DRIVERS AND BARRIERS TO THE ADOPTION OF CARGO CYCLES: AN EXPLORATORY FACTOR ANALYSIS

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ABSTRACT

A variety of drivers and barriers to the adoption of cargo cycles has been described in contemporary academic literature. This paper aims at reducing this complexity by identifying their underlying factor structure. To this aim, 389 organizations interested in cargo cycles rated their agreement towards the adoption of cargo cycles with 23 literature-derived drivers and barriers. An exploratory factor analysis yielded three driver factors (*soft factors*, *cost benefits* and *urban advantages*) and four barrier factors (*vehicle limitations*, *worries and perils, riders' concerns* and *infrastructure constraints*) which are interpreted and discussed.

INTRODUCTION

Urban freight transport has been growing considerably in the past years (Schubert et al., 2014). While benefiting the economy, transport-related externalities such as congestion and emissions burden most cities in the world. In Germany, several municipalities took unprecedented measures and imposed bans for older diesel vehicles.

Cargo cycles have proven to be a feasible solution for various last-mile operations with a substantial potential for shifting trips away from conventional vehicles (Gruber and Rudolph, 2016). Although cargo cycles are increasingly used in urban logistics, they still play a marginal role in urban logistics compared to conventional vehicles. As local and federal policy-makers progressively promote cargo cycle use, a detailed understanding of drivers and barriers to the adoption of cargo cycles is crucial.

Several studies and reports that have described a variety of drivers and barriers to the adoption of cargo cycles will be briefly presented in the following.

One of the first and most extensive collections, Transport for London (2009), performed several case studies and expert interviews in order to produce a list of pros (purchase cost, running costs, parking costs and congestion-charge, speed in congestion, driver training requirement, low environmental impact) and cons (security, limited range and payload, driver fatigue, seasonality) to the adoption of cargo cycles.

Cyclelogistics is a multi-phase European project trialing and supporting cargo cycle use among municipalities, companies, and households (Vijayakumar, 2017). Given the bicycle-advocating nature of the project, cargo cycles' advantages are described to a greater extent. However, when evaluating pilot projects, insights concerning barriers can be derived, such as the need for increased political regulation with regards to restriction conventional vehicles' use and providing more financial incentives for cargo cycle use (Wrighton and Reiter, 2016).

Vijayakumar (2017) provided a Toronto-based perspective on benefits and barriers of cycle logistics. Among the benefits described were emissions reduction, increase in efficiency (cost savings and/or speed advantages) compared to conventional vehicles, improved traffic flow, positive image and health. Barriers were seen in bicycle infrastructure, operative implementation barriers when exchanging logistics data, a lack in cultural understanding, and unclear Canadian e-bike regulations)

Drawing on project reports and expert interviews, an extensive overview of more than 30 parameters influencing the adoption of cargo cycles was provided by Rudolph and Gruber (2017). These parameters have been categorized along the adoption process and distinguish between environment-specific, company-specific, and product-specific elements of influence.

In summary, an extensive qualitative description of drivers and barriers to the adoption of cargo cycles has been provided in literature. However, to the best of our knowledge, this variety of items has not yet been quantified in order to identify an evidence-based overarching factor structure. In addition, few data exist to indicate which of these items rank higher in importance than others. Some issues might clearly be seen as advantages or disadvantages of cargo cycles by most potential users, other parameters might be seen more ambiguously. Hence, this paper aims at finding an evidence-based classification of drivers and barriers to the adoption of cargo cycles, as well as providing a quantification of these factors.

METHOD

Project background and sample

Data for this study were collected in the context of Europe's largest public cargo cycle testing scheme conducted by the German Aerospace Center (DLR) and funded by the German Ministry for the Environment. The cargo cycle testing scheme (titled "*Ich entlaste Städte*", meaning "*Taking the load off cities*") consists of 150 cargo cycles that are offered to both public and private organizations for testing over a three-months-period (see Figure 1 for an image of cargo cycles offered in this project). Organizations interested in participating were given an online questionnaire including a set of 23 items about potential drivers and barriers of cargo cycle use as listed in Table 1. The respondents stated their agreement with these statements in randomized order on a 5-point-Likert scale ranging from "*I don't agree*" (1) to "*I completely agree*" (5).

Figure 1. Cargo cycles offered for testing within this research project. Photo: DLR

Table 1. Set of 23 items with positive and negative statements concerning cargo cycle use

Item (with direction)	Item wording as presented to the survey respondents
– Spatial coverage	Cargo cycles cannot cover our business catchment area.
– Loading capacity	The loading capacity of the cargo box is insufficient.
– Weather	Bad weather restricts usability of cargo cycles. – s
+ Electric range	The electric range is sufficient for our purposes.
+ Health	Cargo cycles promote employees' health.
+ Image	Cargo cycles promote our image.
+ Travel time reliability	Cargo cycles' travel times can be planned reliably (not affected by congestion)
– Theft	The cargo cycle could get stolen.
– Organizational effort	The implementation of cargo cycles requires organizational effort.
– Implementation cost	The implementation of cargo cycles is costly.
– Payload damage	The payload could be damaged during transport.
+ Purchase cost	Cargo cycles are cheaper than motor vehicles.
+ Maintenance cost	Cargo cycles have lower maintenance costs than motor vehicles.
+ Flexible parking	Cargo cycles offer greater flexibility concerning parking or loading/unloading.
+ Accessibility	Using cargo cycles I can reach access-restricted areas (e.g. pedestrian zones)
+ Environmental goals	Cargo cycles help to reach corporate environmental goals.
+ Travel time	I reach my destinations faster by cargo cycle than by car.
– Employee acceptance	Employees will not accept cargo cycles.
– Handling experience	Riding cargo cycles requires experience.
+ Fun	Employees enjoy using cargo cycles.
– Cycle infrastructure	Cycle infrastructure is inadequate.
– Safety	Using cargo cycles in traffic is dangerous.
– Service network	There is no service network for cargo cycles.

A total of 389 ratings collected between May and December 2018 were included into analysis for the present article. The sample consists of 80 female and 309 male respondents. Most respondents are fleet decision-makers in their organization (92%). The mean age is 43.9 years (SD=10.3). Respondents represent a broad variety of organization types (54% self-employed, 20% private corporations, 12% public organizations and 14% nonprofit or other organizations), as well as sizes, with a share of 63% corresponding to organizations with a maximum of 9 employees. Other organization sizes were 10-24 employees (14%), 25-49 employees (9%), 50-250 employees (8%) and more than 250 employees (7%).

Statistical analysis

Exploratory factor analysis (EFA) is a data reduction method applied to a larger pool of items in order to identify an underlying factor structure (Field, 2013, Mulaik, 2009). We used principal component factor extraction with varimax rotation, because it allows for a clear interpretation of the factor structure by aiming for each item to load highly on one factor and minimizing loadings on the remaining factors. The number of factors was determined by using standard recommendations of scree cut-off points (Cattell, 1966) and the Kaiser rule, stating to extract only factors with an eigenvalue larger than 1 (Kaiser, 1960).

The data’s suitability for factor analysis was determined prior to analysis by applying a Kaiser-Meyer-Olkin (KMO) criterion. In the present sample, the KMO criterion was .71 which is above recommended cut-offs ranging between .5 (Cleff, 2015, Field, 2013, Hartas, 2015) and .6 (Möhring and Schlütz, 2013, Tabachnick and Fidell, 2007). Additionally, Barlett’s test hypothesizing no correlation between items produced a significant result (*p*

< .001), indicating a satisfactory number of correlations between items (Bartlett, 1954). Taken together, the KMO criterion and Barlett's test indicate the appropriateness of the data set for EFA.

In a second step, unweighted factor scores for each respondent were calculated by averaging item scores of the three or four items with the highest loading on a specific factor. Scores of items with negative loading are reversed. Finally, factor scores were averaged across all respondents to calculate total mean scores.

RESULTS

Factor structure

Exploratory factor analysis yielded seven factors. Three of these factors describe drivers to the adoption of cargo cycles, while four factors represent barriers to the adoption of cargo cycles. Item loadings on these factors are listed in Table 2.

Factor scores

Figure 2 show unweighted factor scores, averaged across the complete sample. These factor scores quantify how strongly respondents agree with the suggested drivers and barriers.

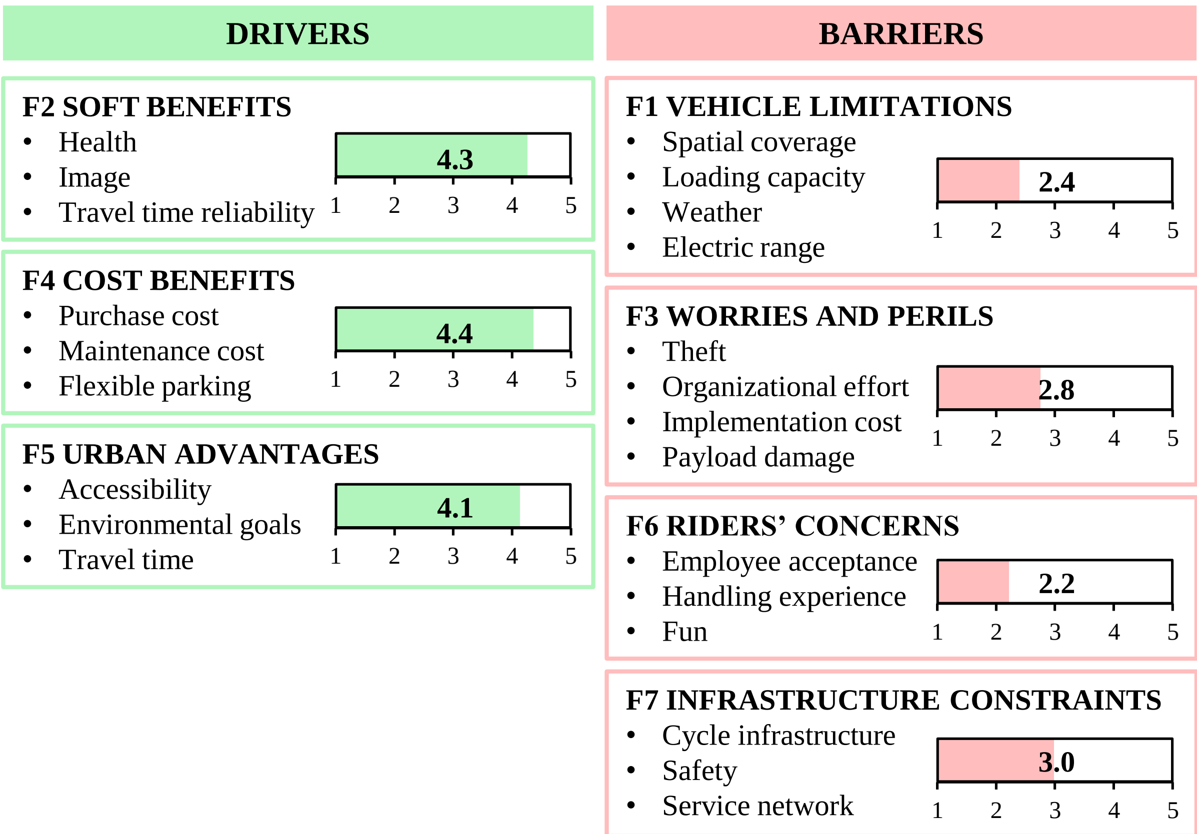

Figure 2. Allocation of the surveyed 23 items to the seven factors F1 to F7; unweighted factor scores showing respondents' mean agreement.

Table 2. Results of the exploratory factor analysis displayed in the rotated component matrix. Given are item loadings on the seven factors, as well as communality (h^2) for each item and total explained variance in % for each factor.

Item	**F1** Vehicle limitations	**F2** Soft benefits	**F3** Worries & perils	**F4** Cost benefits	**F5** Urban advantages	**F6** Riders' concerns	**F7** Infrastructure constraints	***h2***
Spatial coverage	**.641**	-.108	.033	-.084	.057	.078	-.063	.44
Loading capacity	**.593**	-.267	.122	.025	.014	-.215	.218	.53
Weather	**.524**	-.084	.229	.165	-.210	.241	.042	.47
Electric range	**-.497**	-.213	.180	.378	.106	-.041	-.125	.50
Health	-.041	**.673**	.088	.127	.024	-.119	-.051	.50
Image	.004	**.615**	-.133	-.028	.324	.189	.060	.54
Travel time reliability	-.238	**.547**	.121	.225	.135	-.089	.024	.45
Theft	-.141	.057	**.646**	-.044	-.067	.172	.144	.50
Organizational effort	.228	.016	**.590**	-.067	.148	.297	-.234	.57
Implementation cost	.153	.071	**.583**	-.112	.129	-.329	.105	.52
Payload damage	.085	-.062	**.466**	.163	-.378	.116	.289	.49
Purchase cost	-.257	.017	-.074	**.752**	.045	.065	.089	.65
Maintenance cost	.130	.220	-.103	**.604**	.091	-.032	-.215	.50
Flexible parking	.028	.174	.013	**.486**	.263	-.058	-.010	.34
Accessibility	.033	.060	-.002	.156	**.697**	.028	-.020	.52
Environmental goals	-.065	.218	.011	.149	**.524**	.030	.244	.41
Travel time	-.405	.075	.208	.218	**.463**	-.168	.004	.50
Employee acceptance	.321	-.023	.026	.068	-.044	**.653**	.084	.54
Handling experience	-.245	-.032	.261	-.072	.050	**.607**	.028	.51
Fun	-.270	.443	.077	.117	-.010	**-.462**	-.065	.51
Cycle infrastructure	.020	.030	-.042	-.076	.083	-.025	**.719**	.53
Safety	.159	.183	.246	-.042	-.276	.292	**.527**	.56
Service network	.050	-.297	.210	-.020	.195	.049	**.484**	.41
Explained Variance (%)	13.9	9.1	6.2	5.8	5.3	5.0	4.6	

INTERPRETATION

Factor structure

In the following, the seven factors will be interpreted in order of their explained variance. To facilitate readability, item names are printed in italics (for example *electric range*) and numeric item loadings are not stated in the following descriptions. Please refer to Table 2 for exact item loadings.

F1. Vehicle limitations. The first factor represents common critical perceptions about cargo cycles' limitations. Most importantly, these limitations concern range, both in terms of *spatial coverage* and in terms of *electric range, payload capacity* and *weather* dependency. Another item with a lower though still substantial loading on this factor is *travel time*, implying that this factor is associated with considering cars to be faster than cargo cycles.

F2. Soft benefits. The second factor describes benefits that are of secondary importance. More specifically, this factor includes high item loadings for soft aspects such as *health* and *image* benefits of cargo cycles. To a lesser extent, *reliable travel times* are also included in this factor. *Fun* is the secondary item with the highest loading on this factor, equally describing a soft aspect related to cargo cycles.

F3. Worries and perils. The third factor describes worries about risks associated with cargo bikes. It shows high item loadings for hazards such as *theft* and *payload damage*, and worries about *implementation cost* and *implementation effort*. Not surprisingly, of all secondary items on this factor, *safety* reaches the highest loading.

F4. Cost benefits. The fourth factor includes high item loadings for the costs associated with cargo cycles. More precisely, items covering lower *purchase cost* and *maintenance costs* as compared to motor vehicles display high loadings on this factor, as well as the advantages of free and *flexible parking*. Another item with a lower loading on this factor includes *electric range*, which is a critical parameter and imperative to be considered when assessing the economic benefits of shifting to cargo cycles.

F5. Urban advantages. The fifth factor combines items that represent advantages of cargo cycles that are particularly relevant in urban environments, such as *accessibility* of access-restricted areas (e. g., pedestrian zones), reaching *environmental goals* (such as lower emissions) and *travel time* advantages as compared to cars.

F6. Riders' concerns. The sixth factor involves concerns about cargo cycle rejection by riders. Items with high loadings on this factor include low *employee acceptance* of cargo cycles, concerns about the high level of *handling experience* required for navigating cargo cycles and whether the riders think it is *fun* to use the cargo cycle.

F7. Infrastructure constraints. The seventh factor represents infrastructural limitations to the use of cargo cycles. Most importantly, the lack of adequate *cycle infrastructure* has by far the highest loading on this factor, followed with some distance by *safety* risks in street traffic and the lack of a professional *service network* for cargo cycles. *Payload damage* has the highest secondary loading on this factor, suggesting that jolting due to bad infrastructure such as uneven surfaces might result in damaging the payload.

Factor scores

As shown in Figure 2, the three identified drivers receive higher agreement ratings than barriers. This preference might be explained by the fact that our sample consists of organizations which are interested in testing cargo cycles and therefore likely have a positive general attitude towards cargo cycles.

With regards to the drivers, there are only minor differences between the three factors. The factor with the strongest agreement rating is *cost benefits* (F4). This result indicates that among organizations interested in testing cargo cycles, financial advantages related to cargo cycles are considered as particularly pertinent. However, as *soft benefits* (F2) follows closely, it is evident that not only economic considerations spark interest in cargo cycles, but also secondary benefits commonly associated with this type of vehicle.

The factor with the lowest agreement ratings among the drivers is *urban advantages* (F5). Two explanations are conceivable for this result. First, not all respondents are planning to use the cargo cycle within dense city centers, so it seems logical that the advantages summarized in this factor are of lower relevance to them. Second, it is possible that even for respondents wishing to use the cargo cycle in city centers, the advantages summarized by this factor are of lower relevance as compared to the other two driving factors.

With regards to the factors describing barriers to the use of cargo cycles, there is a substantial advance of *infrastructure constraints* (F7). This seems highly plausible as to date, very little bicycle infrastructure in German cities is suitable with regards to surface quality and width for cargo cycles. This lack of infrastructure is likely also related to safety issues in motorized street traffic for cargo cycles. Additionally, as cargo cycles are not yet widespread, only few service providers offer maintenance services. Taken together, the comparatively high agreement ratings for this factor suggest barriers for the adoption of cargo cycles with regards to infrastructure.

Worries & perils (F3) reach the second highest agreement ratings among the barrier factors. It is worth noting that most of respondents have little experience with cargo cycles. Hence it is conceivable that worries about implementation of cargo cycles into organizational routines are of particular pertinence. Moreover, worries about theft and damage are possibly particularly relevant prior to own testing experience, as worries tend to be of greater importance prior to confronting them with real life experiences.

Ranging third among the barriers, *vehicle limitations* (F1) seem of minor relevance to the respondents. This is possibly due to the fact that the sample consists of interested users who already consider cargo cycles as suitable transportation options for their organizations, likely after assessing the given limitations when switching operations to a smaller vehicle.

Finally, *riders' concerns* reach (F6) the lowest score of 2.0 which is equivalent to the reply option "I rather don't agree". This finding might be interpreted as that respondents generally represent a sample of interested cargo cycles users who are expecting that riding the cargo cycle tends to be a rather fun activity. In addition, respondents represent in large parts fleet decision-makers and represent rather small companies, which seem to be less concerned about employee acceptance.

CONCLUSION

The present paper described an exploratory factor analysis of 23 literature-derived drivers and barriers to the adoption of cargo cycles. The analysis yielded seven factors (three drivers and four barriers). This factor structure reduces the complexity of a large variety of items influencing the adoption of cargo cycles. This classification can serve as theoretical framework for further research about the adoption of cargo cycles. One potential application of our results is to identify how different types of cargo cycle users can be differentiated with regards to their ratings in these seven factors.

In addition, we calculated overall agreement scores for the respective factors. The results indicate higher agreement ratings for drivers than for barriers. The barrier with the highest agreement rating is infrastructure, suggesting that policy-makers could address these concerns in order to promote cargo cycle use.

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