Transportation Research Part A 155 (2022) 31–45

Contents lists available at ScienceDirect

Transportation Research Part A

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

Purchase intention and actual purchase of cargo cycles: Influencing factors and policy insights

Santhanakrishnan Narayanan [a,*], Johannes Gruber [b], Gernot Liedtke [b,c], Constantinos Antoniou [a]

[a] *Technical University of Munich, Arcisstrasse 21, 80333 Munich, Germany*
[b] *German Aerospace Center (DLR), Rudower Chaussee 7, 12489 Berlin, Germany*
[c] *Technical University of Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany*

ARTICLE INFO

Keywords:
Cargo cycles
Cargo bikes
Commercial transport
Purchase decision modeling
Vehicle procurement
Sustainable urban freight

ABSTRACT

To support the penetration of cargo cycles in commercial transport, this research aims at identifying the significant influencing factors for their purchase, using data from Europe's largest cargo cycle testing project "Ich entlaste Städte". This is achieved by developing binary logit models for the intention to purchase (stated at the end of a 3-month vehicle trial), and the actual purchase decision made (queried three months or later, after the end of the trial). Prior to the estimation of the logit models, latent variables have been constructed using explanatory factor analysis. Based on the estimation results, factors that influence the actual purchase decision include catchment area of cargo cycle trips, daily usage during the trial phase, trial phase season, type of cargo cycle tested, mode substituted by cargo cycles during the trial phase and business sector. Furthermore, four other factors, which are latent variables constructed through exploratory factor analysis, are found to have significant influence: perception of operational, soft and cost benefits, as well as importance of deterioration of conditions for conventional vehicles. Based on the influence of these factors, policy measures are suggested under the following categories: (i) Regulation, (ii) Infrastructure, (iii) Finance, (iv) Campaigns and (v) Trial schemes. The data from the project shows the existence of a difference between the intention and the actual purchase decision (around 50% higher intent compared to realized purchase). This implies that there is a need to convert intention to actual decision, when making conclusions based on intention. A comparison, made between the binary logit models of intention and actual purchase decision, brings out the reality that the latter is influenced by hard facts like the deteriorating conditions (e.g., vehicle access restrictions) for conventional vehicles, while the former is influenced by operational concerns towards cargo cycles. This observation suggests the necessity of formulating measures to foster the market penetration of cargo cycles.

1. Introduction

Emissions from the transport sector are continuing to rise, with a substantial portion coming from commercial transport (freight deliveries and service trips). With increasing commercial activities on the one hand and concern for the environment on the other hand, there is a growing pressure to mitigate the negative externalities from the commercial transport sector. For example, the

* Corresponding author.
E-mail address: santhanakrishnan.narayanan@tum.de (S. Narayanan).

https://doi.org/10.1016/j.tra.2021.10.007
Received 7 January 2021; Received in revised form 21 July 2021; Accepted 16 October 2021
Available online 18 November 2021
0965-8564/

European Commission sued Germany, U.K., France, Italy, Romania, and Hungary for failing to achieve emission goals (European Commission, 2018), subsequent to setting a goal to achieve emission-free urban freight transportation by 2030 (European Commission, 2011). Besides emissions, commercial vehicles also cause traffic congestion and reduction of road capacity (Giuliano, 2013). Furthermore, they can create unsafe conditions for other road users through illegal parking (Schmid et al., 2018). To minimize these negative impacts, several cities are exploring a range of policy measures, such as vehicle access restrictions, driving bans and parking fines (Holguín-Veras et al., 2020). Hence, currently, there is both the need and the will (Kassyda, 2016) to bring in a change in commercial transport.

Within this regard, the application of environmental-friendly smaller vehicles such as electric cargo cycles are being considered as a potential solution (Schliwa et al., 2015; Holguín-Veras et al., 2020). These vehicles can carry between 50 and 250 kg (110–1102 lb) of payload, and their battery capacity ranges from 50 to 80 km (31.1 to 49.7 mi) (Lenz and Riehle, 2013). Utilization of cargo cycles can reduce emissions, save space, lower costs, increase access for goods delivery, improve the image of an organization and enhance the quality of life in cities (Hagen et al., 2013; Tipagornwong and Figliozzi, 2014). In several situations, cargo cycles are competitive to conventional motorized vehicles in terms of travel time (Gruber and Narayanan, 2019; Conway et al., 2017). Concerning theoretical substitution potential, cargo cycles are expected to replace between 8 and 23% of commercial trips in Germany (Gruber and Rudolph, 2016). This potential is even larger in cities or areas with a high density of shops and offices [e.g., 15% of the freight trips in Stockholm is generated by offices (Sanchez-Diaz, 2020)]. Projects and real-life applications of cargo cycles in commercial transport show that they are capable of fulfilling the requirements of freight service providers as well as the expectations of cities through case-specific adaptations (Lenz and Gruber, 2021).

Although the pertinent literature shows several advantages and replacement potential, there are still reservations among fleet decision-makers and logistics operators to use this type of vehicle. The purchase of cargo cycles has still not been studied in the literature, and hence, it is unclear who will purchase cargo cycles and which factors will influence the purchase. Therefore, the objective of this research is to identify the factors that influence the actual purchase decision of cargo cycles by commercial users. A secondary objective of this research is to have a comparison between the actual purchase decision with purchase intention stated at the end of a 3-month vehicle trial. Several researchers make conclusions based on intentions (e.g., based on stated preference surveys), and not on the actual decision. Hence, the comparison is carried out to ascertain the suitability of such conclusions.

The contributions of this research work are the following: (1) Identification of factors affecting the actual purchase decision of cargo cycles by commercial users, (2) Comparison between the factors that affect the actual purchase decision and the earlier stated purchase intention and (3) Insights for policymakers and industry. The identified factors can help to understand the underlying reasons for the purchase of cargo cycles, while the comparison can throw light on the rationale behind the difference in purchase intention and actual purchase decision. The insights for policymakers and industry can support them in improving cargo cycle penetration and reduce the reservations against their use in commercial transport.

The remainder of this paper is structured as follows: A summary of the existing literature is presented next (Section 2), followed by a section on methodology (Section 3). After that, the details about data collection and the descriptive statistics of the research sample are presented (Section 4). Then, the modeling results are consolidated (explanatory factor analysis in Section 5.1 and binary logit models in Section 5.2). Subsequently, a discussion is made, based on the modeling results and the methodology employed in this study (Section 6). Finally, conclusions are elucidated (Section 7).

2. State of the art

This section consists of literature findings concerning (i) purchase of cargo cycles (as well as their usage) by commercial users and (ii) comparison of purchase intention and the actual purchase of market products. Since there is no substantial literature on the purchase decision of cargo cycles, factors that affect the willingness-to-use will also be explored, with an assumption that such factors could also have an influence on the purchase decision.

Starting with cargo cycle adoption, Thoma and Gruber (2020) enlist different latent variables that could potentially influence the adoption. The enlisted latent variables include vehicle limitations, soft benefits, worries and perils, cost benefits, urban advantages, riders' concerns, and infrastructure constraints. Heinrich et al. (2016) state that technical deficits have a decisive impact on the user acceptance of cargo cycles. Hence, adequate cargo cycle models are required to lower the technology failure likelihood. Utilization of cargo cycles could affect the workplace dynamics, especially for the organizations that previously relied more on cars or vans (Faxér et al., 2018). Therefore, there could be a delay in the planning phase, discouraging the use of cargo cycles. For people to change, incentives are required. Furthermore, the following are found to influence cargo cycle penetration: lack of over-night storage facilities, cargo cycle design and the necessity to share the road with automobiles. Similarly, Nürnberg (2019) states that the vehicle specifications (e.g., suitable construction types) and local policy decisions (e.g., provision of better cycling infrastructure and public presentation of the cargo cycle benefits) could affect the introduction of cargo cycles into a city's logistics system. Based on a survey, the perception of bike and car messengers on electric cargo bikes and the factors driving the willingness-to-use them are analyzed in Gruber et al. (2014). The authors conclude that the critical factors for the implementation of electric cargo bikes include electric range, purchase cost and publicly available information. In another related study (Gruber et al., 2013), the bike and car messengers are found to state an improvement in their jobs' image and a better possibility to have on-the-job exercise (soft benefits), when electric cargo cycles are utilized. Also, the messengers are found to be in support for the use of innovative technology. Payload capacity of cargo cycles are stated to be sufficient. In Choubassi et al. (2016), application of cargo cycles in regions with high population density (e.g., city center), provision of a dedicated right-of-way for them, policies that discourage the use of trucks and motorized vehicles, and monetary incentives to shift to cargo cycles are stated to be the contributing factors for cargo cycle use.

Concerning the comparison of purchase intention with the actual purchase decision, such a comparison for commercial decision-making (B2B) with respect to transport vehicles does not exist in literature, to the best of the authors' knowledge. Hence, findings from B2C market research are summarized here. One of the earliest studies on the comparison between purchase intention and the actual purchase comes from 1959 (Namias, 1959). The study states that even if a research correctly ascertains a consumer's purchase intentions at any given time, unforeseeable events, spontaneous and external, may intervene and change those intentions. However, purchase intention is stated as a best predictor of actual purchase in Peter and Olson (2010). Interestingly, the literature review of Morwitz (2012) concludes that the purchase intention is correlated with the actual purchase, and predict future sales, but does so imperfectly. Concerning automobile market, purchase intention and the actual purchase decision for automobiles and household appliances are compared in Morrison (1979). The study suggests that the automobile purchase intention is more correlated with the actual purchase decision, when compared to the purchase intention of household appliances. Nevertheless, there is a clear difference between purchase intention and the actual purchase for both the products.

Literature findings show that the adoption of cargo cycles as well as its use could be affected by a range of factors, including latent variables. However, identifying and quantifying the factors that significantly influence the actual purchase decision is yet to be carried out. Further, there is no existing research that compares the factors that influence the purchase intention and the actual purchase. Such a comparison is a necessity, as the literature from the B2C market research point towards the difference in factors influencing them. Based on the literature findings, major factors that should be explored during this research include organizational characteristics (i.e., location, work place dynamics, attitude towards technology and innovation, and provision of over-night facilities), vehicle characteristics (i.e., construction types and battery range), benefits (operational, soft and costs benefits) and issues associated with cargo cycles, and local transport policy (i.e., infrastructure, incentives and public promotion of the benefits). Apart from the aforementioned factors, this research will also analyze the influence of other organizational characteristics such as business sector, fleet decision-making process (Nesbitt and Sperling, 2001) and fleet size currently utilized.

3. Methodology

The overall methodological framework is outlined in Fig. 1 and described in the following subsections. Based on the research objectives described in Section 1 and the literature findings presented in Section 2, data collection through a trial scheme and a longitudinal survey is performed initially, followed by a descriptive analysis to understand the research sample. Then, Latent Variables (LVs) are constructed using Exploratory Factor Analysis (EFA). These are the variables that are not directly observable. They are inferred from and expressed as a function of other variables (usually called items), which are observable (i.e., directly measurable). Based on the variables obtained through data collection and the latent variables constructed through EFA, binary logit models for the intention to purchase cargo cycles and the actual purchase decision are estimated. The R statistical computing software (R Core Team, 2021) is used for both EFA and binary logit model estimation. The complete analysis framework is presented in Fig. 1.

EFA is applied to three sets of variables collected during the surveys, i.e., drivers and barriers (LV Set 1), attitudes with respect to corporate environmental responsibility and technology (LV Set 2), and incentive variables (LV Set 3). EFA is utilized primarily to identify the overarching idea behind the three sets of variables (i.e., latent constructs) and secondarily to reduce the data dimensionality. Before carrying out EFA, the suitability of the three sets of variables for EFA is confirmed based on Bartlett's test and Kaiser–Meyer–Olkin (KMO) index. The following EFA procedure is implemented: Multi-Variate Normality (MVN) test, tests for determining number of factors, factor extraction, and finally, reliability analysis for the estimated factors. The number of factors for extraction is decided based on Kaiser–Guttman method (eigenvalue > 1), scree plot (elbow point) and parallel analysis. The final factor model is decided based on the factor model quality, i.e., number of items per factor, variance explained by the factors, Root Mean Square Error (RMSE) value and Tucker Lewis index. The communality of the individual items is also considered. For the number of items per factor, a minimum value of three is considered, as suggested in Costello and Osborne (2005). However, a 2-item factor is accepted, if the correlation between the two variables is high (>0.50) and the correlation with the other variables is low. Non-normality of all the three set of variables are confirmed by MVN tests, and hence, principal axis factoring is used as the factor extraction method, as suggested in Brown (2015). After testing different rotations, varimax orthogonal rotation is utilized. Following the factor extraction, a reliability analysis (Cronbach alpha test) is carried out for each extracted factor. Factor scores are then computed based on the Bartlett method.

Following EFA, the estimation of logit models for purchase intention and actual purchase decision is carried out. The objective is to identify and analyze the factors that significantly affect purchase intention and actual purchase decision (dependent variables). Both the purchase intention and the actual purchase decision are binary variables, with 1 representing the intention to purchase in the case of former and the actual purchase of a cargo cycle in the case of latter. Models are developed in a stepwise fashion, first backward (from saturated models), where only variables of high significance (90% confidence interval) are kept, then forward (from empty models), where significant variables are added one after the other (using the same confidence level). When adding or removing a variable from a model specification, log-likelihood test is carried out to determine the significance in model improvement, along with the comparison of the values of statistical parameters 'AIC' and 'BIC'. Variables analyzed in the estimation process include the ones obtained through data collection and also the latent variables constructed through EFA. As mentioned earlier, the latent variables from EFA represent the perception of drivers and barriers for cargo cycle use, attitudes with respect to corporate

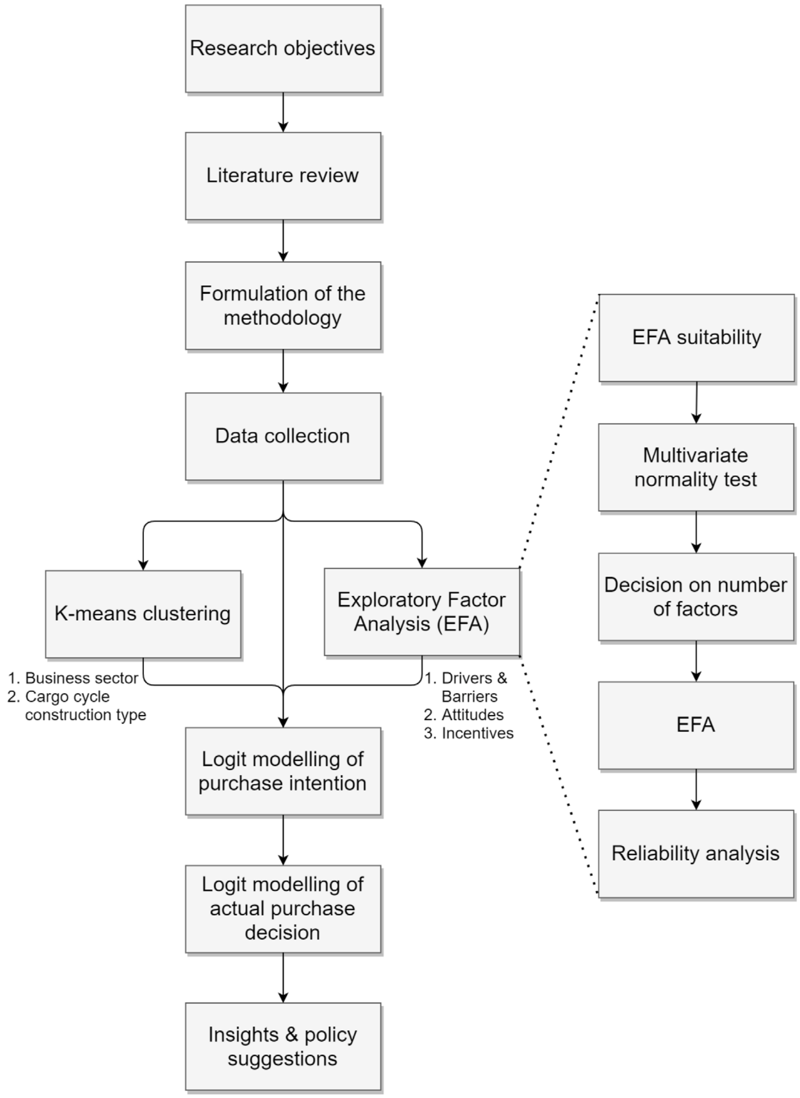

Fig. 1. Analysis framework.

environmental responsibility and technology and importance of incentives for cargo cycle use, which can influence the purchase intention and the actual purchase decision.

When added individually as dummy variables, business sector and cargo cycle construction type (both are categorical variables with multiple levels) are found to be insignificant. Hence, it is decided to reduce the number of categories in each of the these through a clustering analysis. The value used for clustering is the coefficient value obtained for the dummies corresponding to each of the categories in the univariate analysis. K-means clustering (Lloyd, 1982) is utilized, and a 2-cluster model [decided based on Silhouette coefficient (Rousseeuw, 1987)] is developed for all categorical variables. Based on the two clusters, a dummy variable is constructed from the original categorical variables, with the value '0' for one cluster and '1' for the other.

4. Data collection & results

4.1. Data collection

This research is based on the data collected during a publicly funded cargo cycle trial scheme, named "Ich entlaste Städte" [I relieve cities (from environmental burdens)]. The trial scheme is funded as part of the National Climate Initiative (NKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The aim of NKI is to promote and initiate climate protection projects throughout Germany, thereby supporting the nation to become climate-neutral by 2045. Thus, NKI funding is a lever which motivates and supports municipalities, companies and consumers to contribute to climate protection.

The objective of the trial scheme is to improve the knowledge on the operative feasibility of cargo cycles and reduce negative reservations against them, thereby promoting their use in commercial transport and supporting the emission reduction goals. Between September 2017 and December 2019, freelancers, private companies, public organizations, and NGOs across Germany had the opportunity to test a cargo cycle for three months at a very low cost (roughly US $30 monthly). Because of the heterogeneous demand and use patterns, eighteen different cargo cycle models, of five different construction types, have been made available for the participants. During the trial phase, cargo cycle trips have been tracked through a smartphone project application, as well as through a GPS device attached to the cycles. Furthermore, using the total tracked trips, the catchment area of the commercial trips carried out using the cargo cycles are estimated for each participating organization.

A longitudinal survey has been designed to collect data from the participating organizations, before (T0) and at the end (T1) of the trial phase. The data collected from the surveys include the location of the organization, business sector (Statistisches Bundesamt, 2008), organization type, main purpose of cargo cycle use, modes substituted during the trial phase, required cargo cycle battery range, details about storage and charging, and change in work process within the organization during the trail phase. In addition, a set of 23 items about potential drivers and barriers of cargo cycle use, a set of 12 items capturing the attitudes with respect to corporate environmental responsibility and technology, and a set of 6 items corresponding to incentives for cargo cycle purchase are also collected. The items within the three sets are based on five-point Likert scale agreement statements. Within the survey T1, the participants stated their intention to purchase a cargo cycle. Subsequent to T1, a follow-up query (T2) is made regarding the actual purchase decision, between three to twelve months after the end of the trial phase.

The data collection method employed in this paper (i.e., a trial scheme with longitudinal survey and GPS tracking, along with provision of different vehicle types) could be replicated to study other emerging transport options, both in commercial and passenger transport. For example, Autonomous Vehicles (AVs) are already being envisioned for freight delivery (Narayanan et al., 2020). A pilot scheme could be designed to allow operators to test AVs. Based on the experiences from the current study, we would like to suggest the future researchers to have an adequate testing period (e.g., three months) for such pilots. Multiple models may be provided to allow operators to find out a suitable type. The span of the pilot have to be designed to cover different seasons and weather conditions. The sample must be ensured to be heterogeneous, with inclusion of different operating contexts. The GPS traces shall carefully be examined during the initial stages to confirm that the data is properly obtained in the required format, and if required, the collection procedure have to be adapted. Monitoring and evaluation scripts can be developed to ensure that the vehicles are actively used by the testers. Finally, it is suggested to send weekly or monthly usage reports, based on the GPS traces, to the testers to provide them insights.

4.2. Descriptive statistics

A summary of the geographic and organizational background of the research sample is presented in this section, along with details on the vehicle types tested by the participating organizations and the characteristics of the trips carried out using the cargo cycles.

4.2.1. Geographic and organizational background

The research sample consists of data pertaining to 400 organizations located in 187 different municipalities, spread across all the sixteen states of Germany. 90% of the organizations do not have any cargo cycle experience prior to the project. Around two-thirds of them are located in a large city (kreisfreie Stadt). A varied organizational background is observed in the sample. Starting from the business sectors, the sample contains organizations from the following eighteen business sectors: (1) Agriculture, forestry and fishing (A); (2) Manufacturing (C); (3) Electricity, gas, steam and air conditioning supply (D); (4) Water supply, sewerage, waste management and remediation activities (E); (5) Construction (F); (6) Wholesale and retail trade, repair of motor vehicles and motorcycles (G); (7) Transportation and storage (H); (8) Accommodation and food service activities (I); (9) Information and communication (J); (10) Financial and insurance activities (K); (11) Real estate activities (L); (12) Professional, scientific and technical activities (M); (13) Administrative and support service activities (N); (14) Public administration and defense (O); (15) Education (P); (16) Human health and social work activities (Q); (17) Arts, entertainment and recreation (R); (18) Provision of other services (S). These business sectors are based on (22), and the letters included inside the brackets will be used to denote the business sectors in the subsequent sections. Almost half of the participating organizations are companies, followed by a quarter of freelancers or self-employed individuals. Apart from these two categories, the sample also includes public institutions (around 14%), and NGOs and associations (around 13%). Most of the organizations (81%) follow autocratic fleet decision-making structure (low formalization and high centralization), while one-tenth of the sample belong to hierarchic decision-making (high formalization and centralization). The rest of the sample fall under either democratic (low formalization and centralization) or bureaucratic (high formalization and low centralization) decision-making categories. While centralization refers to the number and independence of decision-makers involved, formalization refers to the level of rules and procedures guiding the decision process of the fleet purchase and utilization (Nesbitt and Sperling, 2001). About 72% of the sample belong to the category of micro-enterprises (turnover < € 2 million), while the remainder is evenly distributed among small (turnover € 2 – € 10 million), medium-sized (turnover €10 – € 50 million) and large enterprises (turnover > € 50 million).

4.2.2. Vehicle characteristics

Eighteen different vehicle models are made available for the participating organizations to select. The models can be categorized into five construction types, namely pizza delivery bike, Long John bike, longtail bike, front-load trike and heavy-load trike. All models have a minimum payload capacity of 50 kg (110.2 lb.). Excepting two models, the rest of the models have electric assist. Among the models with electric assist, one of the models has electric assist up to 45 km/h (28.0 mph), known as S-Pedelec or fast e-bike. The others have electric assist up to 25 km/h (15.5 mph), commonly known as Pedelecs or standard e-bikes. The reader is referred to Ich entlaste Städte (2020) for more details about the vehicle models.

4.2.3. Trip characteristics

Concerning the spatial extent, the catchment area of the commercial trips carried out using cargo cycles range from a section of a typical German city district to the size of a medium-sized city, with an average of 26 km^2 (10 mi^2). The average daily mileage during the trial phase is around 16 km (9.9 mi). Around 41% of the participating organizations utilize cargo cycles for service trips, as shown in Fig. 2. The trip purpose of one-third of the participants fall under the category of goods delivery and pick-up. The battery capacity required for effectively carrying out the commercial trips, as stated by the participants, range from 2 to 200 km (1.2 to 124.2 mi). Around 7% of the participating organizations has tested the cargo cycles during the winter season (between November 1 and March 31).

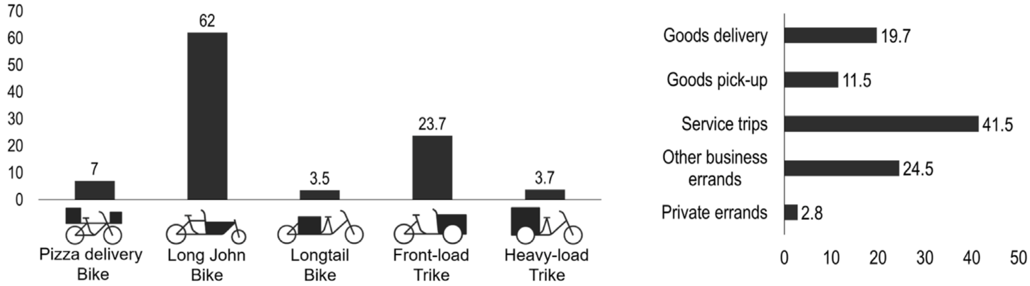

Fig. 2. Distribution of the sample in percentage according to the cycle construction type tested (left) and use purpose (right).

Table 1 presents the relevant descriptive statistics of the analyzed sample. From the table, it can be stated that the dataset contains a wide variety of organizations, with an extensive range of trip characteristics. As shown in the table, only about one-third purchased a cargo cycle, although around half of the sample stated that their intention is to purchase a cargo cycle. This suggests that there is a need to convert intention to actual purchase, when making conclusions based on intentions. A deeper look into the purchase intention and the actual purchase decision values gives the shares shown in Table 2.

Table 1
Summary of sample characteristics (n = 400).

Located in a large city (Kreisfreie Stadt)	Yes	61.2%	Start-up (share of participating organizations)	Yes	11.5%
CC electric assist (share of participating org.)	No assist	8.8%	Work process change	Negative	4.8%
	Pedelec-25	85.7%		No change	53.0%
	Pedelec-45	5.5%		Positive	42.2%
CC catchment area (km^2)	Min	0.7	Daily mileage during the trial phase (km)	Min	7.9
	Mean	26.3		Mean	15.9
	Median	19.5		Median	15.7
	Max	143		Max	32.7
Decision-making	Autocratic	81.2%	Required battery range (km)	Min	2
	Democratic	4.1%		Mean	33.5
	Hierarchic	9.9%		Median	30
	Bureaucratic	4.8%		Max	200
Organization type	Self-employed	25.0%	Trial phase season: Winter (share of participating org.)	Yes	6.5%
	Company	47.5%			
	Public institution	14.5%			
	NGO, associations	13.0%			
Purchase intention (D)	Yes	48.5%	Actual purchase (D)	Yes	32.0%

Note:
- CC: Cargo Cycle.
- D: Dependent variables used in the binary logit models.

Table 2
Purchase intention and actual purchase decision shares.

Actual	Intention	
	Yes	No
Yes	24.3%	7.7%
No	24.3%	43.7%

5. Estimation results

5.1. Exploratory factor analysis

For variables related to drivers and barriers (LV Set 1) from T1 survey, four factors are extracted, explaining a cumulative variance of 45%. These four factors are not only selected based on the statistical measures mentioned in Section 3, but also with a consideration of the findings in the existing literature (Thoma and Gruber, 2020). Looking at the first factor, the variables under it are related to operational benefits, and hence, it has been named as perception of operation benefits (F-OB). On the other hand, the second factor is connected with risks and concerns, and therefore, is called perception of risks and operational concerns (F-OC). The third and the fourth ones are associated with soft and cost benefits, and are labeled as perception of soft benefits (F-SB) and cost benefits (F-CB). The outcome of the factor analysis is presented in Table 3. As indicated in Section 3 (Model Estimation), Cronbach alpha value is not applicable to a factor with less than three items and correlation is considered for such a case. The two items in the fourth factor (F-CB) have a high correlation of 0.60. Their correlations with the other variables in the set are less than 0.5. Hence, F-CB with 2 items is acceptable.

Table 3
Factor analysis results for the latent variable set 1 (Drivers and barriers).

Loadings	Factor 1	Factor 2	Factor 3	Factor 4
Possible to access areas that are closed to CVs	0.66			
CCs are faster than CVs for my case	0.56			
CCs offer greater flexibility concerning parking or loading/unloading	0.80			
Travel time can be reliably planned	0.59			
Payload could be damaged during transport		0.59		
Using CCs in mixed traffic is dangerous		0.67		
Riding CCs requires experience		0.61		
Cycling infrastructure is inadequate		0.46		
Implementation of CCs requires organizational effort		0.60		
There is no established service network for CCs		0.50		
CCs could get stolen		0.47		
Employees enjoy using CCs			0.63	
CCs help to reach corporate environmental goals.			0.51	
CCs improve the health of the employees			0.73	
CCs promote the image of the organization			0.54	
CCs are cheaper than CVs (purchase cost)				0.76
CCs have lower maintenance costs than CVs				0.48
SSL	2.30	2.27	1.84	1.12
Proportion variance	0.14	0.13	0.11	0.07
Cumulative Variance	0.14	0.27	0.38	0.45
Cronbach alpha	0.72	0.71	0.65	–
Factor interpretation: Perception of	Operational Benefits (F-OB)	Risks & Operational Concerns (F-OC)	Soft Benefits (F-SB)	Cost benefits (F-CB)

Note:
- SSL: Sum of Square of Loadings; CVs: Conventional Vehicles (Diesel/petrol operated cars, vans and trucks); CCs: Cargo Cycles.
- Loadings lower than 0.4 are not shown.
- Although F-CB has only a proportion variance value of 0.07, the decision to keep it is based on other criteria such as RMSE and Tucker Lewis index.

For the attitude variables (LV Set 2), two factors are obtained, as shown in Table 4, explaining a cumulative variance of 40%. By looking at the latent meaning that these variables may have, the factors are interpreted as interest towards sustainability transformation in transport (F-ST) and interest towards technology and innovation (F-TI). Finally, two factors are constructed from the incentive variables (LV Set 3), explaining a cumulative variance of 67%. The constructed factors, shown in Table 5, are importance of deterioration of conditions for combustion-engine vehicles (F-DC) and importance of purchase cost of cargo cycles (F-PC). The two items in the second factor have a high correlation of 0.63. Their correlations with the other incentive variables are less than 0.5. Hence, F-PC with 2 items is acceptable.

Table 4
Factor analysis results for the latent variable set 2 (Attitudes).

Loadings	Factor 1	Factor 2
Willing to invest into climate protection	0.56	
Policymakers should restrict CV traffic	0.73	
All stakeholders of society should fight global warming	0.57	
Economy is more important than environment	−0.52	
CCs are a temporary phenomenon	−0.58	
CCs can be used by all as an alternative to the car	0.51	
CCs will generally prevail in my industry	0.40	
Following technological progress is important		0.77
We use new technologies, even if they are expensive		0.75
We are pro innovation organization		0.62
SSL	2.29	1.72
Proportion variance	0.23	0.17
Cumulative Variance	0.23	0.40
Cronbach alpha	0.69	0.72
Factor interpretation: Interest towards	Sustainability Transformation in Transport (F-ST)	Technology and Innovation (F-TI)

Note:
- SSL: Sum of Square of Loadings; CVs: Conventional Vehicles (Diesel/petrol operated cars, vans and trucks); CCs: Cargo Cycles.
- Loadings lower than 0.4 are not shown.

Table 5
Factor analysis results for the latent variable set 3 (Incentives).

Loadings	Factor 1	Factor 2
Interest towards cargo cycles will increase if		
Parking cost for CVs increases	0.80	
Fuel (diesel/petrol) becomes more expensive	0.83	
More access restrictions for CVs are implemented	0.83	
Purchase cost incentive is provided for CCs		0.79
Purchase cost of CCs is reduced		0.78
SSL	2.05	1.31
Proportion variance	0.41	0.26
Cumulative Variance	0.41	0.67
Cronbach alpha	0.89	–
Factor interpretation: Importance of	Deterioration of Conditions for CVs (F-DC)	Purchase Cost of CCs (F-PC)

Note:
- SSL: Sum of Square of Loadings; CVs: Conventional Vehicles (Diesel/petrol operated cars, vans and trucks); CCs: Cargo Cycles.
- Loadings lower than 0.4 are not shown.

5.2. Factors affecting purchase intention and actual purchase decision of cargo cycles

To understand the factors that affect the purchase intention and the actual purchase decision, two different binary logit models are estimated. The model specifications and the estimation results are shown in Table 6, and the description of the coefficients are included in Table 7. The coefficient estimates are in general reasonable in terms of sign and consistent with the prior expectations. The negative intercept values for both purchase intention and actual purchase decision are considered to be indicative of the general negative tendency towards cargo cycles.

Concerning purchase intention, a larger catchment area covered for the commercial trips could have a negative influence. Contrastingly, higher daily mileage during the trial phase results in a positive impact on the purchase intention. Winter testing period also has a significant positive impact. Estimates for the latent variables F-OB and F-SB (i.e., perception of operational and soft benefits from LV Set 1) are highly significant and positive. A positive estimate is also obtained for F-TI (i.e., interest towards technology and innovation from LV Set 2). On the other hand, F-OC (i.e., perception of risks and operational concerns from LV Set 1) has a negative estimate.

With regards to the actual purchase decision, a negative impact is also obtained for the catchment area of the commercial trips, and a positive impact for the daily mileage carried out during the trial phase, winter testing period, F-OB (i.e., operational benefits) and F-SB (i.e., soft benefits). However, F-OC (i.e., operational concerns) and F-TI (i.e., interest towards technology and innovation) are insignificant for the actual purchase decision. On the other hand, there are other significant variables that have a positive impact. The most significant among them is the dummy variable constructed for the business sector using the clustering analysis (as

Table 6
Estimation results.

Purchase Intention					Actual Purchase Decision				
Variable	Coeff.	Estim.	S.E.	t-stat	Variable	Coeff.	Estim.	S.E.	t-stat
Intercept	β_{CON}	**−0.36**	**0.19**	**−1.85**	**Intercept**	β_{CON}	**−1.81**	**0.31**	**−5.84**
catchmentArea (km^2)	β_{CA}	**−0.01**	**0.01**	**−1.84**	**catchmentArea** (km^2)	β_{CA}	**−0.01**	**0.01**	**−1.78**
dailyMileage (km)	β_{M}	**0.11**	**0.04**	**3.00**	**dailyMileage** (km)	β_{M}	**0.11**	**0.04**	**2.89**
winterTesting (D)	β_{WT}	**0.98**	**0.48**	**2.03**	**winterTesting (D)**	β_{WT}	**0.74**	**0.45**	**1.64**
operationalBenefits (L)	β_{OB}	**0.42**	**0.11**	**3.98**	**operationalBenefits (L)**	β_{OB}	**0.29**	**0.12**	**2.39**
softBenefits (L)	β_{SB}	**0.37**	**0.10**	**3.55**	**softBenefits (L)**	β_{SB}	**0.36**	**0.11**	**3.13**
operationalConcerns (L)	β_{OC}	−0.24	0.10	−2.32	costBenefits (L)	β_{CB}	0.23	0.12	1.89
technologyInnovation (L)	β_{TI}	0.20	0.10	1.94	deteriorationOfConditions (L)	β_{DC}	0.34	0.11	3.00
					carSubstitution (P)	β_{CS}	0.67	0.32	2.10
					lightVehicleSubstitution (P)	β_{LS}	1.79	1.09	1.64
					businessSector (D)	β_{BS}	0.84	0.24	3.45
Summary statistics					Summary statistics				
ρ^2 (McFadden): 0.10					ρ^2 (McFadden): 0.12				
AIC:	496.78				AIC:	448.20			
BIC:	528.40				BIC:	491.69			

Note:
- D: Dummy variable; L: Latent variable; P: Percentage in decimal format.
- t-stat value displayed is the actual one, and may be different to the value obtained through $Estim./S.E.$, due to rounding off to two decimal places.
- For coefficient description and interpretation, please refer to Table 7.
- Variables that are common to both purchase intention and actual purchase decision are made bold.

mentioned in Section 3). Similarly, the dummy variable constructed for the cargo cycle construction type is also found to significantly impact the actual purchase decision, when interacted with the variable accounting for the substitution of commercial light vehicle trips. The variable accounting for the percentage of car trips substituted during the trial phase also has a positive influence, although without any interaction. Finally, F-DC (i.e., deterioration of conditions for conventional vehicles) and F-CB (i.e., cost benefits) are also decisive for the actual purchase decision.

Detailed information about the variables analyzed for the actual purchase decision (both significant and insignificant) and their effects, along with the interpretation of the effects, is included in Table 7. The research sample has payload data only for 55% of the organizations. Hence, it is not possible to test the influence of the payload adequately. However, a binary model with the reduced sample show that the payload does not have a significant influence on the actual purchase decision. This is in line with Gruber et al. (2013), wherein the bike and car messengers state that the payload capacity of cargo cycles is sufficient. Similarly, a dummy constructed for the effect of electric assist (i.e., a cargo cycle with electric assist vs a cargo cycle with no assist) is found to be insignificant.

6. Discussion

6.1. Insights for policymakers and industry

This section elucidates the insights obtained based on the factors affecting the actual purchase decision of cargo cycles, which are identified in Section 5.

6.1.1. Insights for policymakers

Commercial users perceive the political framework to be important for their business, indicating that policy measures majorly drive the design of their networks (Fraunhofer IML, 2010). The enforcement of regulations influences the type of delivery model deployed by companies (Janjevic and Winkenbach, 2020). Supporting this view, the significance of F-DC shows that policies, which deteriorate the conditions for conventional vehicles, could be used as levers to reduce the usage of conventional vehicles and increase the cargo cycle penetration. Examples for such policies from the literature include infrastructural (road pricing, congestion zones, traffic calmed areas, low noise zones, zero emission zones, truck bans, parking reservation systems and increased parking fines), temporal (time access restrictions, daytime delivery restrictions and daytime delivery bans) and vehicular restrictions (loading-, size- and engine-related restrictions) (Yannis et al., 2006; Holguin-Veras et al., 2020). Organizations which utilize cargo cycles to substitute a higher number of car trips during the trial phase are more likely to purchase cargo cycles. Therefore, policies that deteriorate conditions for the conventional vehicles could be effective to shift current car users.

Concerning the benefits of cargo cycles, not only operational benefits but also soft benefits play a major role in the purchase decision. Interestingly, lower vehicle purchase cost alone is no significant driver for cargo cycle purchase, as shown by the insignificance of F-PC. However, a factor (F-CB) combining vehicle and maintenance cost has a significant effect. Hence, when vehicle design failures are present, purchase subsidies and lower vehicle cost may not be adequate and helpful. Therefore, robust and efficient cargo cycle designs are required to lower maintenance cost, along with provision of purchase subsidies. With regards to soft benefits, campaigns that aim at improving the perception of the soft benefits could be effective in increasing the cargo

Table 7
Effects of the independent variables on the actual purchase decision.

Variable group	Variable name & coeff. (if any)	Description	Coeff. sign	Interpretation & related literature (if any)
Significant variables				
NA	Intercept (β_{CON})	Model constant	–	The negative sign is interpreted as an indication of the reservation towards cargo cycle purchase.
Spatial	catchment Area (β_{CA})	Catchment area of the commercial trips carried out using CCs (km^2)	–	With higher catchment area, there is a decrease in interest towards CC purchase.
	dailyMileage (β_M)	Average daily distance covered by a CC during the TP (km)	+	The higher the daily usage of CCs during the TP, the higher is the probability to purchase CCs. This could imply that organizations were able to ascertain the suitability of cargo cycles through trial schemes. Some organizations might have reservations against CCs, although CCs are suitable for their use case. However, testing CC's suitability in a trial scheme increases their confidence.
Temporal	winter Testing (β_{WT})	Dummy variable: tested CC during winter	+	Organizations who tested CC during winter season have higher probability to purchase. Some organizations might have reservations that the CCs cannot be effectively used in winter. However, having tested them in the winter increases their confidence to purchase.
Attitudinal (Latent)	operational Benefits/ F-OB (β_{OB})	Perception of operational benefits of CCs	+	Perception of higher operational benefits such as accessibility, flexible parking and travel time reliability could have positive impact on the purchase decision of CCs.
	softBenefits/ F-SB (β_{SB})	Perception of purchase cost and soft benefits of CCs	+	Higher probability to purchase CCs, if an organization perceives higher soft benefits. This implies that not only operational benefits could induce an organization to purchase CCs, but also soft benefits. In line with Gruber et al. (2013)
	costBenefits/ F-CB (β_{CB})	Perception of cost benefits of CCs	+	Organizations which perceive higher cost benefits are likely to purchase CCs. Hence, purchase subsidies, along with robust and efficient cargo cycles (which ensure lower maintenance cost) are required. In line with Gruber et al. (2014), Heinrich et al. (2016)
	deterioration OfConditions/ F-DC(β_{DC})	Importance of deterioration of conditions for conventional vehicles	+	The higher the perception of negative impacts of the deterioration of conditions for CVS (e.g., vehicle access restriction, higher fuel prices and parking cost), which would affect the operations of an organization, the higher is the probability to purchase. In line with Choubassi et al. (2016)
Vehicular	carSubstitution (β_{CS})	Stated % of car trips substituted by CC during the TP	+	The higher the substitution rate, the higher is the probability to purchase CCs. This shows that the organizations perceive CCs to be more suitable to substitute car trips.
	lightVehicle Substitution (β_{LS})	Stated % of commercial light vehicle trips substituted by CC types 3 (longtail bike) or 5 (heavy-load trike) during the TP	+	The likelihood of purchasing CCs increase, if the organizations utilized CC types 3 and 5 to substitute commercial light vehicle trips during the TP. This reflects the suitability of those two types to replace commercial light vehicles (e.g., vans), to carry bulky and heavy goods.
Org. Nature	business Sector (β_{BS})	Dummy variable: Organization belongs to one of the sectors — D, E, G, H, I, J, K, L, R	+	Organizations belonging to the sectors D, E, G, H, I, J, K, L, R & S are more likely to purchase CCs, compared to organizations belonging to the sectors A, C, F, M, N, O, P & Q.
Insignificant variables				
Spatial	locatedInA LargeCity	Dummy variable: Organization is located in a large city	+	Large cities (kreisfreie Stadt) offer more suitable conditions for CCs.
Attitudinal (Latent)	operational Concerns F-OC (β_{OC})	Perception of risks & operational concerns associated with CCs	–	Higher perception of risks and operational concerns negatively influences CC purchase.
	purchase Cost/F-PC	Importance of purchase costs of CCs	–	The higher the importance of purchase cost, the lesser is the probability to purchase CCs. The reduction of purchase cost or provision of monetary incentives may have a positive impact on CC penetration. In line with Choubassi et al. (2016), Gruber et al. (2014)

(continued on next page)

Table 7 (*continued*).

Variable group	Variable name & coeff. (if any)	Description	Coeff. sign	Interpretation & related literature (if any)
	sustainable Transform/F-ST	Interest towards sustainability transformation in transport	+	Organizations with higher interest towards sustainability transformation in transport are likely to purchase CCs.
	technology Innovation/F-TI (β_{TI})	Interest towards technology and innovation	+	Technology and innovation enthusiasts are more probable to purchase CCs. In line with Gruber et al. (2013)
Vehicular	isElectricCC	Dummy variable: CC with electric assist used during the TP	+	Organizations who tested CC with electric assist are more probable to purchase CCs.
	alternMoped, alternOther	Stated % of moped/bike & PT trips substituted	–	Organizations perceive CC to be less suitable to substitute moped, bike and PT trips.
	required Range	Required CC battery range in km (stated)	–	The necessity of a higher battery range would negatively impact the CC purchase. In line with Gruber et al. (2014)
Org. Nature	isAutocratic	Dummy variable: Organization's decision-making is autocratic	+	Organizations with autocratic decision-making are more likely to purchase CCs.
	fleetSize	Stated number of vehicles utilized for CT	+	The higher the fleet size used, the higher is the probability to purchase CCs.
	storePrivate	Stated % of nights during when the CC must be stored in a private area	–	The necessity to store CCs in private places, instead of in a public or business space, could have a negative influence on CC purchase. In line with Faxér et al. (2018)
	chargePrivate	Stated % of times during when the CC must be charged in a private area	–	The lesser the need to charge CCs in private places, the higher is the probability to purchase CCs. This points out the requirement of charging spots for CCs in public or business spaces.
	workProcess	Dummy variable: Whether the use of CC led to positive changes in the work processes (Base value: both negative and no change)	+	Introduction of CCs must lead to a positive change in work processes. If not, CCs will be less preferred. This could be translated as a requirement of incentive to change, which in this case is the positive impact on the workplace dynamics. In line with Faxér et al. (2018)

Note:
- CCs: Cargo Cycles; CVs: Conventional Vehicles (Diesel/petrol operated cars, vans and trucks); TP: Trial Phase; CT: Commercial transport; Org.: Organizational.
- Refer to Section 4.2.1 for the business sector names

cycle penetration. Enforcement of strict corporate environment goals and certifying businesses with ecological fleets, such as cargo cycles, may also be beneficial. Concerning operational benefits, better cycling infrastructure, especially implementation of shortcuts and dedicated cycle lanes, can support cargo cycle penetration. Furthermore, for a safe operation, large cargo cycles require an appropriate cycling infrastructure (Taefi et al., 2016), including, but not limited to, larger lane widths and smooth turning angles.

The significance of the 'dailyMileage' variable shows that cargo cycle trials can help organizations to ascertain the suitability of cargo cycles for their use case. Such trials can increase the confidence of those organizations, which have reservations against cargo cycles, although cargo cycles are suitable for their use case. Every additional kilometer driven per day during the testing period increases the probability to purchase, on average, by 2.3%. Hence, trial schemes can be concluded as useful tools to increase cargo cycle penetration. Another supporting evidence to this statement is the significance of the dummy variable 'winterTesting': organizations which tested the cargo cycles during winter are more probable to purchase cargo cycles. The marginal effect show that the expected probability of purchase increases by 0.17, when the testing is done during winter. This proves that the trial schemes can reduce reservations against cargo cycles, i.e., the thought that cargo cycles cannot be effectively utilized in winter could be reduced.

Organizations covering a wider geographical area might still have negative reservations against the procurement of cargo cycles. Nevertheless, organizations that are able to restructure their catchment areas may find the cargo cycles suitable for purchase. Cargo cycles are competitive to motorized vehicles for smaller catchment areas and shorter delivery distances (Gruber and Narayanan, 2019), and hence, a feasible option is to introduce network configurations with intermediate shifting (i.e., parcels and packages are transferred to cargo cycles from other vehicles for last-mile delivery). Different types of intermediate shifting points are found in literature, which are Urban Consolidation Center (UCC), Micro-hub/Micro Consolidation Centre (MCC) and Transit Point (TP). For more information on network configurations with intermediate shifting, the reader is referred to Narayanan and Antoniou (2021).

As the negative intercept from the model points out, there exist multiple reservations towards cargo cycle purchase, which need to be taken care through policy instruments. To have a better view of the insights discussed in this section, which enable to reduce the reservations against cargo cycle purchase, the factors identified in Section 5.2 have been grouped and summarized according to policy measures in Table 8. The marginal effects of latent variables show that the deterioration of conditions for conventional vehicles and soft benefits have a higher effect, than operational benefits and cost benefits. Therefore, among the policy instruments suggested based on latent variables, regulations and campaigns on soft benefits will play a pivotal role in the penetration of cargo cycles.

Table 8
Policy measures based on identified factors.

Policy measure	Relevant factors	Recommendation
Regulation	deteriorationOfConditions carSubstitution lightVehicleSubstitution	Regulative framework that discourage the use of conventional vehicles are encouraged to ameliorate the competitiveness of cargo cycles.
Infrastructure	operationalBenefits	Cycling infrastructure must be strengthened to improve operational benefits. Policies, such as implementation of dedicated cycles lanes (which ensures better travel time reliability), shortcuts and better cycle parking facilities, are recommended.
Finance	costBenefits	Purchase subsidies are suggested. However, given that subsidies alone would not be adequate, robust and efficient cargo cycle designs are required to lower maintenance cost. When vehicle design failures are present, purchase subsidies may not be adequate and helpful.
Campaigns	softBenefits	Campaigns can be conducted to improve the perception of the soft benefits. Techniques from the field of growth hacking and application of persuasive technology can be beneficial in projecting the soft benefits. Enforcement of strict corporate environment goals and certifying businesses with ecological fleets, such as cargo cycles, may also be beneficial.
Trial schemes	dailyMileage winterTesting catchmentArea	Trial schemes, especially during winter seasons, have to be implemented to enable commercial users to ascertain the suitability of cargo cycles for their use case, thereby reducing negative reservations.

6.1.2. Insights for cargo cycle manufacturers

While the availability of the cargo cycle construction types 2 (Long John bikes) and 4 (front-load trikes) are high, types 3 (longtail bike) and 5 (heavy-load trike) are less common. However, estimation results show that the organizations which utilized types 3 and 5 to substitute commercial light vehicles are more probable to purchase cargo cycles. This could be seen as a market opportunity for manufacturers. Hence, cargo cycle manufacturers should concentrate on improving and optimizing these two models with the view to substitute commercial light vehicles.

Given the significance of soft benefits, cargo cycle manufacturers should also work on promoting the soft benefits of cargo cycles. In this regard, advertising campaigns through different types of media might be helpful, especially when car users are targeted, since the estimation results show that the cargo cycles have higher potential to substitute car trips. A collaboration between policymakers and cargo cycle manufacturers for conducting campaigns to promote the soft benefits of cargo cycles (e.g., better company image, higher enjoyment, improved employees' health and the possibility to achieve corporate environment goals) is a viable option to increase cargo cycle penetration, especially when combined with purchase incentives. Techniques from the field of growth hacking and application of persuasive technology can be beneficial in projecting the soft benefits.

The significance of cost benefits, which includes maintenance costs, points out the need for robust and efficient cargo cycle designs. As stated in Heinrich et al. (2016), technical deficits have a decisive impact on the penetration of cargo cycles. Hence, cargo cycle manufacturers are required to ensure proper design of cargo cycles to lower the technology failure likelihood, thereby lowering the maintenance costs.

6.1.3. Insights for organizations looking out for alternatives to conventional vehicles

For organizations which face higher deteriorating conditions for their operations using conventional vehicles, especially cars, it is a good time to shift to cargo cycles. Organizations with negative reservations regarding the effectiveness of cargo cycles during winter can be more confident. For organizations looking out for an alternative to commercial light vehicles (e.g., van), longtail bikes and heavy load trikes are suggested. Organizations belonging to the business sectors D, E, G, H, I, J, K, L, R and S (see "Geographic and Organizational Background" for the business sector names) are found to have higher probability of purchasing cargo cycles. The marginal effect shows that the probability to purchase is around 18% higher for organizations belonging to these business sectors.

The reason for the higher probability could be better suitability of cargo cycles for operations in those sectors. Hence, organizations that have no cargo cycle testing experience but belong to these sectors can be more confident about the suitability of cargo cycles for their operations. Concerning the business sectors with lower probability, involvement of heavy and large materials could be a reason for the lesser likelihood to purchase cargo cycles in the following business sectors: (1) Agriculture, forestry and fishing (A); (2) Manufacturing (C); (3) Construction (F). With regards to the business sectors (1) Professional, scientific and technical activities (M); (2) Administrative and support service activities (N); (3) Public administration and defense (O); (4) Education P); (5) Human health and social work activities (Q), the reason for lower probability is still not clear, and hence, we cannot provide a consistent explanation at this point. Although a probable reason could be that individuals from these sectors may expect a better comfort level for travel (i.e., they prefer cars to cargo cycles), the effect could also be due to the existence of heterogeneity within each of the sectors. Therefore, this needs to be explored in future research works.

6.2. Comparison between purchase intention and actual purchase decision

The descriptive statistics in Section 4.2 show that a higher share of intent is observed (48.5%), compared to the actual purchase (32.0%). Although only the final model is shown in Section 5.2, a model for actual purchase decision with intention as an explanatory variable was estimated. This model shows that the intention has a significant positive impact on the actual purchase decision. Nevertheless, as shown in Table 6, there are factors which are not common to both. Based on the sample descriptive statistics and the influencing factors, one can conclude that there is a need to convert intention to actual decision, when making conclusions based on intentions. This implies that the results from surveys, such as stated preference surveys, have to be carefully considered and corrections are needed to make right conclusions.

A comparison of the significant variables for the purchase intention and the actual purchase decision points out the differences in factors influencing them. The significance of F-OC for the purchase intention shows that the organizations have been thinking about the operational concerns associated with the cargo cycles, when they stated their purchase intention. However, despite the operational concerns, organizations tend to purchase cargo cycles (i.e., they do not care about potential concerns). This is shown by the insignificance of F-OC for the actual purchase decision. On the one hand, the participating organizations could have ascertained that the deteriorating conditions for the conventional vehicles might lead to a negative impact on their operations in future and on the other hand, they could have also thought about the cost benefits of cargo cycles. The significance of F-CB and F-DC for the actual purchase decision shows that organizations, which perceive the cost benefits of the cargo cycles and the negative impacts of the deteriorating conditions for the conventional vehicles, are more probable to purchase cargo cycles. To summarize, operational concerns takes precedence for the purchase intention, while cost benefits and deterioration of conditions for conventional vehicles take precedence for the actual purchase decision.

Furthermore, decision-makers favoring technology and innovation seem to be enthusiastic when they state their intention to purchase cargo cycle (which is something expected). However, when they have to make the actual purchase decision, they could have perceived more disadvantages (e.g., larger catchment area of operations), reducing their interest to purchase cargo cycles. Hence, F-TI (i.e., interest towards technology and innovation) is significant for the purchase intention, while it is insignificant for the actual purchase.

7. Conclusions

The commercial transport sector involves multiple stakeholders and is a complex system, requiring careful planning. Given that the planning depends on the typical performance of any initiative, application of cargo cycles in commercial transport necessitates detailed studies for making an informed decision. Cargo cycles have the potential to reduce cost, emissions and travel time, when utilized for the right application. However, when compared to the theoretical potential concluded in the pertinent literature, their actual uptake is comparatively low. Therefore, identifying the factors affecting the purchase of cargo cycles is a necessity to maximize their penetration. Based on data from 400 organizations across Germany and using a binary logit model, this research identifies factors that significantly influence the actual purchase decision of cargo cycles. In addition, a comparison between the factors affecting the purchase intention and the actual purchase decision is carried out.

Looking into the factors affecting the actual purchase, cargo cycles have the potential to substitute car trips, supporting cities to achieve air quality and carbon emission reduction goals. Hence, there is a need to support their penetration. Regulative framework that discourages the use of conventional vehicles by establishing access-restricted zones, congestion zones (e.g., tolls), higher parking fines, truck bans and traffic calmed areas (e.g., 30 km/h zones, shared space) can significantly improve the competitiveness of cargo cycles and support their penetration. Furthermore, campaigns that promote the soft benefits of cargo cycles (such as better company image, higher enjoyment, improved employees' health and the possibility to achieve corporate environment goals) will have a substantial positive impact on cargo cycle purchase. Techniques from the field of growth hacking and application of persuasive technology can be beneficial in projecting the soft benefits. Policy makers could also enforce strict corporate environment goals. It is to be noted that lower purchase cost, without the possibility of lower maintenance cost, may not result in intended cargo cycle penetration. Hence, robust and efficient cargo cycle designs are required to ensure lower maintenance cost. In addition to regulative framework, purchase subsidies and campaigns promoting soft benefits, cities should aim at enhancing the operational benefits by improving the cycling infrastructure. Policies, such as implementation of dedicated cycles lanes (which ensures better travel time reliability) and better cycle parking facilities, are suggested to improve the operational benefits.

For commercial light vehicle users, cargo cycle construction types 3 (longtail bike) and 5 (heavy load trike) are more suited. Vehicle manufacturers and policy makers are advised to target the development of these models, to substitute commercial light vehicles. Finally, although trial schemes may not ensure the purchase of cargo cycles by every participating organization, they are effective tools in reducing the negative reservations towards cargo cycles and hence, support their penetration. To summarize, cities are suggested to implement push measures such as regulative frameworks deteriorating the conditions for conventional vehicles and pull measures such as improving the operational benefits and perception of the soft benefits, and implementation of trial schemes, along with ensuring robust and efficient cargo cycle designs. Within the context of Germany, there exists hardly any comprehensive data about the commercial transport. Nevertheless, Gruber and Rudolph (2016) conclude that the potential use of cargo cycles in Germany is between 8 to 23% of the commercial trips. This potential could be improved with a combination of other measures, such as urban consolidation centers. Thus, the successful penetration of the cargo cycles can reduce the use of conventional vehicles and decrease the negative externalities (e.g., local emissions) caused by the German commercial transport, thereby supporting the aim of the nation to become climate-neutral by 2045. The federal government has already began to implement initiatives, such as the provision of 25% purchase price subsidy and the introduction of new traffic signs for cargo cycles, the positive effects of which can already be perceived, i.e., a continuous growth of the cargo cycle market (Zweirad-Industrie-Verband, 2020). The findings in this study can support the government (both the local and the federal) to design further policies.

Several researchers, both in passenger and commercial transport research, base their conclusions on the intentions (e.g., based on stated preference surveys). However, the descriptive statistics show that a high share of intent is observed, while the share of actual purchase is less. In the current study, although intention is found to be a significant factor for the actual purchase decision, nevertheless, there are factors which are not common to both. A comparison of these factors shows that the actual purchase decision is influenced by the deterioration of conditions for the conventional vehicles (e.g., vehicle access restriction, higher fuel prices and higher parking cost), while the purchase intention is influenced by the operational concerns towards cargo cycles. Furthermore, the purchase intention of technology and innovation enthusiasts is naturally more inclined towards cargo cycle purchase. However, when it comes to the actual purchase decision, the scenario is different, i.e., interest towards technology and innovation is not a significant contributing factor. All these clearly show the difference in thought process when stating the purchase intention and when planning for the actual purchase. Hence, there is a need to convert intention to actual decision, when making conclusions based on intentions.

CRediT authorship contribution statement

Santhanakrishnan Narayanan: Conceptualization, Data collection, Methodology, Formal analysis, Interpretation of results, Writing – original draft, Writing – review & editing. **Johannes Gruber:** Funding acquisition, Conceptualization, Data collection, Interpretation of results, Writing – original draft, Writing – review & editing. **Gernot Liedtke:** Support for funding acquisition, Conceptualization, Interpretation of results, Writing – review & editing . **Constantinos Antoniou:** Conceptualization, Interpretation of results, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in the context of the National Climate Protection Initiative (project 03KF0066), and supported by EU's H2020 research and innovation program under grant agreement No. 815069 [project MOMENTUM (Modelling Emerging Transport Solutions for Urban Mobility)]. We would like to express our sincere gratitude to the anonymous reviewers, who helped to improve our manuscript substantially.

References

Brown, T.A., 2015. Confirmatory factor analysis for applied research, second ed. In: Methodology in the social sciences, The Guilford Press, New York and London.

Choubassi, C., Seedah, D.P.K., Jiang, N., Walton, C.M., 2016. Economic analysis of cargo cycles for urban mail delivery. Transp. Res. Record 2547 (1), 102–110. http://dx.doi.org/10.3141/2547-14.

Conway, A., Cheng, J., Kamga, C., Wan, D., 2017. Cargo cycles for local delivery in New York City: Performance and impacts. Res. Transp. Bus. Manag. 24, 90–100. http://dx.doi.org/10.1016/j.rtbm.2017.07.001.

Costello, A.B., Osborne, J.W., 2005. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Practical Assess. Res. Eval. 10, 1–9. http://dx.doi.org/10.1063/1.5092073.

European Commission, 2011. Roadmap to a single European transport area – Towards a competitive and resource efficient transport system. URL https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf.

European Commission, 2018. Air quality: Commission takes action to protect citizens from air pollution. URL https://ec.europa.eu/commission/presscorner/detail/en/IP_18_3450.

Faxér, A.Y., Olausson, E., Olsson, L., Smith, G., Pettersson, S., 2018. Electric cargo bike with a twist - A field test of two innovative bicycle concepts. In: 31st International Electric Vehicle Symposium and Exhibition, EVS 2018 and International Electric Vehicle Technology Conference 2018, EVTeC 2018, Kobe, URL https://www.scopus.com/inward/record.uri?eid=2-s2.0-85073121242&partnerID=40&md5=a9fa0d89fe8375361c83adc458d81f6c.

Fraunhofer IML, 2010. Trends in Der Handelslogistik: Ergebnisse Einer Online-Befragung führender Handelsunternehmen in Deutschland, Österreich und der Schweiz. EHI Retail Institute, Köln.

Giuliano, G., 2013. Synthesis of Freight Research in Urban Transportation Planning. In: NCFRP report, vol. 23, Transportation Research Board, Washington DC, http://dx.doi.org/10.17226/22573.

Gruber, J., Ehrler, V., Lenz, B., 2013. Technical potential and user requirements for the implementation of electric cargo bikes in courier logistics services. In: 13th World Conference on Transport Research, Rio de Janeiro.

Gruber, J., Kihm, A., Lenz, B., 2014. A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services. Res. Transp. Bus. Manag. 11, 53–62. http://dx.doi.org/10.1016/j.rtbm.2014.03.004.

Gruber, J., Narayanan, S., 2019. Travel time differences between cargo cycles and cars in commercial transport operations. Transp. Res. Record 2673 (8), 623–637. http://dx.doi.org/10.1177/0361198119843088.

Gruber, J., Rudolph, C., 2016. Untersuchung des Einsatzes von Fahrrädern im Wirtschaftsverkehr (WIV-RAD). URL: https://www.bmvi.de/SharedDocs/DE/Anlage/StV/wiv-rad-schlussbericht.pdf?_blob=publicationFile.SchlussberichtandasBundesministeriumfrVerkehrunddigitaleInfrastruktur(BMVI).

Hagen, J., Lobo, Z., Mendonça, C., 2013. The benefits of cargo bikes in Rio de Janeiro: An exploratory case study. In: The 13th World Conference on Transport Research, WCTR, Rio de Janeiro, URL https://academiccommons.columbia.edu/doi/10.7916/D8DZ089R.

Heinrich, L., Schulz, W.H., Geis, I., 2016. The impact of product failure on innovation diffusion: The example of the cargo bike as alternative vehicle for urban transport. Transp. Res. Proc. 19, 269–271. http://dx.doi.org/10.1016/j.trpro.2016.12.086.

Holguin-Veras, J., Amaya Leal, J., Sánchez-Diaz, I., Browne, M., Wojtowicz, J., 2020. State of the art and practice of urban freight management. Transp. Res. A 137, 360–382. http://dx.doi.org/10.1016/j.tra.2018.10.037.

Holguín-Veras, J., Amaya Leal, J., Sanchez-Diaz, I., Browne, M., Wojtowicz, J., 2020. State of the art and practice of urban freight management Part II: Financial approaches, logistics, and demand management. Transp. Res. A 137, 383–410. http://dx.doi.org/10.1016/j.tra.2018.10.036.

Ich entlaste Städte, 2020. Der Fuhrpark. URL https://www.lastenradtest.de/testraeder/.

Janjevic, M., Winkenbach, M., 2020. Characterizing urban last-mile distribution strategies in mature and emerging e-commerce markets. Transp. Res. A 133, 164–196. http://dx.doi.org/10.1016/j.tra.2020.01.003.

Kassyda, C., 2016. Urbaner Wirtschaftsverkehr. Herausforderungen für leichte Nutzfahrzeuge und Vorstellung der Projektinitiative Urbane Logistik Hannover (USEfUL). URL https://www.now-gmbh.de/content/1-aktuelles/1-presse/20171023-now-startet-austausch-zu-nachhaltigen-konzepten-fuer-staedtischen-wirtschaftsverkehr/now_ws-urbaner-wirtschaftsverkehr_vortrag_kassyda.pdf.

Lenz, B., Gruber, J., 2021. Bicycles for urban freight. In: International Encyclopedia of Transportation. Elsevier, Amsterdam, pp. 488–494. http://dx.doi.org/10.1016/B978-0-08-102671-7.10603-7.

Lenz, B., Riehle, E., 2013. Bikes for urban freight?: Experience in europe. Transp. Res. Record 2379, 39–45. http://dx.doi.org/10.3141/2379-05.

Lloyd, S., 1982. Least squares quantization in PCM. IEEE Trans. Inform. Theory 28 (2), 129–137. http://dx.doi.org/10.1109/TIT.1982.1056489.

Morrison, D.G., 1979. Purchase intentions and purchase behavior. J. Market. 43 (2), 65. http://dx.doi.org/10.2307/1250742.

Morwitz, V., 2012. Consumers' purchase intentions and their behavior. Found. Trends Market. 7 (3), 181–230. http://dx.doi.org/10.1561/1700000036.

Namias, J., 1959. Intentions to purchase compared with actual purchases of household durables. J. Market. 24 (1), 26–30. http://dx.doi.org/10.2307/1249361.

Narayanan, S., Antoniou, C., 2021. Electric cargo cycles - A comprehensive review. (submitted for publication)).

Narayanan, S., Chaniotakis, E., Antoniou, C., 2020. Shared autonomous vehicle services: A comprehensive review. Transp. Res. C 111, 255–293. http://dx.doi.org/10.1016/j.trc.2019.12.008, URL http://www.sciencedirect.com/science/article/pii/S0968090X19303493.

Nesbitt, K., Sperling, D., 2001. Fleet purchase behavior: decision processes and implications for new vehicle technologies and fuels. Transp. Res. C 9 (5), 297–318. http://dx.doi.org/10.1016/S0968-090X(00)00035-8.

Nürnberg, M., 2019. Analysis of using cargo bikes in urban logistics on the example of stargard. Transp. Res. Proc. 39, 360–369. http://dx.doi.org/10.1016/j.trpro.2019.06.038.

Peter, J.P., Olson, J.C., 2010. Consumer Behavior & Marketing Strategy, ninth ed. McGraw-Hill, Boston.

R Core Team, 2021. R: A language and environment for statistical computing. URL https://www.R-project.org/.

Rousseeuw, P.J., 1987. Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. J. Comput. Appl. Math. 20, 53–65. http://dx.doi.org/10.1016/0377-0427(87)90125-7.

Sanchez-Diaz, I., 2020. Assessing the magnitude of freight traffic generated by office deliveries. Transp. Res. A 142, 279–289. http://dx.doi.org/10.1016/j.tra.2020.11.003.

Schliwa, G., Armitage, R., Aziz, S., Evans, J., Rhoades, J., 2015. Sustainable city logistics — Making cargo cycles viable for urban freight transport. Res. Transp. Bus. Manag. 15, 50–57. http://dx.doi.org/10.1016/j.rtbm.2015.02.001.

Schmid, J., Wang, X., Conway, A., 2018. Commercial vehicle parking duration in New York City and its implications for planning. Transp. Res. A 116, 580–590. http://dx.doi.org/10.1016/j.tra.2018.06.018, URL http://www.sciencedirect.com/science/article/pii/S0965856416310588.

Statistisches Bundesamt, 2008. Classification of economic activities (WZ 2008). URL https://www.klassifikationsserver.de/klassService/jsp/common/url.jsf?variant=wz2008&lang=EN.

Taefi, T.T., Kreutzfeldt, J., Held, T., Fink, A., 2016. Supporting the adoption of electric vehicles in urban road freight transport – A multi-criteria analysis of policy measures in Germany. Transp. Res. A 91, 61–79. http://dx.doi.org/10.1016/j.tra.2016.06.003.

Thoma, L., Gruber, J., 2020. Drivers and barriers for the adoption of cargo cycles: An exploratory factor analysis. Transp. Res. Proc. 46, 197–203. http://dx.doi.org/10.1016/j.trpro.2020.03.181.

Tipagornwong, C., Figliozzi, M., 2014. Analysis of competitiveness of freight tricycle delivery services in urban areas. Transp. Res. Record 2410 (1), 76–84. http://dx.doi.org/10.3141/2410-09.

Yannis, G., Golias, J., Antoniou, C., 2006. Effects of urban delivery restrictions on traffic movements. Transp. Plan. Technol. 29 (4), 295–311.

Zweirad-Industrie-Verband, 2020. Zahlen - Daten - Fakten zum Fahrradmarkt in Deutschland. URL https://www.ziv-zweirad.de/fileadmin/redakteure/Downloads/Marktdaten/PM_2021_10.03._ZIV-Praesentation_10.03.2021_mit_Text.pdf.