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A public transport based crowdshipping concept: Results of a field test in Denmark

Andreas Fessler [a,*], Philip Cash [b], Mikkel Thorhauge [a], Sonja Haustein [a]

[a] Technical University of Denmark, Department of Technology, Management and Economics, 2800 Kgs. Lyngby, Denmark
[b] Northumbria University, School of Design, UK

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ABSTRACT

Increasing e-commerce and accompanying last mile delivery traffic challenges cities worldwide in terms of congestion, emissions, and road safety. This paper presents the main results of a full-scale field test of a public transport based crowdshipping concept aiming to address these challenges, by utilizing passenger flow to reduce the amount of delivery vehicles entering central city districts. The aim of this work was to assess adoption potential as well as the practical and conceptual aspects that may affect this.

The test took place in Denmark's capital region and northern Jutland over a two-month period, in which 28 automated parcel lockers (APLs) were placed at public transport stations/stops. Passengers were rewarded for bringing along empty test parcels on their trips, from APL to APL via an app developed for the purpose. Along with the app data, pre- and post-survey data was captured.

The practical viability of the concept was validated from a user perspective, with a high degree of post-measure acceptance. Regression results show that ease of interacting with the service affected acceptance of the tested concept, but not the intention to participate in a future realized concept. Perceived behavioural control was the most important predictor of intention, acceptance and behaviour during the trial. Our results highlight the relevancy of contextualizing and supplementing intention as a practice-based measure for adoption propensity.

1. Introduction

The growth of e-commerce represents an increasing challenge for logistics operators and the communities they cater to (Mangiaracina et al., 2019). Especially the last stretch of the transport chain, the last mile, is agreed by both practitioners and academics to be the most critical and inefficient element of the delivery process, both in environmental and economic terms (Macioszek, 2018; SOTI 2020). With customer expectations that set high service level targets, speed and flexibility must be prioritized to ensure competitiveness. The resulting lacking possibilities for consolidation means that costs of the last mile amount to half of total costs (Chen et al., 2018; Rodrigue et al., 2016), as well as necessitating fleets of delivery operators contributing to increasing congestion issues in cities (Allen et al., 2018; Taniguchi et al., 2016). Public transport based crowdshipping represents an opportunity to mitigate some of the abovementioned challenges. However, it has received very little attention academically or practically. In contrast to private vehicle based crowdshipping (e.g. Allahviranloo and Baghestani, 2019; Ermagun et al., 2020; Punel et al., 2018), utilization of public transport passengers' excess capacity would solely make use of non-dedicated trips and thus avoid the problem of detours that often cause crowdshipping with private vehicles to result in higher emissions than traditional delivery modes (Buldeo Rai et al., 2018). To enable this, a public transport system would make use of Automated Parcel Lockers (APLs), which in themselves have shown a range of advantages compared to traditional home delivery (e.g. Buldeo Rai et al., 2021; Wang et al., 2014).

Initial explorations of implementing such a system in the city of Rome found potential savings to be made (Simoni et al., 2019). Concurrently with the work of the present paper, substantial potential for economic and environmental savings were found using real-world data from a freight operator to simulate public transport based crowdshipping scenarios for the last part of deliveries to Copenhagen (see Fessler, 2022 for more details).

Although such a solution has shown potential for mitigating the issues of the last part of delivery chains, its efficacy is dependent on user

* Corresponding author.
E-mail address: andfes@dtu.dk (A. Fessler).

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up-take. Recent work has shed some light on public transport passengers' willingness to act as crowdshippers (Fessler et al., 2022; Fessler et al., 2023b; Gatta et al., 2018), but has been based on Stated Preference experiments and surveys measuring intention to participate. Though intention – as proposed by the Theory of Planned Behaviour (Ajzen, 1991) – has proven useful in predicting behaviour, frequently low empirical intention-behaviour relationships (e.g. Armitage and Conner, 2001) has also pointed to the value of contextualizing evaluations within the everyday practices in which the behaviour should actually take place (e.g. Lockton, 2012; Madsbjerg, 2017). In particular, in case of future mobility services, it has been found difficult to give a realistic indication of future adoption based on hypothetical scenarios, while hands-on experience can uncover practical limitations and lead to more accurate assessments of future use (Millonig and Haustein, 2020). As such, there is a need to ground research on crowdshipping solutions in contextualized practical interactions to evaluate theoretical and practical understanding of adoption potential.

In response to this need, this paper proposes and investigates a public transport based crowdshipping concept in which APLs are placed at public transport stations and stops, in spots that are convenient for passing passengers. Registered users then get the opportunity to bring along parcels on their matching public transport trips, from APL to APL. As such, this paper presents the main results of the (to our knowledge) first field test of a public transport based crowdshipping concept, and provides important practical and conceptual insights for the field.

The remainder of this paper is organized as follows. The next section introduces the relevant theoretical background before Section 3 describes the contributions we aim for with the paper. Section 4 introduces the method of the study, including a description of the practical test, the procedure and participants, survey content and the analysis approach. Section 5 presents results. Lastly, Section 6 presents main conclusions and discussion points, including limitations and practical implications.

2. Theoretical background

The Theory of Planned Behaviour (TPB, Ajzen, 1991) is one of the most frequently applied frameworks for understanding user acceptance and is applied in a wide variety of domains including transport behaviour (Vlassenroot et al., 2010). Intention is the main determinant and immediate precursor of behaviour in TPB, and an indication of an individual's readiness to perform a given behaviour. Intention is shaped by 1) attitude toward behaviour 2) subjective norms and 3) perceived behavioural control (PBC). TPB is open for the inclusion of additional factors. Relevant extensions in the context of transport behaviour are, for example, the inclusion of habit (Klöckner and Blöbaum, 2010) and of symbolic motives and self-identity (e.g. Fallah Zavareh et al., 2020). Specifically, applying an extended TPB to predict people's willingness to participate in a public transport-based crowdshipping concept, Fessler et al. (2023a) identified a joint factor including the social value from participation and the expected support from important others (subjective norm) as the most important predictor of the intention to serve as a crowdshipper. The study also highlighted the importance of Perceived Behaviour Control, operationalised as the perceived ease of use and convenience. Participation in the service would need to be a smooth experience that merges well with individuals' transport routines and habits, in order to be worth their while with the relatively small remunerations that would be possible within the current margins of deliveries. This brings attention to practical aspects of implementation, such as concept simplicity, app usability, and parcel locker placement, and followingly on the practical experience of participation.

Intention, acceptance, and acceptability are examples of terms that have been used interchangeably to describe (potential for) user uptake of new technology. Within the domain of transport psychology, one distinction between acceptability and acceptance has been defined by Schade and Schlag (2003, p. 47). *Acceptability* is here understood as "*the prospective judgement of measures to be introduced in the future*", and a construct that is measured prior to an individual's experience with the object of interest. *Acceptance* on the other hand is here referred to as individuals' attitudes, including behavioural reactions, after this object of interest has been introduced. Thus, for the purpose of this study, we are not only interested in evaluations of the concept (acceptability), but in the evaluation of participants' interaction with it – its acceptance (Nadal et al., 2020). In other words, how will conceptual and practical aspects of the interaction with the concept serve to (de)incentivize future adoption. Intention, on the other hand, is applied in this paper as a measure, which is more related to the core concept rather than the practical experience with the service, although hands-on experience is still expected to enrich the post-measures for intention and increase the reliability of the results.

3. Research aims

Based on insights from a practical test of a public transport based crowdshipping concept, we aim for three main contributions:

- to achieve a more realistic measure for intention to participate in a realized public transport based crowdshipping concept, by providing practical experience as basis for evaluations;
- to examine what worked from a practical perspective and what should be iterated in a future concept;
- to model how psychological constructs related to the TPB affect different evaluation criteria: post-intention, acceptance, and engagement in the trial (behaviour).

Based on our results, we shed light on motivational and demotivational aspects relevant to the proposed crowdshipping concept.

4. Method

In order to answer the above research aims as well as provide a practical experience-based empirical foundation, a real world experiment was conducted in which public transport passengers were offered the opportunity to get economically rewarded for bringing (empty) test parcels from APL to APL along on their matching public transport trips between stations/stops included in the test.

The user experience of the crowdshipping concept was measured through a pre-survey, the field test and a post-survey that was split into two separate surveys; one for participants who took part in the practical test by bringing 2 or more parcels and one for those who did not take part in the practical test (to examine reasons for not participating). The survey responses were linked to data from the 'CrowdShip' app developed for the purpose. The app served as a tool for communication between participants and the system (opening of APL, feedback, reminders) and trip registration. Given this context, we first outline the practical aspects of the field test (Section 4.1), before providing details on the participants and procedure (Section 4.2), survey approach (Section 4.3) and data analysis (Section 4.4).

4.1. Practical test

Participation in the practical test was possible from September 2nd, 2020 and originally scheduled to last throughout September. However, as a national COVID19-lockdown[1] was announced on September 18th, the experiment period was extended to last throughout October, in order to compensate for the vastly diminished number of public transport trips taken due to being sent home from work etc.

In order to gain the required approvals, access to necessary locations and the facilities needed to maximize realism of the experience, the

[1] During the lockdown, travel with public transport was still possible, but work from home was strongly encouraged.

experiment was organized in collaboration with municipalities, DSB (the Danish national rail company), Metroselskabet (Metro company) and Nærboks (the APL-provider, partly owned by the Danish national postal service). This made it possible for participants to interact with an app, APLs and parcels as outlined in the following two sections.

4.1.1. App and participation process

A smartphone app, 'CrowdShip', dedicated to the experiment was developed for both IOS (iPhone) and Android, which through Bluetooth-connection facilitated the interaction with the placed APLs. Through the app, participants could 1) book a test parcel with a matching route, by entering their departure and destination station (Fig. 1, screen 1); 2) use the app to open the APL at their departure station (one of the 28 included stations/stops in Fig. 2) through Bluetooth (Fig. 1, screen 2); and 3) open the APL to hand it in at their given destination (Fig. 1, screen 3).

The whole process of booking a parcel for a matching trip, opening the locker through the app and closing it again after taking the parcel could be completed in less than 20 s, which comes close to the scope of the imagined realized solution. To imitate the imagined realized concept more closely, a booking of a parcel lasted 30 min. If the parcel was not collected within this time, a new booking had to be made. In a full implementation, it could be considered to extend the booking time frame.

The app gathered information about each participant's interaction with the service, registering each trip a parcel was brought, with date/time and departure/destination point.

To incentivize participation and reward participants for the time spent on surveys and installation of the app, they received a basic compensation of a 50 Danish kroner (6.7 €) gift certificate for completing a pre-survey, bringing a parcel on two trips, and completing a post-survey. In order to mimic the basic incentivization scheme of a realized concept in the most realistic way possible, participants moreover received 10 kr. (1.3 €), for each additional trip, which was added to their gift certificate. Maximum total amount per person was 100 kr. (=7 trips). In a realized concept, crowdshippers would receive their remuneration as credit for the transit system, and it would be possible to bring multiple parcels to earn more credit.

4.1.2. APLs and parcels

During a two-month period, 28 APLs were placed at public transport stations and stops; S-train, Metro, Bus and Train. In order to imitate the imagined operational area and direction of a last mile solution overseeing deliveries from city outskirts to central districts, 22 of these APLs were placed in the Greater Copenhagen area. The lockers were distributed within the operational area of S-trains, representing both satellite towns, suburban areas and central city areas. In addition to these 22, six APLs were placed throughout a larger geographical area of Northern Jutland, a less densely populated region of Denmark, of which four were placed in small towns and two in the larger town of Aalborg.

To ease localization as imagined in a realized solution, APL placements were depicted in the app when relevant; a picture of the departure APL with surroundings was displayed upon booking a parcel, and displayed for destination APL upon closing the locker door after pickup as seen in Fig. 1. Further, in order to make participation as easy as possible, all APLs at S-train stops were placed on the station premises, as imagined for a realized concept. All metro station APLs were placed above ground, in the immediate vicinity (max 20 m away) of the entrance. Some stations included both S-train, metro, bus and/or train connections. This provided the opportunity to test participation for multimodal trips, but was also a natural result of including some of the city's most central and frequented stations. APLs placed at bus stops varied more in terms of distance, with some placed immediately by the stop, and others placed up to 100 m away. This was dictated by what was logistically possible, but was also seen as an opportunity to test for any influences of the varying distances.

Only one "locker" in each installed APL (that each contained 13 separate lockers) was used, and thus contained multiple test parcels, of which participants were instructed to bring just one. The empty test parcels where therefor of relatively small size, with dimensions of 19 × 12 × 4 cm, allowing 60 parcels to be placed in each at the beginning of the experiment. The parcels only weighed the few grams of their own cardboard material. This solution was chosen in order to limit complexity of the technical development of the app. In a realized concept, each individual locker would of course only contain the parcel (s) for the individual crowdshipper to bring, and the size and weight of parcels would vary. The test solution thus closely mimicked the experience of participating in the proposed realized concept, where a specific parcel with a matching itinerary would be booked, except for this aspect of the lockers containing multiple parcels and the weight/size of parcels. Possible implications of this are discussed in Section 6.

4.2. Procedure and participants

Recruitment took place through a sign-up link where participants registered with their email, after which they received a pre-survey link via email. This sampling was not chosen with the goal of being representative for a larger population, but rather to be illustrative of potential early adopters, which has previously been used as a purposeful sampling strategy in exploratory pilot studies, where the aim is general insights in uncharted territories (Storme et al., 2020). Sign-up links were distributed from September 1st' 2020 via social media and was mentioned in various national and local tv-, radio- and online news outlets. Upon completion of the pre-survey, participants received an email with download links and installation-guides for respectively IOS and Android users, as well as a guide on how to participate by bringing parcels during the experiment. Immediately after the experiment period, post-survey links were distributed via email to all respondents completing the pre-survey (respectively to those who participated, which was automatically registered through the app, and those who did not).

Throughout most of the experiment period, emails reminding to participate were sent on a weekly basis to all pre-survey respondents who had not yet brought a parcel, with higher frequency in the last two weeks. The last four days, daily reminders were sent.

All Android-users (both those who had already participated and those who had not) also occasionally received push-notifications reminding to participate.[2]

This resulted in 454 completed pre-surveys (64% women, 34% men) from respondents between 16 and 73 years of age ($M = 29$; SD 11.50) (see Table 1). 157 of these respondents (35%) also participated in the practical test, while 144 of those who did so (92%) also completed the post survey (60% women, 38% men). Participants were likewise between 16 and 73 years of age ($M = 29$; SD 10.90). 145 respondents who completed the pre-survey but did not participate in the practical test completed the post survey for non-participants.

4.2.1. Participants

The main reasons for not participating in the practical test was being sent home due to COVID19 and thus not travelling as usual. 22% of non-participating respondents who installed the app, and 32% of those who did not, indicated this as the main reason. Additionally, 39% of app-downloaders and 29% of those who did not download, selected "Other" as main reason. A large proportion of these respondents elaborated in accompanying text entry, that their lacking participation was due to COVID19. Amongst non-participating respondents who installed

[2] Push-notifications are messages that can be sent to pop up on the users' phone screen without them having to be in the app and allow the user to go directly to the app by pressing it. Push-notifications for IOS were more complex to implement, and were therefor not prioritized given the available resources for the test setup.

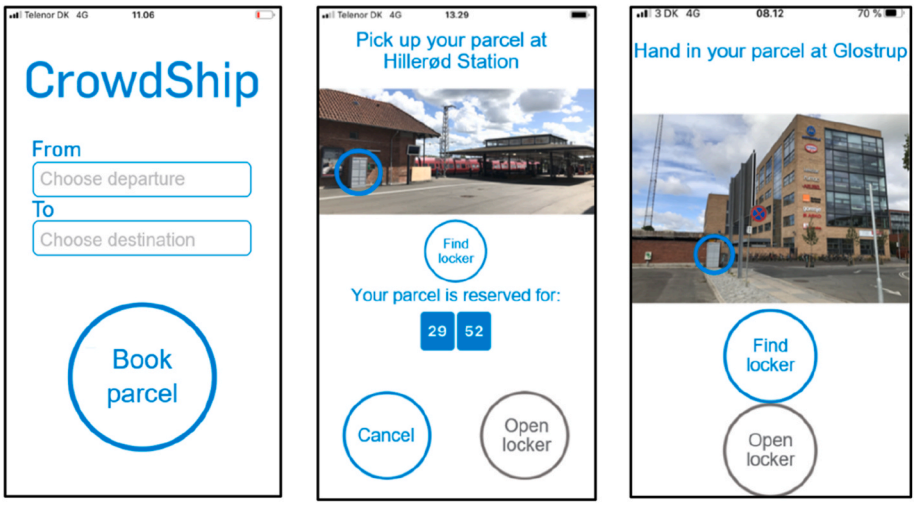

Fig. 1. App screenshots: Screen 1,2,3.

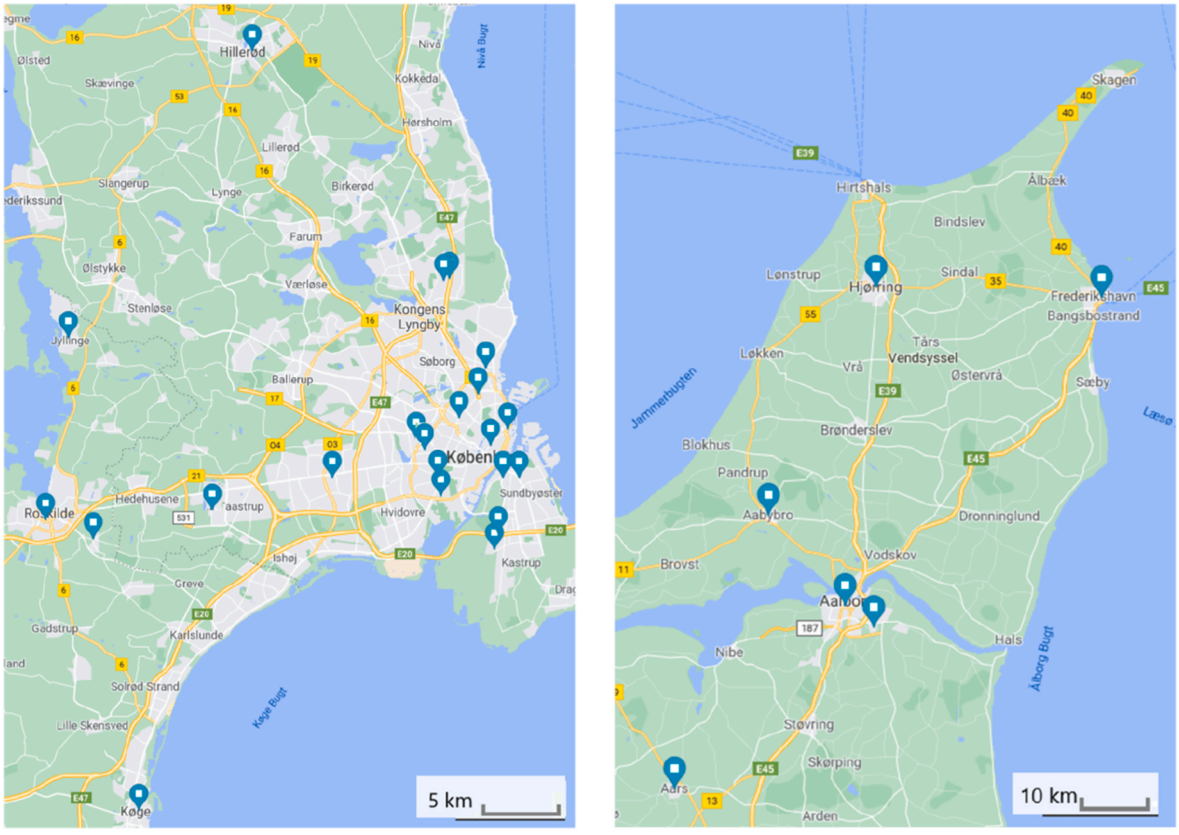

Fig. 2. APL map for capital area and Northern Jutland.

the app, the main reason was forgetting to participate when travelling by public transport although they intended to (27%). There were found no attitudinal or demographic differences between those who downloaded the app, but forgot to participate and those who remembered to participate (in an independent samples *t*-test, the lowest *p*-value was .3).

Participants did not differ significantly from non-participants in any attitudinal variables, including intention to participate in a realized concept ($p > .10$). Concerning demographics, one significant difference regarding participation was found. People from Northern Jutland (16.8% of pre-survey participants) were significantly underrepresented as participants in the practical test (9.7%) compared to Copenhagen-based respondents (84.4% vs. 90.3%), χ^2 (2, N = 454) = 6.6, p = .038. The main reasons for not participating given by respondents from Northern Jutland were the same as for the rest of the sample.

In our sample 86% of participants are below 40 years old, compared to 57% of public transport users in the Copenhagen area (the population), and 53% of participants are students compared to 29% of the population. 13% of participants are retired/not working, compared to 26% of the population. This is in line with previous results comparing sociodemographic characteristics related to participation propensity with the general population of public transport users in the Copenhagen area (for details, see Fessler et al., 2022). In the sample of the present

Table 1
Sample characteristics.

Variables	Pre-survey only	Pre- & non-participant-survey	Pre- & post-survey test participants
N	152	145	144
Gender			
Female	63.5%	65.2%	60.4%
Male	31.7%	31.6%	38.2%
Other/Do not wish to answer	3.7%	1.0%	1.4%
Age			
25 and below	55.0%	51.3%	52.1%
26–39 years	27.5%	29.0%	34.0%
40–64 years	14.3%	16.8%	13.2%
65 years and above	1.1%	1.0%	0.7%
Employment status			
Working	36.0%	37.7%	32.6%
Student	57.1%	53.5%	52.8%
Non-working	4.2%	5.5%	8.3%
Retired	1.1%	1.6%	4.2%
Education level			
Low	50.3%	47.4%	43.1%
Medium	26,5%	27.4%	31.3%
High	19.6%	21.6%	22.9%
Income			
Below median	62.6%	62.5%	63.7%
Median	21.6%	20.7%	16.1%
Above median	15.8%	16.8%	20.2%
Geography			
Copenhagen Outskirts	39.7%	44.5%	50.7%
Copenhagen Central Districts	41.3%	37.1%	39.6%
Northern Jutland	16.4%	16.8%	9.7%

study, women are overrepresented, with 60% compared to 46% of the population (Transport DTU, 2020).

4.3. Survey content

Some data-points where included in both pre- and post survey, while others we only necessary to include in one of the two. In addition to a common core part with psychological items, the pre-survey additionally included a sociodemographic background part, while the post-survey included specific questions on the experience with and evaluation of the tested crowdshipping solution.

4.3.1. Pre-survey

Following from our theoretical lens as well as the results of a prior study distributing a similar survey to a representative sample of the Greater Copenhagen area (for details see Authors, 2022), items included in the pre- and post-survey were intended to cover the following factors that were inspired by an extended version of the Theory of Planned Behaviour (Ajzen, 1991):

Intention was measured with three items that for various trip types asked how often the respondent imagined to make use of the opportunity to check in and out with packages if there were always packages to bring (e.g. "How often would you make use of the opportunity to check in and out with packages if there were always packages to bring – On your most used route in the Copenhagen area (outbound)"). Answers were provided on a five-point frequency scale (1 = never; 5 = always).

Concept attitude – towards the non-specified crowdshipping company – measured the perceived value of participation and the perceived fairness of this in comparison to the imagined gains of the crowdshipping company (four items, see Table 2) (e.g. Morton et al., 2021). In this, items related to symbolic motives (status) and potential feelings of embarrassment of receiving compensation were also included. Statements for concept attitude were assessed on a five-point agreement scale (1 = totally disagree; 5 = totally agree).

PBC measured the perceived difficulty and time-consumption of

Table 2
PCA Factors and items. Note: Results for PBC are underlined.

Principal Component Analysis (Pre-survey)	SVS	Concept attitude and PBC	Losing/ damaging parcel	System flaw	Dangerous/ Illegal goods
Item					
Many of my friends would participate in the concept.	**.559**	−.018	.187	−.057	−.057
I would feel a community spirit with the other users.	**.738**	−.256	−.174	.111	.015
I would feel part of a positive movement.	**.705**	−.182	−.040	.192	−.040
I would feel good about having made a small difference for the environment and my city.	**.695**	.030	−.068	−.169	.063
For me, it would give value to participate.	**.693**	−.192	−.035	−.119	.056
It would be a bit embarrassing to meet someone I know, while I was picking up/delivering a parcel.	−.095	**.700**	.191	.042	.068
I do not want to be associated with parcel couriers.	−.108	**.529**	−.034	.013	.309
Participation is only for 'discount hunters'.	−.253	**.654**	−.075	.117	.121
The concept would unfairly take advantage of me as a form of cheap labour.	−.301	**.487**	−.088	.224	.206
It would be difficult for me to bring parcels on my journeys.	−.030	**.602**	.190	.333	−.097
The whole process of downloading an app and signing up would be too much hassle for me.	.013	**.572**	.164	−.059	.096
Bringing packages on my journeys would be too time consuming.	−.138	**.581**	.149	.247	−.166
I would be nervous about...					
forgetting the parcel and not getting it handed in the locker.	−.006	.173	**.827**	.217	.091
	−.009	.077	**.603**	.329	.386

(continued on next page)

Table 2 (*continued*)

Principal Component Analysis (Pre-survey)	SVS	Concept attitude and PBC	Losing/ damaging parcel	System flaw	Dangerous/ Illegal goods
Item					
accidently damaging the parcel.					
… forgetting to hand in the parcel and accidently bringing it with me.	−.050	.123	**.753**	.275	.061
not being able to find where the package should be handed in.	−.062	.185	.210	**.718**	.049
not being able to open the locker due to technical difficulties.	−.027	.132	.100	**.683**	.241
not being able to open the locker because of my phone running out of battery.	.003	.117	.228	**.613**	.093
what I might be liable for, if the package is damaged somewhere else in the transport chain.	−.031	.007	.240	**.614**	.353
that I might transport something dangerous.	.001	.149	.482	.199	**.498**
that I might transport something illegal.	.003	.142	.132	.160	**.828**
the package being robbed/ stolen on the way.	.047	.070	.116	.236	**.825**
Cronbach's alpha (Pre-survey)	.716	.665/ .557	.786	.727	.770
Cronbach's alpha (Post-survey)	.738	.482/ .643	.767	.659	.768

participation with three items. Additionally, more specific *barriers* for participation were measured with separate items. Of these, five items focused on liability issues in case of damage to the package caused by oneself or others, risk of theft/robbery and fear of transporting dangerous/illegal goods. Three items focused on the risks of forgetting the parcel and thus not handing it in, or not being able to hand it in due to the phone running out of battery. Two items measured the fear of a faulty system such as technical issues or not being able to find the package locker.

Social value and support (SVS) consisted of five items covering 1) social aspects of participation that included subjective norm (Ajzen, 1991) and relatedness (e.g. Schikofsky et al., 2020), covering if participants imagined their friends to participate and potential positive feelings of being part of a movement or community as a result of participation. 2) The imagined potential of participation eliciting positive emotions as a result of contributing towards societal needs and environmental protection, which was covered by the construct of warm glow (e.g. Venhoeven et al., 2013).

We calculated a principal component analysis (PCA) using Varimax rotation based on the larger pre-survey sample to reduce the 22 items to their underlying factors. The PCA resulted in five factors (based on Eigenvalue criterion), as seen in Table 2. As in a previous study, PBC and concept attitude loaded on the same factor. However, they were split up because of a clear conceptual distinction between the control and competence oriented PBC-items and the attitudinal items evaluating the concept from a moral and symbolic perspective (Fessler et al., 2023a). Total variance explained was 55.2%. We conducted a PCA based on the post-survey data, which resulted in a slightly different solution explaining 64.2% of the variance. The deviations of results could be due to the lower number of participants and/or the practical experience of the post-survey sample. As the solution based on the pre-survey data is based on a larger sample and closer to the solution obtained from a representative survey, we used this solution as a basis to create mean scales. Table 2 shows the internal consistencies for the resulting mean scales as identified based on the pre-survey. Concept attitude and system flaw have a much lower internal consistency based on the second survey, while PBC has a low reliability in both the pre- and post-survey data, which needs to be taken into account when interpreting the results. Apart from that, all internal consistencies are above 0.7 and thus considered satisfactory.

Additionally, we used two sub-scales of the Satisfaction with Travel Scale (STS): *time* and *comfort,* with respectively three and four items. *Time* measured whether the participant in relation to their most frequent journey felt stressed, hurried and worried about arriving on time (Ettema et al., 2011). *Comfort* was measured with three items on the ease, functioning and comfort of the trip (Ettema et al., 2011), and additionally one item created for the purpose of this paper which measured the degree to which the participant feels safe on the trip. For consistency with the rest of the survey, the STS items were measured on the same five-point Likert scale as used in the other items. Cronbach's alpha for the common STS scale was .907.

To compare sample characteristics, the pre-survey additionally included the following background variables: postal code, age, gender, household composition (living with children/partner/parents/other adults), income, monthly public transport expenses, employment status (eight categories), work hour flexibility (fixed/flexible work hours) and education (seven categories).

4.3.2. Post-survey

4.3.2.1. Acceptance and post-measures of intention. The post-survey initially gathered information about the extent of participants' public transport travel between included stations during the test period, in order to assess their participation in a relative sense. To identify any differences regarding technical issues, they were then asked whether they installed the app on IOS or Android. Subsequently, the survey included the same attitudinal items as the pre-survey. Additionally, the post-survey included a range of questions about test participation, in order to assess the experience and practicalities of interacting with the concept. These were also answered through five-point agreement scales. In addition to the theoretically based factors mentioned in Section 4.3.1, a range of mean scales were therefor created from selected post survey items evaluating the test experience.

Considering the technology adoption process as a temporal continuum, we employed *acceptance* as a measure for user's first interaction with a service and followingly if this served to motivate future use, as it has been proposed for early stages of a design process (Arbelaez Garces et al., 2016). Like the majority of related studies, we do this by employing custom measures on acceptance to adapt to the specific issues relevant for the test and its relation and comparability to a realized concept (Nadal et al., 2020). This was done through adapted Technology Acceptance Model items on perceived usefulness, perceived ease of use

and motivation as result of test participation (e.g. Arbelaez Garces et al., 2016; Goudsmit and Vos, 2021).

Acceptance was measured with three items included in the post-survey; 'Participation in the test increased my motivation to participate in the concept if it should become realized', 'Participation was easy for me' and 'My overall experience of participating in the test was good'.

A Principal Component Analysis using Varimax rotation was conducted to empirically validate the distinction between the acceptance items and post-survey measures for intention as seen in Table 3. The distinction was confirmed with the items loading onto two separate factors (based on Eigenvalue criterion) following the theoretical divide.

4.3.2.2. Practicalities and other experience measures. A mean scale for 'app difficulties' measured issues with connecting to the APLs with four items ('I experienced issues connecting to the lockers through the app', 'It was difficult to open the parcel lockers with the app', 'It was difficult to open the parcel locker with the app (most used departure station)', 'It was difficult to open the parcel locker with the app (most used destination station)'), with a Cronbach's alpha of .896.

A mean scale for 'APL localization' was created from four items; 'The placement of the parcel locker was good' and 'I had a hard time finding the parcel locker at the station/stop' respectively for the participant's selected Departure and Destination station. As satisfaction with APL placement at departure and destination are not necessarily related, Cronbach's alpha for this joint mean scale was not calculated.

Participants were also asked about the extent of their public transport travel during the experiment and which station they used most often as respectively pickup and drop off location.

For a range of the questions evaluating both the experienced concept, app and interactions with the service at the participant's indicated departure- and destination point, an elaboration through text entry was requested in the case of negative evaluations (values 1 and 2 on the five-point Likert scale). Further to get a deeper qualitative understanding than what could be expressed through quantitative measures, all participants were asked to elaborate via text entry on when and how they remembered to bring a parcel, what should have been done for them to have participated more often as well as the most positive and negative aspect of participation. Lastly, participants had the chance to give additional comments in a concluding open text field, in order to provide the possibility to elaborate or contextualize their answer as well providing an opportunity to catch any aspects that had not been covered by the standardized questionnaire.

4.4. Analysis

Data from pre-survey, Crowdship app and post surveys was merged into one dataset and analysed using SPSS software. After providing descriptive statistics (percentages and means), we performed paired samples t-tests to compare pre- and post-survey results, and Pearson's Correlations to examine linear relations between selected variables. Further, three multiple linear regressions were conducted to find potential relations between a range of post-survey measures (PBC, concept attitude, SVS, app difficulties, APL localization and barriers losing/damaging parcel, system flaw, dangerous/illegal goods, public transport travel during experiment and most used pickup direction) as well as pre-survey intention and STS on respectively post-survey intention, acceptance and amount of trips taken during the experiment with a parcel (= number of parcels brought during the experiment).

Table 3
PCA factors and items (post-survey dependent variables).

Principal Component Analysis (post-survey dependent variables)		
Item	Acceptance	Intention
How often would you make use of the opportunity to check in and out with packages if there were always packages to bring-		
On your most used route in the Copenhagen area (outbound)	.149	**.797**
On your most used route in the Copenhagen area (inbound)	.253	**.772**
On other journeys with public transport in your city/area	.172	**.673**
Participation in the test increased my motivation to participate in the concept if it should become realized	**.688**	.391
Participation was easy for me	**.889**	.198
My overall experience of participating in the test was good	**.868**	.133
Cronbach's alpha	.804	.669

5. Results

5.1. Overall experience

In total, just under 900 trips were taken with a test parcel during the experiment period. On average, participants[3] brought 5.5 parcels (SD = 5.0).

A main purpose of the study was to assess adoption potential. As a backdrop to this, 82% of participants agreed or strongly agreed to the statement 'Participation in the test increased my motivation to participate in the concept if it should become realized'. 6.3% disagreed or strongly disagreed with it. 11.8% neither agreed nor disagreed. Fig. 4 shows a range of acceptance-related items, of which the three retrospective items were compiled in the mean scale, acceptance.

After participating in the test, 46.6% of participants would often or always bring a parcel on their most used outbound trip, while 39.6% would occasionally bring one. 68% of participants would often or always bring a parcel on their most used return trip, while 24.3% would occasionally bring one (see Fig. 5).

As such, the potential for user acceptance of the proposed service was substantiated by the practical interactions with the service. In the next sections, we take a closer look at which practical and conceptual aspects of the service were related to positive experiences with – and subsequently acceptance of – the service.

5.2. Practicalities

5.2.1. App and APL interaction

In the following, results are presented on the main interaction with the service, which was the process of picking up and handing in the parcels in the APLs through the app. This is done to illustrate the influence of the most fundamental practical elements that served as contextualized basis for evaluations of acceptance and intention.

Fig. 3. APL placement example.

[3] Only including respondents of the post survey.

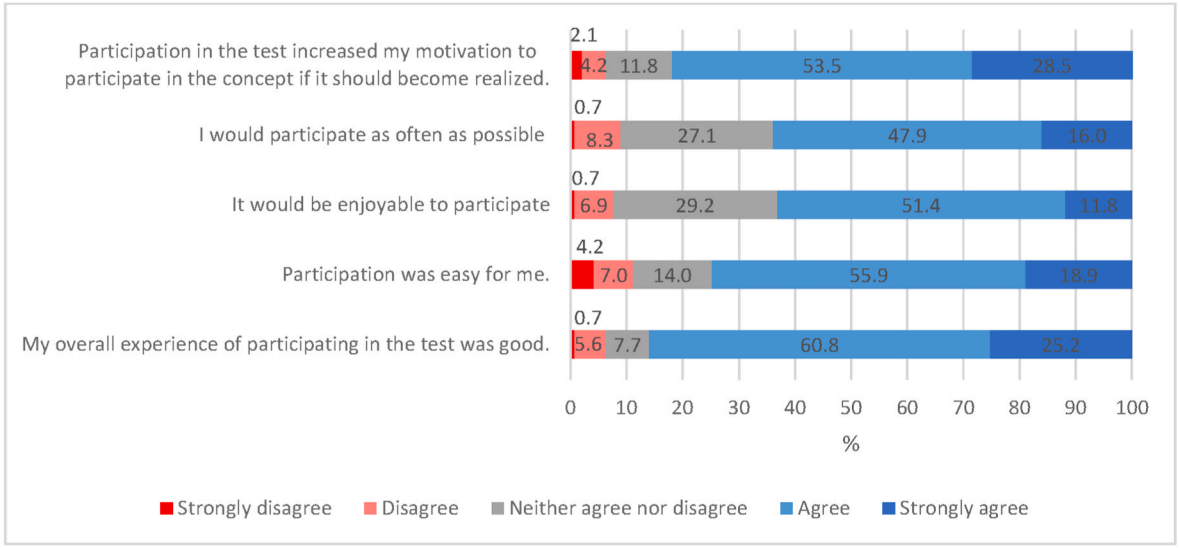

Fig. 4. Agreement to acceptance-related statements on participation (post-survey).

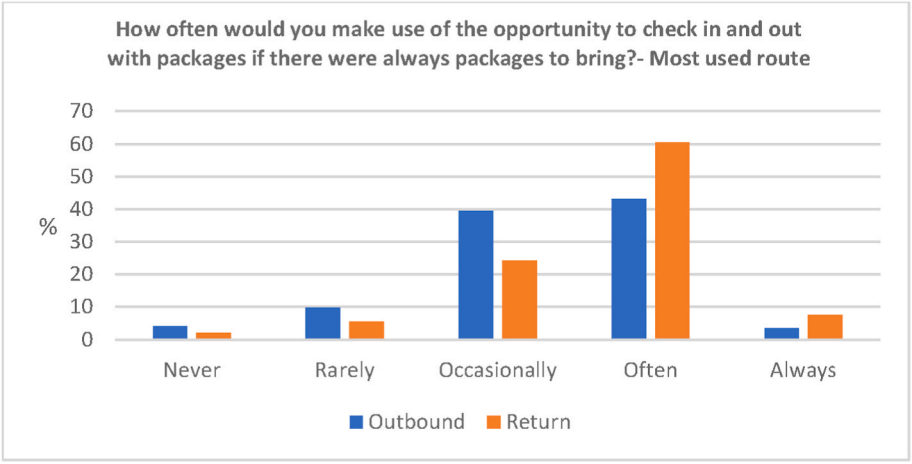

Fig. 5. Expected participation in a realized concept (post-survey).

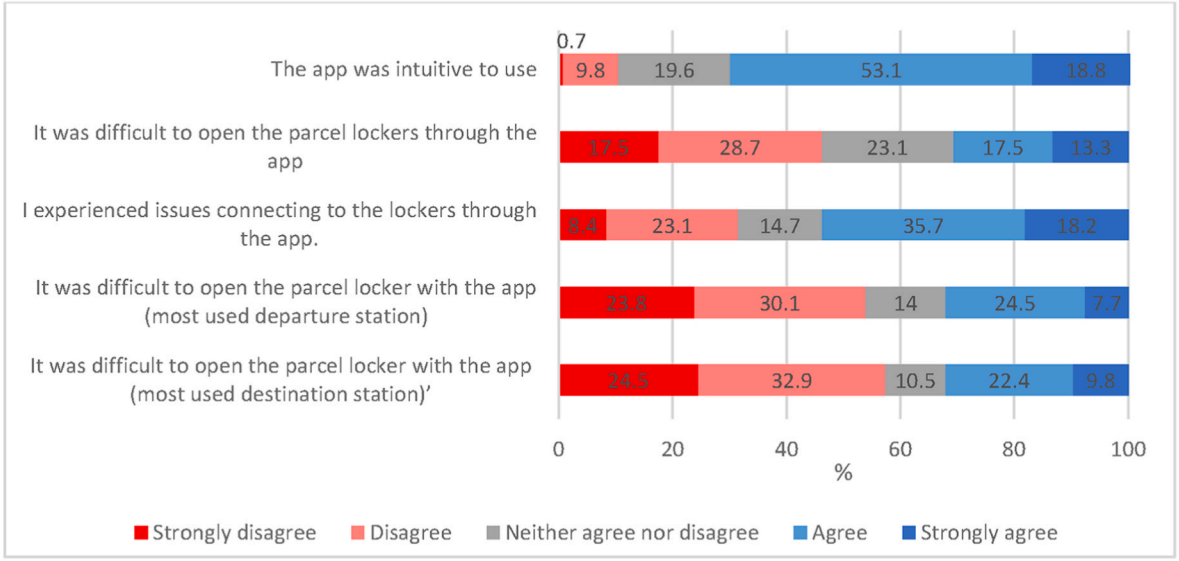

Fig. 6. App-related items (post-survey).

A relatively large proportion of participants experienced difficulties with the app, as for example expressed in the item 'I experienced issues connecting to the lockers through the app', which 36% agreed to and 18% strongly agreed to (see Fig. 6).

The connection issues were also frequently mentioned as the most negative aspect of participation, where it became evident that pace of connecting had fluctuated heavily, with some participants spending 10 min trying to connect and, in some cases, giving up. For a majority of the participants, however, the interaction with the APLs seems to have run relatively smoothly most of the times, with 'only' 32% agreeing that they experienced difficulties connecting to the parcel locker at their given departure station's APL and equally 32% for their destination's APL. Further, as seen in the previous section, about 75% agreed that 'Participation was easy for me' and 86% agreed with 'My overall experience in the test was good'. All participants answering 'Strongly disagree' or 'Disagree' to the item 'My overall experience in the test was good' were subsequently asked to elaborate by text entry. 8 of 9 answers to this was due to connection issues between the app and APL. The remaining one of the 9 was due to APL placement.

5.2.2. APL placement

Together with the app/APL interaction, the placements of the APLs (see Fig. 3) were thought to be a central practical element in the determining how smoothly participation can integrate into existing public transport behaviour.

The APL placements were generally rated positively as seen in the item 'The placement of the parcel locker was good' (departure station $M = 4.06$, $SD = 0.98$; destination station $M = 3.64$, $SD = 1.22$). It is worth noting that even though the same APLs served as both departure/destination, participants seem to have experienced more difficulties with the placement of destination APL than departure APL, which was also seen in the item 'I had a hard time finding the parcel locker at the station/stop' (departure station $M = 1.68$, $SD = 0.88$; destination station $M = 2.15$, $SD = 1.12$). For both items, the same APL placements were evaluated differently as respectively departure and destination. APL satisfaction with departure APL was slightly positively correlated to acceptance, $r(141) = 0.212$, $p = .011$, whereas no significant correlation was found for destination APL $r(141) = 0.148$, $p = .077$. Potential explanations for these differences are discussed in Section 6.

One station stood out, in terms of negative ratings. The APL at the station Østerport was placed at an alternative entry-point located at a bicycle-parking area, far (around 200 m) from the main entrance to the station. Comments also elaborated that this parcel locker had been hard to find for many participants which had led to frustrations (with one participant even spending 40 min searching for it and others eventually giving up). The APL localization mean scale had a mean score of 4.03 for all stations. Østerport scored just 1.65. For negative evaluations of APL placement, an elaboration was requested on where placement should have been instead. All placement suggestions for Østerport were for the main entrance.

The outlying example of Østerport illustrates a tendency found for throughout the list of stations; looking at the opposite end of the spectrum, the highest rated stations had APL placements that were in the immediate vicinity of the direct access point to the mode of transport or – in the cases of stations with entrance points as opposed to e.g. free-standing bus stops – in the immediate vicinity to where all passengers pass by on their way to the access point. For larger stations with multiple entry-points and/or modes of transport it was not possible to cater for all passengers, as only one APL was placed per station/stop.

In sum, APL-placements were generally well rated by participants, with main parameters of success being vicinity to boarding point and/or station entrance point. The placement's quality is related to acceptance and in facilitating participation, but seems to be more critical for picking up parcels than handing them in.

5.3. Pre/post survey results

Although the great majority (82%) of participants agreed that participation in the test increased their motivation to participate in the realized concept, the post ratings of intention, concept attitude, SVS, PBC and two barriers are more negative than the ratings before participation, as paired *t*-test results show (see Table 4).

5.4. Predictors of post-survey intention, acceptance and behaviour

As the study was based on a practical test, we aimed to supplement intention as a measure for future participation propensity, due to its questioned compatibility and adequacy as measure for the degree to which interaction with the concept serves to (de)incentivize future adoption. The purpose of this was to get a measure for the importance of various elements of the practical interaction with the concept, which was "closer to the action" and thus more isolated from influences not directly related to the concrete experience. In other words, a better measure for what concretely worked in the tested service and what did not, from both a conceptual and practical perspective. In this light, it is also relevant to look at pre-survey intention as a predictor for the post-survey measure of intention, and also for behaviour during the field test.

We conducted three multiple regressions: one with post-survey intention, one with acceptance and one with behaviour (the number of trips taken with a parcel) as dependent variables (see Table 5). All models were estimated on the same data.

The pre-survey intention and post-survey results for PBC and SVS were found to have a significant effect on post-survey intention. PBC and SVS were also found to be significantly related to acceptance. By contrast, no significant effect of pre-survey intention was seen on acceptance. Instead, difficulties with the app were significantly related to acceptance. Pre-survey intention also had a significant effect on behaviour during the experiment, measured as number of trips taken with a parcel during the experiment. Additional significant predictors of trips with a parcel were ease of finding the lockers, pre-survey satisfaction with travel, the amount of trips taken with public transport during the experiment period, and whether participant's most used pickup point during the experiment was their outbound departure station (as indicated by the participant in the pre-survey).

6. Discussion and conclusions

Following our aim to provide insights from a practical test of a public transport based crowdshipping concept as an improved basis to evaluate adoption potential as well as practical and conceptual contingencies for crowdshipping solutions, the following section synthesizes and discusses three main findings before discussing the limitations of the study.

First, we confirm the practical viability of a public transport based crowdshipping concept from a user perspective, and thus substantiate the potential indicated by prior survey-based research on the concept (Gatta et al., 2018; Fessler et al., 2023a; Fessler et al., 2022). Specifically, we found that the vast majority, 82% of participants, stated that they, because of test participation, were more motivated to participate in the concept if it should be realized. As such, the results of the test substantiate the potential of realizing a crowdshipping concept from the user perspective, with respectively 47% and 68% of participants who after experiencing the concept would often or always bring a parcel on their most used outbound and return trips. This preference for return trips aligns with previous research, which has shown how predictability affects stress levels of mass transit morning commuters (Evans et al., 2002). Implications of this preference are presented in Section 7. As such, this study provides an important proof of concept for a delivery system that has previously only been explored hypothetically.

Second, we add empirical support and elaborate assumptions regarding the practicalities of participation; ease of interacting with APLs is significantly positively related to acceptance as was seen in the

Table 4
Paired samples t-tests.

Paired samples *t*-test	Mean		*SD*		Diff. Mean	*t*	*df*	*p*
	Pre	Post	Pre	Post				
PBC	2.00	2.16	0.64	0.58	−0.16	−2.78	143	.006
Concept Attitude	2.02	2.19	0.62	0.62	−0.18	−3.39	143	<.001
SVS	3.81	3.58	0.53	0.59	0.23	6.50	143	<.001
Losing/damaging parcel	2.66	2.99	0.92	0.85	−0.33	−4.65	143	<.001
System flaw	3.17	3.23	0.83	0.79	−0.06	−1.01	143	.313
Dangerous Illegal goods	2.82	3.14	1.01	1.11	−0.32	−4.30	143	<.001
Intention	3.72	3.35	0.63	0.64	0.37	6.12	143	<.001

Table 5
Linear regression results.

Independent variables	Intention (post)	Acceptance	Trips w. parcel
	β	β	β
PBC (post)	−.35***	−.37***	−.13
Concept attitude (post)	.08	.11	−.07
SVS (post)	.22*	.19*	.02
Losing/damaging parcel (post)	.18	.05	.18
System flaw (post)	−.19	.12	−.15
Dangerous illegal goods (post)	.02	.02	−.02
App difficulties	.09	−.28***	−.03
APL localization	.03	.06	.14*
Intention (pre)	.29***	−.05	.19**
STS (pre)	−.17	.13	−.38***
PT during experiment	−.13	.03	.37***
Pickup on outbound station	.11	.08	.14*
Model summary			
R^2	.313	.408	.441
Adjusted R^2	.249	.353	.389
n (sample size)	143	143	143

*$p < .05$, **$p < .01$, ***$p < .001$.
Note: All VIF values were below 3 across all models.
[4] We tested for differences in public transport mode (bus, metro, S-train, train), which were all possible to use during the test. We found no significant differences in intention or acceptance when including in the linear regression.

regression analysis. Prior research had highlighted the importance of convenient APL placement (Gatta et al., 2018; Iannaccone et al., 2021). This was also confirmed; APLs should be placed in the immediate vicinity of where passengers naturally pass by. It should be noted though, that Danish stations are – in contrast to e.g. Gatta et al.'s Italian setting – not secluded by ticketing facilities. This blurs the inside/outside station distinction, which their results were based upon. Departure APL placement's higher and significant correlation with acceptance compared to destination APL, could be caused by a (perceived) higher importance of accessing the APL at the departure station swiftly, in order to catch the next train/bus, whereas this pressure might be less present when the trip has been completed, in line with both the prior mentioned research on the negative effects of unpredictability as well the negative effects of increased travel time (Wener et al., 2003). Thus, the found relations between APL placement and acceptance as well as PBC illustrate the importance of providing a solution that interacts smoothly with participants' transport habits.

Third, our approach and results highlighted the relevance of contextualizing and supplementing intention. For a range of constructs, intention, PBC, SVS, concept attitude, forgetting/damaging parcel and dangerous/illegal goods the post survey showed less favourable results than the pre-survey. However, 82% of participants explicitly stated to have become more motivated to participate in a realized concept through their test participation. The differences may therefore simply reflect more reliable – yet still highly supportive – results that are less prone to behavioural equivalents to 'hypothetical bias' where discrepancies are found between intentions and action. Within studies applying a TPB framework, it has previously been shown that people overestimate the likelihood that they will engage in a socially desirable behaviour (Ajzen et al., 2004). In the context of this study, by trying out the service in practice, participants would to a higher degree bring the many situational constraints into consideration for their post-evaluations of intention to participate in a realized concept. This resonates with numerous studies (e.g. Dunning, 2007), which show that individuals' prediction about their future behaviour is often too optimistic. Koehler and Poon (2006) argue that people in the assessment of likelihood of carrying out a behaviour in the future extrapolate and consequently overestimate from their current intentions, while at the same time underestimating external, situational, or contextual factors that may be of hindrance for these translating into action. Our results thus support the findings of Poon et al. (2014), which show that situational constraints are underrated in self-predictions and how 'optimistic bias' increases with intention strength. It is seen in the regression results that participants are able to abstract from the technical difficulties of the pilot setup when evaluating their propensity to take part of a realized concept, with app difficulties being significantly negatively related to acceptance, but not on post-survey intention.

Although the present study's results substantiate the argument of intention's overestimation, they at the same time show support for intention as a valid measure for predicting behaviour, with pre-survey measures having a significant effect on both post-survey results for intention and behaviour during the trial.

6.1. Limitations

The contributions outlined in the discussion should be seen in light of the following limitations.

First, the fact that the experiment was undertaken during COVID-19 in general, and in particular after the national lockdown was announced halfway into the originally scheduled experiment period, is not without consequences for the results and their interpretation. Most notably, there were fewer people able to participate, because of being sent home from work, as the non-participant post-survey results showed. Gathering public attention about the possibility to participate, was a gradual process that was only just starting to pick up at the time of lockdown. But for those still travelling by public transport, the unprecedented circumstances will have had more unpredictable effects on their participation and experience. In fact, research on changing circumstances indicates that participants might actually be more prone to (remember to) participate as a result of disrupted habitual behaviour, which leaves more room for intentionally induced action (Wood et al., 2005). On the other hand, having to cope with the circumstances – and perhaps nervousness (e.g. Przybylowski et al., 2021) – of travelling by public transport during the pandemic might have had an opposite effect. In the context of travel behaviour, it has been shown how divergence from habitual responses is difficult under conditions of cognitive load (Aarts and Dijksterhuis, 2000).

Additionally, the test setup itself is worth noting. The empty test parcels were of small size and weight. On the one hand, they were thus less of a burden to bring along. On the other hand, this might have left participants more prone to forget to hand in the parcel, and thus causing nuisance if for example needing to return to the station to do so (the trip

would not be registered in the app if the destination APL was not opened and closed again using the app). Also, some participants expressed in text entry fields, that the fact that parcels were empty, served as a demotivator to participation, as bringing them could feel pointless. However, we argue that the inclusion of two motivational measures – acceptance and intention – allows us to meet many potentially related validity-issues, as participants were found to be able to distinguish between aspects related to their test-participation (captured by the former) and the propensity to participate in a realized concept (captured by the latter).

Further, the concept attitude factor is also worth noting in relation to the test setup. The factor includes assessments of the perceived fairness of participant compensation in comparison to the imagined gains of the crowdshipping company and whether participants would feel taken advantage of as a cheap form of labour. It seems reasonable to assume that a realized concept operating on market terms would face scepticism in this regard, in comparison to a concept that was promoted as a research project in a joint effort between a university and a company.

As the social dimension was shown to be relevant to consider, future research could advantageously explore interaction effects, where peers' mutual influence could be analysed in more detail (e.g. Gatta et al., 2020).

Lastly, the rather elaborate test setup, an official information website, the relatively thoroughly developed app and user interface as well as the many placed parcel lockers on very commercially attractive public locations might also actually affect some evaluations negatively, as this might cause some participants to evaluate the concept on the premises of a solution closer to being realized than was actually the case for the setup, which rather mimicked the service. For example, some participants mentioned that the registration of users was not thorough enough to prevent theft, which would obviously be necessary in a realized concept. Likewise, it is difficult to estimate to which degree participants who experienced technical issues were able to abstract the test solution from the conceptual idea, in the questions in which such a distinction was relevant. Again, most seem to have been able to make this distinction, as 'app difficulties' was shown to significantly affect acceptance, but not intention (to participate in a realized concept).

6.2. Practical implications

The aim of present study was to provide insights from a practical test of a public transport based crowdshipping concept, in order to further academic and practical work on implementing new mobility- and sharing economic solutions, directly or indirectly related to the proposed concept.

Overall, the experience with the service was rated positively with a high degree of acceptance. Although participation was easy for a majority of participants and the developed app was generally viewed as intuitive to use, a relatively large proportion experienced connection issues with the APLs, which had a negative influence on acceptance as a result of participating. Despite this, participants seem to have been able to abstract from the test experience in their intention for future participation.

The APL placements – the majority placed on the station grounds – were generally rated positively. Here, the main parameter of success was vicinity to boarding point and/or station entrance point. Participants had a harder time finding the APLs when handing in a parcel than when picking up. This may be due to the APLs being placed at street level, or in general being placed to face participants when entering stations, rather than leaving them. This would most likely be solved by more developed localization features, but must nonetheless be considered for future placements. The placement's quality is related to acceptance and in facilitating participation, but seems to be more critical for picking up parcels than handing them in, which indicates that a smooth process for parcel pick-up is more critical to participants than for hand-in. This might be due to stress of making the next train, whereas an added few minutes for e.g. locating the APL is not as critical when having made the trip.

Participants were more willing to bring a parcel on their return trip than outbound, in post-survey results for intention. This could potentially pose a challenge, as a solution would optimally make use of outskirt commuters on their way to work or school in central districts of the city.

Such issues of added unpredictability would be further pronounced for the relatively high number of participants who experienced such connection issues, which was also elaborated upon by many in the various text entry fields, as being the most negative aspect of participation and a reason for hesitation towards bringing a parcel in some instances. Text entry elaborations indicated that this is especially in cases with time constraints, such as going to work or transfers to other public transport. This highlights the need to ensure that a public transport based crowdshipping concept integrates smoothly to the travel routines of passengers, without fear of being delayed by e.g. connection issues to the lockers or not being able to find the APL. For a realized concept, more thorough app-development and troubleshooting should be completed to mitigate such issues, which was not possible with the relatively limited time and resources for app-development for the experiment. To facilitate APL localization, GPS-functionality should be included. However, regression results showed that participants who most often brought parcels on their outbound trips brought significantly more parcels during the experiment, which indicates that the outbound trips may be easier to build into existing routines.

Additionally, with a significant effect of satisfaction with travel scale on behaviour during the trial, regression results highlighted the importance of a well-functioning public transport system as a prerequisite for implementing a crowdshipping service. Again, this may be due to the need for predictability and a certain mental surplus in the relevant situational travel context in order for the user to actually undertake the behaviour which he/she had the intention to perform.

Together these insights provide a basis for further work towards a realized concept, as the practical viability has now been confirmed from a user perspective.

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Author contributions

Andreas Fessler: Conceptualization, Methodology, Formal Analysis, Data Curation, Writing – Original Draft, Funding acquisition **Philip Cash:** Conceptualization, Writing – Review & Editing **Mikkel Thorhauge:** Review & Editing **Sonja Haustein:** Supervision, Conceptualization, Methodology, Writing – Review & Editing, Funding acquisition.

Declaration of competing interest

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Data availability

The authors do not have permission to share data.

Appendix A

In the pre-survey, the crowdshipping concept was first mentioned and described to respondents after completion of more general questions

regarding public transport use. Respondents will however have been aware of the main idea of the concept before, as a general description was necessary for recruitment. Included below, is the description of the concept provided to survey-respondents after the introductory questions. The recruitment material's description of the concept was also drawn from this:

This research project explores the possibilities for passengers with public transport to receive credit for their travel expenses by bringing small parcels from approved senders (e.g. web shops). The idea is to reduce the number of vans going to the central city districts to deliver parcels, as the current method has a negative impact on congestion, urban life and the environment. With an increasing number of parcel deliveries, there is potential for large reductions in CO2 emissions. Therefore, parcel lockers are set up at public transport stops. As a passenger, you can reserve parcels (with an app) that match your start and end stations. With the app you can then open the locker at your departure station, take the parcel and deliver it in a locker at your matching end- or transit station. Thus, the process of collection and delivery is similar to checking in and out with the 'Rejsekort'. This takes a total of approx. 30 s. The locker automatically connects to the phone's Bluetooth. You simply press 'Open Door' in the app. After hand in, a credit amount is received as a 'Thank You'. From here, the customer who ordered delivery for this locker can pick up his/her parcel.

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