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What is the role of weather, built-environment and accessibility geographical characteristics in influencing travelers' experience?

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ABSTRACT

We examine the effect of weather, accessibility and built-environment characteristics on overall travel experience as well as the experience with the latest trips. These are factors that are often disregarded in the travel satisfaction literature even though they are believed to largely influence the first mile of the door-to-door trip. This study fills a research gap in investigating all these factors by using, amongst other, a relatively large travel satisfaction survey from years 2009 to 2015 and by focusing on urban and peri-urban geographical contexts, the city and county of Stockholm (Sweden), respectively. The ordered logit model results show that county dwellers living close to a metro station and in well linked-to-all areas report higher overall travel satisfaction evaluations. In addition, precipitation and ground covered with snow have a negative influence on travel satisfaction. Our findings indicate that built-environment characteristics exert a rather weak influence on the travel experience, especially in the peri-urban context. However, some aspects such as living in areas with medium densities, low income and with high safety perceptions around public transport stations are associated with higher satisfaction levels. In turn, areas with single land uses are found to have lower travel satisfactions. These results are important for public transport planners and designers in devising measures to prevent and mitigate the negative outcome of some weather conditions and to conceive better designed transit oriented developments.

1. Background, aim and purpose

Providing an accessible and inclusive transport service for all is important in ensuring people are not excluded from reaching places of employment, health, education and leisure services, and simultaneously in ensuring equal life opportunities for our diverse communities. However, at the same time, weather, urban form, land use and mix, level of accessibility to Public Transport (PT) and the type of the available infrastructure influence the use of PT service and the quality of the service (Cao et al., 2007; Liu et al., 2015; Litman, 2017). In order to provide a transport service that meets travelerś needs, it is important to understand how the characteristics of the built-environment, weather and the service provided affect traveler's experience and to incorporate this knowledge in the planning of PT services.

Urban and rural environments are contrasting geographical contexts which tend to be considered internally homogenous when, in

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reality, urban environments encompass diverse settings. As a result, travel satisfaction changes within a given region and from region to region. Disparity in overall satisfaction levels depends on the urban area and on the socio-demographic profile (De Vos et al., 2016). Similarly, Diana (2012) concluded that frequency of use is linked with the size of the urban area, being higher for dwellers of city centers and the most populated municipalities, while, on average, overall satisfaction is higher in smaller municipalities. Furthermore, other geographical factors as well as differences in PT service and infrastructure influence the way travelers perceive public transport (Fellesson and Friman, 2008). Accessibility measures defined as proximity and availability of public transport are important drivers of satisfaction and frequency of use. It was found that a low level of accessibility affects negatively the overall assessment of the travel experience (Woldeamanuel and Cygansky, 2011) and the public transport usage frequency (Brons et al., 2009).

Additionally, dissimilarities in prior expectations between urban, sub-urban and rural travelers may influence their travel evaluations (e.g. Tyrinopoulos and Antoniou, 2008). Studies in other domains (Andres and Looker, 2001) have shown that educational expectations vary regarding the geographical context of residence being lower in rural environments compared to urban areas. Therefore, travelers' expectations with PT might be related to the quality of service and infrastructure of the area of residence where one chooses to live. Further, residents of the urban areas tend to be more job-related ambitious and well-traveled than those living in more rural areas (e.g. Gordon, 2015) and thus expectations from urban travelers might be higher also in other domains.

It is still unclear how accessibility, perceptual and non-perceptual built-environment, and weather characteristics impact overall travelers' satisfaction when considered all together. In particular, the relative influence of each of these attributes remains unknown. In addition, no previous studies have looked into these aspects from two contrasting geographical contexts, city and peri-urban to rural areas. These knowledge gaps may actually lead to an unfair evaluation of the service provided by public transport operators and can undermine the impacts of well-designed transit-oriented areas and first and last-mile facilities on traveler's overall travel satisfaction.

In order to address this problem, this study aims at examining whether overall and last trip travelers' satisfaction vary as a function of the characteristics - types of built environment and level of accessibility in particular - of the geographical units where travelers start their last trip and thus of the first impact on door-to-door trips. In addition, this study investigates the impact of weather conditions on travelers experience.

The results of this study may help regional public transport providers, public transport authorities and municipalities in providing a service that better suits their user needs and design geographically-tailored investments that will foster satisfaction in the future.

This study is structured as follows. In Section 2, a literature review with special focus on the impact of weather, accessibility and built-environment characteristics on the travel experience is synthesized. In addition, in the same section, a number of hypotheses partly based on previous research are made. The following Section 3 describes the data and methodology. Next, in Section 4, a profile of the sample and model results are presented. This section also includes a discussion of the results. Finally, in the conclusions Section 5 main findings are highlighted, and limitations and directions for future research are exposed.

2. Theoretical background and hypotheses

2.1. Travel experience: the interplay between travel satisfaction and socio-demographic and travel characteristics

Generally PT travel satisfaction surveys employ an overall measure that encapsulates an evaluation of the entire travel experience. This measure refers to the whole door-to-door trip and either an average trip, i.e. overall travel satisfaction or the last trip undertaken, i.e. last trip satisfaction. They are believed to be an aggregated composite measure of quality of service attributes, price and other aspects not related to the main trip stage.

Literature has widely addressed the varying impact of socio-demographic and travel characteristics on the travel experience. A number of scholars (e.g. Beirao and Cabral, 2008) found that gender exerts a differential impact on travel attitudes, preferences and behaviors while some others (Ettema et al., 2012; Dong et al., 2016) found no significant travel satisfaction differences. It is believed that age plays an important role in determining travel satisfaction. The elderly are commonly found to report higher travel satisfaction (Van't Hart, 2012; Mouwen, 2015; Susilo et al., 2017) together with the younger groups (Mouwen, 2015). In turn, low income was found to be correlated with lower levels of travel satisfaction (Dong et al., 2016).

Regarding travel characteristics, it is still inconclusive how frequency of travel by PT impacts the travel experience. While some authors (e.g. Susilo and Cats, 2014) found a negative effect of PT use, some others (e.g. Woldeamanuel and Cygansky, 2011) found that travelers with a seasonal PT card and thus, it is assumed more frequent users, were more satisfied than their counterparts. Other travel characteristics such as the level of crowding were reported by other authors (e.g. Beirao and Cabral, 2007) as a travel dissatisfier.

To the best of our knowledge, there is no empirical evidence on how car use influences travel satisfaction with PT. However, the authors would assume that frequent car users either due to confirmation bias, to their attitudes or to specific benefits they associate with car use directness – i.e. travel times and comfortability compared to traveling by PT (Beirao and Cabral, 2007) – would report a lower travel satisfaction with their PT trips. Similarly, there is no clear evidence on whether car ownership causes a positive or a negative impact on the travel experience. While in North-American based studies (St-Louis et al., 2014; Zhao et al., 2014), those without access to a car and thus PT captives reported lower levels of travel satisfaction, in a European based study (Abenoza et al., 2017) PT captives better evaluated their PT trips. The main difference between these works might stem from the level of PT service offered in both geographical contexts.

Furthermore, satisfaction across different travel modes varies. There is a wealth of studies that corroborate that active modes such as walking and cycling are associated with higher commuting travel satisfactions (e.g. St-Louis et al., 2014) and that these are followed by car and PT modes. Amongst PT modes train is the highest ranked compared to metro and bus, which is the lowest evaluated by commuters (St-Louis et al., 2014).

All in all, even though the previous set of variables are not in the focus of this study, their influence on the travel experience warrants their inclusion in the statistical analyses.

2.2. Accessibility, weather and built-environment characteristics

A different group of travel aspects are related to travel modes employed in the access and egress stages (other PT modes and active modes) and to the environment where they are used. The degree to which the characteristics of these trip stages influence the overall trip is usually overlooked. It is therefore important to detangle the characteristics of the built-environment such as accessibility, safety perceptions, and land-use together with the weather that shapes that particular environment in a specific day and time.

2.2.1. Accessibility

One of the key aspects in evaluating the performance of a PT system is to consider how accessible it is to potential riders. Accessibility may have to do with, among all other things, the characteristics of the PT stops and stations (e.g. elevator, escalator), of the vehicles (e.g. ramps, seats, designed area for trolleys and wheelchairs), of the surrounding area (urban design, terrain slope, space syntax), and with the walking and/or cycling catchment area distance to PT facilities.

Catchment areas as distance accessibility can be measured in either physical distance or time to PT facilities. Previous research (e.g. Gutiérrez and García-Palomares, 2008; El-Geneidy et al., 2014) indicates the main key aspects that should be taken into account when generating catchment areas. First, mode specific coverage areas should be considered since the quality of the service of PT modes varies in terms of frequency, reliability, network coverage. Second, socio-demographic characteristics and the characteristics of the area where the PT stop/station is located in terms of number of employment and density of population are to be contemplated. Third, street-network distance decay coverage areas are superior to straight-line distances. And finally, urban design and physical and street network barriers should be considered when calculating catchment areas.

Catchment areas are found to be an important factor that influences both mode choice and ridership. For example, Rietveld (2000) based on data from The Netherlands noted that rail use was dependent on the distance between stations and the residential location of travelers. However, distance accessibility is not always the main impediment to PT use. Wardman and Tyler (2000) in a study that considered only train mode found that there might be some other aspects such as cost and total travel distance that play a more important role to decide whether to travel by train.

To the best of our knowledge, Brons et al. (2009) has been the only author that studied the importance of accessibility in assessing the overall travel satisfaction. Their accessibility was not only made up of average distance to PT but also of travel times by PT to train stations and the level of service offered by the PT modes connecting to train stations. In addition, this study also investigated how accessibility impacted on mode choice. These scholars found that the impact of accessibility on overall satisfaction with train trips was marginal while it was relevant in deciding whether to travel by train or other mode.

As it was made evident, previous studies have mainly focused on the impact that accessibility has on mode choice and use. Therefore, with the exception of Brons et al. (2009) which exclusively studied the impact of accessibility on satisfaction with train trips, this aspect has been neglected. In addition, the impact of disaggregated measures of accessibility (see more in Section 3.4) has never been explored at the level of detail considered at the present work.

All in all, considering previous results and after controlling for all individual socio-demographic and travel characteristics variables, the authors expect to find lower levels of reported travel satisfaction in geographical units that have poorer levels of accessibility. In addition, the authors expect a differential impact on overall travel satisfaction of those disaggregated measures of accessibility connected to the weaker links (access, egress, and transfer) of the door-to-door trip.

2.2.2. Weather

There is growing evidence that proves the influence of weather characteristics on travel behavior (Saneinejad et al., 2012; St-Louis et al., 2014; Liu et al., 2015; Guo et al., 2007; Ettema et al., 2017; Tao et al., 2018). For example, ground covered with snow increases the probabilities of going by foot (Liu et al., 2015), higher temperatures and strong winds increase bus ridership (Tao et al., 2018), winter plays a negative role on satisfaction with slow modes (St-Louis et al., 2014) and sunshine has a positive effect on mood and thus on the way travelers evaluate their trip (Ettema et al., 2017).

Most of previous studies dealing with weather and travel have focused on the impact of weather conditions on travel mode choice (Saneinejad et al., 2012; Liu et al., 2015). For example, Saneinejad et al. (2012) for commuting trips proved that rain, temperatures below 15 °C and strong winds reduce the probabilities of cycling and increase the likelihood of using car and walking. However, the results of their study did not show any significant impact of weather on transit use. Similar results were obtained by Liu et al. (2015) when investigating the effect of seasonal and regional variability of weather conditions on mode choice in Sweden. Active modes were more highly impacted by weather characteristics than PT or private car modes. For example, low temperatures, ground covered with snow and precipitation decreases the probabilities of going by bicycle. In turn, snow in the ground has a positive effect on walking while barely impacts the probability of using car and PT modes. Moreover, precipitation increases the chances of using PT modes. Their paper also unveils differential weather seasonal and regional impacts on mode choice. For example, weather impacts differently from region to region and in different seasons for active modes while the effects are mixed for PT modes.

A growing interest amongst some travel behavior scholars (Guo et al., 2007; Tao et al., 2018) is the study of the relationship between weather conditions and PT ridership. Smart card bus data in Brisbane was used by Tao et al. (2018) to investigate the effects of weather characteristics on ridership in a multi-scale setting for weekdays and weekends. Their models unveiled a differential impact of weather depending on whether travelers could skip or postpone their travel (for leisure activity during weekend) or not (for commuting during weekdays). At a bus network level, temperature and wind speed were found to have a positive impact on patronage while rainfall and humidity had a negative one. Other authors (e.g. Guo et al., 2017) considered other PT modes, weather elements and seasonal effects in their studies. Guo et al. (2017) added rail mode, snow, and fog to their investigation of the impact of weather elements on ridership in Chicago. They proved that weather exerts an influence on patronage in an expected way - bad weather impacting negatively and good weather positively on ridership. Further, their results show that bus is more highly impacted than rail due to contrasting intrinsic characteristics of these modes in terms of infrastructure and quality of service. Moreover, no seasonal effects were found and, in accordance with Tao et al. (2018), weather had a larger impact on weekends than weekdays. Both, Guo et al. (2007) and Tao et al. (2018) used daily records of weather. These studies considered weather data from a limited period of time (February to April in Tao et al., 2018) and did not consider other aspects such as the characteristics of the trip, of the trip maker or of the built-environment.

Some studies (St-Louis et al., 2014; Ettema et al., 2017) assessed the impact of weather elements on travel satisfaction. St-Louis et al. (2014) investigated for different travel modes the external factors that influenced a derived overall travel satisfaction measure. Their findings show that cold and snowy winter months in Montreal exert a negative effect on travel satisfaction of mainly active modes but also of bus. However, winter months have no impact on satisfaction with trips made by car, train, and metro. They also found that across all seasons travelers who remained using certain travel modes – such as bus and metro had a higher travel satisfaction even during winter time. In addition, the impact of weather conditions on commuting travel satisfaction (Ettema et al., 2017) revealed that sunshine has a negative effect on trips made by active modes only. In addition, any form of precipitation positively impacts on travel satisfaction evaluations, and winds over 4 m/s have a positive effect on activation for PT trips.

It is clear that the impact of weather on travel satisfaction has not been fully covered in depth by previous studies. St-Louis et al. (2014) and Ettema et al. (2017) considered commuting trips exclusively and the latter work only summer and winter data, trips made by a single travel mode and to the same destination. All these aspects are therefore included in the present study. Based on previous results we would hypothesize that weather conditions will have an influence on travelers satisfaction with their access and egress legs and thus on their overall travel evaluation.

2.2.3. *Built-environment*

Perceptual and non-perceptual built-environment characteristics may also influence the traveler experience. Results of previous research show that an attractive built-environment increases the probability of walking longer distances to BRT stations (Jiang et al., 2012). In addition, Zhang (2004) found a higher likelihood of using active and PT modes in areas with a balanced land-use at destination for non-commuting trips and in areas with larger population density at origin for commuting trips. In the same vein, Ye and Titheridge (2017) found that some built-environment characteristics such as access to transit, home and job proximity to greenery and living in car dependent neighborhoods had an impact on travel mode choice. Notwithstanding, the results of their empirical study showed no effects whatsoever of built-environment variables on travel satisfaction.

To date, the influence of land-use on travel behavior is inconclusive. For instance, while some authors postulate that land use does not sway the capacity of travelers living in an area that is suitable for walk and cycle (e.g. Cervero et al., 2006), some other (Saelens et al., 2003) found the opposite. Part of the reason for these inconclusive results can be due to the perceptual built-environment characteristics.

Perceptual built-environment characteristics such as crime perceptions have been found to influence not only the starting time of the trip (night-time to day-time) but also route and travel mode choice (e.g. Loukaitou-Sideris et al., 2009). Moreover, Handy et al. (2005) found that a composite variable consisting of: safety feelings on the neighborhood, the level of crowding, and lighting conditions, was one of the most influential factors influencing driving and walking. This happened after controlling for self-selection by including travel attitudes and socio-demographic characteristics. Furthermore, the presence of real or perceived crime – safety perceptions - has been proved to be an important determinant of travel satisfaction (Cats et al., 2015).

On the whole, the influence of built-environment characteristics has been proved on mode choice but not yet on the travel satisfaction evaluation. In any case the authors would expect that travelers living in areas with mixed land use, higher densities of population, better lighting conditions and that are regarded as safe would report higher satisfaction evaluations.

3. Data

This study employs a rolling survey known as the Swedish customer satisfaction barometer. The travel satisfaction survey, collected by *Svensk Kollektivtrafik,* inquiries PT users and non-users and includes questions concerning satisfaction with the overall and last trip and with individual service attributes, as well as socio-demographics and travel characteristics. Overall travel satisfaction refers to the evaluation of an average trip undertaken during the previous year while last trip satisfaction refers to the assessment of the last door-to-door trip undertaken, if any, on the previous day. The data collection is carried out via landline phone calls on a regular basis year-round and comprises an average of 3128 samples per year in Stockholm County.

This work is based on the most recent set of available samples (mid-2009–2015) of travelers from Stockholm County who travel at least once a month and thus who have some experience of using PT. In addition, responses related to the last trip that reported trips starting and ending in the same postcode area and starting or ending outside Stockholm County are excluded. After the data was checked for completeness, correctness and consistency across all variables included in each model, a sample of 3862 respondents remained for Stockholm City and 8011 respondents for Stockholm County. Both samples were randomly distributed across their

Table 1
Databases used, sources, and year of origin.

Category	Variables	Source	Geographical unit	Year
Travel satisfaction perceptions	Overall trip and last trip satisfactions	SKT (Swedish customer satisfaction barometer	Postcode area	2009–2015
Socio-demographic characteristics	Age, gender, car in HH, occupation and driving license	SKT (Swedish customer satisfaction barometer	Postcode area	2009–2015
Travel characteristics	Travel mode, frequency of travel by car and by PT	SKT (Swedish customer satisfaction barometer	Postcode area	2009–2015
Perceptual built-environment characteristics	Safety perceptions related to neighborhood and previous victimization	Trygghetsundersökning Stockholm (Safety perceptions survey Stockholm)	Postcode area	2014
	Cleaning, maintenance and lighting	Trygghetsundersökning Stockholm (Safety perceptions survey Stockholm)	Postcode area	2014
Non-perceptual built-environment characteristics	Density of population	SCB (Statistics Sweden)	Postcode area	2012
	Purchasing power	SCB (Statistics Sweden)	SAMS area	2013
	Land use	Corine land cover	Continuous data	2012
Weather characteristics	Temperature, precipitation, wind speed, snow depth, humidity	SMHI (Swedish Meteorological and Hydrological Institute)	4 weather stations in Stockholm County	2009–2015
Accessibility measures	Generalized costs from one to all postcodes	Tailored made and based on PT service frequencies from SL (Stockholm's PT authority)	Postcode area	2014
	Disaggregated accessibility measures	Tailored made and based on PT service frequencies from SL (Stockholm's PT authority)	Postcode area	2014
	Proximity to high capacity PT	Tailored made based on location of PT stops	Continuous data	2009–2015

respective geographical areas and can be considered representative of the population.

This study also employs a Safety perceptions survey for Stockholm City (2014) which includes questions related to vulnerability to different types of crimes, social and built-environment perceptions about the area where one lives and safety perceptions. This survey comprises 16,481 responses of a random sample of people between 16 and 79 years old living in every postcode area of the City. The survey is collected every third year starting in 2008 and during winter and spring time. The data collection is carried via post survey and complemented with phone calls to increase the responses of the areas with lower response rates.

Stockholm County is composed of 26 municipalities and 1960 five-digit postcode areas and encompasses a territory ranging from highly urbanized to rural areas which are characterized by having a very different transport infrastructure, service provisions and built-environment characteristics. Following Köppen classification (Peel et al., 2007), Stockholm County has a warm-summer humid continental climate with daily mean temperatures moving from −1.7 °C in February to 18.8 °C in July. Temperatures below 0 °C are very common from December to March while summer temperature rarely go over 25 °C. Precipitation is not abundant (531 mm/year) but is fairly evenly distributed across the year. On average the period when the ground is covered with snow goes from mid-November to early April. Wind is more common in winter than summer season. However average wind speed is low and ranges from 3.6 m/s in July to 8.3 m/s in January.

Two types of data, individual and geographically based data are employed in this paper. Individual related data includes socio-demographic and travel characteristics. Geographically based characteristics include accessibility and proximity measures, weather characteristics, and perceptual and non-perceptual built-environment characteristics. Table 1 shows variables' category and name, data source, geographical availability, and year of origin.

3.1. Perceptual built-environment characteristics

There are two types of perceptual variables connected to the neighborhood where the traveler lives and one related to previous victimization. The first type of variable is related to subjective evaluations of the built-environment (cleaning, lighting, safety perceptions) while the second type has to do with previous crime experience and with the concern of becoming a victim of crime.

Built-environment perceptual characteristics consist of three variables regarding the satisfaction with whether graffiti is removed *(graffiti removal),* the level of *cleanliness* and the *lighting* conditions of the area where the traveler lives.

Safety perceptions are related to subjective feeling of personal safety either in general (*Safety in the neighborhood*) or around PT stops and stations (*Safety around PT*). Previous victimization variables are related to the self-reporting of having been a victim or having been concerned of becoming a victim of crime in the previous 12 months, either in first-person (*Victim own*) or for a friend or relative (*Victim 3rd person*).

3.2. Non-perceptual built-environment characteristics

The non-perceptual built-environment variables include population density, purchasing power and land-use characteristics. The original spatial unit of purchasing power was SAMS areas (Small Areas for Market Statistics) while land-use spatial units have a random shape. These two variables were spatially aggregated into postcode areas by using a weighted method based on the share of overlapping area.

Density of population data was categorized into five levels by using a quantile classification method. A measure of income, *purchasing power*, which takes into account the disposable income was in turn classified into three levels (low, medium and high). All the data classification can be found in Table 2.

Land Use was reclassified into two main categories: mixed and single uses. Mixed land use group consists of: a) continuous or discontinuous urban fabric which is made up of a minimum land coverage of 33% of one of the uses plus (an)other use(s); b) other

Table 2
Summary statistics of sample profile for each of the models.

			M1 City - OS	M2 City - LTS	M3 County -OS	M4 County -LTS
Satisfaction [1 to 5 scale]	Overall trip		3.68	na.	3.54	na.
	Last trip		na.	4.16	na.	4.05
Socio-demographics [% mean]	Female (male)		56.30	55.30	56.50	55.00
	Age	15–20	11.00	10.40	13.30	14.80
		21–40	37.70	41.00	31.80	34.10
		41–64	40.70	40.80	41.90	42.90
		> 64	10.50	7.90	13.00	8.20
	Worker (other)		66.00	73.60	62.80	71.70
	With car available (without)		69.80	72.10	84.70	85.50
	With driving license (without)		73.60	75.60	75.9	76.50
	With disability (without)		2.60	1.10	2.90	1.70
Travel characteristics [% mean]	Frequency travel PT	Daily	43.00	49.70	33.70	41.60
		Weekly	42.20	38.30	39.50	35.10
		Monthly or less often	14.80	12.10	26.80	23.30
	Frequency travel car	Daily	14.60	15.80	28.40	29.70
		Weekly	44.20	44.70	48.70	48.00
		Monthly or less often	41.20	39.50	22.90	22.30
	Travel mode usually employed	Bus	27.00	na.	50.10	na.
		Metro	62.30	na.	16.90	na.
		Commuter	8.50	na.	31.5	na.
Built-environment characteristics [% mean]	Population density [inhab/sq km.]	0–509	0.60	na.	17.60	na.
		510–1880	5.80	na.	40.70	na.
		1881–4520	32.40	na.	22.60	na.
		4521–10,235	29.40	na.	13.30	na.
		10,236–86,538	31.70	na.	5.80	na.
	Income [€]	Low [< 24,000]	26.40	na.	39.10	na.
		Average [24 K-30 K]	46.40	na.	43.70	na.
		High [> 30,000]	27.20	na.	17.20	na.
	Land use	C. & D. U.F[1]	3.70	na.	0.40	na.
		Mixed 2 * 25%	51.60	na.	55.80	na.
		Other mixed	5.70	na.	12.30	na.
		> 75% C.U.F.[2]	10.40	na.	0.20	na.
		> 75% D.U.F.[3]	15.60	na.	12.20	na.
		> 75% I.,Comm.,T. Const.[4]	5.60	na.	1.80	na.
		> 75% G.U.A.,S.,L.F.[5]	5.90	na.	1.20	na.
		> 75% Agric., forest, SN.[6]	1.50	na.	16.20	na.
Built-environment - Cont. -	Built-environment perceptions [1 to 5]	Graffiti	3.28	3.28	na.	na.
		Cleaning	3.41	3.41	na.	na.
		Lighting	3.41	3.41	na.	na.
	Crime experience	Own [1 to 5]	4.29	4.29	na.	na.
		Third-person [1 to 4]	3.31	3.32	na.	na.
	Safety perceptions [1 to 5]	In Neighborhood	3.04	2.96	na.	na.
		Around PT stops/stations	4.21	4.2	na.	na.
Weather	Temperature [in %]	< 0 °C	na.	24.3	na.	25.9
		0–10	na.	39.1	na.	36.4
		10.1–20	na.	30.8	na.	31.8
		> 20	na.	5.9	na.	5.8
	Precipitation	Precipitation % days	na.	11.3	na.	9.9
		Precipitation [in mm.]	na.	0.07	na.	0.06
	Wind	Wind [in m/s]	na.	3.19	na.	3.23
	Snow [in %]	Snow % days	na.	21.9	na.	21.8
		0.1–10 (depth in cm.)	na.	5.1	na.	5.2
		10.1–20	na.	7.1	na.	8.3
		> 20	na.	13.5	na.	13.0
		No snow	na.	74.2	na.	73.5

(*continued on next page*)

Table 2 (*continued*)

			M1 City - OS	**M2** City - LTS	**M3** County -OS	**M4** County -LTS
Accessibility	Proximity to [in %]	Commuter (1000m.)	20.9	48	29.9	47.8
		Metro (800m.)	68.3	69.2	10.4	39.5
		Tram (800m.)	0	3.1	0	2.9
	Generalized cost to all other destinations [Scale −7 to 10]		9.15	na.	6.9	na
	To T-Centralen [in min.]	access walking time	11.77	na.	16.27	na
		initial waiting time	4.58	na.	9.63	na
		in-vehicle time	17.45	na.	50.48	na
		transfer waiting time	2.84	na.	4.54	na
		transfer walking time	2.58	na.	2.07	na
		egress walking time	10.76	na.	2.77	na
	From Origin to Destination [in min.]	access walking time	na.	11.92	na.	13.23
		initial waiting time	na.	3.38	na.	7.77
		in-vehicle time	na.	9.3	na.	39.95
		transfer waiting time	na.	1.47	na.	6.48
		transfer walking time	na.	2.16	na.	3.09
		egress walking time	na.	2.72	na.	14.26

[1] Continuous and discontinuous urban fabric,
[2] Continuous urban fabric,
[3] Discontinous urban fabric,
[4] Industrial, commercial transport, mine dump and construct,
[5] Green urban areas, sport and leisure facilities,
[6] Agricultural, forest and wetlands and water bodies.

mixed use, which is made up of three land uses with a share equal or larger to 14.28%[1] each, c) Mixed 2x25; which is made up of two or more land-uses with a minimum land coverage of 25% each. Single land uses are areas with a minimum land coverage of 75%. They include: a) continuous urban fabric, b) discontinuous urban fabric, c) industrial, commercial transport, mine dump and construct, d) green urban areas, sport and leisure facilities or e) agricultural, forest and wetlands and water bodies.

3.3. Weather characteristics

Temperature, precipitation, wind speed, and snow depth are the weather characteristics considered in this research. Some other, such as humidity, wind direction, and cloud cover are left out of the analysis due to their assumed lower impact on the travel experience and to data limitation.

Weather characteristics are extracted from four weather stations spread over the entire Stockholm County. The assignment of weather data to each postcode area is based on data availability and geographical proximity between postcode centroids and weather stations. The application of this assignment method in a study area with small variability in terms of weather conditions increases the reliability that all weather characteristics (temperature, wind speed, snow depth) with the exception of local showers are well captured.

With the exception of snow depth all other weather characteristics are ascribed to each last trip with an accuracy of an hour from the start of the trip. Snow depth is in turn ascribed to the day when the last trip takes place. Fig. 1 shows a map with the location of the weather stations and postcode areas alongside a table showing the origin of the weather data and the time unit of study.

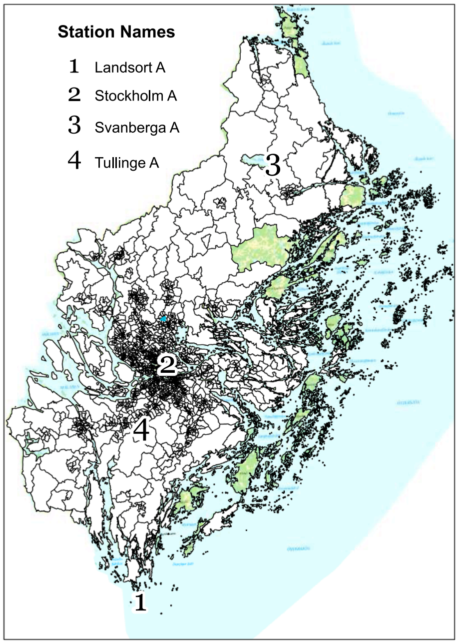
The impact of temperature is tested by using different approaches which involve testing the inclusion of absolute values, extreme weather events (very heavy rainfall, very strong winds and very low and high temperatures) and categorical data. In addition, and in order to capture the impact of expected weather conditions on the given time of the year, a normal-extreme method is tested. Therefore temperature data included in some testing models is the relative change (Z score) with regard to the climate values for the same day and time of the year. Z-scores were grouped in three categories (below normal < -0.5, normal -0.5 to 0.5 and above normal > 0.5) and climate was taken from the same weather stations in a 20 years-period going from 1996 to 2016.

Continuous absolute values and categorized precipitation, wind speed and snow depth data are tested in the models. However the time normal-extreme method is not examined in the above variables since we assume that these weather events are not strongly memory-attached to specific dates of the year.

While absolute and categorized weather values are tested in different regression models, weather data employed in the final model specification is in absolute number for wind and rain and in categories for snow and temperature. The categorization of the latter variables can be found in Table 2.

With the aim of measuring the contrasting impact that the same weather characteristic may have in different times of the year season dummies were also tested. These dummies were inserted to control for the differential impact of, for example, having a temperature of 10 °C in summer or winter, or to have the ground covered with snow in winter or spring.

[1] Considering that there are 7 different land uses this is equivalent to 1/7.



Weather / Station	Temp. (hour)	Precip. (hour)	Wind Speed (hour)	Snow cover (day)
1.Landsort A	x	x		
2.Stockholm A			x	x
3.Svanberga A	x	x	x	x
4.Tullinge A	x	x		

Fig. 1. (a) Location of weather stations, postcode areas in Stockholm County; (b) Weather characteristics, their time unit and their provenience.

3.4. Proximity and accessibility measures

Proximity and accessibility measures are found in the literature to influence travel behavior and thus they are considered as important factors to be tested in this paper. Proximity is measured using catchment areas, i.e. Euclidean distance from PT high capacity modes (tram, metro and commuter train) to postcode centroids. Buffer proximity distances employed range between 800 m. for tram and metro stations and 1000 m for commuter train stations. The considered buffer distances are somehow longer that the ones obtained by previous research (Gutiérrez and García-Palomares, 2008; El-Geneidy et al., 2014) since they are calculated from stops/stations to postcode centroids and not from exact O-D pairs. These catchment areas represent the distances that travelers are willing to walk to in order to use any of the high capacity travel modes. Depending on the models, proximity measures are calculated either from the traveler home postcode area (overall satisfaction) or from the postcode area where the traveler starts his/her trip (last trip satisfaction).

Three types of accessibility measures are employed in the different models: a) generalized cost from one to all postcode areas; b) disaggregated accessibility measures from Origin to Destination[2]; c) disaggregated accessibility measures from the postcode area where the traveler lives to the most central point in Stockholm County and City (T-centralen). For some observations it was not possible to calculate the accessibility measures due to: an incomplete origin or destination, to trip origin or destination lying outside of Stockholm County or due to the trip starting and ending within the same postcode area. The full list of calculated accessibility measures includes:

- Access walking time: Walking time from starting point to PT stop/station.
- Initial waiting times: Half the service headway (assuming random arrival).
- In-vehicle time: Time spent in-vehicle.
- Transfer walking time: Walking time while transferring between PT modes.
- Transfer waiting time: Expected waiting time according to the scheduled headway.
- Egress walking time: Walking time from PT stop/station to destination.
- Generalized Logsum cost: Aggregated measure of accessibility that considers all the above disaggregated measures and is calculated from each postcode area to all other.

Given a traveler from a trip origin zone A to a destination zone B by PT, he/she may have several possible PT routes to choose from. Therefore, different route choices may result in calculated accessibility measures for this OD pair. In this study, the “Optimal Strategy” routing approach is adopted to calculate accessibility measures. Optimal Strategy assumes that, for travelers from a given OD pair, they will first select a set of attractive routes out of all possible routes given the accessibility measures provided by each route. Then the method assumes that the travelers from this OD pair will be distributed proportionally over all attractive route

[2] At a postcode level.

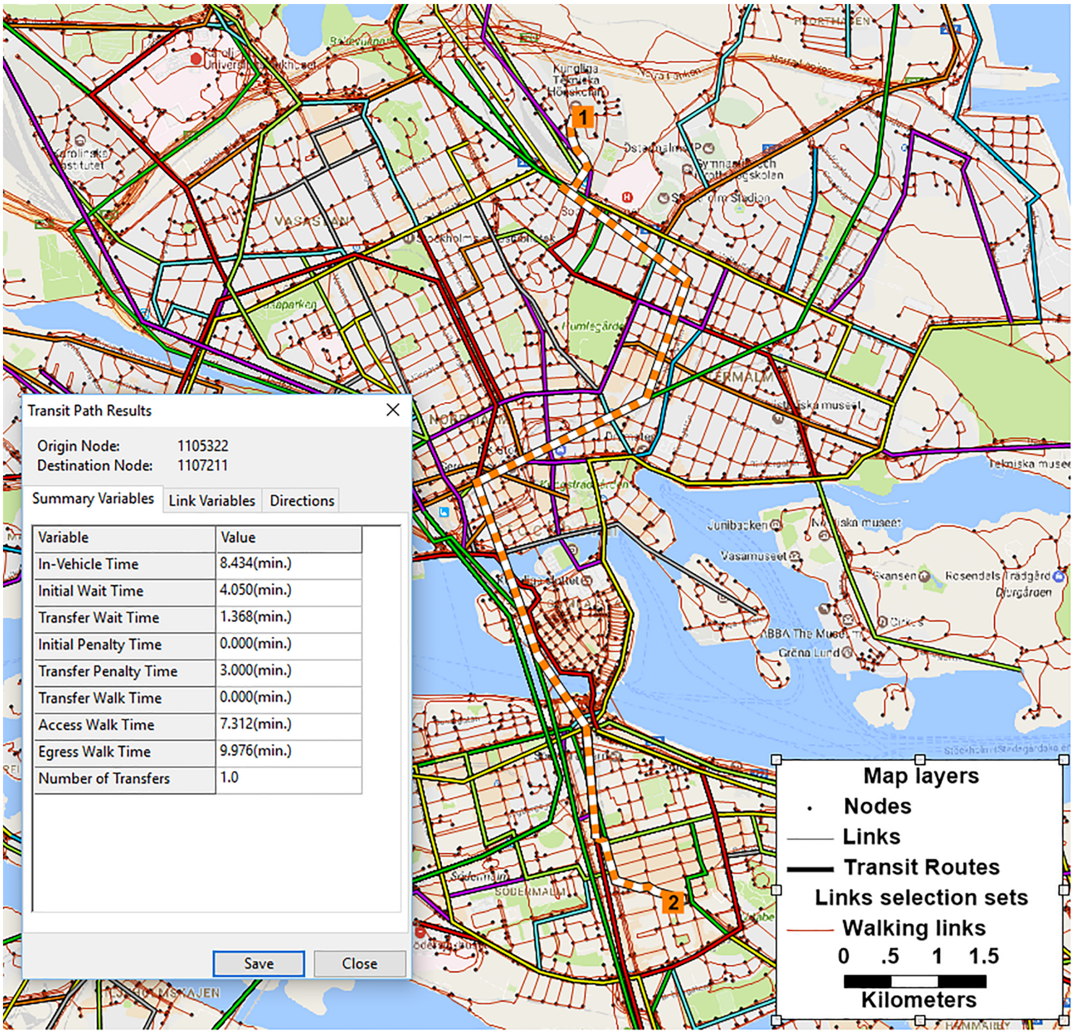


Fig. 2. Example of the calculation of accessibility measures in Transcad.

according to their frequencies. A detailed mathematical description of the Optimal Strategy method can be found in Spiess and Florian (1989). To exclude unrealistic routes when constructing the choice set of attractive routes, the following constraints are considered:

– Maximum walking time to the closest PT stop/station was set to 45 min.
– Maximum transfer time was set to 20 min.
– Maximum travel time from Origin to Destination was set to 240 min.
– PT schedule considered was based on a weekday and morning rush hour.
– Waiting times were calculated based on the average schedule headway.
– Biking trips are not included since they represent a very small modal share in the City and a meagre share in the County.

For the disaggregated measures of accessibility larger values (in minutes) mean a lower accessibility level while this is the opposite for the generalized cost estimates (index).

In this study, the public transport routing is carried out in the transport planning software TransCad. Fig. 2 presents a routing result from TransCad with an OD pair from Royal Institute of Technology (KTH) to the southern inner-City island of Södermalm. To ensure a precise estimation of walking time, a complete road network (Walking links in Fig. 2) is connected to a PT network. An extra penalty time for transfer, 3 min, is introduced to represent the discomfort attributed to transferring. This example shows the accessibility measures of this OD pair: Access Walk time 7.31 min; Initial waiting time 4.05 min; In-vehicle time 8.43 min; Transfer walking time 0 min; Transfer waiting time 1.38 min; Egress walking time: 9.97 min.

After calculating the accessibility measures from each start zone i to each end zone j, the generalized cost is calculated as a linear combination of travel time elements and population at the destination zone:

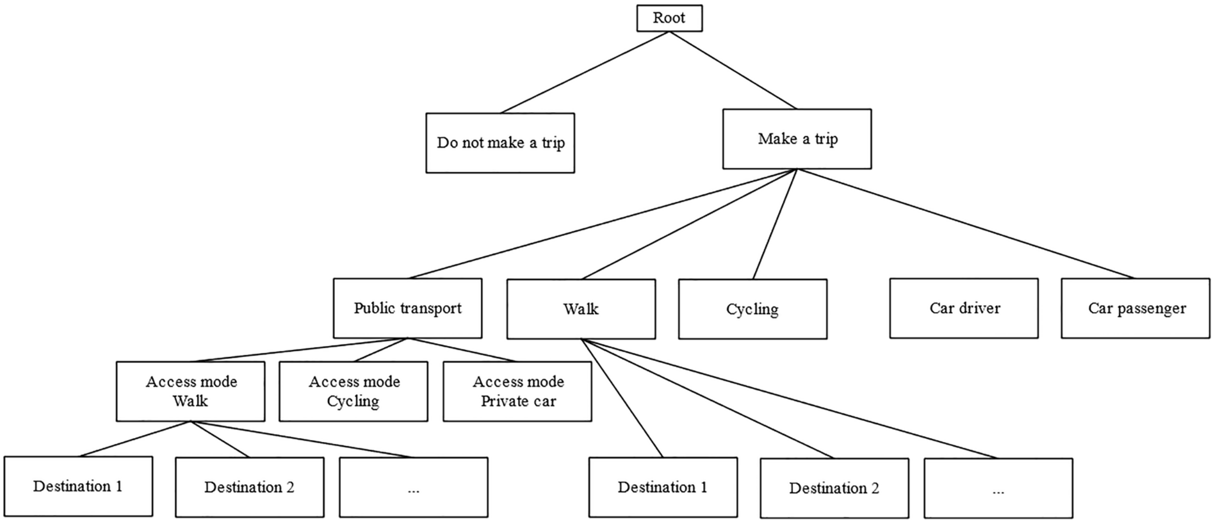


Fig. 3. The nested Logit mode structure.

$$GC_{i,j} = 0.7294 \times Population_j - 0.0725 \times AccessWalkTime_{i,j} - 0.0679 \times InitialWaitingTime_{i,j} - 0.0438 \times InVehicleTime_{i,j} - 0.045 \times (TransferWaitingTime_{i,j} + 1.5 \times NumberOfTransfer_{i,j}) - 0.0753 \times TansferWalkTime_{i,j} - 0.0878 \times EgressWalkTime_{i,j} \quad (1)$$

The weights used in the above equation are estimated in a large scale nested logit model using Stockholm regional travel survey from 2015. Fig. 3 depicts the model structure of the large scale nested logit model.

The generalized cost function presented in Eq. (2) below is in principal the estimated utility function of the destination choice sub-model under the alternative "Access mode walk". Therefore, the accessibility measures have negative weights to represent utility diminishing or lower probabilities of taking PT if the given travel time component by PT increases. Destination postcode areas are weighted based on their attractiveness represented by the proxy of total population as used by Kristoffersson et al. (2018). The details of the model description and estimation results can be found in Liu et al. (2018). The Generalized Logsum cost of a given origin zone *i* is then defined, according to the nested logit model:

$$\text{GeneralizedLogsumcost}_i = log\left(\sum_{j \in J} e^{GC_{i,j}}\right) \quad (2)$$

In addition, ArcGIS is used to obtain geographical distributions, proximity measures and to aggregate the data into the same geographical units while SPSS is used to run all the multivariate statistical analyses.

4. Analysis and results

4.1. Descriptive analysis

Table 2 presents summary statistics of the socio-demographic, travel characteristics, weather, built-environment and accessibility measures. The statistics are given for each of the four final models run in Section 4.3. These models have either last trip or overall travel satisfaction as dependent variables and are applied to distinct data samples, - County and City. County and City samples are mutually exclusive rather than the former including the latter. The data is shown either as the percentage of respondents by category (%) or as the mean of a measurement unit for a given variable. Other measurement units such as a five-level Likert-scale (satisfaction), degrees Celsius, meters/second, millimeters, centimeters (weather variables), built-environment perceptions and safety perceptions (1 to 4 or 5) and accessibility measures (in minutes) are shown in square brackets. Generalized cost to all other postcode areas is a measure that ranges from −7 to 10. For the remaining nominal variables the alternative response category is shown in brackets.

In line with previous research (Pedersen et al., 2011; Susilo and Cats, 2014) overall travel satisfaction evaluations are lower than last trip satisfactions. The difference is of half a point, 3.6 versus 4.1, and is attributed to the way travelers recall their trips. Both trip evaluations are lower in the County which may have to do with either differences in expectations or with lower accessibility and service levels associated to peri-urban and rural areas compared with urban environments.

There is a similar proportion between young and old adults (40%) and between teenagers and the elderly (10%). In the last trip models, there is a smaller share of the elderly and of people reporting a disability that limits their travel. This could be expected since people that are on an active age travel more often than other. A larger share of car ownership is found amongst County dwellers who also travel much more frequently by car (30% daily) compared to City dwellers (15% daily). These figures together with longer travel distances and differences in accessibility levels impact the frequency of travel by PT which is higher in the City samples with almost a half of respondents traveling daily than in the County samples. Most commonly used travel modes are metro (62%) in the City and bus (50%) in the County. Densities of population are much higher in the City than in the County.

Urban (City) and rural and peri-urban areas (County) show a very contrasting pattern in terms of built-environment characteristics. In the latter, more than half of the respondents live in postcode areas with population densities below 1880 inhab/sq km., compared with 6% in the City samples. A larger concentration of wealth and of human-made landscape in the City area is reflected in the income distribution and the land use types found in the City compared to the County samples. These variables exhibit a larger proportion of high income and continuous and discontinuous urban areas in the City samples.

Respondents living in the City are on average rather satisfied (about 3.3 on a 1 to 5 scale) with graffiti removal, with the cleaning and with the lighting conditions of the area where they live. Travelers are on average not worried of becoming a victim of crime in the past 12 months either for themselves (4.29) or for someone they know (3.31). In addition, travelers are almost never worried of becoming a victim of crime around PT stops and stations (4.21). In turn, when asked for their safety perceptions in their neighborhood they feel on average neither safe nor unsafe (3 on a 1 to 5 scale).

Weather traits for Stockholm City and County are on average similar. This is due to the limited area (6000 sq km), the lack of any orographic barrier, elevation difference and with the fact that the capital is placed right in the middle of the County. Therefore average yearly temperatures are around 7 °C, with precipitation on 10% of the days and with snow covering the ground on 25% of the days.

Proximity to PT stops and stations shows that about half of the respondents are within a feasible walking distance to a commuter train station. While 70% of the travelers have access to a metro station in the City this share drops to 40% for the County. This indicates that about 40% of the County respondents live in postcodes areas of neighboring municipalities served by metro network (Solna, Sundbyberg, Danderyd and Botkyrka). Not surprisingly generalized travel costs are higher in the City than in the County. Average travel times to the most accessible point in the entire County (T-centralen) range from 50 min. in the City to 85 min in the County. In turn, travel times from reported origins to destinations rise from 31 min. in the City to 85 min in the County. Travel times in the City are aligned with the ones from Stockholm travel surveys (SLL, 2015) while the ones from the County are somehow longer.

4.2. Methodology

Ordered Logit regression Models (OLM) are employed to systematically investigate the influence of weather characteristics, built-environment and accessibility measures on the traveler experience. OLM is deemed to be the most adequate technique to handle the ordinal nature (from 1 to very dissatisfied to 5-very satisfied) of the models' dependent variables assuming that the incremental changes between the categories of the independent variables are linear and the same.

Two-way interaction terms were tested and calibrated for the combinations of age, accessibility measures, seasons and weather conditions. In Models 1 and 3, meaningful two-way interactions effects were tested between age groups and accessibility measures while in Models 2 and 4, interaction terms where tested between age, accessibility and weather characteristics.

Weather related interaction effects were tested in order to investigate whether the impact of some of the weather characteristics (temperature, rain and snow cover) differs depending on the season of the year during which they occur (e.g. snow in autumn and cold temperatures in spring might be worst perceived than in winter). Interactions between temperature and strong winds were also examined.

In Models 2 and 4, additional two-way interaction effects were tested with the aim of examining whether gender and weather exert a differential impact on accessibility measures. Interactions between generalized cost and density of population as a proxy of residential location (core of Stockholm city, outskirts and rural areas densities) were also tested given that accessibility expectations may vary depending on the place of residence (as a result of whether self-selection or experience). Access and egress walking times and initial waiting times were tested with temperature, snow and also with precipitation (absolute and z-scores) since these two weather conditions may particularly impact longer walking and waiting times.

A manual stepwise backward method was employed to test all the aforementioned interaction effects. This method consisted of, at first, main effect variables and all two-way interaction effects. Then, after checking the model output, all main effects are retained but only significant interaction effects are kept. Interaction effects results showed that from the about 30 interaction effects tested only two were found significant in M2. These were a positive but small effect of high temperature with wind speed and a negative effect of precipitation on longer access walking times. However, after all the interaction effects model were examined and due to the insignificance of the vast majority of the results we decided to better display a parsimonious models where only direct effects are included. These results are in line with Ettema et al. (2017) where no seasonal effects of weather were found.

A total of four different conceptual models (M1-M4) with direct effects only are then specified. The main differences across these models are: the geographical scope (Stockholm City Vs County), the travel experience they refer to (overall and last trip) and the set of explanatory variables included. Table 3 shows the final model specifications.

The different model specification is due to: a) data limitation such as no availability of perceptual built-environment characteristics data for the County; b) the impossibility to link weather characteristics of an average overall trip to specific weather conditions, and c) different accessibility measures included for overall (M1&M3) and last trip (M2&M4) models.

Since the dependent variables (overall and last trip satisfactions) are ordinal, ranging from 1 (completely disagree) to 5 (completely agree), ordered logit models are most adequate. In general, order logit model can be expressed as:

Table 3
Model specification M1-M4.

		M1	M2	M3	M4
Geographical extent	**Stockholm City**	x	X		
	Stockholm County			x	X
Dependent variable	**Overall trip**	x		x	
	Last trip		X		X
Independent variables	**Socio-demographic characteristics** (age, gender, car in HH, occupation, driving license)	x	X	x	X
	Travel characteristics (travel mode, frequency of travel by car and by PT)	x	X	x	X
	Safety perceptions (previous victimization, referring to a neighborhood and around PT stations)	x	X		
	Built-environment perceptions	x	X		
	Weather characteristics (temperature, rainfall, wind speed, snow depth, % coverage days, humidity)		X		X
	Built-environment characteristics (land-use, density of population, purchasing power)	x	X	x	X
	Accessibility measures				
	Generalized costs from one to all postcodes	x		x	
	Generalized cost from Origin to Destination		X		X
	Proximity to high capacity PT	x	X	x	X

$$y_k^* = X_k\beta + \varepsilon_k \tag{3}$$

where y_k^* is the latent dependent variable of individual k. X_k is the explanatory variable set of individual k, which includes all the aforementioned independent variables for individual k. Note that the intercept is dropped for identification issues. β is the corresponding vector of parameters to be estimated.ε_k is the error term which is assumed as an identically distributed logistic error-term. The latent dependent variables are then associated with the observed dependent variables, y_k (5 likert scale), with m = 1.5, defined as follows:

$$y_k = \begin{cases} 1, & \text{if } -\infty < y_k^* < \mu_1 \\ 2, & \text{if } \mu_1 < y_k^* < \mu_2 \\ & \cdots \\ M, & \text{if } \mu_{m-1} < y_k^* < +\infty \end{cases} \tag{4}$$

4.3. Model results and discussion

For each of the four models, Table 4 displays the estimated coefficients in one column (Estim.) and the significance values (Sig.) in another. Significance levels are represented in the table by one, two or three asterisks for values of 99%, 95% and 90% confidence interval respectively. Insignificant variables (< 90%) are displayed in the table without an asterisk. Not applicable 'na' refers to the variables that do not apply for a specific model.

Table 4 continuation shows the widely used Nagelkerke pseudo R square index. The goodness of fit of the models explains between 3% (Last trip satisfaction model –M4) and 9% (Overall Satisfaction County – M3) of the variation in overall and last trip satisfaction models. R square coefficients are low but in line with similar works in the field (Guo et al., 2009; Zhen et al., 2018) where no service attributes are included and where only the access part of the door-to-door trip is taken into consideration. In addition, the lower fit of the County models might be explained by the larger variability and heterogeneity of this geographical area. All models are superior to the intercept-only models as confirmed by the log-likelihood ratio test.

A large number of socio-demographic variables are found significant in the models. Female travelers in the City (M2) are likely to experience higher satisfaction levels with their latest trips while overall travel satisfaction is lower for them in the County (M3). In the vast majority of models age is significant. The elderly are significantly more satisfied with the overall and last trip than other age groups which is in line with previous studies (Mouwen, 2015; Susilo et al., 2017). Models reveal that workers and thus commuters in the County report lower overall travel satisfaction (M3). This is concurrent with previous works showing that higher exposure to peak-hours and longer travel distances to workplaces have a negative impact on travelers' trip evaluation. Concurrent with some previous research (Abenoza et al., 2017) having a car in the household has a negative impact on overall travel satisfaction in the County (M3). In addition having a disability that limits traveler's opportunity to travel has a negative impact on travel satisfaction, however the coefficient is only significant for an overall trip in the City (M1).

Results regarding travel characteristics shed some more light on the inconclusive findings of previous research. The more one travels by PT the more one is satisfied with their overall travel experience in both the City and the County models (M1 and M3) which strengthen Woldeamanuel and Cygansky (2011) findings. Therefore this seems to suggest that having a good knowledge of PT in terms of schedule and routes and knowing what to expect from the service positively impacts the travel experience. On the contrary, those who travel more often by car have lower overall and last trip satisfaction in most of the models (M1, M3 an M4). All travel modes considered are found to have no significant effect on the travel experience.

Overall, few of the non-perceptual built-environment characteristics are found to have a significant effect in the City model. Results show that living in areas with mid-level densities (1881–4520 inhab/sq·km) has a positive effect on travel satisfaction. In addition, travelers with fewer economic resources (below the average) are more satisfied than others which is inconsistent with Dong

Table 4
Overall and last trips satisfaction model results.

	M1 City -OS		**M2** City - LTS		**M3** County - OS		**M4** County-LTS	
	Estim.	Sig.	Estim.	Sig.	Estim.	Sig.	Estim.	Sig.
Gender (Female)	0.025	0.694	0.288*	0.008	−0.126*	0.004	0.091	0.265
Age	−1.050*	0.000	−0.403	0.149	−0.697*	0.000	−0.377***	0.070
(15–20)								
(21–40)	−1.283*	0.000	−0.538**	0.025	−0.857*	0.000	−0.404**	0.029
(41–64)	−0.985*	0.000	−0.499**	0.045	−0.642*	0.000	−0.408**	0.029
(> 64)	Ref. value		Ref. value		Ref. value		Ref. value	
Worker (Other)	0.017	0.839	−0.117	0.457	−0.174*	0.003	−0.126	0.309
Car available	−0.083	0.350	−0.045	0.770	−0.248*	0.001	−0.065	0.643
With driving license	−0.077	0.391	−0.174	0.255	0.015	0.821	−0.025	0.850
With disability	−0.624*	0.001	−0.374	0.451	−0.057	0.658	−0.479	0.121
Freq. PT	0.402*	0.000	0.119	0.511	0.407*	0.000	0.107	0.397
(Daily)								
(Weekly)	0.170***	0.086	0.125	0.479	0.476*	0.000	0.064	0.586
(Monthly or <)	Ref. value		Ref. value		Ref. value		Ref. value	
Freq. Car	−0.598*	0.000	−0.363***	0.053	−0.633*	0.000	−0.352**	0.013
(Daily)								
(Weekly)	−0.171**	0.044	0.007	0.961	−0.326*	0.000	−0.285**	0.017
(Monthly or <)	Ref. value		Ref. value		Ref. value		Ref. value	
T.M.	−0.011	0.959	na.	na.	0.025	0.841	na.	na.
(Bus)								
(Metro)	0.107	0.622	na.	na.	0.103	0.424	na.	na.
(Commuter)	−0.291	0.231	na.	na.	−0.151	0.245	na.	na.
(Other)	Ref. value		na.	na.	Ref. value		na.	na.
Pop. Dens(0-509inhab/sq·km)	0.094	0.837	na.	na.	−0.148	0.281	na.	na.
(510–1880)	0.266	0.128	na.	na.	0.027	0.819	na.	na.
(1881–4520)	0.229**	0.042	na.	na.	0.020	0.867	na.	na.
(4521–10,235)	0.115	0.243	na.	na.	−0.032	0.778	na.	na.
(10,236–86,538)	Ref. value		na.	na.	Ref. value		na.	na.
Inc. (Low < 24 K €)	0.207**	0.049	na.	na.	0.041	0.534	na.	na.
(Avg. 24–30 K €)	0.047	0.584	na.	na.	0.064	0.319	na.	na.
(High > 30 K €)	Ref. value		na.	na.	Ref. value		na.	na.
L.U. C. & D. U.F[1]	0.389	0.246	na.	na.	0.114	0.739	na.	na.
Mixed 2 * 25%	−0.468***	0.088	na.	na.	0.019	0.794	na.	na.
Other mixed	0.285	0.341	na.	na.	−0.021	0.807	na.	na.
> 75% C.U.F.[2]	0.361	0.238	na.	na.	0.066	0.899	na.	na.
> 75% D.U.F.[3]	−0.506***	0.077	na.	na.	0.085	0.373	na.	na.
> 75% I. Comm. T. Const.[4]	−0.558***	0.069	na.	na.	0.035	0.848	na.	na.
> 75% G.U.A.,S., L.F.[5]	−0.520***	0.083	na.	na.	0.080	0.706	na.	na.
Built-Envir. Perc.	−0.019	0.871	0.129	0.465	na.	na.	na.	na.
(Graffiti)								
(Cleaning)	0.052	0.711	0.153	0.502	na.	na.	na.	na.
(Lighting)	−0.160	0.239	−0.034	0.867	na.	na.	na.	na.
Crime exp.	0.159	0.310	0.172	0.513	na.	na.	na.	na.
(Own)								
(third-person)	−0.302	0.160	0.512	0.162	na.	na.	na.	na.
Safety Perc.	−0.056	0.154	0.328	0.173	na.	na.	na.	na.
(in the neighborhood)								
(aroundPT)	0.383**	0.014	0.711**	0.018	na.	na.	na.	na.

		M1 City -OS		**M2** City - LTS		**M3** County -OS		**M4** County –LTS	
		Estim.	Sig.	Estim.	Sig.	Estim.	Sig.	Estim.	Sig.
Temperature	< 0 °C	na.	na.	0.507***	0.068	na.	na.	0.085	0.683
	0–10	na.	na.	0.240	0.310	na.	na.	−0.161	0.381
	10.1–20	na.	na.	0.053	0.824	na.	na.	−0.085	0.642
	> 20	na.	na.	Ref. value		na.	na.	Ref. value	
Precipitation		na.	na.	−0.451*	0.005	na.	na.	−0.334*	0.007
Wind		na.	na.	0.053***	0.076	na.	na.	−0.010	0.653
Snow cover	0.1–10	na.	na.	−0.449***	0.078	na.	na.	−0.300	0.117
(in cm.)	10.1–20	na.	na.	0.216	0.353	na.	na.	−0.315**	0.046
	> 20	na.	na.	−0.525**	0.010	na.	na.	−0.240	0.117
	No snow	na.	na.	Ref. value		na.	na.	Ref. value	

(continued on next page)

Table 4 (*continued*)

	M1 City -OS		**M2** City - LTS		**M3** County -OS		**M4** County –LTS	
	Estim.	Sig.	Estim.	Sig.	Estim.	Sig.	Estim.	Sig.
Proximity (Comm.)	0.034	0.734	−0.065	0.582	−0.006	0.922	−0.040	0.648
(Metro)	−0.133	0.180	−0.119	0.462	0.350*	0.000	0.042	0.659
(Tram)	na.	na.	−0.093	0.755	na.	na.	0.222	0.376
Gen. Cost all destinations	0.366**	0.049	na.	na.	0.065***	0.059	na.	na.
To T-Cent. (access walk. time)	0.013	0.158	na.	na.	0.001	0.748	na.	na.
(initial waiting time)	−0.017	0.534	na.	na.	−0.002	0.497	na.	na.
(in-vehicle time)	0.005	0.601	na.	na.	0.002*	0.049	na.	na.
(transfer waiting time)	0.016	0.579	na.	na.	−0.007	0.105	na.	na.
(transfer walk. time)	0.015	0.322	na.	na.	0.012	0.189	na.	na.
(egress walk. time)	−0.018	0.824	na.	na.	0.269*	0.000	na.	na.
From O-D (access walk. time)	na.	na.	−0.004	0.555	na.	na.	−0.006	0.187
(initial waiting time)	na.	na.	−0.021	0.352	na.	na.	0.005	0.369
(in-vehicle time)	na.	na.	−0.002	0.406	na.	na.	−0.001	0.457
(transfer waiting time)	na.	na.	0.002	0.871	na.	na.	−0.001	0.795
(transfer walk. time)	na.	na.	−0.025	0.109	na.	na.	−0.003	0.799
(egress walk. time)	na.	na.	0.002	0.766	na.	na.	−0.007	0.107
Log- LL zero	8558.175		3182.01		18656.225		5511.744	
Log- LL final	8295.517		3092.15		17976.862		5447.893	
Nagelkerke Rsq	0.074		0.073		0.090		0.032	
N	3862		1293		8011		2146	

[1] Continuous and discontinuous urban fabric,
[2] Continuous urban fabric,
[3] Discontinous urban fabric,
[4] Industrial, commercial transport, mine dump and construct,
[5] Green urban areas, sport and leisure facilities.

et al. (2016) findings but in line with the fact that PT captives have higher levels of travel satisfaction (Abenoza et al., 2017). Land use classes when significant play a negative effect on overall travel satisfaction. With a similar strength, almost every single land use class negatively influences the traveler experience in the City. The exception is continuous urban fabric which is in practice a mixed-land use involving amongst other residential, commercial and recreational activities. In addition, areas with two land uses (2*25%) have a smaller but also negative impact on the overall travel experience. Non-perceptual built-environment characteristics have no significant effects in the County model.

All perceptual built-environment variables (graffiti removal, cleanliness and lighting conditions) are found to be insignificant. The same is true for previous victimization. Therefore whether travelers are concerned or not of becoming a victim of crime either in first person or for someone else (third-person) does not impact their travel satisfaction. The results of the safety perceptions variables are mixed. While it is observed that general safety perceptions of the neighborhood where one lives are found insignificant those related to the surroundings of the PT stops and stations are showed to positively impact on the overall and last trip satisfaction. So increasing safety feelings around PT facilities may raise travel satisfaction.

All weather characteristics (see Table 4 Cont.) are found to have a significant impact on the travel experience. In the City (M2) temperatures below freezing (< 0°C) are associated with higher travel satisfaction compared to the reference point (> 20 °C). A possible explanation to this is that travelers see PT as place to shelter from the cold while during summer (Swedish) heat-waves, without functioning air conditioning PT is more poorly perceived. Precipitation negatively impacts the travel experience in both City and County. Precipitation may hinder walking to and from the station and may also cause service delays due to an increase in traffic. Wind has a small but significant positive effect on the travel experience in the City model (M2). Finally, snow cover negatively impacts last trip satisfaction in both geographical areas. In the City new snow (0.1–10 cm) and large quantities of snow (> 20 cm) negatively influence travelers evaluations. In the County, only medium quantities of snow (10.1–20 cm) are found to have a negative impact. However, small and large quantities of snow are close to be significant and have similar effects in sign and strength.

In regard of accessibility measures, generalized cost to all other destinations positively correlates with overall travel satisfaction (M1 and M3). This may indicate that living in an accessible area, in terms of well linked with respect to other frequently visited areas, is valued by travelers and this positively reverts on higher overall travel satisfaction evaluations. Accessibility to T-Centralen (the most central hub in Stockholm PT network) shows that only longer in-vehicle and egress walking times positively impact the travel experience. These at first counterintuitive results may indicate that the very long in-vehicle times of County dwellers (50 min) may be well used for working or carrying out some other pleasurable activities. Average egress walking times to the centroid of the postcode area where T-centralen is located are shorter than 3 min. Such a negligible walking time experienced in a part of the City with buzzing streets and many activities may produce positive effects on walking. In turn, accessibility disaggregated measures for last trips O-Ds are found insignificant for the City and County models.

Overall, distance proximity to high capacity PT stops and stations (commuter, metro and tram) is found to be insignificant. Yet model results reveal that County travelers living close to metro stations report higher travel satisfaction than others (M3). These high appreciations towards the prime metropolitan PT mode might be explained by the fact that metro is highly appreciated in suburban environments. No evidence is found that having a good accessibility with regard to the last trip impacts in any way last trip satisfactions (M2 and M4).

5. Conclusions

This paper aims to examine the effect of weather, accessibility and built-environment characteristics on the travel experience, for both overall and last trips. Factors that are often disregarded in the travel satisfaction literature and that are believed to largely influence the first and last-mile of the door-to-door trip. This study fills a research gap in investigating all these factors by using, amongst other, a relatively large travel satisfaction survey from years 2009 to 2015 and by focusing on two geographical contexts, the City and County of Stockholm (Sweden).

5.1. Main findings and policy implications

The results of this study show that, in general, and concurrent with previous research (e.g. Beirão and Cabral, 2008; Mouwen, 2015) a large number of socio-demographic (i.e.gender, age) and travel characteristic variables (i.e. frequency of travel by PT and car) impact the travel experience.

Perceptual and non-perceptual built-environment variables are found to have a rather weak effect which is only present in the overall satisfaction model for the City. Nonetheless, safety feelings around PT stations/stops have an effect on the overall travel experience while safety feelings related to travelers' neighbourhood of residence have none. This, together with the fact that safety perceptions in the PT premises greatly influence the travel experience (Cats et al., 2015), suggests that travelers hold only those who are responsible for law enforcement in-and-around PT premises accountable rather than the local government. An alternative explanation is that the surrounding areas of the PT stations/stops are more criminogenic than other (Ceccato et al., 2013).

We found that weather conditions at the time of the start of the trip exert an impact on travel satisfaction. The cause for the positive impact of wind speed on travel satisfaction is unknown but might be related to its combined effect with other weather characteristics (i.e. high temperature with wind turns the temperature feel more pleasant). The negative impact that ground covered with snow has on the travel experience is clear in both geographical contexts and for any snow depth. This is true even when the effect that snow may generate the same day it falls on PT disruptions and on the walking conditions has not been specifically captured in this work. This result is consistent with the lower travel satisfaction for bus trips during winter time in Montreal (St-Louis et al., 2014). Possible explanations for the negative impact that precipitation (all models) and temperatures above 20 °C (City model) have on the travel experience include an increase in road traffic and a poor design of PT waiting infrastructure for the former, and, lower PT frequencies associated to summer time or a lack of in-vehicle air-conditioned for the latter.

Weather conditions lie of course outside stakeholders and planners control but the results presented here show that it may be possible to mitigate their impact. So transport planners and those in charge of designing PT stops and vehicles should address the weather issues found in this research by for example providing air-cool in the vehicles and providing a better shelter in PT stops and stations. Moreover, in future studies scholars should consider and control for weather characteristics in travel satisfaction related studies.

Accessibility results indicate that living in an area that is well-connected to all other areas, and in particular to the relevant ones, has a positive impact on the overall travel experience. This implies that living in highly accessible areas does not only have an effect on travel mode choice but also positively influences traveler's satisfaction. However, disaggregated accessibility measures (e.g. in-vehicle time) do not exhibit a significant effect, which suggests that improving only one aspect of accessibility would not significantly improve the overall travel experience.

A word of caution would be needed to interpret the results since self-selection has not been controled for. Self-selection may confound the impact that built-environment has on travel behavior. In other words, the characteristics of the environment where the traveler lives may have a lesser influence on travel behavior if travel attitudes and preferences are considered. In any case, even though self-selection issues should be taken into account when interpreting the impacts of built-environment characteristics, some studies (e.g. Handy et al., 2005) proved that built-environment alone exerts an influence on travel behavior.

This study aimed at capturing the differential impact that several factors have on two distinct geographical contexts, City and peri-urban and rural environment. Yet, the varying model specification of City and County models (ie. Non-inclusion of perceptual built-environment characteristics) calls for care when comparing the results of both geographical areas. The main findings show no relevant differences in terms of accessibility and perceptual built-environment and travel characteristics. County travelers, however, report higher travel satisfactions when no car is available at their household. This seems to be in line with Abenoza et al. (2017) and may indicate that in the County PT infrastructure and service are satisfying enough. Furthermore, peri-urban dwellers show positive appreciations towards living in areas located close to metro stations which highlights higher appreciations towards this, in essence, urban PT mode. In contrast, temperature and wind speed are found to be significant in the City models only. The latter may imply that sub-urban and rural travelers have a higher acceptance towards harsh weather phenomena than that of City travelers who expect to find shelter in PT. All in all, differences between County and City travelers are constrained to a few variables.

This study shows that, in general, from all three main factors studied, weather conditions have the largest and more cross-regional (City and County) effect on Overall and Last trip satisfactions. The effect of built-environment and accessibility and proximity characteristics is more limited and could not be tested in the selected geographical contexts. While the study of direct effects of these three factors was found to be superior to their combined effect (interaction terms), controlling for the simultaneous effect of the other explanatory factors is recommended in future studies.

5.2. Limitations and future studies

This study has a number of limitations. First, the limited effect of built-environment characteristics might be due to the differing size of the postcode areas which range from 0.007 sq. km. of the smallest to 205.79 sq km of the largest. This may cause travelers living in the smallest areas experimenting not only the characteristics of their postcode area but also the ones of the neighboring surrounding postcode areas. Given the smaller size of postcode areas belonging to the City we would assume that this issue has a larger impact on the City models.

Care should be taken when interpreting the results of the accessibility and proximity measures, especially for the County models. The assignment of the start of the trip to the centroid of the postcode areas together with the larger size of the postcode areas included in the County models may not capture well the impact of accessibility and proximity measures of travelers living on the edges of the postcode areas.

Important aspects such as PT disruptions, mood and subjective well-being variables are not considered in this work even though they are likely to mediate the effect of weather impact. In addition, the collection of travel evaluations during the last trip experience would help to avoid recall bias in future studies). As Eboli et al. (2018) did in their analysis of the spatial variation of service quality attributes, future studies may also investigate the same issue by using geo-statistics. This technique takes the geographical spatial component as the pivotal part of the analysis and would allow obtaining an enriching understanding of the travel experience. No claim is made in relation to the transferability of our findings to geographical contexts with very different climatic conditions such as tropical and dry climates.

In the meantime, while future studies address the above limitations this work provides with important policy implications that we can learn from. This is a relevant study for transit planners and transit-oriented developers since they can design neighborhoods and adapt transport infrastructure to the specific built-environment and weather characteristics that have been found to impact on the travel experience.

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