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Transportation Research Procedia 79 (2024) 146–153

Transportation Research Procedia

www.elsevier.com/locate/procedia

City Logistics 2023

Results and learnings from Europe's largest cargo bike testing program for companies and public institutions

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Abstract

To enhance the empirical knowledge of commercial cargo bike utilization, 755 companies and public institutions throughout Germany tested cargo bikes in operational use for a duration of three months. This article provides a characterization of the users, their experiences and evaluation of the vehicle type and addresses its use and environmental impact. Three waves of online surveys were conducted over three years, and around 30,000 vehicle trips were recorded. The organizations showed considerable heterogeneity in terms of size, economic sector, and location. The study identified environmental protection and taking a pioneering role as the main motivations for participation. Cargo bikes were used more frequently for services than for deliveries, with an average of 2.8 days per week and 12 km per day of use. The general suitability of cargo bikes was positively assessed, but potential product improvement was seen, e.g., with regard to the handling of the cargo box. About one third of the participants decided to buy their own cargo bike after the test phase. The study suggests that policy measures such as purchase incentives during the market ramp-up period and improvements to bicycle infrastructure, should be taken, while the industry should improve the reliability of vehicle components and offer better maintenance services to customers.

Keywords: cargo bike; sustainable urban freight; mobile service provision; vehicle shift; user acceptance; policy making; GPS tracking; fleet trial

1. Introduction

As the third-largest source of greenhouse gas emissions in Germany, the transport sector currently has an annual emission level of around 147 million t CO_2, which is still 90% of the 1990 value (UBA, 2023). In order to be able to achieve the climate protection targets of the German government, changes in the transport sector are unavoidable. Commercial transport plays a particularly important role in this transformation, as about one in three vehicle trips in Germany is assigned to commercial transport, with much higher shares in inner cities (Arndt, 2010). The commercial

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10.1016/j.trpro.2024.03.021

use of cargo bikes can be perceived as a promising attempt to replace previous systems, concepts and routines and thus to handle transport in a climate-neutral and urban-compatible way (Lenz & Gruber, 2021). However, the cargo bike has by no means become established in all business sectors. Previous initiatives have in common that fleet tests were only carried out with a small number of cargo bikes and that the focus was on the parcel sector. Little knowledge and experience have been available to date on the possibilities for commercial use on a broader scale or in other industries. The German government addressed this knowledge gap with the project, “Ich entlaste Städte” (I relieve cities), which ran from 2017-2020.

The aim was to offer a few hundred companies from a heterogeneous cross-section of the German economy the opportunity to test cargo bikes instead of conventional vehicles. The scientific aim of the vehicle test was to evaluate the traffic-related and emission-related effects, the willingness of companies to use them, and the drivers and barriers to further market penetration.

The next section presents the study design, following this the results are discussed in detail. After the implications, the article ends with a conclusion.

2. Study design

2.1. Conception and realization

Despite considerable potential, cargo bikes have so far played a minor role in urban commercial transport. The vehicle test scheme is intended to raise awareness of the cargo bike as an alternative means of transport among a wide range of commercial and public users. Companies and public institutions were offered the opportunity to use a cargo bike over a period of three months. A total of 152 cargo bikes were available for this purpose. With a few exceptions, one vehicle was assigned to one company. Depending on individual transport requirements, 23 different cargo bike models in five designs were available (Fig. 1a). The 23 types of cargo bikes provided a broad representation of the vehicle market available at the time of the test, including small, maneuverable cargo bikes or large tricycles for transporting heavy loads. A total of 85% of the cargo bikes were equipped with electric pedal assistance up to 25 km/h, 10% were non-motorized, and 5% were equipped with electric-assist up to 45 km/h (category L vehicle according to Directive 2002/24/EC).

a

No. of wheels	Construction type	Side view of typical model	No. of models	No. of vehicles
2	Pizza de-livery bike		1	8
	Long John bike		9	56
	Longtail bike		2	4
3	Tricycle, front load		5	15
	Heavy-load tricycle		1	1

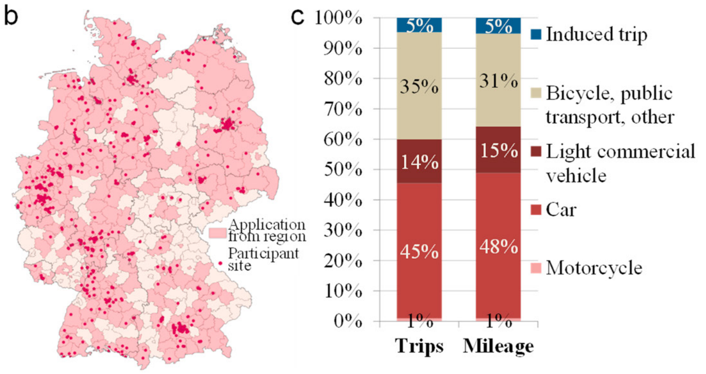

Fig. 1. (a) overview of provided test vehicles; (b) location of applicants (N=1,935); (c) substituted means of transport (N=503)

Private-sector companies, municipal institutions and NGOs throughout Germany were invited to participate in the project. A total of 1,935 applications were registered in the period from spring 2017 to fall 2019 (see Fig. 1b) and around 70% of the applications were assessed as suitable. Assessment criteria included mandatory commercial use, willingness to provide data for research and payment of a monthly usage fee of €30. Companies with existing cargo bike experience were downgraded. In total, 755 companies and public institutions across Germany were given the opportunity to test cargo bikes in operational use. For the characterization of participants see below. The cargo bikes were given out for three months without larger investment costs for the companies (besides the monthly rate of €30).

A practical introduction, maintenance, insurance and repairs were provided. The direct purchase of a vehicle after the test was deliberately not made possible, as otherwise distortions would have been expected in the assessment of willingness to buy. Ex-participants who were willing to buy therefore had to match their requirements for a cargo bike with the market availability of the respective vehicle.

2.2. Data collection and methods

In order to derive knowledge on the commercial use of cargo bikes and their effects in urban transport, data had to be collected. This included quantitative surveys of the participating companies, (i) qualitative interviews, (ii) and the collection of traffic data in combination with trip-specific information. Over a period of three years, three online questionnaires were handed out. The first survey of users took place before the start of the cargo bike test, the second survey at the end of the three-month testing phase, and the third survey three to twelve months after the test. Guided telephone interviews were conducted with decision-makers and drivers before and during the test. Vehicle movements during the test period were recorded using the built-in bicycle speedometer (mileage only), a passive GPS tracker, and a smartphone-based app (DLR's MovingLab, see https://movinglab.dlr.de/) After completion of each trip, participants were asked additional trip-specific questions by the app, such as trip purpose.

Descriptive statistical methods were essentially used to derive the results for this contribution. Additionally, Tews et al. (2020) served as the basis for calculating the greenhouse gas reductions achieved. By querying the substituted mode of transport, it was possible to determine the substitution effect for each specific trip. For the shifted mileage of passenger cars and light commercial vehicles up to 3.5t, fleet emission factors were calculated according to the Handbook Emission Factors for Road Transport (HBEFA 4.1). As a result, values for passenger cars and light commercial vehicles are available for both urban and extra-urban use, ranging from 202 to 277g CO_2/km.

3. Results

This section contains 7 subsections: At first, the participating companies and their fleets will be described. Further, motivation for usage and the perception of drivers and barriers before and after the test will be highlighted. The following two subsections depict vehicle usage and the corresponding effect on emissions reduction. Finally, we describe the final verdict of the participants and whether they purchased their own cargo bike after the test.

3.1. Characterization of interested and participating organizations

Classifying the approximately 1,900 applications and the 755 companies and public institutions that ultimately participated, a diverse interest in the commercial use of cargo bikes becomes apparent. On the one hand, this concerns spatial aspects: Applications were registered from all German federal states and municipality size classes. Cargo bikes were not only requested in (centers of) large cities, but also in small towns or suburban areas (Fig. 1b). The spatial origin of applications is relatively proportional to the population distribution in Germany. In the large cities, such as Berlin and Hamburg, interest in participation is disproportionately high, but substantial interest was also noticeable in medium-sized and even small cities. In fact, rural communities and small towns with up to 20,000 inhabitants (13% of the German population) are even slightly overrepresented among the participants (18% of the participants). There is thus great potential for cargo bikes not only in large cities, where pioneers for sustainability innovations are primarily assumed to exist.

The distribution by type of organization is 50% private companies, 24% 1-person-companies (freelancers, self-employed), 14% public institutions and 12% NGOs and associations. Heterogeneity could also be observed in the size of the participating organizations in terms of number of employees or turnover. Furthermore, looking at the distribution of participants by economic sector, there is a great deal of heterogeneity: in addition to logistics and other service industries, also crafts, construction, manufacturing industries, and municipal enterprises are strongly represented, suggesting that cargo bikes can basically be utilized in all economic sectors and that there is not the one predestined industry for their use.

3.2. Existing fleet and fleet-related decision-making

The survey on existing vehicles showed that about 50% of the respondents belong to a company that has a corporate fleet of two to six fleet vehicles. The corresponding daily mileage of this middle half of the distribution (Q1-Q3) is 13–46 km per vehicle with 2–6 daily stops (such as for deliveries or customer visits). Differentiation by vehicle type shows that the existing fleets tend to be small, with an average of nine vehicles (1.7 cargo bikes, 3.8 cars, 2.3 light commercial vehicles, and 0.6 trucks > 3.5 t). The majority of mileage is currently provided by internal combustion engine (ICE) vehicles (median: 98.7%).

At the individual level of the respondents, there is a clear preponderance of male participants (84%), a high level of education (49% university degree) and a high proportion of management responsibility (82%). Two thirds of the respondents are responsible for the selection and purchase of vehicles. Vehicle procurement decisions can be assigned to so-called "autocratic fleet decision-making" in around 80% of companies, based on a typology by Nesbitt & Sperling (2001). These companies are characterized by a high degree of centralization (i.e., few people are involved in fleet decision-making) and a low degree of formalization (i.e., decisions are made intuitively rather than following a fixed set of rules). The high proportion of participants with autocratic fleet decision-making supports the authors' statement that these types of companies are well suited for testing and implementing alternative vehicle concepts.

3.3. Motivation for use, perception of drivers and barriers

Why did companies decide to use a cargo bike? Concerning usage motivation, it is evident that the interest in environmental protection through the use of an emission-free vehicle predominates, with around 9 of 10 respondents stating they rather agree or agree strongly. However, for many companies it is similarly important to act as a role model and to set an example for other companies or institutions in the same business sector. Only about half of the test participants expect economic benefits. Only a few tested a cargo bike to prepare for potential driving bans for conventional vehicles.

Table 1. changing perceptions of drivers and barriers through the cargo bike test (N=530)

Driver Item	T0/pre	T1/post	Change	Barrier Item	T0/pre	T1/post	Change
Flexible parking	4.40	4.39	o	Handling experience	3.23	3.55	+
Image	4.40	4.33	o	Cycle infrastructure	2.91	3.62	++
Health	4.37	4.17	o	Implementation cost	2.90	3.26	+
Electric range	4.34	4.07	–	Weather	2.89	3.42	++
Purchase cost	4.29	4.16	o	Theft	2.67	2.99	+
Maintenance cost	4.23	4.25	o	Service network	2.37	2.72	+
Environmental goals	4.21	4.12	o	Safety	2.36	2.90	++
Fun	4.13	4.05	o	Loading capacity	2.19	2.69	++
Accessibility	4.12	4.34	o	Organizational effort	2.16	2.50	+
Travel time reliability	3.97	3.96	o	Spatial coverage	2.11	2.73	++
Travel time	3.54	3.30	o	Payload damage	1.84	2.14	+
				Employee acceptance	1.67	2.04	+
Color reference	1.0	5.0		*Color reference*	1.0	5.0	

The participants rated 23 items on their perception of drivers and barriers before the test (T0/pre) and at the end of the three-month vehicle test (T1/post). In Table 1, the 11 drivers and 12 barriers are sorted by their perceived strength on a scale of 1 to 5 points. The greener the colored background, the stronger a driver is perceived or the weaker a barrier is perceived. Conversely, a red spectrum indicates strong barriers or weak drivers. The last column shows the change after the test experience ('o' was used for deviations below 0.25 points; '+' or '–' for deviations between 0.25 and 0.5 points; '++' or '––' for deviations larger than 0.5 points).

Hardly any perceptual changes could be observed in the drivers as a result of the test. Since a piloting project primarily appeals to an ex-ante optimistic target group, the pre-test benefits were perceived to be very strong, including operational benefits (e.g., use of route shortcuts, flexible parking) or soft aspects such as fun and health benefits. Most drivers confirmed in a positive effect at the end of the three-month test.

Barriers were rated as low to moderate in advance, but after the test this assessment deteriorated. All aspects were perceived as (in some cases significantly) stronger, i.e., more constraining, after the test. It can be concluded from this that certain disadvantages of the use of cargo bicycles were underestimated before gaining personal experience with this vehicle. The test program identified a need for improvements, which is addressed to different target groups (see Implications section).

3.4. Vehicle use during the test period

The participants each tested one of 152 cargo bikes in commercial use for three months and covered around 307,000 kilometers in a total of around 30,000 trips. On average, the participants covered 412 km during the test period. The cargo bike was used on an average of 2.8 days per week and 12 km per day of usage.

*** In line with the heterogeneous field of participants, the test vehicles were used for a wide variety of transport tasks. To simplify, the purpose of use of the vehicles can be divided into two main categories: 42% used the cargo bike primarily to transport goods and merchandise and 58% rather to provide a service at the destination, e.g., tradesmen trips. This suggests that, against the background of highly optimized and cost-driven logistics services, cargo bikes tend to be more suitable for service providers and other industries whose business purpose is not only the transport of goods.

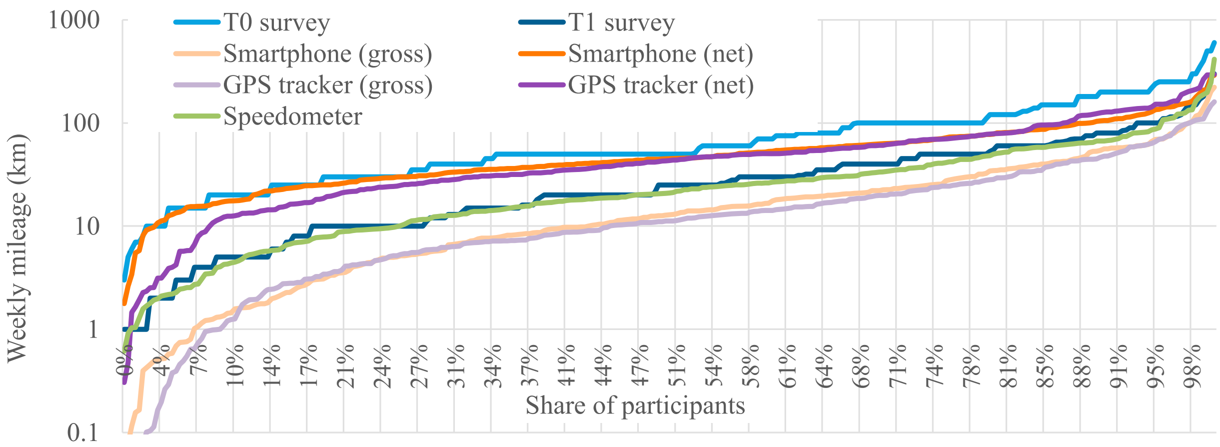

Fig. 2. cumulative frequencies of mileage: comparison of data collection methods (N=297)

The collection of mileage data was carried out as shown in the "data collection and methods" section via surveys before the test (T0: predicted mileage) and after the test (T1: stated actual mileage) and by bicycle speedometer, GPS tracker, and smartphone app. Fig. 2 shows a comparison of the collected data, normalized to weekly mileage. Gross values are mileage divided by number of days of the test period, net values are mileage divided by number of days that the tracking device was used. To avoid bias, only participants from whom data from all sources were available were examined here (N=297). The following conclusions can be drawn concerning the usage behavior of a heterogeneous cross-section of the German economy with businesses having little or no prior cargo bike experience:

- Regardless of the different absolute level of the curves, the distribution can be roughly divided into three groups of usage intensity. There is about one fourth of dropouts and low-intensity users (<10 km per week by speedometer), a majority of 70% with weekly mileages of 10-100 km, and a very small group with high intensity usage of over 100 km on a weekly average.
- T0>T1: The prediction made before the test overestimated the mileage reported at the end.
- T1≈speedometer: reported mileage in T1 survey is confirmed by speedometer values.
- Large difference between gross and net values, both for smartphone and GPS tracker. This is due to the fact that the vehicle was not usually used on all working days during the test period, but on average on 2.8 days per week.

3.5. Emissions reduction

With regard to the potential of cargo bikes to replace trips made by conventional vehicles, it was found that about two thirds of the trips as well as of the mileage would have been made with an ICE vehicle if the test vehicle was not available (Fig. 1c). Only every 20th trip or every 20th kilometer driven was induced, i.e. would not have taken place without a project vehicle. Around 30% of the participants would have made all trips exclusively by ICE vehicles if there was no cargo bike. Extrapolated to one year, the value for the absolute GHG savings is, on average, 245 kg CO_2 per year per cargo bike, including all test dropouts and low-mileage users. This value thus results from a usage intensity as achieved during the test period, which is very likely lower than a usage intensity with established operational embedding of a cargo bike. A usage intensity of 4.3 days per week (average value among subsequent cargo bike purchasers) therefore results in higher annual savings of 403 kg CO_2 per year per cargo bike.

3.6. General evaluation of the testers

Overall, around two-thirds of the participants rated the general suitability of cargo bikes for their organizations' purposes as good to very good. In addition to general suitability, satisfaction with the specific vehicle model was also surveyed. There are only minor deviations between general suitability (mean of 3.8 on the 5-point scale) and model satisfaction (mean: 3.7) averaged over the entire sample. For individual subgroups, however, the evaluation differs. The largest difference between the two dimensions is among logistics service providers (industry H), who are highly convinced of the general suitability of cargo bikes in their industry (mean: 4.8), but relatively dissatisfied with the cargo bike models tested (mean: 3.7). This difference is an indication that the vehicles tested (manufactured in 2017 and 2018) have not reached full market maturity for usage in (parcel) logistics. However, it was not only the logistics experts who saw a need for vehicle design improvements, but 78% of all participants, especially with regard to the handling of the cargo box (65%). The e-drive or the electric range, on the other hand, were less frequently seen as requiring improvement (35%).

Regarding the expected profitability of cargo bike use, out of 10 respondents, about six decision makers are optimistic, one is pessimistic, and three are undecided. About one fifth of the participants did not make satisfactory use of the cargo bike or abandoned the test early. A qualitative interview was conducted among 49 participants to determine the main reasons for terminating the test early. The most frequently cited reasons were: Handling of the cargo bike (31), personnel problems, such as sick or unmotivated staff (18), defects in the cargo bike and resulting safety concerns (15), test-specific problems (10), weather-related problems (6).

3.7. Acquisition of own cargo bikes after the test

As described above, a direct purchase option of a test vehicle was not offered, in order to not distort the measurement of real purchase intention. Half of the respondents stated a high or very high likelihood for purchasing an own cargo bike at the end of the test. Subsequently, the status of the purchase decision was asked two more times, on average 107 days (T2) and 251 days (T2*) after the end of the test. At these points in time, 25% of the companies, and 32%, respectively, had actually purchased at least one cargo bike for operational use. In survey wave T2, respondents were also asked to evaluate possible factors influencing the purchase decision. For around 70% of those who bought cargo bikes, soft benefits such as the fun factor and being a role model were decisive, but operational benefits such as flexibility in parking were also frequently mentioned (63%). For organizations that decided not to buy, implementation costs were by far the most frequently cited reason (stated by 42%). Other aspects, such as poor bicycle infrastructure, vehicle handling, or weather dependency, are of importance for around 20% of the non-buyers.

The self-procured vehicles had an average purchase price of €4,432 and an electric range of 73.8 km. They were used on average 4.3 days per week by an average of 1.9 men and 0.7 women, i.e. 2.6 persons. The purchase costs were higher for actual purchasers than for most participants who stated an intention to buy at the end of the test period. Among those, one fourth would only spend under €2,500, one fourth between €2,500 and €3,500, one fourth between €3,500 and €5,000 and one fourth over €5,000. This could be an indication that potential adopters did not purchase due to cost reasons. Finally, the desired degree of electrification was queried. The most popular was an electric drive up to 25 km/h: 87% of those testing such a vehicle would choose it again. 61% of those testing cargo bikes without e-drive would also switch to that degree of electrification. Of those testing a category L vehicle with up to 45 km/h, half would switch to a 25 km/h pedal-assisted cargo bike, the other half would again choose a category L vehicle.

4. Implications

4.1. For research

The Germany-wide vehicle test with more than 750 participating companies provides research with a hitherto unknown data basis for studying the commercial use of cargo bikes and the decision-making behavior of companies with regard to this alternative type of vehicle. The purpose of this paper is to provide a broad overview of the results of the field trial and the experiences of the participating organizations. In addition, the data enabled more in-depth analyses, for example of the differences in travel times between cargo bikes and cars. For this purpose, real recorded journeys were compared with virtual car journeys. The results show that in a distance range of up to 3 km, cargo bikes can compete time-wise with passenger cars and provide indications for the further exploitation of the operational advantages of cargo bikes (Gruber & Narayanan, 2019). The purchase decision could also be analyzed more deeply (Narayanan et al., 2022). The authors found spatial, temporal, attitudinal, vehicle-related and organizational factors. The extensive set of 23 drivers and barriers could be simplified to 7 factors with the help of an exploratory factor analysis (Thoma & Gruber, 2020).

4.2. For potential adopters

The test has motivated many companies and institutions from practically all sectors of the economy to consider modifying their vehicle fleets and often to purchase a cargo bike. Cargo bikes can be used across all industries, there is no one purpose, in this respect, no company should categorically exclude its own (potentially) profitable use. The results suggest that the craft and service sectors with moderate mileages are a very relevant target group for further market development. If there is the possibility to test a vehicle over several weeks, this should be utilized, because testing and checking one's own expectations in reality is a catalyst for later purchase.

4.3. For policy-makers

It was possible to demonstrate that cargo bikes can be a real alternative to conventional vehicles in many sectors of the economy and also public sectors. Everywhere, the continuous improvement of the bicycle infrastructure is a basic prerequisite for a further increase in bicycle-based city logistics. At the end of the test phase, one third of the participants purchased their own cargo bike. The high acquisition costs are also perceived a key barrier. This demonstrates the ongoing need for action to support the market ramp-up. In particular, the German federal government's cargo bike purchase premium program (BMWK, 2023), which came into effect in 2021 and will run at least until 2024, offers financial support for the purchase of cargo bikes (25% of the acquisition costs, up to €2,500).

The diverging assessment of barriers before and after the own test experience underlines the importance of test programs among future potential users. Such programs can counter misconceptions about vehicle handling and help in normalizing the shift from ICE vehicles to cargo bikes. In order to further reduce existing reservations, information campaigns should be conducted to strengthen the perception of the crucial soft usage benefits.

A total of 14% of the participants were public institutions, many of them municipal actors. Municipalities can play an interesting dual role. By promoting cargo bike logistics, they can contribute to achieving their own climate protection goals or strengthening the local economy. At the same time, they can promote the transformation of their own vehicle fleets and act as role models, for example in the field of urban cleaning or green maintenance. For further recommendations at the municipal level see Rudolph & Gruber (2017).

4.4. For industry

The bicycle industry is called upon as well. Almost 80% of those surveyed saw a need for design improvements. This can be seen as a call to invest even more in increasing the quality and reliability of vehicle components. Another issue is the vehicle's weather dependency, an aspect that seems obvious but has tended to be underestimated. Therefore, flexible weather protection might substantially increase user comfort. Furthermore, a professionalization of the after-sales market is urgently needed, especially for the provision of maintenance or repairs. There is still a big gap compared to the high service levels of conventional vehicles. However, players from other sectors, such as IT or automotive, are becoming increasingly involved and contributing to innovation processes. The growing sales figures are likely to be both a consequence and motivation for this development: The sales of electric cargo bikes in Germany were only around 15,000 in 2016, rising to 54,000 in 2019 and 165,000 in 2022 (ZIV, 2023).

5. Conclusion

To address knowledge gaps in understanding commercial cargo bike use, over 750 companies and institutions tested this type of vehicle under scientific guidance. To our knowledge, this was the largest public cargo bike test for commercial operators in Europe. It became evident that cargo bikes can replace conventional vehicles in commercial transport and thus contribute to reducing emissions and improving the quality of life in cities. However, as cargo bikes are only used for relatively short distances and with low payloads, they serve a niche market, which is also reflected in the users' profile. The potential users are diverse, with ecological attitudes and soft benefits being the main reasons for the decision-makers' interest rather than economic motives. In many cases, the trial phase also led to the decision to buy an own cargo bike. In the further course, the transformation process that a fleet conversion entails should be examined in detail together with representatives of various private and public branches. This should be linked to the goal of making the fleet transformation even more ambitious and permanent. The result could be "blueprints" for other companies and institutions, for which there is likely to be high demand across all sectors.

Acknowledgements

The author would like to thank the reviewers for their valuable comments. The generation and publication of the results shown were made possible by the projects "Ich entlaste Städte" (funding code 03KF0066) and "Ich entlaste Städte 2" (funding code 67KF0154) of the German National Climate Initiative, funded by the Federal Ministry for the Environment and the Federal Ministry for Economic Affairs and Climate Action.

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