on non-road infrastructure and fewer space requirements in traffic and during parking are advantageous in comparison to delivery vehicles in size of cars or vans. Also, the range of the Ducks is sufficient to carry out half of the CEP tours considered. A partial load or exchange of the battery can cover about another quarter of the tours.

However, replacing a Sprinter with Ducks is considered difficult as the dimensions of a convoy of ducks exceed those of a sprinter with the same payload. From a purely technical point of view, any number of Ducks can drive in convoy. However, it is questionable whether such a large group of Ducks can be used sensibly in urban areas. This question will need to be investigated by means of microscopic simulations, which is beyond the scope of this paper.

This first analysis confirms the Ducks' and Ducktrains' suitability for urban last-mile delivery. Particularly, they can strengthen bicycle delivery concepts, e.g., with cargo bikes. Looking at the concepts recommended by Bogdanski (2019) to reduce urban delivery traffic, the Ducks also offer good solutions in multiple of these areas. The scientific literature proposes autonomous vehicles as the most promising approach for urban delivery (Patella et al., 2021; Bucsky, 2018). This is also the case for the Ducks, as the fully automated generation, the Auto Duck even increases the potential of the Follow-Me Duck for traffic reduction as they can serve as (inter-provider) moving micro-depots, parcel stations, or mobile pick-up stations.

To gain first insights on the acceptance of the Ducks by the general public in their roles as road users sharing the infrastructure and as

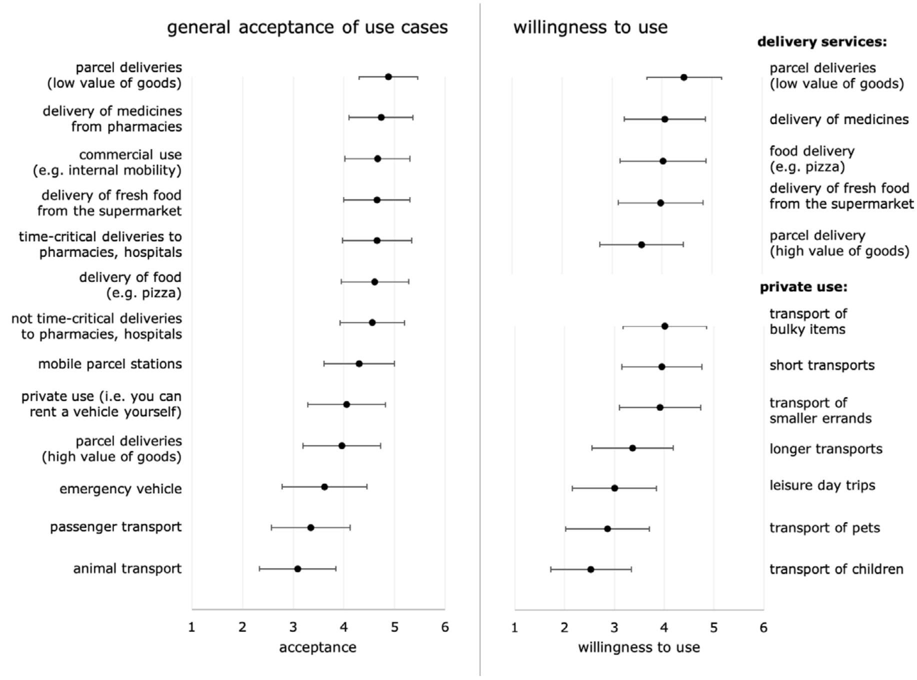

Fig. 8. General acceptance of use cases and willingness to use delivery services and private use (error bars depict standard deviation; n = 1007).

potential delivery customers or even private users of the Ducks, we used interviews and an online questionnaire study. All in all, most participants in both studies showed positive perceptions of the Ducks, which corresponds to high acceptance in the prior U.S. American surveys (US Postal Service, 2018; Edmonds, 2019).

Perceived barriers and benefits were identified in the interviews. As main barriers for acceptance, effects on safety and road traffic are mentioned by the participants, again showing that there is a need for in-depth traffic analysis to determine these effects as well as good communication strategies to broadcast these results. Also, participants pointed to the disadvantages of battery usage, including concerns about life-cycle sustainability and social aspects of production and disposal. These barriers need to be taken into account for all electric vehicles. There is a large need for transparency and legal obligations regarding the production and disposal process of these batteries. Moreover, the reduction of CO2 emissions in electric vehicle only reaches its full potential if they use electricity from renewable energy sources. This emphasizes the need to advance the expansion of renewable energies in order for electric vehicles and new mobility concepts to counteract the climate crisis.

Besides these barriers, the participants perceived various benefits from the use of the Ducks for themselves as citizens and road users. The main benefit regarded the positive effect on the environment, climate, and the quality of life in the city as a result of the reduction of delivery vans and positive effects of the Ducks on road traffic. These benefits and barriers only partly mirror the results found by Antonakopoulou et al. (2021), who identified mostly personal benefits like comfort and transportation speed as well as personal barriers like the charging and parking infrastructure when questioning light electric vehicle users. However, the focus of our study being other road users as well as delivery customers and a delivery vehicle in contrast to private use may explain that most identified benefits and barriers regard advantages for the public.

This positive view of the Ducks could be validated in the quantitative results. The acceptance of and willingness to use the Ducks was high, particularly regarding delivery services, e.g., parcels, medicines, food. Additionally, the private use of the Ducks is also rather positive, widening the use cases, e.g., to the shared use of the Ducks for the transport of bulky items. Participants perceived the transport of animals and passengers as rather less acceptable, which mirrors results of Edmonds (2019). This hints that the trust in these autonomous vehicles is not yet developed. However, risk analyses towards autonomous driving technologies show that the perception of risk regarding autonomous vehicles increases with experience (Brell et al., 2019).

Another advantage of the Ducks are the different Duck generations. Due to the high legal hurdles for admission of autonomous vehicles, especially in Germany, the development of the Trailer Duck as the first generation makes it possible for other road users to get used to the new vehicles and gain trust. This may also have an effect on traffic safety because, at the time that autonomous Ducks are operated in traffic, other road users may have adjusted to the presence of the previous generations vehicles, e.g., made experiences with overtaking and generally sharing space on the streets, bike lanes, and or sidewalks.

6.2. Limitations and future research

The traffic potential analysis confirmed the general suitability of the Ducks for urban last-mile delivery. However, further research is needed to critically examine whether and to what extent the Ducks can help to counteract the current problems of delivery traffic. The share of electrically powered delivery vehicles in the CEP sector is increasing. The goal to reduce local emissions can also be reached by using these electric delivery vans. Therefore, microscopic investigations are needed to examine whether the smaller width of the Ducks compared to conventional delivery vehicles has less of a negative effect on the obstruction of traffic, giving it again an advantage over electric delivery vans. Furthermore, traffic and safety-related effects resulting from the shift of delivery traffic to the cycling infrastructure need to be investigated. To do this, it is first necessary to investigate the specific problems caused by stopping conventional delivery vehicles in the second row and how serious these effects are for the rest of the traffic.

Also, the Ducktrain concept focuses on urban delivery where the need for new solutions is plain and where the narrow size offers usage benefits (cf. Section 2). Because of its range limits it offers no solutions for deliveries in less densely populated and rural areas. Moreover, for the private transport of bulky items, people living in more remote

Table 2
Detailed characteristics of the sample (n = 1007).

Age	18–30 years	196	19.4%
	31–40 years	165	16.4%
	41–50 years	177	17.6%
	51–60 years	178	17.7%
	61–70 years	194	19.3%
	71–80 years	97	9.6%
Gender	Women	508	50.4%
	man	499	49.6%
Education	No certificate	2	0.2%
	Certificate of secondary education	108	10.7%
	General certificate of secondary education	302	30.0%
	General qualification for university entrance	259	25.7%
	University degree	312	31.0%
	Other	24	2.4%
Household income	< 1000€	141	14.0%
	1000€–2000€	277	27.5%
	2000€–3000€	335	33.3%
	4000€–5000€	198	19.7%
	> 5000€	56	5.6%
Residential area	Suburbs	28	2.8%
	City outskirts	325	32.3%
	Inner city	654	64.9%
Preferred role in traffic	Pedestrian	423	42.0%
	Cyclist	141	14.0%
	Car driver	396	39.3%
	Other	47	4.7%

locations may use alternatives like (electric) cargo bikes to reduce car trips.

For first impressions on the acceptance of the Ducks, the two empirical studies gave valuable insights. However, their meaningfulness is limited by the early development stage of the Ducks. The interviewees experienced a Trailer Duck in traffic during a test ride; the survey participants only had a detailed description. This two-tiered approach combines the advantages of the hands-on experience with the large census-representative sample. However, the effects of the operation of multiple Ducks in real traffic could only be anticipated in both studies. This is also pointed out by the fact that some participants perceived the effects of the Ducks on road traffic and traffic safety as positive, others as negative.

The diverging opinions on the effects of the Ducks on traffic also depended on the perspective, meaning the role in traffic as either car driver, cyclist, or pedestrian. Here, further research from social sciences but also from traffic engineering is needed to determine the effects for the different traffic participants. And eventually, politics need to regulate traffic and invest in infrastructure based on their views of which traffic participants should be supported, e.g., to promote cycling — be it for private mobility or delivery services.

Furthermore, managerial and organizational implications of this vehicle concept for existing systems need to be analyzed further. From the point of view of logistics planning, the Duck Trains' great potential is to bring more flexibility. This is, among other factors, through the possibility to flexibly adapt the number of vehicles in convoy to the current transportation need, the option to follow any leading vehicle (besides bikes, cargo bikes, and pedestrians, other micro-vehicles are a feasible option), and to use Ducks as mobile micro-hubs. Therefore, an increase in efficiency of city logistics is expected, but needs to be confirmed in future research. Another important aspect is that the need for conventional micro-hubs – which take up valuable space in the inner cities – is reduced. Due to their range of 50 km and the option to quickly replace the battery, the Duck Trains can start their delivery tours at the city outskirts, where there is more space for micro-hubs. The replaceable batteries also reduce the need for dense charging infrastructure, as they make the Duck Trains independent for most typical delivery tours (the traffic potential analysis showed that the range of 50 km is sufficient for half of CEP tours in typical German cities, another quarter of tours can be carried out with a replacement of batteries). However, besides an analysis of the expected efficiency gains, economic analyses, including the purchase and operation of Ducks in comparison to other means of transport (including other "green vehicles") are needed, as the logistics market is very competitive.

This paper examined the important perspective of other road users and delivery customers, which is very important when introducing new technologies (Roberts, 2004; Brell et al., 2021). This view needs to be expanded regarding social, ethical, and legal aspects of such autonomous vehicles (Borenstein et al., 2019).

Another limitation of the generalizability of the results in this paper is the focus on Germany. The traffic potential analysis as well as the acceptance analysis relied on data from Germany, as this is the development and current test environment of the Ducks. Whether these results can be transferred to other countries and continents needs to be confirmed in future studies as not only the traffic laws and norms differ between countries but also perceptions of mobility concepts vary culturally (Jing et al., 2020; Müller, 2019).

7. Conclusion

Duck Trains are automated electric light/micro vehicles which offer much flexibility for urban last-mile delivery. This preliminary potential analysis from transport planning and social science perspectives reveals a high potential, especially for dense urban areas. Duck Trains (of several Ducks) are competitive regarding their payload to conventional delivery vehicles, like vans or station wagons; and, at the same time, their range and speed are comparable to (electric) cargo bikes, which seems sufficient for urban last-mile delivery. In comparison to other (automated) micro-vehicles solutions, their combined high payload, speed, and flexibility stand out. However, future research and microscopic simulations are needed to further study the Duck Trains' and other light vehicles' impacts on traffic and other road users as well as sustainability and (economic) efficiency of delivery. Public acceptance is high, especially for delivery services. However, concerns regarding the impact on traffic and traffic safety as well as the sustainability of the batteries remain. Here, future research should focus on what drives the acceptance of such "green" vehicle technologies and how customers, delivery companies, and private users may be persuaded to more sustainable, ecologically friendly transport behavior.

CRediT authorship contribution statement

Eva-Maria Schomakers: Conceptualization, Methodology (Social Sciences), Validation (Social Sciences), Formal Analysis (Social Sciences), Investigation (Social Sciences), Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Marcus Klatte:** Methodology (Traffic Science), Validation (Transport Planning), Formal analysis (Transport Planning), Investigation (Transport Planning), Writing – original draft, Visualization. **Vivian Lotz:** Methodology (Social Sciences), Validation (Social Sciences), Formal analysis (Social Sciences), Investigation (Social Sciences), Writing – original draft, Writing – review & editing. **Hannah Biermann:** Methodology (Social Sciences), Validation (Social Sciences), Investigation (Social Sciences), Writing – original draft. **Fabian Kober:** Writing – original draft, Writing – review & editing, Resources, Project administration, Funding acquisition. **Martina Ziefle:** Funding acquisition.

Acknowledgments

We thank all participants for sharing their opinions. This work was supported by the Federal Ministry of Transport and Digital Infrastructure, Germany (Project SULEICA, no. FKZ 01MM19012D).

Appendix

See Table 2.

References

ADAC, 2020. Marktübersicht: Die aktuellen elektro-transporter. URL: https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/kaufen/e-transporter/.

Allen, J., Piecyk, M., Piotrowska, M., Mcleod, F., Cherrett, T., Ghali, K., Nguyen, T., Bektas, T., Bates, O., Friday, A., Wise, S., Austwick, M., 2017. Understanding the impact of e-commerce on last-mile light goods vehicle activity in urban areas: The case of London. Transp. Res. D 61, http://dx.doi.org/10.1016/j.trd.2017.07.020.

Amaya, J., Arellana, J., Delgado-Lindeman, M., 2020. Stakeholders perceptions to sustainable urban freight policies in emerging markets. Transp. Res. A 132, 329–348.

Anna, 2018. New DHL 'PostBOT' helps the postie carry the mail. URL: https://roboticsandautomationnews.com/2018/07/02/new-postbot-helps-the-postie-carry-the-mail/18025/.

Antonakopoulou, A., Rigos, A., Portouli, E., Amditis, A., 2021. Explaining the public acceptance of electrified L-category vehicles towards sustainable urban mobility planning. In: International Conference on Applied Human Factors and Ergonomics. Springer, pp. 288–297.

Appunn, K., 2021. German cities push for 30 km/h speed limit and reform of road traffic law. URL: https://www.cleanenergywire.org/news/german-cities-push-30km-h-speed-limit-and-reform-road-traffic-law.

Arvidsson, N., Pazirandeh, A., 2017. An ex ante evaluation of mobile depots in cities: A sustainability perspective. Int. J. Sustain. Transp. 11 (8), 623–632.

Baum, L., Assmann, T., Strubelt, H., 2019. State of the art - Automated micro-vehicles for urban logistics. IFAC-PapersOnLine 52 (13), 2455–2462. http://dx.doi.org/10.1016/j.ifacol.2019.11.575.

Bogdanski, R., 2019. Quantitative untersuchung der konsolidierten Zustellung auf der letzten Meile. URL: https://www.c-na.de/fileadmin/templates/global/media/Pedelistics/Download/Kurzstudie_Konsolidierte_Zustellung.pdf.

Borenstein, J., Herkert, J.R., Miller, K.W., 2019. Self-driving cars and engineering ethics: The need for a system level analysis. Sci. Eng. Ethics 25 (2), 383–398.

Brell, T., Philipsen, R., Biermann, H., Ziefle, M., 2021. Social acceptance of autonomous driving–the importance of public discourse and citizen participation. In: Smart Transportation. CRC Press, pp. 1–17.

Brell, T., Philipsen, R., Ziefle, M., 2019. Scary! risk perceptions in autonomous driving: The influence of experience on perceived benefits and barriers. Risk Anal. 39 (2), 342–357.

Bucsky, P., 2018. Autonomous vehicles and freight traffic: Towards better efficiency of road, rail or urban logistics? Urban Dev. Issues 58 (1), 41–52. http://dx.doi.org/10.2478/udi-2018-0022.

Bundesvereinigung Logistik, 2014. Nachhaltige logistik in urbanen Räumen. URL: https://www.bvl.de/misc/filePush.php?id=24558&name=BVLA14+Gruenbuch+Urbane+R%C3%A4ume.pdf.

BVL.digital, 2019. Analyse Verkehrsdaten. URL: https://go.engage.here.com/rs/142-UEL-347/images/20191018_HERE_Erreichbarkeit_Analyse_Charts-2.pdf.

Cregger, J., Machek, E., Behan, M., Epstein, A., Lennertz, T., Shaw, J., Dopart, K., 2020. Emerging Automated Urban Freight Delivery Concepts: State of the Practice Scan. Final Report FHWA-JPO-20-825, US Department of Transportation, URL: https://rosap.ntl.bts.gov/view/dot/53938.

Deutsche Post AG, 2017. dpdhl.com, Neuer Zustell-Roboter unterstützt Postboten beim Austragen ihrer Sendungen. URL: https://www.dpdhl.com/de/presse/pressemitteilungen/2017/neuer-zustell-roboter-unterstuetzt-postboten.html.

Digiesi, S., Fanti, M.P., Mummolo, G., Silvestri, B., 2017. Externalities reduction strategies in last mile logistics: A review. In: Proceedings - 2017 IEEE International Conference on Service Operations and Logistics, and Informatics, SOLI 2017. 2017-January, pp. 248–253. http://dx.doi.org/10.1109/SOLI.2017.8121002.

DroidDrive GmbH, 2022. Ducktrain.io. Make urban transportation smart, clean and efficient. URL: https://ducktrain.io/.

Edmonds, E., 2019. Three in four Americans remain afraid of fully self-driving vehicles. AAA believes testing, experience and education will aid consumer acceptance. URL: https://newsroom.aaa.com/2019/03/americans-fear-self-driving-cars-survey/.

Greiving, S., Flex, F., 2016. Neuaufstellung des Zentrale-Orte-Konzepts in Nordrhein-Westfalen. Verlag der ARL, Hannover.

Gringer, J., 2021. Electric ducks instead of trucks. URL: https://motionist.com/en/electric-ducks-instead-of-trucks/.

Hunecke, M., Blöbaum, A., Matthies, E., Höger, R., 1999. Umweltwahrnehmung & -wissen: Problemwahrnehmung spezifisch (Environmental perception & knowledge: Specific problem perception) Zusammenstellung Sozialwissenschaftlicher Items Und Skalen (ZIS) URL: http://dx.doi.org/10.6102/zis177.

Hunecke, M., Blöbaum, A., Matthies, E., Höger, R., 2014. Verantwortungszuschreibung intern spezifisch (Specific responsibility attribution) Zusammenstellung Sozialwissenschaftlicher Items Und Skalen (ZIS) URL: http://dx.doi.org/10.6102/zis63.

Hyvönen, K., Repo, P., Lammi, M., 2016. Light electric vehicles: Substitution and future uses. Transp. Res. Procedia 19, 258–268.

INKAR, 2021. Indikatoren und Karten zur Raum- und Stadtentwicklung (INKAR). Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR), Bonn, URL: https://www.inkar.de/.

Javaid, A., Creutzig, F., Bamberg, S., 2020. Determinants of low-carbon transport mode adoption: Systematic review of reviews. Environ. Res. Lett. 15 (10), 103002.

Jing, P., Xu, G., Chen, Y., Shi, Y., Zhan, F., 2020. The determinants behind the acceptance of autonomous vehicles: A systematic review. Sustainability 12 (5), 1719.

Kapser, S., Abdelrahman, M., 2020. Acceptance of autonomous delivery vehicles for last-mile delivery in Germany–extending UTAUT2 with risk perceptions. Transp. Res. C 111, 210–225.

Matusiewicz, M., Rolbiecki, R., Foltyński, M., 2019. The tendency of urban stakeholders to adopt sustainable logistics measures on the example of a polish Metropolis. Sustainability 11 (21), 5909.

Melo, S., Baptista, P., Costa, A., 2014. The cost and effectiveness of sustainable city logistics policies using small electric vehicles. Transp. Sustain. 6, 295–314. http://dx.doi.org/10.1108/S2044-994120140000006012.

Müller, J.M., 2019. Comparing technology acceptance for autonomous vehicles, battery electric vehicles, and car sharing—A study across Europe, China, and North America. Sustainability 11 (16), 4333.

de Oliveira, C.M., De Mello Bandeira, R.A., Goes, G.V., Gonçalves, D.N.S., De Almeida D'Agosto, M., 2017. Sustainable vehicles-based alternatives in last mile distribution of urban freight transport: A systematic literature review. Sustainability 9, 1324. http://dx.doi.org/10.3390/su9081324.

Onomotion GmbH, 2022. ONO. Moves your business, move the world. URL: https://onomotion.com/en/.

Patella, S.M., Grazieschi, G., Gatta, V., Marcucci, E., Carrese, S., 2021. The adoption of green vehicles in last mile logistics: A systematic review. Sustainability 13 (6), http://dx.doi.org/10.3390/su13010006.

Roberts, N., 2004. Public deliberation in an age of direct citizen participation. Am. Rev. Public Adm. 34 (4), 315–353.

Schulz, W., Kaindl, M., Waska, B., Leskovich, I., Rappold, E., 2002. Verkehrsfreiheit der eigenen Wohngegend (Traffic freedom of the residential area) Zusammenstellung Sozialwissenschaftlicher Items Und Skalen (ZIS).

StreetScooter GmbH, URL: https://www.streetscooter.com/wp-content/uploads/2019/01/StreetScooter-Broschuere.pdf.

StVZO, 2021. Straßenverkehrs-Zulassungs-Ordnung vom 26. April 2012 (BGBl. I S. 679), die zuletzt durch Artikel 11 des Gesetzes vom 12. Juli 2021 (BGBl. I S. 3091) Geändert worden ist. URL: https://www.gesetze-im-internet.de/stvzo_2012/BJNR067910012.html.

US Postal Service, 2018. Summary report: Public perception of delivery robots in the United States. RARC-WP-18-005, Office of Inspector General. United States Postal Service, URL: https://www.uspsoig.gov/document/public-perception-delivery-robots-united-states.

Wermuth, M., Neef, C., Wirth, R., Hanitz, I., Löhner, H., 2012. Kraftfahrzeugverkehr in deutschland 2010 (KiD 2010). URL: https://daten.clearingstelle-verkehr.de/240/9/KiD2010-Schlussbericht.pdf.