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Analysing the influence of station location, characteristics and perceived safety on public transport ridership: A case study from Copenhagen

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Abstract Perceptions of safety and security within the public transport system is regarded of high importance among passengers according to multiple passenger satisfaction surveys. However, among the many studies analysing the determinants of public transport mode choice and ridership less focus has been on the influence of safety and security perceptions on travellers' desire to choose public transport. This study contributes to existing literature by specifically investigating the influence of perceived safety on public transport mode choice using a large-scale travel survey from the multimodal Greater Copenhagen Area. This makes it possible to analyse safety and security at stations while still taking into account other main determinants of public transport usage, e.g. socio-economic characteristics of the travellers and characteristics related to the public transport system. Specifically, the study also includes walking distances to various public transport stops, e.g. metro, suburban, and regional train stations, and bus stops, hence taking into account possible differences in attitudes towards different public transport modes. The results confirm the hypothesis of higher perceived safety at stations being positively associated with public transport mode choice, however at a smaller magnitude than that of the service characteristics in terms of service frequency. The study also revealed that travellers' perceived high-class public transport modes such as metro and suburban rail services as more attractive, as compared to local rail and bus services. Hence, vicinity to such stations was associated with higher likelihood of choosing public transport, thus highlighting the importance of close vicinity to high-class services being most important for attracting passengers to public transport while perceived safety being of minor, yet significant, importance.

Keywords: Ridership · Perceived safety · Travel survey · Mode choice

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1. Introduction

Perceptions of personal safety and security have been highlighted to be of major importance for passengers in the public transport system. Results from a UK study suggested that 10% would reconsider using public transport if their fears were addressed (Crime Concern, 2004), and in Denmark, only 77% of passengers reported to be satisfied with safety in the public transport system according to a recent satisfaction survey (Passagerpulsen, 2017). Furthermore, perceived safety and security has been reported as an essential parameter across multiple other passenger satisfaction studies (Fellesson and Friman, 2012; Iseki and Taylor, 2010; Spears et al., 2013; Stuart et al., 2000), together with the traditional service level elements, e.g. service coverage, frequency, and travel speed (Mouwen, 2015; van Lierop et al., 2017).

While no direct correlation between reported crime levels and fear of crime has been identified a potential fear might influence travellers' choice of using public transport. Despite this, only few studies have explicitly analysed the influence of perceived safety on travel behaviour in general and on public transport ridership in particular. Kim et al. (2007) analysed factors influencing mode choice between home and light rail stations, i.e. access/egress trip legs, and found that crime had a significant impact on mode choice as female transit riders were more likely to be dropped off and picked up at the station instead of walking. In Börjesson (2012) the influence of perceived safety on the valuation of walking time was analysed. This study found that walking in closed environments were associated with higher disutility for both women and men during night hours suggesting an effect of perceived safety. Only Delbosc and Currie (2012) have analysed explicitly the influence of safety perceptions on public transport usage finding a significant impact on public transport use frequency, which was only slightly smaller than the negative effect of car ownership. This finding was consistent across gender and age groups suggesting the importance of perceived safety across most user groups of public transport. However, the main limitation of this study was the use of a small convenience sample of 535 respondents, which were not representative of the general population (Delbosc and Currie, 2012).

These studies suggest the influence of perceived safety as a contributing determinant of travel behaviour, but they do have shortcomings in terms of analysing its significance on actual public transport ridership. This study fills the gap in research by analysing on a larger scale the influence of perceived safety on mode choice of public transport in the Greater Copenhagen area. The contribution is three-fold.

- *Firstly*, the study deploys a large-scale dataset based on the Danish national travel survey (Christiansen, 2015). This ensures a large representative sample of the general population as approximately 10,000 responses are collected every year. The survey data holds a vast amount of information about the respondents, including important socio-economic background information. This allows for controlling for important trip and traveller characteristics, which previous research has highlighted as important determinants of ridership (Taylor and Fink, 2013). This also makes it possible analyse the influence of vicinity to public transport stops served by different public transport modes with varying attractiveness.
- *Secondly*, the study analyses the actual influence of perceived safety at the station-level for each trip performed by travellers. This allows for estimating the effect on mode choice, thereby determining the actual effect on ridership in the public transport system. Furthermore, important characteristics influencing the perceived safety level, e.g. station characteristics in terms of availability of shops, and the time-of-travel, can be included as these characteristics might also influence the perceived safety level.

The remainder of the paper is structured as follows. Section 2 reviews the literature on the determinants of public transport ridership. In section 3 the study area is briefly presented whereas the data sources used for the model estimations are described in section 4. The results are presented in Section 4 while section 5 concludes the work by discussing results and implications.

2. Determinants of public transport ridership

Many previous studies have investigated the factors affecting public transport ridership focusing on the influences of land uses, the built environment and characteristics related to the public transport system and the travellers, see a review in Ingvardson & Nielsen (2018, in press). Most of the studies range from analysing station-level ridership over line- or corridor-level ridership to full network ridership, with only few studies analysing individual mode choice, and even fewer considering perceived safety. In this section focus is on recent studies involving perceived safety as well as traditional socio-economic, land use and service quality variables. Hence, highlighting the important characteristics to be included in the subsequent analyses.

2.1 Safety and security

The importance of safety and security has been analysed thoroughly with regards to the influence on travel satisfaction in the public transport system, e.g. van Lierop et al. (2017). However, only limited research has focused on the influence on actual public transport usage despite it being highly relevant as fear of crime can restrain travellers from using public transport (Abdul Hamid et al., 2015). Specifically, Badiora and Okunola (2015) suggested that fear of crime is a stronger influential factor against public transport usage than actual crime levels. And, according to a British study ridership increases were suggested to be up to 10% when travellers feel safe at stations (Cozens and Van Der Linde, 2015). Hence, proper transport planning should ensure safe, secure and comfortable public transport environments (Ceccato, 2014; Cozens and Van Der Linde, 2015).

Results from several of the studies relating perceived safety and travel behaviour agree that the perception of personal security is more important for female passengers than men (Fan et al., 2016; Kim et al., 2007). Therefore, particular attention must be paid to the needs and desires of the women in both design and management of stations (Şimşekoğlu et al., 2015; Van Lierop and El-Geneidy, 2016). Specifically, stations should have proper route and schedule information (Iseki and Taylor, 2010), as well as good lighting, vigilant guards and a clear as the layout of stations can positively influence passengers' safety perceptions (Abdul Hamid et al., 2015). Finally, Masoumi et al. (2016) reviewed the literature finding that the use of modern technology, e.g. surveillance cameras, increased the perception of safety.

2.2 Socio-economic characteristics

Much research has analysed the influence of various socio-economic characteristics on public transport ridership. Several studies found that females generally use public transport more often than men (Beirão and Sarsfield Cabral, 2007; Limtanakool et al., 2006). In Netherlands, this was suggested to be because of public transport being less stressful than driving a car. And in Smith (2008), it was suggested that women, and children, need to feel safe

and secure at stations to use it more extensively. However, among residents in Calgary, Canada, it was found that men use public transport more than women and children (Pasha et al., 2016).

Similarly, inconsistent results regarding the influence of age on public transport usage has been identified in the literature. In Sweden and Denver, Colorado, it was found that seniors make fewer and shorter trips (Boschmann and Brady, 2013; Heikkinen and Henriksson, 2013). In Hjorthol (2013) this is suggested to be because seniors face more difficulties travelling by public transport than if walking or driving. On the other hand, Limtanakool et al. (2006) found that people start using public transport more for medium and long-distance trips as they get older in the United States.

Many studies found a negative income effect suggesting lower ridership among higher-income travellers. Some studies even found income to be the most influential factor (Chakraborty and Mishra, 2013; Levinson and Zhu, 2013). This can be attributed to a positive correlation between higher-income people and car ownership rates, which results in lower public transport usage (Paulley et al., 2006). Specifically, car ownership has been reported as significantly negatively correlated with public transport usage, potentially with larger impacts than the characteristics of the public transport system itself (Taylor and Fink, 2013). Similarly, lower income and unemployment rate are positively correlated with transit ridership (Barton and Gibbons, 2017; Pasha et al., 2016). However, inconsistent findings from unemployment has been reported by other studies where positive effects on ridership can be observed, e.g. due to the financial crisis in Spain resulting in increased bus usage (Cordera et al., 2015), whereas negative effects on ridership were seen in several other studies, possibly due to reduced travel frequency. On the other hand, ownership and use of bicycles has been found to be positively related to public transport usage, possibly because bicycles can be used in conjunction with public transport, e.g. as feeder mode to rail stations. Hence, Chen and Zhao (2013) suggests adding more bicycle parking spaces at transit stations, thus enabling travellers to use bicycles for their last mile of travel.

2.3 Land use and built environment

Ridership and proximity to transit stations are significantly positively correlated (Chen and Zhao, 2013; Liu et al., 2016). Hence, high population and employment densities around transit stations ensure a larger share of travellers in close proximity to stations thus resulting in greater use of public transport (Chakraborty and Mishra, 2013; Gutiérrez et al., 2011). Specifically, Ewing and Cervero (2010) suggested an 2.66% increase in ridership if population density increased 10% around transit stations, hence highlighting the importance of dense urban areas in connection with public transport. Other studies reported significant positive influence from more parking around stations as well as mixed land use areas (Pasha et al., 2016).

2.4 Service quality

Many studies have investigated the effects of various service quality elements and characteristics of the public transport system on ridership. Studies agree on the importance of providing fast, reliable and highly accessible public transport to ensure high ridership (de Oña et al., 2013; Guirao et al., 2016). Hence, the most important determinants are related to the experienced service quality. Many indicators for this have been used in previous studies on ridership determinants, including the service frequency (e.g. (Chiou et al., 2015; Taylor et al., 2009)) and number of lines serving the station (e.g. (Derrible and Kennedy, 2009; Jun et al., 2015; Zhao et al., 2013)).

However, many studies have also highlighted the availability of various service and station characteristics to be positively related to ridership (Guo and Wilson, 2011). This included provision of real time information at bus stops (Dziekan and Kottenhoff, 2007), integrated ticketing (Crampton, 2002; Currie et al., 2011), availability of bicycle amenities (Blainey and Mulley, 2013; Zhao et al., 2013), and park-and-ride facilities for car users (Cervero et al., 2010; Guerra et al., 2012; Kuby et al., 2004). In terms of station amenities, it has also been suggested that the presence of medical, financial, shopping and food services (shops) will increase ridership while education and recreation related services will decrease transit ridership (Hong et al., 2017). And in Dyrberg and Christensen (2015), it was concluded that the route choice of passengers were negatively affected by easy station layouts and availability of shelters and shops at stations, hence suggesting the importance of station amenities and simple layouts to attract passengers. Thus, these findings suggest that many characteristics influence whether travellers choose public transport or not.

3. Data and measures

3.1 Travel survey data

This study mainly deployed data from the Danish National Travel survey (TU) collected from the Greater Copenhagen area (Christiansen, 2015). The data is a travel diary covering all trips performed by the respondent during the interview-day. As 10-12,000 respondents are interviewed every year the dataset used for this study covering the Greater Copenhagen area in the period 2009-2017 included a total of 81,804 trip legs.

This data also holds a vast amount of background information about the respondents including socio-economic characteristics (e.g. gender, age, household and respondents' income, education level, job type) and travel related characteristics (e.g. car availability, driver's license, bicycle ownership, public transport season ticket, distance to nearest station). The detailed information makes it possible to include many relevant parameters in the model estimation, thereby allowing controlling for the relevant determinants of mode choice as identified in the literature review in section 2.

3.2 Station characteristics

The dataset was linked to characteristics related to every station in the study area. This included the characteristics related to the perceived safety level experienced by passengers. The main variable was the result of a passenger survey, which ranked the perceived safety at each station using a 10-point scale. The state railway company, DSB, performed the survey every year in the period 2009-2015 for all stations except metro stations, and the average number of respondents per station was 100-300 for the years included in this study.

For all stations several other characteristics were collected. This included the availability of shops, which might be related to the perceived safety as stations might be perceived as more attractive when shops are available. Also, the availability of shelters, i.e. small or large, and whether the station is located underground was collected. Finally, the ease of wayfinding at the station was included as this might have an effect on whether passengers perceive stations as attractive. These data were collected from Dyrberg and Christensen (2015).

3.3 Service quality

The perceived attractiveness of each station was considered by incorporating the actual service frequency. This was taken from public transport timetables in terms of number of departures per hour, which then was linked to the travel survey data. This variable was included for the nearest station when performing the trip, both at origin and destination. To also take into account possible differences in perceptions of different public transport modes, spatial analyses were performed to analyse the distance from the origin and destination of a trip to nearest public transport stops of all modes. This included all relevant rail lines, i.e. metro, suburban rail, regional/long-distance rail and local rail as well as bus lines, which were categorised based on service frequency. The bus network in Copenhagen incorporates S-bus lines (high-frequency and fast buses with longer stop spacings), A-bus lines (high-frequency buses with shorter stop spacings), and regular buses. Hence, bus stops were categorised in terms of whether they were serviced by high-class bus lines (S- and A-buses) or regular bus lines (all other buses). By calculating the distance to nearest rail stations, high-class bus stops and regular bus stops, it allowed for incorporating detailed public transport characteristics in the subsequent model estimations.

3.4 Sample statistics

The full travel survey dataset included 81,804 trips performed by 26.936 respondents in the Greater Copenhagen area during 2009-2017. This area covers the commuting area of the city of Copenhagen which holds a population of approximately 1.2 million.

For the subsequent analyses two important assumptions were made. First, station characteristics were linked to the station located nearest to the origin of the trip, but it was required that the station was located within 2,000 meters from the trip origin. This was chosen due to the assumption of station characteristics not being important if the station is located far from the trip origin. Second, short trips with trip distances below 2,000 meters were excluded from the dataset. This was chosen to better analyse the importance of public transport service characteristics on mode choice. For very short trips the walking mode share is relatively high, and public transport is very rarely an attractive choice due to long access and egress time. These two assumptions resulted in a full dataset of 38,705 trips performed by 16,393 respondents.

The resulting summary statistics are shown in Table 1. From this it can be seen that the survey characteristics correspond well to the general population of the Greater Copenhagen area, which is not surprising as the survey is collected as a representative sample. However, there are discrepancies, especially due to the two restrictions put on the data.

The mode share of public transport for trips above 2,000 meters in the Greater Copenhagen area is around 19%, with larger shares in the inner city areas where the public transport network is more dense and frequent. It can also be seen that bicycling constitute a relatively large mode share of almost 20% of all trips in the region, and 15% of non-short trips. This is mainly due to its even larger share of around 1/3 of trips in the city of Copenhagen (Christiansen, 2015). The relatively large share of walking trips can be seen to be specifically for very short trips.

Table 1 Summary statistics for the dataset of trips from the Danish national travel survey (official figures from the study area based on Statistics Denmark in parenthesis)

Variable	Categories [%]				
Gender	Male	Female			
	50.8 (*49.3*)	49.2 (*50.1*)			
Age	0-15	16-25	26-45	46-67	> 67
	5.9 (*16.6*)	15.4 (*12.4*)	35.7 (*26.5*)	34.2 (*31.3*)	8.8 (*13.3*)
Car ownership	Yes	No			
	77.3 (*54.0*)	22.7 (*46.0*)			
Employment status	Employed	Student	Retired	Unemployed	Other
	57.3 (*58.8*)	8.7 (*16.3*)	12.5 (-)	2.9 (*2.5*)	18.5 (*22.4*)
Education level	High-School	Tertiary	Bachelor	Graduate	Other
	11.6 (*10.8*)	23.5 (*31.7*)	26.3 (*17.2*)	18.3 (*13.4*)	20.4 (*26.9*)
Annual household	0-250	250-500	500-750	750-1,000	> 1,000
income (1,000 DKK)	20.4 (*28.7*)	29.6 (*34.1*)	29.4 (*15.4*)	13.2 (*10.4*)	7.4 (*11.5*)
Trip distance	2-5 km	5-10 km	10-20 km	20-30 km	> 30 km
	36.8	26.1	21.4	9.1	6.6
Mode choice (all)	Public transport	Car	Bike	Walk	Other
	9.6	49.0	19.7	19.6	2.1
Mode choice (>2km)	Public transport	Car	Bike	Walk	Other
	18.7	61.3	15.3	2.2	2.6
Perceived safety at nearest station (0-10)	< 6	6-7	7-8	8-9	9-10
	0.6	11.4	72.0	16.1	0.0

It has been hypothesised in previous US studies that perceived safety (and crime levels) are related to average household income in a given area (Iseki and Taylor, 2010; Kim et al., 2007; Loukaitou-Sideris, 2014). However, other studies argue that the actual crime level is not an adequate indicator for perceived safety and security (Badiora and Okunola, 2015). For the Copenhagen data no clear relationship could be found between the perceived safety at stations and the average income of households in the station vicinity area of that given station, cf. Figure 1. Hence, this suggests that stations located in low-income areas do not generally have problems related to the perceived safety. However, this could be due to a relatively higher perceived safety level in Denmark (and possibly other Scandinavian or North European countries) than in the US, where crime is a bigger issue.

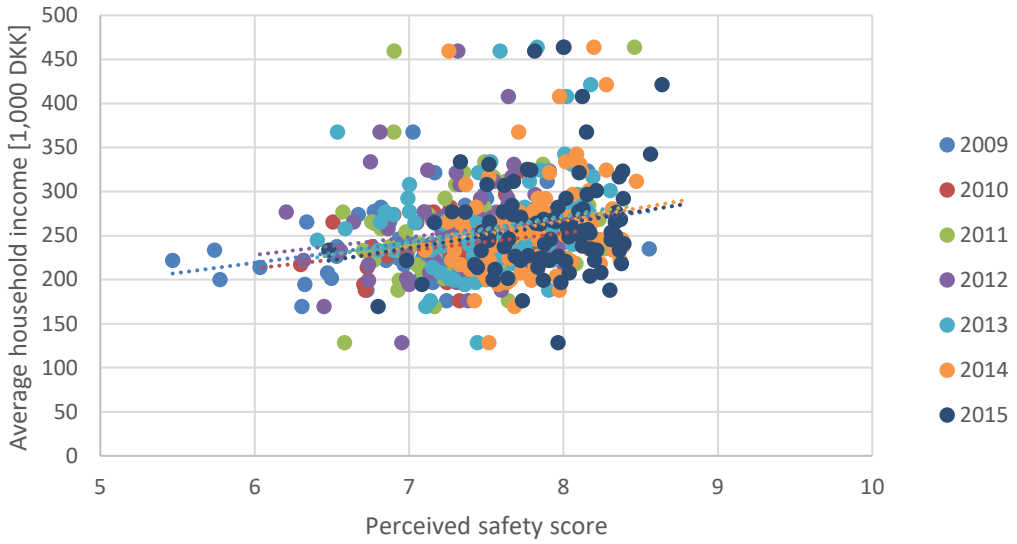

Figure 1 Relationship between perceived safety at stations and the average income of households in the vicinity area of stations (data for different years plotted separately)

4. Analyses and results

For the analysis of the determinants of public transport ridership, and specifically the influence of station vicinity and station characteristics, this study deployed logistic regression on the data using the SAS/STAT software, Version 9.4 (SAS Institute Inc., 2014). A binary choice variable was created for each trip denoting whether public transport was chosen or not. No distinction was made between different modes of public transport, e.g. bus, suburban train, regional train, metro, etc. Hence, the results show which variables relates to the choice of public transport in a mode choice context.

Due to not having perceived safety data for all combinations of stations and years in the dataset it was decided to run two sets of estimations. Hence, Model I included all observations, but did not include perceived safety, whereas Model II included 85% of the data, which had information on perceived safety. By this, it was possible to include all data for the estimation of the influence of background variables and vicinity to various public transport modes.

The results of the model estimations for the choice of public transport, cf. Table 1, confirms the hypothesis of a positive association between perceived safety and public transport ridership. Specifically, the results indicate that travellers are more likely to choose public transport if the nearest station is associated with a higher perception of safety and security, hence actually emphasising the importance of safe station environments. However, the effect is notably smaller than that of the service frequency, hence suggesting larger influence from service characteristics than station characteristics. More specifically, the service frequency at the nearest station (both at origin and destination of the trip) is positively associated with the likelihood of choosing public transport. The highest likelihood are for stations where service headway is below 5 minutes. This is mainly on metro stations and large

suburban train stations served by multiple lines. For service headways from 5 to 12 minutes positive effects are also seen with decreasing effect as headway increases. No effects were seen for larger headways. The use of threshold dummies provided better model fit than if using service frequency as continuous explanatory variable, hence suggesting a non-linear relationship between service frequency and likelihood of choosing public transport. Thus, improving service frequency at an already high frequency achieves a relatively larger increase in ridership than at lower service frequency, possibly due to passengers not needing to plan their trip when service frequency is sufficiently high.

In terms of socio-economic characteristics, the results revealed that males travel less frequently than females, which is accordance with most previous studies (Beirão and Sarsfield Cabral, 2007; Limtanakool et al., 2006). Young adults choose public transport more frequently, often due to being captive users, e.g. students. This could be seen directly in the dataset as these two variables were highly correlated. On the other hand, elderly travellers choose public transport less often, which might be related to this travel segment being less mobile, hence preferring to use a car, either as a car driver as passenger. Finally, low-income respondents travel less than middle-income respondents, while those with higher incomes travel less frequently. This is in accordance with most previous studies identified in the literature review.

There also seems to be a variation across respondents with different education levels. Those with a vocational or short secondary background use public transport least frequently, while university graduates with the longest education are more likely to choose public transport. This could be explained by workplace location differences as high-education jobs are more frequently located in downtown, which has good public transport coverage. Finally, those without education level choose public transport more often.

As expected, car ownership and the possession of a driver's license is negatively associated with choosing public transport, which is in line with much previous research. Similar results are seen for bicycle ownership, which suggests that also bicycling is a competitor to public transport rather than being complementary. Also, the likelihood of choosing public transport increases with trip length, i.e. the choice of public transport is higher for longer trips. This is likely due to public transport being more competitive on longer trips whereas access and egress times are substantial parts on shorter trips leading to low average travel times.

Closer proximity to train stations and bus stops also had an effect on the likelihood of choosing public transport, however the effects depend on the various modes of the Copenhagen public transport network. Figure 2 shows the parameter estimates graphically for the explanatory variables included in Model I. The largest effects are seen for trips with origin or destination within 200 meters of metro stations. This suggests that the metro has the largest effect in attracting passenger, even when controlling for the high service frequency. This could be related to the high reliability of the metro, but also that the metro is located in dense urban areas. Similarly, proximity to S-train stations is significantly related higher likelihood of choosing public transport, however at a slightly smaller magnitude. Almost similar results are seen for proximity to regional train stations. These are often served at lower service frequencies, but provide fast travel speeds from outside the Greater Copenhagen area to downtown locations. On the other hand, local train services seem to have limited effects, hence travellers do not perceive access to these station as attractive.

Table 2 Logistic regression results for the choice of public transport

	Model I		Model II	
Variable name	**Estimate**	**p-value**	**Estimate**	**p-value**
Intercept	-2.370	<.0001	-2.378	<.0001
Trip characteristics				
Perceived safety (orig.), low	-	-	-	-
Perceived safety (orig.), high	-	-	0.145	0.0206
Service headway (orig.), <5 min	0.588	<.0001	0.832	<.0001
Service headway (orig.), 5-5.9 min	0.350	<.0001	0.560	<.0001
Service headway (orig.), 6-9.9 min	0.331	<.0001	0.452	<.0001
Service headway (orig.), 10-11.9 min	0.299	<.0001	0.404	<.0001
Service headway (dest.), <5 min	0.610	<.0001	0.763	<.0001
Service headway (dest.), 5-5.9 min	0.340	<.0001	0.455	<.0001
Service headway (dest.), 6-9.9 min	0.344	<.0001	0.401	<.0001
Service headway (dest.), 10-11.9 min	0.291	<.0001	0.308	<.0001
Trip length (km)	0.052	<.0001	0.054	<.0001
Socio-economic characteristics				
Male	-0.248	<.0001	-0.244	<.0001
Age, 16-25	0.583	<.0001	0.619	<.0001
Age, > 67	-0.378	<.0001	-0.396	<.0001
Income, low (<100,000 DKK)	0.136	0.001	0.130	0.0033
Income, high (>500,000 DKK)	-0.508	<.0001	-0.555	<.0001
Education, high school	-0.422	<.0001	-0.431	<.0001
Education, vocational	-0.520	<.0001	-0.551	<.0001
Education, university short	-0.515	<.0001	-0.540	<.0001
Education, university medium	-0.328	<.0001	-0.364	<.0001
Education, university long	-0.321	<.0001	-0.288	<.0001
Bicycle ownership	-0.208	<.0001	-0.224	<.0001
Car ownership	-1.238	<.0001	-1.226	<.0001
Driver's licence	-0.968	<.0001	-0.911	<.0001
Public transport card	2.247	<.0001	2.225	<.0001
Number of observations	38,705		33,019	
Log Likelihood	-10,699		-9,299	
R^2 (McFadden)	0.470		0.465	

For bus stops served by higher-class bus services the results also revealed a significant, but small, effect. Hence, the results suggest that travellers are more likely to choose public transport if providing fast and frequent services, also when providing buses. However, it should be noted that this positive effect might be related to higher service frequency as this was not possible to include directly in the model in the same manner as for train stations.

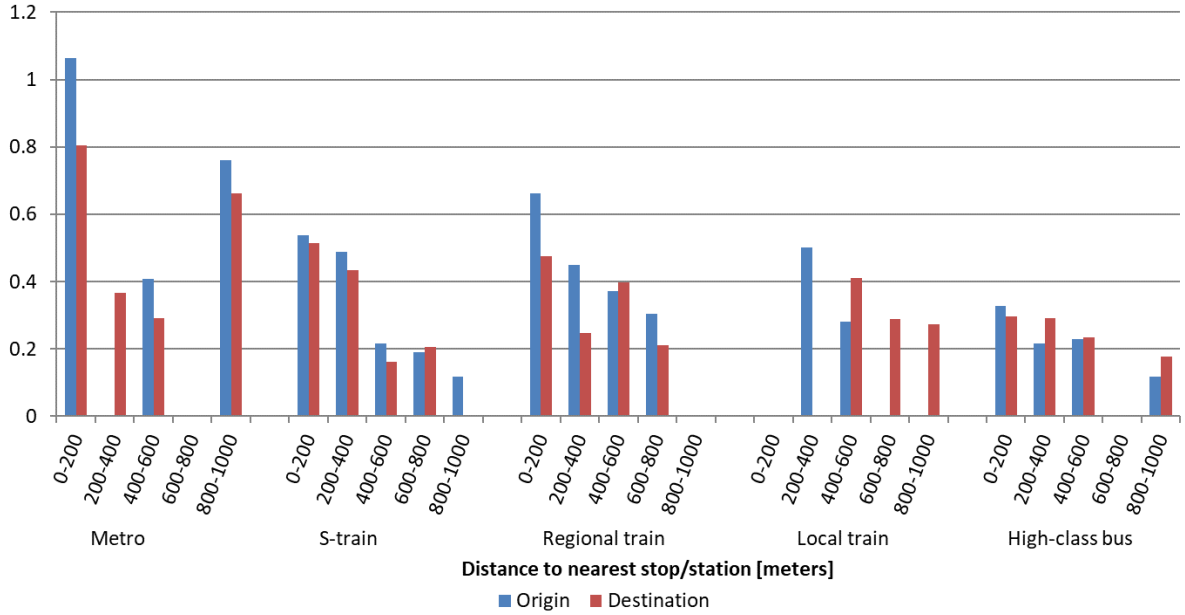

Figure 2 Parameter estimates for vicinity to various public transport stops and stations.

Finally, most of the characteristics related to the station layout and amenities did not significantly influence public transport mode choice. It was hypothesised that the availability of shops might entail more attractive stations, which then was more likely to be used by passengers. Both because travellers have the possibility to spend their time efficiently while waiting, and because such stations might be perceived more safe and secure. However, the results did not reveal any significant effects. Possible reasons for this result could also be that a possible effect is more dependent on detailed characteristics related to the shops, e.g. opening hours, number of customers, etc. rather than solely whether a shop is present or not.

4.1 Discussion and study limitations

While the current study provided new insights on the influence of perceived safety on public transport mode choice it did have important limitations which future studies should address. First, the service frequency of the public transport system were included only for the train station located closest to the origin and destination of each trip in the dataset, and the perceived safety level was only included for the station nearest to the origin of the travellers' trips. By this, the study implicitly assume that passengers will base their decision to use public transport on characteristics related to their nearest train station. While travellers in most cases will use the nearest station when travelling by train, this assumption might not be fully adequate as passengers can choose to use a bus stop, which might be nearer. For train stations the assumption is mostly suitable, except in the city centre where some

might prefer to use a slightly more distant metro station rather than an s-train station (or vice versa). Hence, efforts could be made to improve this aspect, e.g. by taking into account characteristics from multiple stations in vicinity to the origin and destination of each trip.

Second, the study did take into account service characteristics of the public transport system in terms of service frequency at the nearest train stations, which was significantly positively related to choosing public transport. However, no such measure was included for bus stops as this information was not available, mainly due to travel survey data spanning over a long time period of seven years during which bus services shift much more often than train services. Instead, walking distances to nearest two types of bus stops were included, namely those served by regular buses and those served by high-frequency buses. Future studies could incorporate more detailed service characteristics related to bus services as well as for train services.

Third, while the results revealed that passengers are more likely to choose public transport if the nearest station is associated with a high level of perceived safety and security, no opposite effects were observed for stations associated with low level of safety. This finding is not intuitive; however it might be explained by a relatively high general level of perceived safety and security in the Copenhagen area where no stations have notable problems with high crime rates and low perceived safety. Hence, future studies could analyse possible effects in a study area with larger variation in perceived safety levels, and in particular where some stations do have notably lower perceptions of safety and security.

5. Conclusions

The current study analysed the likelihood of choosing public transport using logistic regression and utilising a large-scale travel survey. Mainly, the results confirmed the hypothesis of perceived safety at stations being positively associated with choosing public transport. Specifically, high perceived safety was positively related to choosing public transport whereas no effects were observed for stations with low perceived safety, possibly due to few stations in the study area associated with low perceptions of safety. The effects of safety were smaller than those related to the service frequency, and no effects were observed from any of the station characteristics, e.g. availability of shops and station layout. Hence, the findings suggest larger influence from service characteristics rather than station characteristics.

Furthermore, the results did not show any significant correlations between perceived safety and average household income around stations. This suggests that perceived safety is more related to station characteristics and less influenced by the socio-economic characteristics of the neighbourhood. In the context of the study area this finding is important as improvements to station facilities to support a safe and secure environment for passengers are easier to implement than longer-term changes in socio-demographics. Hence, the findings highlight the importance of addressing perceived safety when planning public transport.

The study also revealed the influence of station vicinity as proximity to rail stations were associated with higher likelihood of choosing public transport, even when controlling for service frequency. The largest effects were observed for close proximity to metro stations, but S-train and regional train stations had almost similarly large influence, whereas proximity to high-class bus services were least positively associated. Hence, on an aggregate

level these findings suggests that rail-based public transport are more attractive as seen from the passengers point of view, however this should be investigated in more details if general conclusions are to be drawn.

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