Satisfaction with Public Transport Trips

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Sammanfattning

Kontinuerlig urban tillväxt, miljöfrågor, konkurrens om begränsat utrymme, längre pendlingsavstånd samt behovet att främja rättvisa och jämlikhet i samhället är de primära orsakerna till varför förbättringar av kollektivtrafik (KT) är ett centralt område inom policyfrågor i många länder världen över.

Desk research identifierade ett antal viktiga frågor som tidigare studier hade försummat. Dessa kunskapsbrister innefattar utredningen av: (a) utvecklingen över tiden för faktorerna (serviceattribut) för resetillfredsställelse, (b) de viktigaste faktorerna för resetillfredsställelse för olika resenärssegment och färdsätt; (c) Den mest relevanta delen av från-dörr-till-dörr resor för olika typer av resekonfigurationer; (d) Påverkan av reseupplevelsen av väder-, tillgänglighets- och närhetsmått och stadsmiljöegenskaper för resans första och sista mil. (e) den [icke]-linjära och [a]-symmetriska karaktären av förhållandet mellan KT-serviceattribut och övergripande resetillfredsställelse för olika resenärer och färdlägen.

De fem artiklar som denna doktorsavhandling innehåller presenterar en mängd olika tillvägagångssätt och metoder som ämnar öka övergripande resetillfredsställelse med KT-tjänster och samtidigt fyller kunskapsluckorna som tidigare forskning har misslyckats adressera.

Artikel I undersöker faktorerna för KT-tillfredsställelse och deras utveckling över tid (2001-2013) baserat på den svenska kundnöjdhetsbarometern. Resultaten visar att: (a) Försämringen av övergripande tillfredsställelse med KT i Sverige de senaste åren drivs av en minskning av tillfredsställelse med kundgränssnitt och körtid. (b) Dessa två serviceaspekter samt drift påträffas som viktiga faktorerna för övergripande tillfredsställelse som användare konsekvent räknar bland de minst tillfredsställande.

Artikel II reducerar mångfalden av behov och prioriteringar hos svenska resenärer till fem distinkta multimodala resenärssegment. Med tanke på vikten av serviceattributen uppvisar dessa resenärssegment geografiska skillnader och mellan-grupper övergripande likheter. Ändå kan vissa märkbara skillnader observeras. Tjänsteattributens betydelsenivåer visar övergripande förändringar i värderingar och konsumtionsmål över tiden. De mer frekventa KT-användarsegmenten är mer nöjda över hela linjen och kännetecknas av en mer balanserad fördelning av attributbetydelse medan en av grupperna - lantliga motoristpendlare - är markant missnöjd med servicefunktionerna.

Artikel III syftar först och främst till att förstå hur resenärer kombinerar färddelars

tillfredsställelse i en övergripande utvärdering av sin resa och sedan undersöker den relativa vikten av tillfredsställelse med tillgång, huvud- och exklusionssegment för hela från-dörr-till-dörr-resan. Ett antal regler för både normativ och heuristisk tillfredsställelseaggregering testas för olika typer av resekonfigurationer. Resultaten visar att normativa regler bättre kan återge övergripande resetillfredsställelse än heuristiska regler, vilket indikerar att alla färddelar måste övervägas när man utvärderar den övergripande reseupplevelsen. Viktningsnöjdhet med enskilda färddelar med upplevd färddelsvaraktighet ger i synnerhet den bästa förutsägelsen för den totala resetillfredsställelsen, speciellt vid tillämpning av ett straff för varje väntetid på tre eller fyra gånger fordonstimmar eller gångtid.

Artikel IV undersöker vilken inverkan som stadsmiljö, tillgänglighet och väderkarakteristika från resans tillträdes- eller avstigningsstadium har på den övergripande reseupplevelsen. Detta görs i två geografiska sammanhang (urban/perifer-urban och landsbygd) och med modeller för de senaste och de övergripande resorna. Resultaten tyder på att perceptuella och icke-perceptuella variabler för stadsmiljön har en ganska svag effekt i övergripande tillfredsställelse. Känslor av säkerhet kring KT-stationer påverkar den övergripande reseupplevelsen, medan känslor av säkerhet relaterade till de resandes bostadsområde inte har någon.

Tillgänglighetsresultat visar att vara boende i ett område som är välknutet till alla andra områden, och särskilt för de mer attraktiva boendeområdena, har en positiv inverkan på den totala reseupplevelsen. De flesta av de testade väderförhållandena vid tidpunkten för resans start har en inverkan på resetillfredsställelsen.

Baserat på trefaktorteori klassificerar artikel V kvaliteten på serviceattributen angående deras inflytande (positivt, negativt eller båda) på den totala resetillfredsställelsen. Analysen är gjord för olika resenärssegment och färdsätt och presenteras i form av en serie tre-nivå cylindrar. För en allmän resa kan attribut som i huvudsak ger missnöje när de inte är välskötta vara personal och assistans och biljettillgänglighet (grundläggande faktor). Dessa följs av attribut som kan ge både tillfredsställelse och missnöje på ett liknande sätt och beroende på deras prestationsnivå (prestationsfaktor). Prestandatillstånd är relaterade till driftsaspekter (restid och drift) och säkerhetsuppfattning vid resande. Kvaliteten på serviceattribut som i huvudsak kan ge tillfredsställelse när de är välskötta är Nätverks- och ombordsförhållanden (spänningsfaktor). Antalet kvalitetsbetjäningsattribut som är klassade i samma trefaktorkategori är likartat bland resenärssegment och färdsätt. Ändå avslöjar det här arbetet viktiga skillnader mellan färdsätt och segment som tyder på att en "en storlek passar alla"-metod inte rekommenderas att användas.

Denna uppsättning av artiklar kan hjälpa myndigheter att bättre utvärdera och tillgodose resenärernas behov genom att stödja resursfördelningen och prioritera politiska åtgärder i den mest betydelsefulla delen av en från-dörr-till-dörr-resa.

Abstract

Continuous urban growth, environmental issues, competition for limited space, longer commuting distances as well as the need to promote equity and equality in society are the primary reasons that make the improvement of public transport (PT) services a key policy area in many countries across the globe. Travel satisfaction measures the perceived quality of the PT service and it is an important aspect that operators and PT authorities need to consider when improving the service offered.

Desk research identified a number of important issues that previous studies had neglected. These knowledge gaps include the investigation of: (a) the evolution over time of the determinants (service attributes) of travel satisfaction, (b) the main determinants of travel satisfaction for different traveler segments and travel modes; (c) the most relevant part of door-to-door trips for different types of trip configurations; (d) the impact on the travel experience of weather, accessibility and proximity measures and built-environment characteristics of the first mile of the trip; (e) the [non]linear and [a]symmetric nature of the relationship between PT service attributes and overall travel satisfaction for different travelers and travel modes.

The five papers included in this doctoral thesis present an array of approaches and methodologies aiming at increasing overall travel satisfaction with PT services while covering the knowledge gaps that previous research failed to address.

Paper I, investigates the determinants of PT satisfaction and their evolution over time (2001-2013). The results show that: a) *customer interface* and *operation*, and at a lesser extent *trip duration* are the quality of service attributes that need to be prioritized; b) while satisfaction, in general, remains rather constant, relative importance fluctuates year after year. However, the QoSAs remain in the same quadrant of the priority map and thus the determinants of travel satisfaction stay invariable.

Paper II, reduces the diversity of needs and priorities of Swedish travelers to 5 distinctive multi-modal travelers' segments. Considering the importance attached to service attributes, these travelers' segments exhibit geographical disparities and in between-groups overall similarity. Nevertheless, some noticeable differences can be observed. Service attributes' importance levels reveal overall changes in appreciations and consumption goals over time. The more frequent PT user segments are more satisfied across the board and are characterized by a more balanced distribution of attribute importance while one of the groups - rural motorist commuters - is markedly dissatisfied with the service operation attributes.

Paper III, first aims to understand how travelers combine trip legs' satisfactions into an overall evaluation of their trip, and then to investigate the relative importance of satisfaction with access, main and egress segments for the entire door-to-door travel experience. A number of both normative and heuristic satisfaction aggregation rules are tested for different types of trip configurations. The results show that normative rules can better reproduce overall travel satisfaction than heuristic rules, indicating that all trip legs need to be considered when evaluating the overall travel experience. In particular, weighting satisfaction with individual trip legs with perceived trip leg durations yield the best predictor of overall travel satisfaction, especially when applying a penalty for each waiting time of 3 or 4 times in- vehicle or walking time.

Paper IV, investigates the impact that built-environment, accessibility and weather characteristics from the access stage of the trip have on the overall travel experience. This is done in two geographical contexts (urban and peri-urban and rural) and with models regarding the last and the overall trips. The results indicate that perceptual and non-perceptual built-environment variables have a rather weak effect in the overall satisfaction. Safety feelings around PT stations/stops have an effect on the overall travel experience while safety feelings related to travelers' neighborhood of residence have none. Accessibility results indicate that living in an area that is well-connected to all other areas, and in particular to the attractive ones, has a positive impact on the overall travel experience. Most of the tested weather conditions at the time of the start of the trip exert an impact on travel satisfaction.

Based on the three-factor theory, Paper V classifies quality of service attributes regarding their influence (positive, negative or both) on overall travel satisfaction. The analysis is done for different traveler segments and travel modes and presented in the form of a series of three-level cubes. For a general travel, attributes that can mainly bring dissatisfaction when they are not well-provided are, *staff and assistance* and *ticket accessibility* (basic factor). These are followed by attributes that can provide both satisfaction and dissatisfaction in a similar way and depending on their performance level (performance factor). Performance attributes are related to operational aspects (*trip duration* and *operation*) and *safety* perceptions while traveling. Quality of service attributes that can mainly bring satisfaction when they are well provided are *network* and *on-board conditions* (exciting factor). Important differences are found in the attribute factor classification between travel modes and segments which indicates that a "one size fits all" approach is not recommendable to adopt.

This set of papers can help authorities to better evaluate and cater for travelers' needs by

supporting the allocation of resources and prioritizing policy measures in the most impactful part of the door-to-door trip and to the most important factors.

Resumen

El rápido crecimiento urbano, problemas medioambientales, la competencia por el uso de espacios cada vez más limitados, el aumento de la distancia en los viajes pendulares así como la necesidad de fomentar una sociedad más equitativa e igualitaria, son algunas de las principales razones que hacen de la mejora de los servicios de transporte público (TP) una política clave en muchos países alrededor del mundo. La satisfacción con el viaje mide la calidad percibida con el servicio de TP y por lo tanto es un elemento importante que los operadores y autoridades de TP necesitan considerar para mejorar el servicio.

Tras una investigación documental se identifican un número de cuestiones que no han sido consideradas suficientemente en estudios previos. Estas lagunas de conocimientos incluyen la investigación de: (a) la evolución temporal de los determinantes (atributos del servicio) de la satisfacción con el viaje; (b) los principales determinantes de satisfacción para diferentes tipos de usuarios y modos de transporte; (c) la importancia que otras etapas del viaje (acceso y egreso), diferentes a la principal, pueden ejercer sobre la valoración global del viaje; (d) el efecto que tienen sobre la experiencia del viaje las condiciones meteorológicas, medidas de proximidad y accesibilidad, y características del entorno construido de la primera milla; (e) la naturaleza [no]lineal y [a]simétrica de la relación entre los atributos del servicio de TP y la satisfacción global con el viaje para distintos viajeros y modos de transporte.

Los cinco artículos incluidos en esta tesis doctoral presentan una variedad de enfoques y métodos que tienen como objetivo incrementar la satisfacción global con los servicios de TP, a la par de cubrir cuestiones importantes que no han abordado estudios previos.

El primer artículo, estudia los determinantes de la satisfacción con el TP y su evolución temporal (2001-2013). El artículo muestra que: a) el modo en el que la agencia de TP gestiona las quejas y el trato con los usuarios (*customer interface*), la frecuencia y fiabilidad del servicio (*operation*) y, en menor medida, la duración del viaje (*trip duration*) son los atributos del servicio que deben priorizarse; b) en general, la satisfacción con los atributos del servicio no varían a lo largo del tiempo, lo que varía es la importancia que los viajeros confieren a los atributos del servicio. Sin embargo, la alteración temporal de la importancia no es suficiente para modificar la lista de atributos a priorizar.

El segundo artículo, se basa en las características de tipo socio-económico, de las del viaje y en coeficientes de accesibilidad para reducir la diversidad de necesidades y prioridades de los viajeros en Suecia. Se obtienen cinco grupos de viajeros que exhiben disparidades en su distribución geográfica y semejanzas en cuanto a la importancia que confieren a los atributos del

servicio. Sin embargo, también existen diferencias notorias entre los grupos de viajeros. Por ejemplo, los grupos de viajeros que viajan más frecuentemente con TP se muestran, generalmente, más satisfechos con el viaje y manifiestan una distribución más equilibrada de la importancia conferida a los atributos del servicio. Por último, el análisis temporal de la importancia de los atributos del servicio revela cambios que demuestran variaciones generales en las apreciaciones y objetivos de consumo del viajero.

El tercer artículo investiga como combinan los viajeros la satisfacción con cada una de las etapas del viaje, para generar su valoración global del viaje. Además, el artículo investiga la importancia relativa que cada una de las tres etapas del viaje (acceso, principal y egreso) tienen sobre la experiencia de un viaje completo, puerta a puerta. Con ese fin, se examina la calidad con la que modelos que utilizan normas heurísticas y normativas agregan la satisfacción con cada una de las etapas del viaje. Los resultados muestran que, en comparación con las reglas heurísticas, las reglas normativas pueden reproducir de una mejor manera la satisfacción global con el viaje; indicando que todas las etapas del viaje tienen su importancia cuando se evalúa la experiencia global del viaje. Sin embargo, la etapa principal seguida, a distancia, por el acceso se alzan como las etapas más relevantes del viaje, independientemente de la configuración del viaje estudiada. Otros resultados de este estudio muestran como los viajeros aplican una penalización por cada minuto de espera equivalente a 3 o 4 veces de tiempo en movimiento y/o caminando.

El cuarto artículo investiga el impacto que (i) las características subjetivas y objetivas del entorno construido, (ii) las medidas de accesibilidad y proximidad, y (iii) las condiciones meteorológicas de la primera milla del viaje (acceso), tienen sobre la satisfacción con el viaje. El estudio se realiza en dos contextos geográficos diferenciados (urbano y periurbano y rural) y utilizando modelos relativos a un viaje global (*overall travel*) y al último viaje realizado (*last trip*). Los resultados indican que las variables del entorno construido tienen un débil efecto sobre la satisfacción global del viaje. La sensación de seguridad alrededor de las paradas y estaciones de TP ejerce un efecto positivo sobre la satisfacción global y con el último viaje. En cambio, el sentirse seguro en el barrio en el que el viajero reside no tiene ningún efecto significativo. Los resultados relativos a la accesibilidad demuestran que residir en una zona que está bien comunicada con TP, tienen un impacto positivo en la satisfacción global. Por último, la mayoría de las condiciones meteorológicas estudiadas que tienen lugar al comenzar el viaje impactan en la experiencia del viajero.

El quinto artículo, se basa en la teoría de los tres factores (*three-factor theory*) para clasificar los atributos del servicio en relación al tipo de influencia que ejercen (positiva, negativa o ambos)

sobre la satisfacción global del viaje. El análisis se realiza para distintos segmentos de viajeros y modos de viaje, y se presenta en una serie de cubos de tres niveles. Para un viajero general, los atributos del servicio que principalmente pueden producir insatisfacción cuando no se proveen correctamente son, la amabilidad del personal y de los conductores (*staff and assistance*) y la accesibilidad y facilidad para adquirir billetes (*ticket accessibility*). A continuación existen atributos del servicio que dependiendo de lo bien o mal que sean provistos pueden producir satisfacción o insatisfacción (factor *performance*) en la satisfacción global del viaje. Los atributos *performance* están relacionados con aspectos operacionales del servicio, duración y operación (*trip duration* y *operation*) y con las percepciones de seguridad cuando uno viaja. Los atributos del servicio que pueden principalmente producir satisfacción global con el viaje cuando se proveen bien son la idoneidad de la red de TP para las necesidades del viajero (*network*) y las condiciones abordo (*on-board conditions*), Factor *exciting*. El número de atributos que se clasifican en el mismo factor difiere entre segmentos de viajeros y modos de viaje, lo cual demuestra que no es recomendable adoptar una única solución para todos los viajeros.

Éste conjunto de artículos pretende ayudar a los operadores y autoridades de Transporte Público pertinentes a proveer de la mejor manera posible las necesidades de los viajeros mediante la priorización de medidas y asignación de recursos a los elementos más importantes y a la parte más relevante del viaje multimodal puerta a puerta.

Included papers

I. Cats, O., Abenoza, R., Liu, C. and Susilo, Y. Evolution of Satisfaction with Public Transport and Its Determinants in Sweden: Identifying Priority Areas. (2015) *Transportation Research Record: Journal of the Transportation Research Board,* No. 2538, Transportation Research Board of the National Academies, Washington, D.C., pp. 86-95.

Presented at National Conference in Transport Research, Norrköping, Sweden, October 21-22nd 2014.

Presented at Transport Forum, Linköping, Sweden, January 8-9th 2015

II. Abenoza R.F., Cats O. and Susilo Y.O. (2017) Travel satisfaction with public transport: determinants, user classes, regional disparities and their evolution. *Transportation Research Part A: Policy and Practice*. Vol. 95, pp. 64-84.

Presented at the National Conference in Transport Research, Karlstad, Sweden, October 21-22nd 2015.

III. Abenoza R.F., Cats O. and Susilo Y.O. (2018) How does travel satisfaction sum up? Decomposing the door-to-door experience for multimodal trips**.** *Transportation*. pp. 1-28.

Presented at the National Conference in Transport Research, Lund, Sweden, October 18 - 19th 2016.

Presented at NECTAR Conference, Madrid, Spain, May 31st - June 2nd 2017

IV. Abenoza, R.F., Liu, C., Cats, O. and Susilo, Y.O. (2019) What is the role of weather, built-environment and accessibility geographical characteristics in influencing travelers' experience? *Transportation Research Part A: Policy and Practice.* Under review.

Presented at CIT Conference, Gijón, Spain, Juner 6th – 8th 2018.

Presented at hEART Conference, Athens, Greece, September 8-9th 2018.

V. Abenoza R.F., Cats O. and Susilo Y.O. (2019) Investigating the nature of Public Transport service attributes. Submitted to *Transportation Science*. Under review.

Presented at National Conference in Transport Research, Gothemburg, Sweden, October 15th - 16th 2018.

Presented at Persontrafik Public Transport Fair, Stockholm, Sweden, October 23th 2018.

Other related papers (not included in the thesis)

- Susilo, Y.O., Abenoza, R.F., Woodcock, A., Liotopoulos, F., Duarte, A., Osmond, J., Georgiadis, A., Hrin, G.R., Bellver, P., Fornari, F., Tolio, V., O'Connell, E., Markuceviciute, I., and Diana, M. (2015) Findings from measuring door-to-door travellers' travel satisfaction with traditional and smartphone app survey methods in eight European cities. *European Journal of Transport and Infrastructure Research*. Vol. 17, no 3, pp. 384-410.

- Susilo, Y.O., Woodcock, A., Liotopoulos, F., Duarte, A., Osmond, J., Abenoza, R.F., Anghel, L.E., Herrero, D., Fornari, F., Tolio, V., O'Connell, E., Markuceviciute, I., Kritharioti, C. and Pirra, M. (2016) Deploying traditional and smartphone app survey methods in measuring door-to-door travel satisfaction in eight European cities. *Transportation Research Procedia.* Vol. 25, pp. 2257-2275.

- Ettema, D.F., Abenoza R.F. and Susilo, Y.O. (2016) Satisfaction with intermodal trips in Stockholm: How do service attributes influence satisfaction with the main mode and with the journey as a whole?, The 95th Annual Meeting of Transportation Research Board, Washington DC, USA.

- Susilo, Y.O. and Abenoza, R.F. Chapter 7: Implementing various different tools to measure door-to-door travel satisfaction. In: Tovey, M., Woodcock, A. and Osmond, J. (2016) Designing Mobility and Transport Services: Developing traveller experience tools. Abingdon, Oxon: Routledge ed.

- Susilo, Y.O. and Abenoza, R.F. Chapter 9: METPEX trial results: investigating different key determinants of travel satisfaction for different groups of travelers. In: Tovey, M., Woodcock, A. and Osmond, J. (2016) Designing Mobility and Transport Services: Developing traveller experience tools. Abingdon, Oxon: Routledge ed.

- Abenoza, R.F., Ettema, D. and Susilo, Y.O. (2018) Do accessibility, vulnerability, opportunity, and travel characteristics have uniform impacts on traveler experience? *Transportation Research Part A, Special issue in New trends in analyzing and modelling public transport quality of service.* Vol. 114, pp. 38-51.

- Abenoza, R.F., Ceccato, V., Susilo, Y.O. and Cats, O. (2018) Individual, travel and bus stop characteristics influencing travelers' safety perceptions. *Transportation Research Record.* pp. 1-10.

- Abenoza, R.F., Romero, J.R., Cats, O. and Susilo, Y.O. Chapter 15: User experiences and perceptions of women-only transport services in Mexico. In: Uteng, T.P, Levin, L. and Christensen H.R. (2019) Gendering smart mobilities. Abingdon, Oxon: Routledge ed.

Declaration of contribution

I. In paper I, Roberto F. Abenoza was responsible in performing the large majority of the analyses; in the preparation of figures, tables and maps, in writing the first draft of chapter 4, and in revising the paper and providing comments. Oded Cats wrote the first draft of the remaining sections of the paper and revised the paper. Chengxi Liu calculated the marginal effects. Abenoza. Yusak O. Susilo revised the paper and provided comments.

II. In paper II, Roberto F. Abenoza was responsible for the majority of the work in all of it stages. Chengxi Liu calculated the marginal effects. Oded Cats improved the readability of the writing, revised the paper and provided comments. Yusak O. Susilo revised the paper and provided comments.

III. In paper III, Roberto F. Abenoza was responsible for the majority of the work in all of it stages. Oded Cats improved the readability of the writing, revised the paper and provided comments. Yusak O. Susilo revised the paper and provided comments.

IV. In paper IV, Roberto F. Abenoza was responsible for the majority of the work in all of it stages. Chengxi Liu calculated the accessibility measures in TransCad. Oded Cats improved the readability of the writing, revised the paper and provided comments. Yusak O. Susilo revised the paper and provided comments.

V. In paper V, Roberto F. Abenoza was responsible for the majority of the work in all of it stages. Oded Cats improved the readability of the writing, revised the paper and provided comments Yusak O. Susilo came up with the idea of the paper, revised it and provided comments.

Contents

1. Introduction

People need to move from one place to another to carry out a wide range of activities including compulsory and non-compulsory activities such as working, studying, doing the grocery, meeting friends and family or performing some leisure.

The need to travel, in conjunction with continuous urban and population growth and increasing travel distances, may entail a large pressure on the transport infrastructure which, if inappropriately handled, may constrain local and regional economies. For example, estimates indicate that congestion problems are a sheer economic burden worldwide representing a 2% of the GDP in Europe and a 2-5% in Asia (MSTfD, 2014). Moreover, air pollution costs, due to illness and premature deaths, are estimated to be 3.5 trillion US $ annually in the 35 OECD countries plus China and India (MSTfD, 2014). Furthermore, in developed societies, there is a growing need to achieve a healthier lifestyle, where active modes such as walking and cycling are the best exponent. Frequently, active modes are a component of multi-modal Public Transport (PT) trips, and thus PT trips involve a higher physical activity than private motorized modes. An additional concern in today's world is road safety. Here again, PT modes cause considerably fewer fatalities per billion kilometers traveled than that caused by private motorized and active modes (Savage, 2013). Moreover, PT has the potential to be socially equalitarian since it can provide transport for all and thus it does not exclude the young, the elderly, students, low income and disabled travelers from traveling (Holmgren, 2007).

To this extent, keeping and increasing PT ridership has become a priority at different geographical levels. At a global scale, in 2014, the United Nations established that sustainable transport is one of the fundamental pillars to accomplish the goals set in their 2030 agenda for sustainable development. This agenda consists of 17 sustainable development goals which are directly or indirectly related to sustainable transport via targets and indicators. Some of the recommended measures to achieve sustainable transport are connected with promoting and improving PT. At an international level, in 2009, the International Association of Public Transport (UITP) set the goal of doubling the market share of PT worldwide by 2025. UITP's high ambitious goal would mean to almost double 2012 PT shares of the developed (39%) and developing cities (23%). At a continental scale, in 2011, the EU set out a White Paper with a more realistic goal of doubling PT use in urban areas by 2030. Finally, a national effort, "the Swedish doubling project", aims to double 2006 Swedish PT market share (18%) by 2020 proving the importance given to PT.

There is a rather consensus that an increase in overall travel satisfaction leads to an increase in customer loyalty (e.g. Minser and Webb, 2010; Chou et al., 2014) which can result in customer retention and ridership increase (e.g. Cervero, 2000; Syed and Khan, 2000). Maintaining and increasing PT ridership might be thus attained by means of offering a PT service that fulfills travelers' needs, and that also is affordable and accessible. The provision of a (more) satisfactory PT service from travelers' perspective usually comes with expensive investments that are made with public funds. Given the limited economic resources available for improvements, it would be therefore essential to identify the factors that positively influence the travel experience.

This study connects with previous research investigating the factors (service attributes, trip elements and trip stages) that increase overall travel satisfaction and expands its focus by studying differently related and interconnected aspects that previous research has widely overlooked.

The identified knowledge gaps include the investigation of:

(a) the evolution over time of the determinants (service attributes) of travel satisfaction;

(b) the main determinants of travel satisfaction for different traveler segments and travel modes;

(c) the most relevant part of door-to-door trips for different types of trip configurations;

(d) the impact on the travel experience of weather, accessibility and proximity measures and built-environment characteristics of the first mile of the trip;

(e) the [non]linear and [a]symmetric nature of the relationship between PT service attributes and overall travel satisfaction for different travelers and travel modes.

This thesis first identifies the main determinants of travel satisfaction by means of Importance-Performance analysis (Paper I). This paper continues by setting priorities areas and by investigating the stability over time of the results. Paper II classifies Swedish travelers into distinctive multi-modal segments and then investigates their determinants of travel satisfaction without forgetting the temporal component and the analysis of geographical dissimilarities. Paper III, explores whether generally overlooked parts of the door-to-door trip (access and egress legs) influence overall satisfaction and thus whether they are of relevance to improving travelers' experience. The investigation is done for different trip configurations which are classified in regard of their purpose, presence of transfers, trip complexity

and their travel modes. Paper IV, examines the effect of weather, accessibility, proximity and built-environment characteristics on overall travel experience as well as the experience with the latest trip. This is done for urban and peri-urban and rural environments. Paper V, classifies PT service attributes based on their influence (linear or non-linear and symmetric or asymmetric) on overall traveler satisfaction. This is done for different traveler segments and travel modes. The results are presented in multi-level cubes that represent different essentiality of needs.

This doctoral summary consists of seven sections. Section 1, introduction, presented a general background to the topic, mentioned the main thesis's objective and the research gaps and presented the importance of the research in this doctoral thesis. A literature review of the state-of-the-art research in travel satisfaction with PT services is provided in Section 2. This is followed by an in-depth presentation of both; the general and the paper-specific objectives of this thesis, Section 3. Data and methods are included in the following section, Section 4. Section 5, research contribution, contains the main results of the five articles. Section 6 discusses the more remarkable aspects, interrelate the articles, and proposes future research. The collection of articles included in this thesis are appended at the end.

2. Previous Research

2.1. Theoretical models on customer satisfaction

This thesis is mainly based on human perceptions. Perceptions related to how satisfied a traveler is with their PT trip. Perceptions of satisfaction towards a particular service (experience or product) are formed in what Oliver (1997) defined as a "black box". The "black box" is nothing more than a mental process, which processes and evaluates the experience based on many aspects such as the objective performance of the service under evaluation and previous expectations, and yields a satisfaction judgment.

A number of theories have explained what matters in this mental process. One of the most prominent theories is the expectancy-disconfirmation theory (Oliver, 1977) which postulates that travelers' satisfaction is a function of expectations with the service and the perceived performance of the service. As displayed in Figure 1, the contrast between expectations and perceived performance of the service results in either confirmation or disconfirmation. Confirmation matches expectations and brings neutral or satisfying results. Positive disconfirmation emerges when perceptions of the service exceed expectations while this is the opposite for negative disconfirmation.
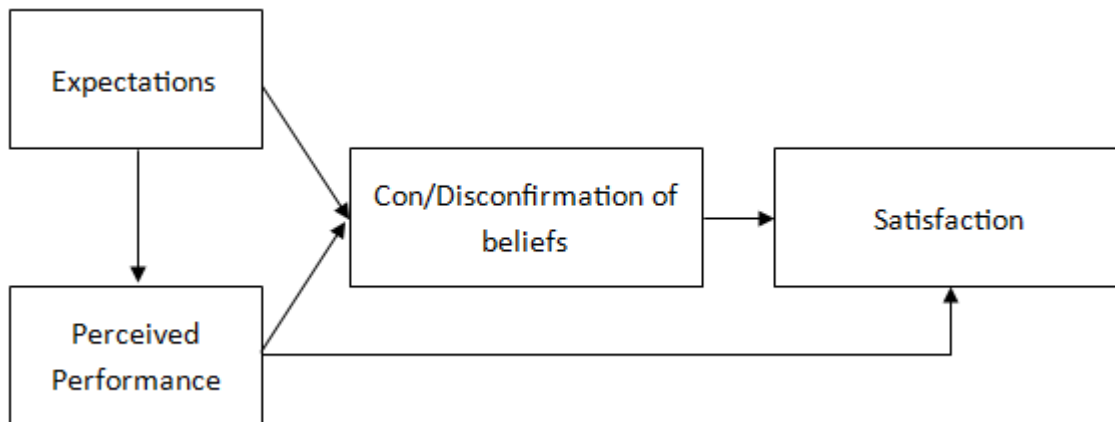
Figure 1. Expectation-disconfirmation theory

A modification of the comparison level theory (La Tour and Peat, 1979) posits that the expectation-disconfirmation theory disregards other sources of expectations. The comparison level theory postulates that other elements serve as reference levels of comparison. These elements are: (a) customer's previous experiences with the service, (b) the image of the company offering the service, and (c) other people's experience.

Importance-performance model (Martilla and James, 1977) conceptualizes customer satisfaction as an

outcome resulting from the contrast of attribute performance and the importance attached to it. Barsky (1992) argued that the overall level of (dis)satisfaction toward a service is determined by the importance given to attribute service characteristics and how they are perceived to be provided.

Satisfaction gap theory (Parasuraman et al., 1985; Zeithaml et al., 1990) explains the factors affecting service quality based on a series of gaps between marketer (provider) and customer (traveler). The existing gaps are given: between customer expectations and marketer perceptions about these expectations (Gap 1); between management perceptions of customers' expectations and service quality specifications (Gap 2); between service quality specifications and service delivery (Gap 3); between service delivery and external communications to customers about the service delivery (Gap 4) and, between customer's expectations and their perceptions on service quality (Gap 5). In addition, this model identifies word of mouth, personal needs and past experience as elements that influence the expected service.
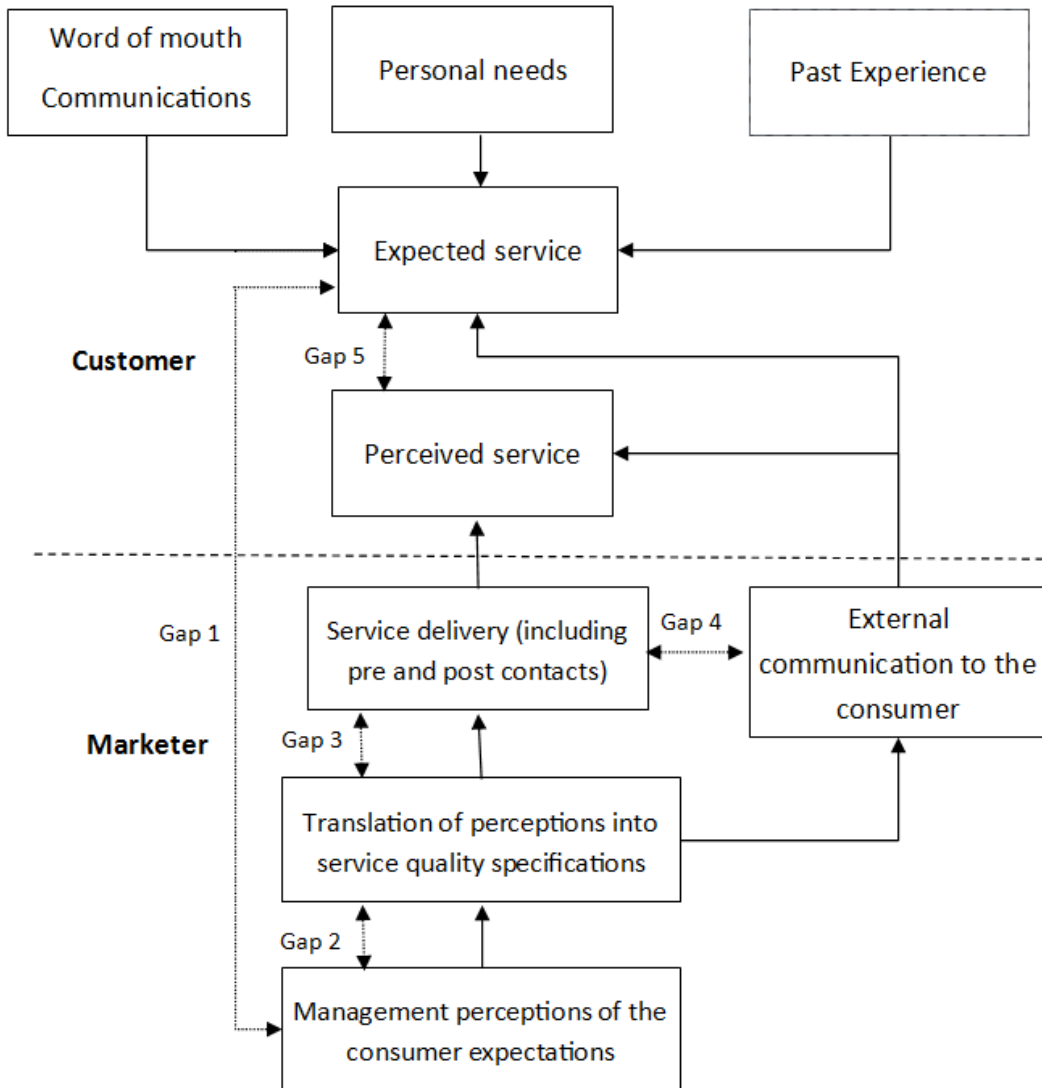
Figure 2. Quality service model (own from Parasuraman et al., 1985)

Other authors also provided with definitions of customer satisfaction. Hensher et al. (2003) argued that although travelers may perceive specific aspects of service quality as either positive or negative, it can be assumed that the overall level of travel satisfaction is best measured by how an individual evaluates the total package of services offered. Customer satisfaction was also defined by Tyrinopoulos and Antoniou (2008) as the overall level of fulfillment with customers' expectations and as the outcome of cumulative and single-experience encounters.

The European Customer Satisfaction Index - ECSI conceptual model best summarizes a large amount of aspects that influence overall travel satisfaction. Figure 3, displays a series of components (drivers of satisfaction) that influence and explain customer satisfaction. These components include:

1) Image: linked with customers' perception of the company running the service, but also to the perception of the whole PT service or of the one particular mode. Mass-media and hearsay may influence this component.

2) Customer expectations: related to the fore-judgment of the service made by the customer and in part based on their prior experiences.

3) Perceived quality of product: it entails the quality of the product itself (i.e. frequency).

4) Perceived quality of the service: it involves services that are provided around the product (i.e. customer service and travel guarantee).

5) Price-quality relationship: It is a function of the expectations placed in the product and its quality.

PT service use, reflected through the optic of the customer satisfaction index, will result in either satisfaction or dissatisfaction with the overall travel experience. Travel satisfaction may lead to customer retention, the recommendation of the service and greater price elasticity. On the other hand, travel dissatisfaction may result in losing customers, discouragement of use and less price tolerance.

Figure 3. Personal adaptation of ECSI customer satisfaction model
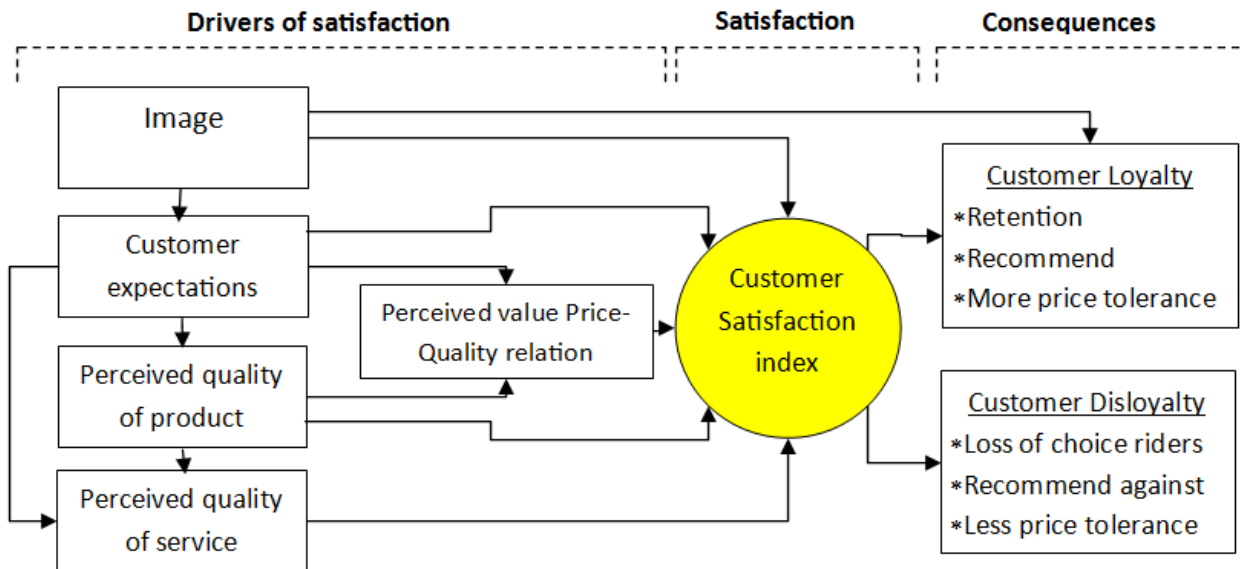
As seen in Figure 3, customer loyalty is considered a product of customer satisfaction and can be defined as customer attitude encompassing repurchase and recommendation intentions (e.g. Zeithaml et al, 1996). Previous empirical studies carried out in different industries proved that customer satisfaction positively influences customer loyalty (Lai and Chen, 2011).

2.2. Three-factor theory

Three-factor theory postulates that QoSA impact on overall travel satisfaction very differently depending on their performance level, and thus relaxing the assumption of the Importance-Performance analysis. While the three-factor theory is based on Kano's model (1984) it reduces the number of factors from five to three and can employ conventional customer satisfaction surveys. The three factors have been defined by authors Matzler et al. (2003) and Busacca and Padula (2005) as follows:

a) Basic factor: when attributes belonging to this category are well delivered, they do not positively influence overall satisfaction, yet when delivered poorly they induce dissatisfaction. They are basic and expected attributes that all service should provide adequately. Their relationship with overall satisfaction is asymmetric and non-linear.

b) Performance factor: this category of attributes can contribute to both satisfaction and dissatisfaction depending on whether their performance is high or low, respectively. They have a linear and symmetric relationship with overall travel satisfaction.

c) Exciting factor: This category is the reverse of the basic factor. Attributes belonging to this category are unexpected attributes that can only bring joy and satisfaction with the service. Their relationship with overall satisfaction is asymmetric and non-linear.
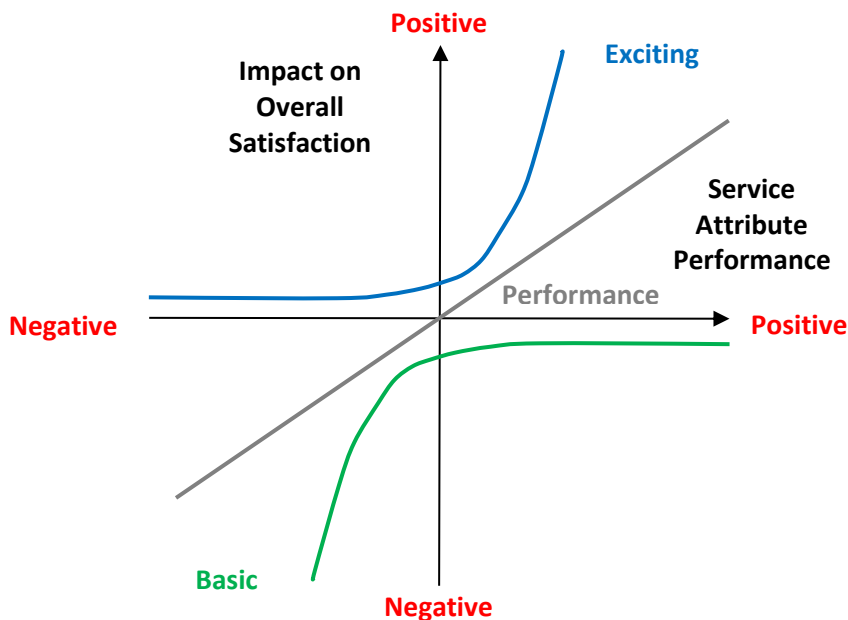

Figure 1. Kano's three factors (own adaptation)

Hitherto, only three studies in the transport field have relaxed the assumptions of linearity and symmetry (Zhang et al., 2017; Cao and Cao, 2017; Wu et al., 2018). However, these studies entail a number of limitations such as the use of relatively small sample sizes per travel mode (Cao and Cao 2017, Wu et al. 2018) and their inability to control for the impact of socio-demographic attributes, travel characteristics and seasonal variations.

2.3. Customer satisfaction surveys and their variables

Measuring perceived service quality in PT is commonly done by means of customer satisfaction surveys. Customer satisfaction surveys can be collected retrospectively or in real-time; can be carried out in different environments (i.e. on-board, at station, on the phone) and through different methods (i.e. web-online, paper and pencil, smartphone apps, focus groups). Customer satisfaction surveys generally consist of questions related to the satisfaction, and importance, with overall (or last trip) travel satisfaction and with specific quality of service attributes, price and other aspects not related to the main trip stage. "Overall" refers to an average trip while "last" refers to the last trip undertaken. Surveys also include instrumental and non-instrumental variables such as socio-demographic, travel characteristics and travel attitudes.

2.3.1. Quality of service attributes (QoSA)

Quality of Service Attributes (QoSAs), refer to a set of instrumental measures which characterize and describe the perceived quality of the PT service. However, some of these service aspects are expected to be more important than others. The importance attached to various QoSAs can be measured using stated preference surveys (which ask people how much they value a particular feature) and revealed preference studies (which evaluate the choices people make when facing trade-offs between various attributes). In addition, QoSA´s importance can be obtained directly or be derived through a large number of statistical methods (De Oña and De Oña, 2014). However, many studies have shown (e.g. Gustafsson and Johnson, 2004) that direct or explicit QoSAs' importance ratings are poor at determining the most relevant service attributes in a model. In this thesis, therefore, the importance that all the investigated factors (QoSAs, trip elements and trip stages) have on the travel experience are derived through statistical analyses.

The set of QoSAs employed in previous travel satisfaction studies varied regarding the goal of the study and the targeted travel mode. Service attributes can be broadly classified into operational, comfort,

information and infrastructure related. A better categorization of QoSAs was, however, provided by the European Committee for Standardization (CEN, 2002). Their standardized norm, EN 13816:2002, contains a catalog of 8 quality criteria: availability, accessibility, information, time, customer care, comfort, security and environmental impact. Each of the quality criteria is composed of a series of general QoSAs which include, in turn, a number of more specific QoSA. For instance, the general QoSA *customer interface*, includes satisfaction with how inquiries are handled and with how complaints are handled.

A large number of studies have investigated the importance of QoSA on the travel experience (e.g. Eboli and Mazzulla, 2013). Brons et al. (2009) argued that functional attributes (e.g. *frequency*, *reliability*) are the QoSAs that influence the most overall satisfaction. Stradling et al. (2007) found that *ticketing arrangements*, *safety, information* and *cleanliness* were to be prioritized. Moreover, Weinstein (2000) added to Stradling's list *accessibility*, *on-board design* and *ride comfort*. Other scholars (e.g. Hernandez et al., 2016; Eboli and Mazzula, 2013), however, found that information related attributes (pre, on-route and on-board information) and the design of station and interchange points were key determinants of satisfaction. In addition, Iseki and Taylor (2009) found that it was much more relevant to reduce waiting times and to improve service *reliability* than dealing with infrastructure issues.

All in all, the set of key QoSA that influence the travel experience remains unclear and deserves further exploration.

2.3.2. Socio-demographic characteristics

Socio-demographic characteristics such as gender, age, level of education, and income are believed to influence both, the overall trip evaluation and the relative importance of QoSA. The effect of gender on travel satisfaction was, depending on the work, found significant (e.g. Beirao and Cabral, 2008) or insignificant (e.g. Ettema et al., 2012). Furthermore, the younger (Mouwen, 2015) and the elderly (Van´t Hart, 2012) were found to report higher overall travel satisfactions than other age groups. In addition, low income was found to be correlated with lower levels of travel satisfaction (Dong et al., 2016).

Dell'Ollio et al. (2011) found that socio-demographic variables impact on QoSA such as the higher importance for the elderly of *ride comfort*. Women were found to feel less *secure* and give more relevance to information (Yavuz and Welch, 2010) while *cleanliness of the vehicle* was more relevant for high income and infrequent travelers (Dell'Olio et al., 2011).

2.3.3. Travel characteristics

According to the literature, travel characteristics such as travel mode used, trip purpose, trip duration or frequency of PT use, influence the overall evaluation of the trip and travelers' needs. It is still inconclusive whether frequency of travel by PT has a positive (Woldeamanuel and Cyganski, 2011) or negative effect (Susilo and Cats, 2014) on the travel experience. Moreover, trips that are longer in duration and distance were reported to negatively influence the overall level of travel satisfaction (e.g. Ory and Mokhtarian, 2005). In addition, two studies based on data from North-America found that travelers with no access to a private car, and thus PT captives, reported lower levels of travel satisfaction. However, the impact of PT captivity is unknown in geographical contexts where there is a better PT provision (i.e. European cities).

The travel mode used largely influences the overall trip evaluation. Trips made by soft modes (walking and cycling), as the main mode, have consistently been found (e.g. Paez and Whalen, 2010) to obtain higher overall evaluations than those made by car, and much higher than those made by PT. Yet, all PT modes are not equally regarded. Some studies indicate that bus travelers are the most satisfied (e.g. Bordagaray et al., 2014) while others demonstrate that rail and light rail travelers are the ones with the highest travel evaluations (Ory and Mokhtarian, 2005; Beirao and Cabral, 2007). Some other authors (i.e. Mouwen, 2015) also demonstrated that travelers using different travel modes have distinct needs. For instance, compared to bus travelers, metro and train travelers attached higher importance to *on-board information*, *driver's behavior* and *on-time performance*.

All in all, previous results show that socio-demographic and travel characteristics are important aspects that, when possible, need to be either studied separately or controlled for in satisfaction related studies.

2.3.4. Other influencing factors

<u>Built-environment</u>

Perceptual and non-perceptual built-environment characteristics may also influence the traveler experience. 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 walking and cycling (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 effect of perceptual built-environment

characteristics such as crime perceptions. For instance, 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 prominent factors influencing driving and walking.

On the whole, the influence of built-environment characteristics has been proved on mode choice but not yet on the travel satisfaction evaluation.

<u>Weather</u>

There is growing evidence that proves the influence of weather characteristics (i.e. temperature, snow, rain) on travel behavior (e.g. Saneinejad et al., 2012). Most of the previous studies focused on the impact of weather conditions on travel mode choice and the relationship with PT ridership (e.g. Tao et al., 2018). Very little attention has thus been given to their impact on travel satisfaction. St-Louis et al. (2014) studied the seasonal impact of weather on different travel modes and found that cold and snowy winters exert a negative effect on travel satisfaction of mainly active modes but also bus. Ettema et al. (2017) revealed that any form of precipitation positively impacts travel satisfaction evaluations and that wind speed over 4 m/s has a positive effect on activation for PT trips. These two studies, however, considered only commuter trips, studied two seasons (Ettema et al., 2017) and trips made to the same destination (St-Louis et al., 2014). It is thus clear that the impact of weather on travel satisfaction has not been fully covered in depth by previous studies.

<u>Accessibility</u>

We hypothesize that distance proximity to PT stops/stations and accessibility generalized costs from origin to destination would impact the travel experience. To date, the impact of distance proximity has mainly been studied on mode choice and use (i.e. Rietveld, 2000) while its impact on satisfaction has been neglected. The exception to this was Brons et al. (2009) who studied the importance of accessibility in assessing the overall travel satisfaction. Their results demonstrated that their measures of accessibility (e.g. distance to PT, travel times by PT) to train stations only marginally affected overall travel satisfaction.

The factors influencing the travel experience are not limited to the ones exposed in this section. Ettema et al. (2010), for instance, hypothesized that overall travel satisfaction is related to social well-being and thus since well-being is larger for the younger and elderly these groups would have higher travel

satisfaction. Moreover, travel attitudes and preferences towards the environment, life and travel modes have also been found to be impactful. For example, for commuter travel attitudes were found to impact their travel satisfaction directly and their mode choice indirectly (Ye and Titheridge, 2017).

2.4. Travelers' Segmentation

A-priori and post hoc market segmentation techniques help in investigating the heterogeneity in travelers' evaluations of PT services. Previous studies have employed as segmenting variables: travel habits and preferences (Krizek and El-Geneidy, 2007), socio-demographic and trip characteristics (e.g. Bhat, 1997; De Oña et al., 2014), travel attitudes and socio-demographics (Shiftan et al., 2008), trip characteristics, satisfaction and trip practicality (Jacques et al., 2013), and travel attitudes (Anable, 2005; Beirao and Cabral, 2008).

To the best of our knowledge only one study (De Oña et al., 2016) have gone a step further and investigated the determinants of travel satisfaction for their studied market segments. De Oña et al. (2016) based their market segments on a set of socio-demographic and travel characteristics and found that overall the most important determinants of satisfaction for bus travelers in Granada (Spain) were *frequency*, *punctuality*, *speed*, *safety* and *space*. However, no previous research has stratified travelers based on a combination of their sociodemographic attributes, travel characteristics and accessibility measures, using an extensive and comprehensive dataset that encompasses diverse traveler groups including non-PT users from different geographical contexts (entire country).

2.5. Travel satisfaction over time and across regions

Reported travel satisfactions are subject to personal expectations and therefore may continuously change over time. For instance, service attributes that are perceived to be modern and fashionable, such as low-floor vehicles, on-board WI-FI, and at-stop real-time information displays, may become prominent, and taken for granted over time (Kano et al., 1984; Diana, 2008; Susilo et al., 2012).

Travel satisfaction and its determinants are also believed to change from region to region. There is a disparity in overall satisfaction levels depending on the urban area/community size and on the socio-demographic profile (Friman and Fellesson, 2009). Furthermore, other geographical factors as well as differences in PT service and infrastructure, culture and tradition, may influence overall travel satisfaction (Fellesson and Friman, 2008) and this is one of the research gaps that will be addressed by this thesis.

2.6. Aggregation of multi-modal door-to-door trips

A trip can be defined as a continuous sequence of legs from an origin to a destination and with a single main purpose (Axhausen, 2007). A trip leg is a continuous movement with one mode of transport which includes any waiting times immediately before or during that movement. Waiting times include any transferring times. Thus, multi-modal door-to-door trips have an origin and a destination, consist of two or more trip legs of which one is identified as the main trip leg, and at least one as access or egress.

Several authors indicated that all trip legs, as part of a multi-episodic experience, are believed to contribute to the overall trip experience (e.g. Susilo and Cats, 2014; Ettema et al., 2016). Almost all previous studies investigated the aggregation of retrospective multi-episodic experiences in a domain different than transport (e.g. Miron-Shatz, 2009). In general, their results showed that heuristic rules (peak, peak-and-end, serial position) are superior in explaining the aggregation of experiences than normative rules (equal average, moving duration weighted, complex duration weighted). The only investigation in the transport field found that the overall trip satisfaction of commuters can be modeled as a weighted average of the satisfaction with individual legs, where legs are weighted by their respective duration (Suzuki et al., 2014). However, further investigation is needed to determine whether this holds and applies to different trips configurations.

2.7. Thesis's conceptual model

A number of conceptual relations and empirical findings found in the literature review are used to construct this thesis' conceptual model. The theoretical models presented in section 2.1 do not consider some other relevant aspects that influence the travel experience and travel satisfaction. Considering the quality of service model (Parasuraman et al., 1985) displayed in section 2.1 this thesis deals with Gap 5, and thus the gap between expected and perceived service quality.

Traveler needs might be a function of the quality of the PT service, traveler characteristics (e.g. gender, age, education level or income), the travel mode used, the trip purpose or the frequency with which one travel by PT (familiarity). It is also hypothesized that environmental factors, such as the built-environment, weather conditions and objective accessibility and proximity measures, that the traveler experience in the first mile of the trip, may impact travelers service perceptions. Therefore, all these aspects, together with some other are investigated in this thesis.

3. Research questions

The overarching aim of this thesis is to gain a better understanding of traveler satisfaction with PT services so stakeholders and practitioners can adopt the right measures to increase it. Traveler satisfaction is relevant for operators as in incentive based contracts their performance is partly measured by means of travel satisfaction. PT authorities are also interested in understanding better traveler satisfaction since they are responsible for ensuring the fulfillment of different traveler needs. Achieving this goal is not an easy task, not only because of the inherent complexity of multi-modal door-to-door trips but also due to the difficulties that entail the study of different profiles of travelers who use distinct travel modes and live in diverse geographical areas.

Figure 4 shows the focus of each paper in terms of the objectives, part of the door-to-door trip studied, and traveler, region and mode on target. The focus of most of the papers is placed in the main trip stage (Paper I, II and V). However, some papers focus on other stages, such as the entire door-to-door trip (Paper III) and the access stage of the trip (Paper IV).

The travel experience is also impacted by existing differences across regions (e.g. Fellesson and Friman, 2008; Diana, 2012). The geographical component is thus accounted for in two papers and shown in Figure 4 as "other". Paper II, considers the spatial distribution of the segments and analyzes differences in travel satisfaction perceptions in five regions while Paper IV gives attention to differences between urban and peri-urban and rural environments.

As can be observed in the top part of Figure 4, this thesis not only considers a general PT traveler (Paper I and IV) but also different groups of travelers (Paper II, III and V) and distinct travel modes (Paper III and V).

Apart from Paper II, all other papers focus exclusively on PT users, and thus on travelers that have some knowledge of the PT service offered. A number of reasons led me to consider almost exclusively PT users. Those that have not used PT in the last year[1], non-PT users, might be car-captives and thus they might not have any viable PT alternative for their trips. Moreover, some studies indicate that many car users, no matter what, are not willing to switch to PT. In Anable (2005), for instance, these car users represented 50% of them and were identified in two traveler segments as "complacent car addicts" and

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[1] Based on Paper II they are a 12% of the respondents.

"die-hard drivers".

Overall, last trip and trip leg are the three satisfaction variables employed in this thesis. Overall travel satisfaction is the most widely used while trip leg satisfaction is employed in Paper III and last trip satisfaction in Papers III and IV.
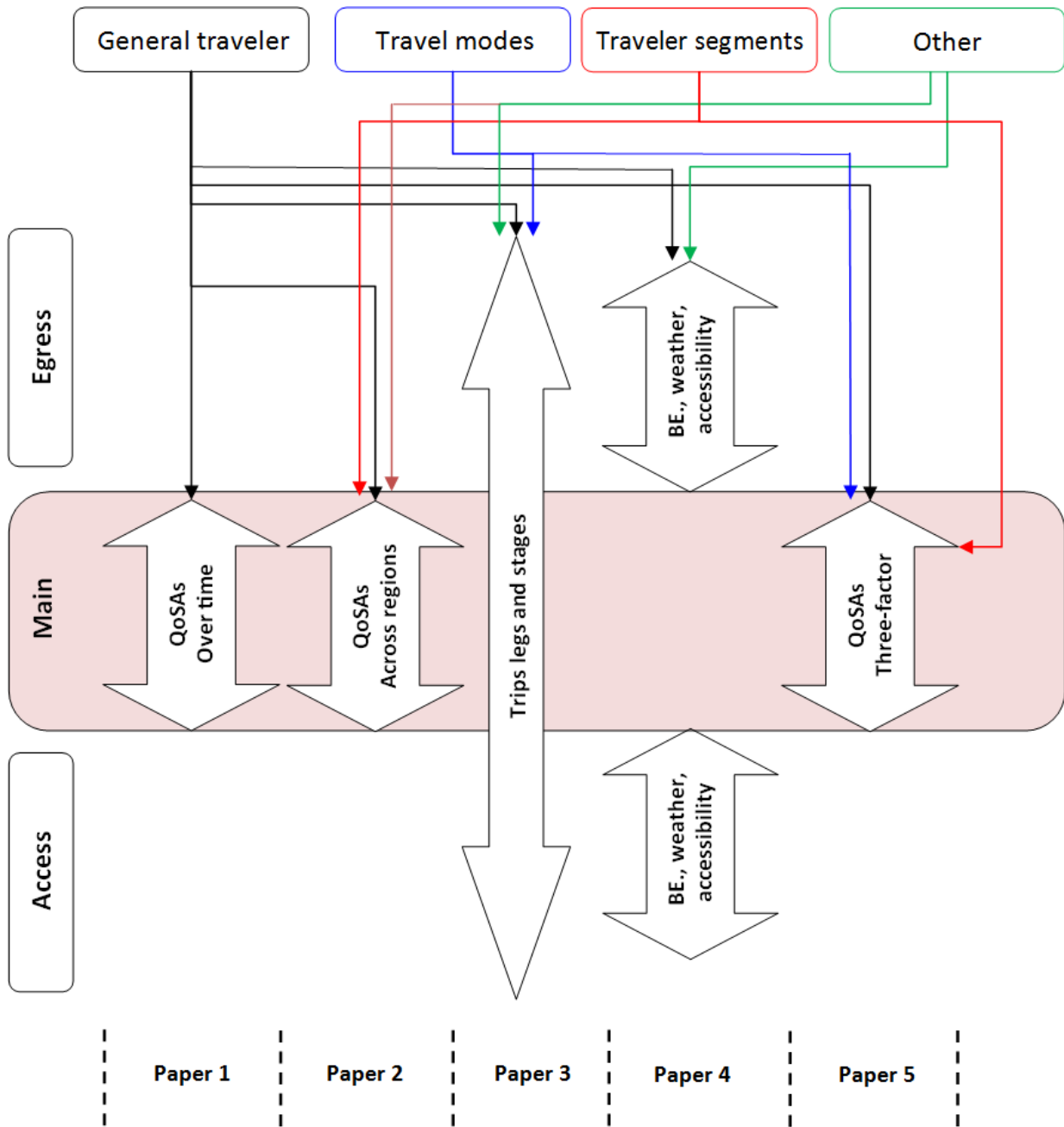

Figure 4. Relationship between trip stages, model specific, and objectives.

Determinants of travel satisfaction may vary not only among individuals but also between different

geographical regions and over long time periods. Since individuals are capable of learning and adapting over time, their appreciation towards service provision may also change over time. Thus, it is of the utmost importance to understand how satisfaction towards specific QoSAs evolves over time. Therefore, *the main research question of Paper I is investigating whether the determinants of PT travel satisfaction, for a general traveler, vary over time or remain constant*.

Yet, studying the determinants for a general traveler might not be sufficient. Previous research showed that different travelers have different needs and priorities and that these are influenced by the characteristics of the main mode (e.g. Ettema et al., 2010). Moreover, differences in terms of infrastructure, operation, information aspects and comfort between travel modes might be perceived differently amongst travelers (e.g. Mouwen, 2015). Therefore, there is a need to understand how expectations and satisfaction with quality of QoSAs, as well as the importance attached to them, varies for different market segments. Furthermore, identifying users' priority areas will help stakeholders to prioritize their investment. This is especially important for making PT more attractive to travelers who do not use it frequently. Evidence-based knowledge on such patterns will facilitate the planning and operations of PT services to better tailor them to travelers' needs. This would help the authorities to concentrate their policies on a manageable group of travelers, rather than performing market segmentation based on numerous combinations of traveler groups' socio-demographic and external characteristics. Therefore, *the main research question of Paper II is to investigate the main determinants of travel satisfaction for different traveler segments*. This work will also examine geographical variations of traveler's satisfaction evaluations.

To date, most studies have neglected the influence of access and egress stages on the travel experience, assuming that the main trip stage represents well the entire door-to-door trip. Understanding how satisfaction with individual trip legs aggregates to the overall travel experience for different types of trips will enable to identify which particular trip stage(s) need(s) to be improved. Therefore, it will allow practitioners to better evaluate and cater for travelers' needs by supporting the allocation of resources and prioritization of measures. *The main research question of Paper III is, for different trip configurations, what is the relative importance of satisfaction with access, main and egress legs for the whole travel experience*.

Literature review showed that the individual and combined effect of the level of accessibility, built-environment and weather characteristics on the travel experience remains either unknown or requires

further investigation. The study of the above factors for the area where the traveler both start their trip and lives would avoid an unfair evaluation of the service provided by PT operators and of the well-designed transit-oriented areas and first and last-mile facilities. Therefore *the main research question of Paper IV is what are the impacts of built-environment and weather characteristics and proximity and accessibility measures on the travel experience*.

Most of previous research assumed that there is a linear and symmetric relation between QoSAs and Overall travel satisfaction. There is, however, evidence suggesting that travel satisfaction may not be a linear function of service attributes. The categorization of QoSAs depending on their varying nature on overall travel satisfaction will guide PT authorities and operators in introducing cost-efficient measures to increase traveler satisfaction with PT services. *The main research questions of Paper V are what is the nature of the relationship between PT service attributes and overall travel satisfaction, as well as whether these vary between modes and traveler groups*.

4. Data and methods

To achieve this thesis's goals we use different methods and rich datasets in terms of sample size, geographical diversity and time span. The data can be classified in core and ancillary data. Core data, is the principal source of data which includes all sort of variables used to carry out the main analyses. The core data sources come from Swedish Public Transport Association – SKT- (Paper I, II, IV and V), and METPEX (Paper III). Ancillary data sources have different purposes such as the identification of the samples, the application of weights and the evaluation and characterization of traveler groups. The sources providing this sort of data include: Sweden Statistics – SCB - (Papers I, II, III and IV), Geonames and Trafikanalys (Paper II), European Environment Agency, Swedish Meteorological and Hydrological Institute and Stockholm municipality (Paper IV).

SKT (*Svensk Kollektivtrafik*), a trade organization representing the regional PT agencies of the 21 Swedish counties, conducts since 2001 a rolling survey aimed to monitor developments in the PT market. Respondents are telephone interviewed on a regular basis year-round. The results of the survey are summarized annually into a 'Swedish Public Transport Barometer' (SPTB) which provides an overview of satisfaction and attitudes towards PT across Sweden. The most recent available dataset and the aim of each study determined the employed timeframes. Thus, the timeframes spanned from 2001 to 2013 (Paper I), from 2001 to 2014 (Paper II), from 2009 to 2015 (Paper IV) and from 2010 to 2015 (Paper V). For similar reasons, the study areas also varied from work to work comprising either the entire Sweden (Papers I and II), Stockholm City and County (Paper IV) or Stockholm County only (Papers V). The standard set of variables was composed of: (i) overall and last trip satisfactions, and (ii) satisfaction with 12 QoSAs. The scale of measurement of the QoSAs was Likert-scale from 1- Very dissatisfied to 5-Very satisfied. Moreover, socio-economic (e.g. gender, age, occupation, driving license) and travel characteristics (e.g. frequency of travel by PT and by car) were employed in descriptive statistics (Paper I and II), correlation (Paper I), segmentation (Paper II and V) and regression analyses (Papers IV and V). Sample sizes differed from paper to paper and ranged from about 9200 (Paper V) to 454000 (Paper II) responses.

The dataset employed in Paper III, METPEX trial survey, was obtained from METPEX, a FP7 EU project which aimed to develop a Pan-European standardized measurement tool to measure travelers' experience across door-to-door trips. This dataset was collected in 2013, through retrospective and on-site surveys, in

8 different European cities (i.e. Stockholm, Bucharest, Dublin). The questionnaire was designed to address the entire door-to-door trip and different travel modes. The set of variables included in the main analysis of Paper III included travel satisfaction with the entire journey and with each of the trip legs; both perceived and expected moving and waiting travel times; trip purposes and travel modes. Additionally, socio-economic variables were used to characterize the dataset.

A summary of the core datasets employed in this thesis is displayed in Table 1.

Table 1: Summary of thesis' core data

Paper	Data	Study area	Timeframe	Total sample size
I	SPTB	Sweden	2001 to 2013	405340
II	SPTB	Sweden	2001 to 2014	453564
III	METPEX	Stockholm, Bucharest, Dublin, Turin and Coventry (89%)	2013	156
IV	SPTB	Stockholm County and City	2009 to 2015	11873
V	SPTB	Stockholm County and City	2010 to 2015	9171

Statistics Sweden (SCB) data was utilized for different purposes. It was used to assign proportional weights on year-specific ratios between both county and gender in the SPTB sample when compared with the general population based on SCB (Paper I and II). In Papers I and II, the geographical regions were based on the density of population at a County level while a unit of urban continuum (*tätort*) was employed in cross-correlation analysis. Paper IV used density and population and purchasing power from SCB in the regression analyses.

Transport analysis (Trafikanalys), a governmental agency responsible for transport analysis policy, is the data source for the proximity and accessibility measures used in the segmentation process of Paper II.

A worldwide geographical database, Geonames, is used in Paper II to link individual samples from SPTB with accessibility measures from Trafikanalys and municipalities.

Paper IV employs an array of ancillary data. The Swedish meteorological and hydrological institute

(SMHI) provides with weather characteristics data; the European Environment Agency provides with Corine land cover, and Stockholm municipality with a survey on safety perceptions and perceptual built-environment characteristics.

4.1. Methods

This thesis carries out empirical investigations by employing quantitative methods that, as shown in the earlier section, are based on revealed preference surveys. The basis of the analyses is hypothesis testing and unveiling relations between variables under consideration.

For this, a large number of statistical techniques are used in all works. Descriptive statistics, t-tests and correlation analyses characterize the data, assist in the hypothesis testing, and in the model specification by studying differences and commonalities between independent variables. A data reduction technique, Principal Component analysis, was employed in Paper I to find relations between QoSAs and reduce the complexity associated with the investigation of a large number of variables. A combination of hierarchical and non-hierarchical methods, two-steps cluster analysis, was employed in Paper II to reduce the complexity of associated to the study of a large number of individuals with distinct characteristics by forming relatively homogeneous groups.

Given that regression models from all works have as dependent variable, either overall or last trip satisfaction, which are ordinal variables, ranging from 1 (very unsatisfied) to 5 (very satisfied), ordered logit models are most adequate. In general, order logit model can be expressed as:

$$y_k^* = X_k \beta + \varepsilon_k \tag{1}$$

Where y_k^* is the latent dependent variable of individual k. X_k is the explanatory variable set of individual k, which consists of the QoSAs values (Papers I, II and V) or other independent variables (Papers III, IV). Note that the intercept is dropped for identification issues. β is the corresponding parameter to be estimated. ε_k is the error term which is assumed as an identically distributed logistic error-term. The latent dependent variable is then associated with the observed dependent variable, y_k (5 likert scale overall or last trip satisfactions), with m=1..5, defined as follows:

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

Parameter estimates obtained from different ordered logit models cannot be directly compared. Instead, the marginal effects on the expected value of the dependent variable (overall satisfaction) were derived from the parameter estimates. For a given explanatory variable i, the marginal effect on the probability of observing individual k having an overall satisfaction equal to n is:

$$M_{k,i,n} = -\beta_i \left[\frac{e^{-(\mu_n - X_k\beta)}}{\left(1+e^{-(\mu_n - X_k\beta)}\right)^2} - \frac{e^{-(\mu_{n-1} - X_k\beta)}}{\left(1+e^{-(\mu_{n-1} - X_k\beta)}\right)^2} \right] \qquad (3)$$

The marginal effect of the explanatory variable i on the expected value $E(y_k)$ for a given individual k is then:

$$E_{k,i} = \sum_{n=1}^{m} M_{k,i,n} \times n \qquad (4)$$

Geo-spatial analyses were employed for combining data from different sources and spatial units, for obtaining proximity measures and to represent the geographical distribution of travelers or certain features under study (Papers II and IV). Aggregated and disaggregated measures of accessibility were calculated in Paper IV from O-D pairs, and from Origins to a central point and to all other destinations.

The software employed includes SPSS (Papers I to V) for the statistical analyses and Matlab (Papers I and II) for the marginal effects. The geospatial analyses were performed in ArcGIS, the accessibility measures in TransCAD, and the figures and tabulations were produced in Excel and NodeXL (excel add-on).

5. Research contributions

5.1. Paper I - Evolution of Satisfaction with Public Transport and Its Determinants in Sweden: Identifying Priority Areas.

Paper I investigates how travelers' satisfaction with PT service and its underlying determinants evolve over time (2001 to 2013).

The main finding of this study is the invariability of the determinants of travel satisfaction over time. The results show that *customer interface*, *operation* and to a lesser extent *trip duration*, are found to be key determinants of overall satisfaction which users consistently rate among the least satisfactory. The two dimensions considered in the priority map, QoSAs' relative satisfaction and relative importance behave differently over time. While satisfaction, in general, remains rather constant, relative importance fluctuates year after year. However, the QoSAs remain in the same quadrant of the priority map and thus the determinants of travel satisfaction stay invariable.

The methodology employed in this paper: calculating normalized average satisfaction values for the QoSAs, estimating satisfaction year-specific Ordered Logit Models, calculating marginal effects from the models' coefficients, and displaying the combination of importance and performance in a priority map, allows for easy comparison amongst QoSAs.

5.2. Paper II - Travel satisfaction with public transport: determinants, user classes, regional disparities and their evolution.

Paper II identifies and characterizes current and potential users of PT in Sweden based on socio-demographic attributes, travel characteristics and accessibility measures, which were found to influence travelers' expectations and needs in previous research. This study also identifies the most important determinants of travel satisfaction with PT services for each segment of travelers. In addition, it investigates the changes over time of attribute importance among the different segments and the inter-segment geographical variation of overall satisfaction.

Swedish travelers are found to be classified into five groups: (i) inactive travelers; (ii) long-distance commuters; (iii) urban motorist commuters; (iv) rural motorist commuters; and (v) students. The contrast of perceived satisfaction and relative importance of the QoSAs reveals the existence of four attributes that

should be prioritized by stakeholders: *customer interface, operation, network* and *trip duration*.

The main finding of this study is the overall similarity in the priority list of QoSAs between travelers' segments. Nevertheless, some noteworthy differences that do not alter the composition of the priority list can be observed. For example, the more PT intensive user segments (i- inactive and v- students) are more satisfied across the board and are characterized by a more balanced distribution of QoSA importance. This might be due to a higher evaluation of more recent experiences and a more integrative knowledge of the service components. Rural motorist commuters (iv) are markedly dissatisfied with service operation attributes (*trip duration, network* and *operation*). Moreover, they consider these QoSAs to be more important compared with other travelers' groups.

This study indicates that there is an overall change in appreciation and consumption goals revealed by the variability of QoSA importance levels over time and across segments. In brief, attributes related to information and the functional and operational aspects of the service have gained importance whilst those related to comfortability, image and the services provided around the product have become less influential. Additionally, the investigation of the variability of overall satisfaction over time and space, across segments, reveals that the smallest county regions report the largest overall satisfaction. These findings are in line with previous research (Diana, 2012).

5.3. Paper III - How does travel satisfaction sum up? Decomposing the door-to-door experience for multimodal trips.

Paper III aims to answer the question "how do travelers combine memories of a series of pleasant and unpleasant episodes of their multi-leg trips to construct an evaluation of their overall travel experience". Therefore the objective is to investigate the relative importance of satisfaction with access, main and egress legs for the whole travel experience. Normative and heuristic rules are tested to define how door-to-door trips' satisfaction is aggregated in relation to each trip leg satisfaction.

In general, normative rules (e.g. simple average or average weighted by waiting/transfer times) are found to be better predictors of retrospectively aggregated experiences than heuristic rules. These findings resonate with previous research (e.g. Suzuki et al., 2014; Miron-Shatz, 2009) and indicate that no trip leg can be neglected since all of them have an impact on overall travel satisfaction. The average weighted rule that considers both moving (in- vehicle/walking) and waiting times (Duration weighted complex - DWC) performs particularly well, especially when applying a waiting time weight of 3 or 4 times in-

vehicle or walking time (DWC3 and DWC4). Nonetheless, the way travelers aggregate their door-to-door trips varies in regard of the type of trip (trip configurations). Hence, trip characteristics should be considered when multi-modal trips are investigated.

As mentioned above, all trip legs are shown to be relevant in constructing an overall evaluation of door-to-door trips. However, the main trip leg followed at a considerable distance by the access leg are identified to be the most relevant part of the trip, regardless of the trip configuration.

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

Paper IV focuses on investigating the impact that built-environment, accessibility and weather characteristics from the access stage of the trip have on the overall travel experience. This is done for two geographical contexts (urban and peri-urban and rural) and with models regarding the Last and an Overall trip.

Perceptual and non-perceptual built-environment variables are found to have a rather weak effect in the overall satisfaction which is only present model for the City model. Nonetheless, safety feelings around PT stations/stops have a positive effect on the overall travel experience while safety feelings related to travelers' neighborhood of residence have none. This, together with the fact that safety perceptions in the PT premises greatly influence the travel experience (Paper I), 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).

Accessibility results indicate that living in an area that is well-connected to all other areas, and in particular to the attractive 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.

Weather conditions at the time of the start of the trip exert an impact on travel satisfaction. 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 the walking conditions has not explicitly been captured in this work. 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.

5.6 Paper V - Investigating the nature of Public Transport service attributes.

Based on the three-factor theory, Paper V aims to classify PT service attributes considering their influence on overall traveler satisfaction. The study examines whether service attributes have a non-linear and asymmetric influence on the overall travel experience. The analysis is done for different traveler segments depending on their level of captivity, travel frequency by PT and travel mode used. Models, in addition, control for important socio-demographic and travel characteristics that were overlooked in previous studies. Results are presented in the form of a series of 3-level cubes of essential needs for travelers determined by the three-factor nature (basic, performance and exciting) of the service attributes.

The main findings of this study indicate that, for a general traveler, 2/3 of the QoSAs can positively or negatively contribute (performance) to overall travel satisfaction depending on how good or bad the given service attribute is perceived to perform. On the contrary, an equal number (1/6) of attributes can either exclusively exert a negative (basic) or a positive (exciting) influence on the overall experience. Overall, the most essential travelers' needs include *staff and assistance*, and *ticket accessibility* while the least essential are *network* and *on-board conditions*. Attribute performance levels and their improvement costs would determine whether these attributes need to be addressed first.

The study shows that the results of the general model do not hold for the distinct travel modes and traveler segments. A QoSA-level comparison of factor classification indicates that 2/3 of the QoSAs are classified differently between city and regional bus services. Furthermore, a number of other differences exist between traveler segments and travel modes. For instance, bus travelers mainly classify information aspects in the basic factor while they are mostly classified as exciting for rail users. Further, *trip duration* is a performance attribute for the more reliable rail modes (SLL, 2014) while it is categorized as exciting for the most unreliable mode (city bus).

6. Discussion and conclusions

Objective-wise the interrelation among the five papers is evident. Their common objective is to gain a better insight into the factors that influence the travel experience of door-to-door trips. In particular, this thesis focuses on investigating the factors that impact travel satisfaction with either an average (overall) or a last trip so stakeholders can apply effective measures to improve the travel experience.

The results of this thesis suggest that the determinants of travel satisfaction have an overall similarity amongst different travelers' groups and travel modes, also when compared to a general model. However, having said that, the existence of differences in needs and priorities among traveler segments calls for the deployment of measures that cater for their specific priorities. For example, inactive travelers are most keen on direct connections, while infrequent PT users such as rural motorists attach greater importance to *customer interface*. Efforts and measures to improve these dimensions should be therefore made in relation to the specific target group.

The overall stability of the determinants of travel satisfaction over time are good news for stakeholders since it suggests that PT users do not rapidly modify their list of QoSA's priorities. Therefore, costly long-term investments and measures carried out to improve the perception of the prioritized QoSA might be well appreciated by future travelers. Moreover, the importance attached to the key determinants of travel satisfaction (*customer interface*, *operation,* and *trip duration*) grows or remains constant over time which strengthens the results.

Most of the papers of this thesis assume that the study of the main trip stage can sufficiently explain overall travel satisfaction. This assumption is derived from the overwhelming focus of previous research on studying the QoSAs and other aspects related to the main trip leg/stage. Findings from this thesis show that the main trip leg's relative weight on overall trip satisfaction is much higher than the one of access/egress legs. This finding provides more validity to the results of my and previous studies that focused on analyzing the determinants of trip satisfaction for the main leg. In addition, the results imply that the most relevant door-to-door trip legs include PT modes, with their associated waiting and (sometimes) transfer times. This fact, together with the success of DWC (Duration weighted complex) rules signify that waiting and transferring times are poorly perceived and penalized by travelers, and thus their perception should be improved. Moreover, practitioners having a limited budget are to investigate PT door-to-door trips they may do better in surveying aspects related to the main PT leg than surveying

some other stages of the trip.

The results of this thesis have policy implications. *Trip duration* as a prominent QoSA needs to be well-catered by practitioners. Improving the perception that traveling by PT is fast involves both shortening nominal on-board travel time and improving seat availability, on-board comfort and travel time usability (Susilo et al., 2012). Providing more frequent services is in line with Paper III results which emphasize the importance of waiting and transferring times. In contrast, the deterioration of satisfaction with *customer interface* is related to the reputation of the PT agency and could be addressed by improving both internal (mechanisms to handle passengers' complaints) and external communication (media, marketing). Moreover, maintaining a sense of security (*freedom from crime*) is also crucial as it is an important determinant of overall satisfaction and an area that PT travelers in Sweden are generally satisfied with. *Freedom from crime* is not only related to the security measures adopted by the PT authority (video surveillance system or security guards) but also to the national regulations fighting and punishing crime and to the crime index of the area that the PT serves.

Some aspects that lie outside operators and PT authorities control matter in evaluating the travel experience. For instance, designing urban areas with mixed land use is the responsibility of mainly urban planners. Weather conditions that impede the walking and the cycling in the access (and egress) legs are again, in hands (if any) of urban planners. However, transport planners and those in charge of designing PT stops and vehicles could address the impact of some of the weather conditions by for example providing air-cool in the vehicles and providing a better shelter in PT stops and stations.

Three-Factor classification of some of the QoSAs into the basic and exciting factor has implications on findings from previous papers and of other research. These results indicate that the effect of certain QoSAs on overall travel experience might have been over- and under-estimated in the past. For instance, the effect on the travel experience of *ticket accessibility* and *staff and assistance* (basic attributes) has been overestimated in works where these attributes are highly evaluated (e.g. Paper I). In turn, the effect of *on-board conditions* (exciting attributes) has been overestimated in works where their perceived performance was low (e.g. Weinstein 2000). These findings exhibit the relevance of classifying QoSAs regarding their influence on the overall travel experience.

All in all, the results of this work demonstrate that a "one size fits all" approach is not adequate for identifying the needs of distinct traveler segments and of travelers using different travel modes.

Differences in travelers' needs between traveler segments and travel modes may require stakeholders to tailor specific measures to improve the travel experience of different groups, which is unique across geographical, weather, built-environment, and infrastructure conditions. Whilst a number of policy actions directed to improve the quality of different traveler groups' priorities can be undertaken, a uniform measure aimed at tackling too diverse and large population and geographical areas can be very complex and may lead to unrewarding results. That being said, there are some general lessons that can be implemented for all travelers as well. For example, the fact that PT-users only and all traveler's' segments regard *operation* as a more important QoSA than *network* suggests that stakeholders could do better by providing direct and frequent services rather than a large number of low-frequency lines in the hope of minimizing the number of transfers required. The former offers economical and operational benefits in addition to the higher importance attached to it in forming travel satisfaction. The formulated 3 level cubes of essential needs can be used to design the policy for different target group.

As for methodological contribution, this project has introduced two different methods to understand the complexity of door-to-door multimodal travel satisfaction better, (1) a method to obtain a fair comparison of priority areas; (2) a method to quantify the impact of different multimodal composition of trip leg(s) to the overall travelers' trip satisfactions

6.1 Future research

Future studies would benefit from issues raised by this thesis.

First, the impacts and knowledge that may be drawn from the inclusion of PT sub-modes in the segmentation process would enable unveiling segments that relate to particular modes and focus on mode-specific market analysis.

Second, conducting a longitudinal study of the attribute importance would be useful to infer causal relations, the plausible impacts of the newly implemented policy, and the behavioral change process of the travelers over a long period of time.

Third, the inclusion of interaction effects between regions, segments and attributes in the models would allow the identification of QoSAs that may have a larger impact in different regions and segments within a given region. Moreover, it would be interesting to contrast PT objective performance indicators with PT travelers' satisfaction, as a way to evaluate the degree to which travelers' satisfaction valuations are at

random.

Fourth, the analysis of cross-sectional data does not allow following the same individual over time. The use of this type of data does not allow assessing whether changes in prevalence reflect a trend or simply differences between different groups of participants sampled from the population. In addition, the use of this type data may produce cohort effects which also alter the results. Therefore, it would be interesting to analyze panel data as a way to determine whether the overall change in QoSAs is driven by a systematic change in individual perceptions. For example, it could be determined whether greater importance is attached to a QoSA with which an individual is less satisfied or to variations in PT traveler groups.

Fifth, it would be recommended that future research base their studies in geographical units with a similar size. Differences in size 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.

Sixth, the collection of instant utilities during the travel experience or the use of methods that have been proven to elicit recall bias-free instant utilities (e.g. ecological momentary assessment, daily reconstruction) could improve the recollection of retrospective experiences. In addition, measuring waiting and transferring times' satisfaction as separate episodes within the multi-modal trip would allow to better single out their impact.

Seventh, future studies should control for important aspects such as PT disruptions and subjective well-being variables since they are very likely to mediate the effect of, for instance, weather impact. Moreover, other studies should incorporate travel attitudes and preferences in the models so to be able to better explain the impact of built-environment characteristics on travel satisfaction. A final recommendation is the examination of the speed and the extent to which QoSAs switch from one-factor category (basic, performance or exciting) to another.

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Papers

Paper I. Evolution of Satisfaction with Public Transport and Its Determinants in Sweden: Identifying Priority Areas.

Paper II. Travel satisfaction with public transport: determinants, user classes, regional disparities and their evolution.

Paper III. How does travel satisfaction sum up? Decomposing the door-to-door experience for multi-modal trips.

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

Paper V. Investigating the nature of Public Transport service attributes