Bicycle Sharing Systems and their role in the promotion of cycling as a mode of transport in Southern European island cities

Student:

Suzanne Maas

Institute for Climate Change and Sustainable Development, University of Malta

Supervisors:

Professor Maria Attard

Institute for Climate Change and Sustainable Development, University of Malta

Professor Loukas Dimitriou

LaB for Transport Engineering, Department of Civil and Environmental Engineering, University of Cyprus

A Doctoral thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy at the University of Malta

L-Università ta' Malta

July 2021

Declaration

This is to declare that this thesis is an original and unpublished study carried out by the undersigned and is presented to the University of Malta for the first time as part of the requirements for the award of Doctor of Philosophy.

Suzanne Maas

Abstract

Across the globe, the approach to transport planning is shifting towards sustainable urban mobility planning, in an effort to address traffic congestion, air pollution, and carbon emission reductions, and to promote a better quality of life for urban citizens. In this context, Bicycle Sharing Systems (BSS) have emerged as a transport innovation, allowing for multimodal travel, without having to own a private bicycle, while normalizing cycling in cities where this was not previously the norm. In the span of two decades, BSS have grown from just a handful to almost 3,000 systems worldwide.

To understand which factors influence cycling, and BSS use specifically, this research used socio-ecological approaches to understand active travel behaviour. A framework was created to assess the influence of individual factors, social environment factors, and objective and perceived physical environment factors, as well as the policy environment shaping these. This research focuses on Southern European island cities, with their specific geographical and socio-cultural context, high population density and car-dependence, and a strong influence of tourists and visitors. The aim of this research is to analyse the use of BSS, and the role they play in promoting cycling as a mode of transport in Southern European island cities, as part of their ambition to promote sustainable urban mobility. A multiple-case study approach is used to analyse the introduction and use of the BSS in Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta). Self-reported usage data from a BSS user survey in the three sites was analysed through descriptive statistics, correlation analysis and binary logistic regression models. BSS trip data provided by the BSS operators, combined with external datasets, enabled the assessment of the influence of objective physical environment factors on observed BSS use in the case study cities through spatio-temporal regression modeling.

The influence of individual, social environment and physical environment factors on shared bicycle use is analysed, looking at differences between frequent and infrequent BSS users, to get a better understanding of the motivators and barriers that influence BSS use. Results show that frequent BSS use is positively associated with frequent use of other 'alternative' transport modes, such as public transport use, as well as with shorter distances from respondents' residence and most frequent destinations to the nearest BSS station. Higher perceived safety of cycling was also associated with more frequent BSS use, as did a positive social norm, including support from friends and family, respect from other road users, and feeling that cycling is an accepted form of transport, confirming the importance of such factors in building a cycling culture. The influence of land use, socio-economic, network and temporal factors on BSS station use is examined through bivariate correlation analysis and the development of linear mixed models for each case study. The results showed a significant positive relationship with the number of cafes and restaurants, vicinity to the beach or promenade and the percentage of foreign population at the station locations in all cities. In Limassol and Las Palmas de Gran Canaria, a positive relation with cycling infrastructure was evident. This association was not found in Malta, as there is little to no cycling infrastructure in the island's conurbation, where most of the BSS stations are located. Elevation showed a negative relationship with BSS use in all three cities. A positive effect of higher temperatures and a negative effect of rainfall were observed in Limassol and Malta, where seasonality in weather patterns is stronger than in Las Palmas de Gran Canaria.

The findings and recommendations of this study contribute to a better understanding of BSS use and cycling in the context of 'starter' cycling cities, as well as suggestions for how to overcome the barriers and leverage the motivators for the promotion of cycling, towards the goal of making sustainable urban mobility a reality.

Keywords: *bicycle sharing systems, cycling, sustainable mobility, island cities, multiple-case studies, socio-ecological models, regression modeling*

Acknowledgements

Firstly, my sincerest thanks to my two PhD supervisors, Professor Maria Attard (University of Malta) and Professor Loukas Dimitriou (University of Cyprus). It has been a joy to work with you both. Thank you for the stimulating conversations and your support, but also for welcoming me to your respective teams at the University of Malta and the University of Cyprus.

A warm word of thanks goes to my colleagues at the Institute for Climate Change and Sustainable Development at the University of Malta, to Romina, Raphael and Thérèse for supporting me in my research, and as well to my direct colleagues and fellow researchers Deborah, Carlos, Mark, Stephen and Karyn, for the many shared lunchbreaks, engaging discussions and fun fieldwork experiences together. A special thanks to the wonderful team at the LαB for Transport Engineering at the University of Cyprus, thank you Eleni, Paraskevas, Theocharis, Charalambos, Michalis, Filippos and Maria, for welcoming me not once, but twice to your team and showing me great generosity and friendship during my visits. A word of thanks as well to Mike Rosner, Professor Liberato Camilleri and Dr. Mark Anthony Caruana at the University of Malta for your guidance and support in designing the data collection and analysis approaches.

I would also like to express my gratitude to the operators of the BSS in the three case study cities included in my research, for the sharing of the trip data, participation in the interviews and their support in disseminating the user surveys. Thanks to Neofytos at Nextbike Cyprus, César and Fernando at Sítycleta and Alan, James, Goran and Maria at Nextbike Malta. Apart from that, a warm word of thanks to everyone who agreed to participate in the interviews and to all the respondents to the BSS user survey. I would also like to thank all the colleagues from the H2020 CIVITAS DESTINATIONS project, bringing together a wealth of local knowledge and enthusiasm to promote sustainable mobility in island destinations. In particular, I would like to thank the team at the Limassol Tourism Board (in Limassol, Cyprus), at SAGULPA (in Las Palmas de Gran Canaria) and Transport Malta (in Malta) for their support during my fieldwork.

A special thanks goes to my parents, for instilling in my brothers and me curiosity and an open outlook to the world. You have always supported me, even when my work and life choices are sometimes a bit off the beaten path. Thanks to my friends and family, for some much needed work-life balance with exciting hiking, cycling, kayaking and camping adventures, shared dinners, and in the final year of writing, many online catch-ups to stay in touch during 'times of corona'. In particular, I would like to thank Beth for proofreading my thesis; your valuable feedback has not only improved the text, but also showed me proof of a great friendship. Finally, a heartfelt thanks to my partner Christian, for your motivational "just do it" pep talks, for always making me a coffee to kick-start the day, for your delicious homemade meals and for ensuring there was plenty of outdoor fun to enjoy life after long hours of work.

This research was funded by the H2020 CIVITAS DESTINATIONS project. The fieldwork was partly funded through an Erasmus+ grant and research travel grants from Student Advisory Services (University of Malta) and KSU (the University Students' Council, University of Malta).

Publications

Parts of this thesis have been published and presented in conferences:

Publications directly emanating from PhD research

Published journal papers

Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2021). Spatial and temporal analysis of shared bicycle use in Limassol, Cyprus. *Journal of Transport Geography*, *93*, 103049. https://doi.org/10.1016/j.jtrangeo.2021.103049

Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2021). Heat, Hills and the High Season: A Model-Based Comparative Analysis of Spatio-Temporal Factors Affecting Shared Bicycle Use in Three Southern European Islands. *Sustainability*, *13*(6), 3274. https://doi.org/10.3390/su13063274

Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2020). Examining spatio-temporal trip patterns of bicycle sharing systems in Southern European island cities. *Research in Transportation Economics*, *86,* 100992. https://doi.org/10.1016/j.retrec.2020.100992

Maas, S., Attard, M., & Caruana, M. A. (2020). Assessing spatial and social dimensions of shared bicycle use in a Southern European island context: The case of Las Palmas de Gran Canaria. *Transportation Research Part A: Policy and Practice, 140,* 81-97. https://doi.org/10.1016/j.tra.2020.08.003

Conference proceedings

Maas, S. & Attard, M. (*forthcoming*). Policies to promote cycling in Southern European island cities: challenges and solutions from three 'starter' cycling cities. *Transportation Research Procedia*.

Maas, S., Attard, M., & Caruana, M. A. (*forthcoming*). Motivators and barriers for shared bicycle use in 'starter' cycling cities: Evidence from BSS user surveys in three Southern European island cities. *Transportation Research Procedia*.

Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (*forthcoming*). Understanding shared bicycle use in Southern European island cities: first insights from Limassol, Cyprus. *IOP Conference Series Earth and Environmental Science*.

Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2021). Classifying bicycle sharing system use in Southern European island cities: cycling for transport or leisure? *Transportation Research Procedia*, *52,* 565-572. https://doi.org/10.1016/j.trpro.2021.01.067

Conference presentations

Maas, S. & Attard, M. (2021, September 9). *Policies to promote cycling in Southern European island cities: challenges and solutions from three 'starter' cycling cities* [Conference presentation]. XXV International Conference Living and Walking in Cities - New scenarios for safe mobility in urban areas (LWC 2021), Brescia, Italy.

Maas, S., Attard, M., & Caruana, M. A. (2021, September 8). *Motivators and barriers for shared bicycle use in 'starter' cycling cities: Evidence from BSS user surveys in three Southern European island cities* [Conference presentation]. EWGT 2021 Conference (online), Aveiro, Portugal.

Maas, S., Attard, M., & Dimitriou, L. (2021, September 3). *Opening up new avenues for cycling? A before and after study of the impact of new cycling infrastructure on shared bicycle use* [Conference presentation]. RGS-IBG Annual International Conference (online), London, UK.

Maas, S., Attard, M., Nikolaou, P., & Dimitriou, L. (2021, January 25-29). *Factors Influencing Bicycle Sharing System Use: Case Studies of three Southern European Island Cities* [Conference poster presentation]. Transportation Research Board (online), Washington DC.

Maas, S., Attard, M., Nikolaou, P., & Dimitriou, L. (2020, September 16-18). *Classifying bicycle sharing system use in Southern European island cities: cycling for transport or leisure?* [Conference presentation]. EWGT 2020 Conference (online), Paphos, Cyprus.

Maas, S., Attard, M., Nikolaou, P., & Dimitriou, L. (2019, November 21-22). *Understanding shared bicycle use in Southern European island cities: first insights from Limassol, Cyprus* [Conference presentation]. SBE Malta 2019 Conference, Malta.

Maas, S. & Attard, M. (2019, October 30). *Shared bicycle use in Malta and other Southern European island cities* [Conference presentation]. Active Travel & Technology Symposium, Institute of Climate Change and Sustainable Development (University of Malta), Malta.

Maas, S., Attard, M. (2019, August 28). *Shared bicycle use and cycling promotion in Southern European island cities: First results from Limassol (Cyprus) and Las Palmas de Gran Canaria (Spain)* [Conference presentation]. RGS-IBG Annual International Conference, London, UK.

Maas, S. & Attard, M. (2018, August 31). *Cycling and the uptake of Bicycle Sharing Systems in Southern European island cities* [Conference presentation]. RGS-IBG Annual International Conference, Cardiff, UK.

Other publications

The below papers, book chapters and conference proceedings have resulted not directly from the thesis research, but from related work at the Institute for Climate Change and Sustainable Development (University of Malta), including for the H2020 CIVITAS DESTINATIONS project:

Book chapters

Maas, S., & Attard, M. (2021). Shared mobility services in Malta. In: T. Tsoutsos (Ed.), *Sustainable Mobility for Island Destinations*. Springer Nature. https://link.springer.com/book/10.1007/978-3-030-73715-3

Maas, S., Attard, M., & Bugeja, M. (2021). Sustainable tourism mobility in Malta: encouraging a shift in tourist travel behavior through an innovative smartphone app for trip planning. In: L. Zamparini (Ed.), *Sustainable Transport and Tourism Destinations* (Chapter 6) (Transport and Sustainability, Vol.13 ed.). Emerald Publishing Limited. https://books.emeraldinsight.com/page/detail/Sustainable-Transport-and-Tourism-Destinations/?k=9781839091285

Pajarito, D., Maas, S., Attard, M., & Gould, M. (2021). Path of least resistance: using geo-games and crowdsourced data to map cycling frictions. In: A. Skarlatidou & M. Haklay (Eds.), *Geographic Citizen Science Design: No one left behind* (Chapter 8). UCL Press. https://www.uclpress.co.uk/products/125702

Conference proceedings

Attard, M., Cañas, C., & Maas, S. (2021). Determinants for walking and cycling to a university campus: insights from a participatory Active Travel workshop in Malta. *Transportation Research Procedia, 52*, 501-508. https://doi.org/10.1016/j.trpro.2021.01.059

Maas, S., & Attard, M. (2020). Attitudes and perceptions towards shared mobility services: Repeated cross-sectional results from a survey among the Maltese population. *Transportation Research Procedia, 45*, 955-962. https://doi.org/10.1016/j.trpro.2020.02.071

Conference presentations (* presenting author)

Attard, M.*, Cañas, C., & Maas, S. (2020, September 16-18). *Determinants for walking and cycling to a university campus: insights from a participatory Active Travel workshop in Malta* [Conference presentation]. EWGT 2020 Conference (online), Paphos, Cyprus.

Maas, S.* & Attard, M. (2019, September 23-24). *Attitudes and perceptions towards shared mobility services: Repeated cross-sectional results from a survey among the Maltese population* [Conference presentation]. TIS Roma, Rome, Italy.

Leonardi, J.*, Maas, S., & Attard, M. (2019, September 23-24). *Developing the first Sustainable Urban Logistics Plan in Valletta, Malta* [Conference presentation]. TIS Roma, Rome, Italy.

Maas, S., & Attard, M.* (2019, May 26). *Attitudes and perceptions towards the introduction of shared mobility services in Malta* [Conference presentation]. World Conference on Transport Research (WCTR), Mumbai, India.

Pajarito, D.*, Maas, S., Attard, M., & Gould, M. (2018, June 14). *Mapping cyclists' routes: involving citizens in collecting open cycling data* [Conference presentation]. AGILE Conference, Lund, Sweden.

Pajarito, D., Maas, S.*, Attard, M., & Gould, M. (2018). *Urban Cycling: Lessons learned from volunteers' use and feedback of the Cyclist GEO-C App* [Conference presentation]. ExCiteS Citizen Science and HCI Workshop, UCL, London, UK.

Reports

Cañas Sanz, C., Maas, S., & Attard, M. (2020). *Active Travel Workshop Report. Findings and recommendations from the symposium on Active Travel and Technology*. Institute for Climate Change and Sustainable Development (University of Malta). https://www.um.edu.mt/__data/assets/pdf_file/0003/432363/ActiveTravelWorkshopReport-ICCSD.pdf

Farrugia, M., & Maas, S. (2020). *Cycling Roundabouts in Malta: Cycling safety issues at local roundabouts and solutions to improve safety*. Malta: Bicycle Advocacy Group (BAG/Rota) Malta; Institute for Climate Change and Sustainable Development (University of Malta). https://bagmalta.org/s/BAG-report-Roundabouts-Feb-2020.pdf

Articles

Maas, S. (2021). Bike sharing. *Section on the website of Rota* (the bicycle advocacy group of Malta). https://www.rota.mt/bike-sharing/

Maas, S. (2019, October 6). Sharing a love for cycling. *THINK Magazine* (University of Malta). https://www.um.edu.mt/think/sharing-a-love-for-cycling/

Maas, S. (2019, September 21). Micromobility: can we focus on opportunities instead of challenges? *The Malta Independent*. https://www.independent.com.mt/articles/2019-09-21/newspaper-opinions/Micromobility-can-we-focus-on-opportunities-instead-of-challenges-6736213778

Maas, S. (2018, December 28). Malta's transport conundrum: What alternative routes to sustainable mobility? *Malta Today*. https://www.maltatoday.com.mt/news/national/91897/malta_public_transport_conundrum_alternative_routes_sustainable_mobility

Maas, S., Cañas Sanz, C., & Attard, M (2018, December 4). We are all pedestrians. *Times of Malta*. https://timesofmalta.com/articles/view/we-are-all-pedestrians-suzanne-maas-carlos-canas-sanz-and-maria-attard.695843

Maas, S. (2018, November 28). Malta's Transport Conundrum: Alternative Routes to Sustainable Mobility. *Isles of the Left* (article and podcast). https://www.islesoftheleft.org/maltas-transport-conundrum-alternative-routes-to-sustainable-mobility

Table of Contents

List of figures

List of tables

List of abbreviations

AIC	Akaike Information Criterion
BC	Black carbon
BCA	Bivariate Correlation Analysis
BLR	Binary Logistic Regression
BRT	Bus Rapid Transit
BSRA	Backward Stepwise Regression Analysis
BSS	Bicycle Sharing System
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CBD	Central Business District
CO	Carbon monoxide
CO_2	Carbon dioxide
CRPD	Commission for the Rights of Persons with a Disability
CUT	Cyprus University of Technology
CVA	Controlled Vehicular Access
D	Destination
DTM	Digital Terrain Model
e-BSS	Electric Bicycle Sharing System
ECF	European Cyclists Federation
ETEK	Cyprus Scientific and Technical Chamber
EU	European Union
FFI	Flat Fee Interval
GC	Gran Canaria
GIS	Geographic Information System
GPS	Global Positioning System
H2020	Horizon 2020 (EU Funding Programme)
IM	Infrastructure Malta
ITDP	Institute for Transportation and Development Policy
LCA	Local Councils Association
LIM	Limassol
LMM	Linear mixed model
LoS	Level-of-Service
LPA	Las Palmas de Gran Canaria
LPGC	Las Palmas de Gran Canaria
MaaS	Mobility-as-a-Service
MAL	Malta
NCDs	Non-communicable diseases
NGO	Non-governmental organisation
NHTS	National Household Travel Survey
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O	Origin
OD	Origin-Destination
OLS	Ordinary Least Squares
OSM	OpenStreetMap
PA	Planning Authority
PM	Particulate matter
POI	Points-of-Interest
P&R	Park & Ride
PT	Public transport

RO	Research objective
RQ	Research question
SD	Standard deviation
SMOTE	Synthetic Minority Oversampling Technique
SPED	Strategic Plan for Environment and Development
SUMP	Sustainable Urban Mobility Plan
TDB	Trips per day per bicycle
TIB	Theory of Interpersonal Behaviour
TM	Transport Malta
TOD	Transit-oriented development
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TRB	Theory of Repeated Behaviour
TTB	Travel time budget
UA	Urban Atlas
UK	United Kingdom
ULPGC	Universidad de Las Palmas de Gran Canaria
UoM	University of Malta
USA	United States of America
V/C	Volume / capacity ratio
VOCs	Volatile Organic Compounds
WHO	World Health Organisation

1. Introduction

This thesis presents the findings of a study on the usage of Bicycle Sharing Systems (BSS) in Southern European island cities, and their role in promoting cycling as a mode of transport. In this first chapter, the first section, 1.1, introduces the research problem. The second section, 1.2, presents the rationale for the geographical focus of this study, Southern European island cities, and the selected case study cities. The third section, 1.3, outlines the aim and objectives of the study. The final section, 1.4, describes the structure of the thesis.

1.1 Research problem

Globally, more people now live in urban areas than in rural areas. It is expected that this figure will continue to rise, and will approximate a 68% urban population in 2050 (UN DESA, 2018). On some continents, this figure is already much higher, for example in Europe (74%), Latin America and the Caribbean (81%) and North America (82%) (UN DESA, 2018). With an ever-growing urban population, there is increased recognition for the importance of city residents' quality of life, and the impact that mobility – both in negative and positive terms – can have in achieving better quality of life (UN Habitat, 2013). It has become increasingly apparent that car-centred mobility has not delivered on its promise of increased individual freedom and urban progress. Instead, urban citizens find themselves faced with problems of congestion and parking, as well as environmental and social issues, such as air and noise pollution, road safety concerns, and declining physical and mental health. This is primarily due to a decrease in exercise and social interaction, as a result of a lack of safe and accessible public open space (Fishman, 2016).

Transport is a major contributor to carbon emissions, air and noise pollution. In the EU, just over one fifth of greenhouse gas emissions is due to transport, excluding international aviation and maritime transport (EEA, 2017a). The European Green Deal, presented in 2020, sets the goal for the EU to be climate neutral by 2050, with an intermediary goal in the 2030 Climate Target Plan of 55% emission reductions compared to 1990 levels by 2030 (European Commission, 2020a). In addition, there are different EU Directives targeting air quality, which are grouped under the Thematic Strategy on Air Pollution, tackling sources of air pollution such as nitrogen oxides (NO_x), particulate matter (PM) and volatile organic compounds (VOCs) (EEA, 2016). Road transport is the main source of noise pollution across Europe (EEA, 2017b). Finding alternatives to fossil fuel based motorised transport becomes increasingly important to meet these European wide targets and the national legislation they are transposed in, thereby contributing to a healthier, more liveable city environment.

The 21st century has seen a wave of change in the mobility systems of cities on every continent, aimed at a modal shift away from private car use, towards more public transport and active modes of transport. From pedestrianisation of city centres and the creation of cycling infrastructure in many European cities, to the introduction of car-free days and public investment in mass transit solutions in Latin America, and the growth of the 'new urbanism' movement in North America, promoting dense, mixed-use, walkable neighbourhoods in an attempt to overcome the myriad problems associated with sprawling, car-oriented urban design (Johnston, 2004; Pucher & Buehler, 2017). Recent advances in information technology are creating scope for smarter, shared mobility options and multimodal transport integration. Increasing accessibility, reducing dependency on fossil fuels and their contribution to climate change, and improving quality of life are some of the main challenges that cities worldwide are trying to tackle (McCormick et al., 2013). As a low-cost, low-polluting and active mode of transport, cycling has gained increased interest from policy makers and urban planners as one of the potential solutions in the move towards more sustainable urban mobility (Handy et al., 2014). Bicycle sharing systems, or BSS, shared bicycle fleets allowing short-term public use, have spread rapidly across the globe in the last two decades (Shaheen et al., 2010). BSS are a relatively new innovation that is enabling cycling for a wider group of citizens, and can be an important component of multimodal trips because of their integration in the public transport network (DeMaio, 2009).

Since the late 1990s, when only a handful of bicycle sharing systems existed, the number of BSS around the world has grown to almost 3,000 active systems in 2020 (Galatoulas et al., 2020). The main growth in BSS can be observed in the last decade (Fishman, 2016). From the growing body of literature on bicycle sharing systems, empirical evidence is showing how and when these systems are used, by whom and for what purpose, and what their contribution to the cycling modal share and to achieving wider sustainable urban mobility goals is. The evidence from cities around the world can provide insight into what are successful approaches and interventions, but also which systems did not manage to achieve success, and why (Médard de Chardon, 2019). Experiences with the introduction of these systems, their implementation and roll-out, and their impact on modal share and modal shift can provide a better understanding of the factors that influence the use of BSS as a mode of transport. These insights are particularly relevant for cities that are lagging behind in the cycling transition, so-called 'starter' cycling cities, with a low cycling modal share and limited cycling infrastructure (Félix et al., 2019).

1.2 Rationale for a geographical focus: Case study selection

Most BSS research has focused on larger systems in capital cities and other large urban areas in Europe, e.g. London (Goodman & Cheshire, 2014; Lathia et al., 2012; Wood et al., 2011; Woodcock et al., 2014); in the USA and Canada, e.g. New York (Basch et al., 2014; Faghih-Imani & Eluru, 2016a; Noland et al., 2016), and Montréal (Faghih-Imani et al., 2014; Fuller et al., 2013a); in Australia, e.g. Brisbane (Ahillen et al., 2015; Fishman et al., 2015), and in China, e.g. Hangzhou (Shaheen et al., 2011; Tang et al., 2011). However, few studies have looked at the dynamics of these schemes in smaller towns and cities (Bakogiannis et al., 2019; Caulfield et al., 2017). As small and medium sized cities typically have shorter distances between origins and destinations, the introduction of a BSS can offer an alternative mode of transport complementary to public transport, increasing travel options and promoting cycling for transport (Martin & Shaheen, 2014; Nikitas, 2018).

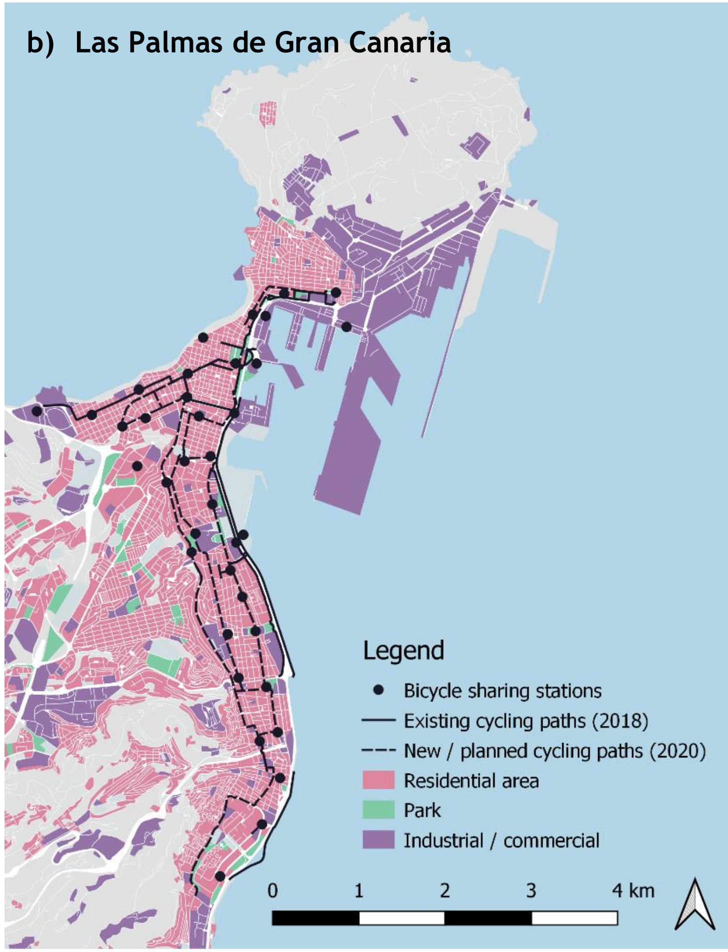
In this research, Southern European island cities have been selected as the unit for investigation, as heavy dependence on private car transport has resulted in pressure on their transport systems and infrastructure, on top of which there is a seasonal influx of tourists. In addition to catering for the daily movements of a standard city, such as for education, work and leisure purposes, these cities also have to provide for tourist flows. In their research, Cavallaro, Galati & Nocera (2017) put forward several reasons for comparison of mobility systems in Mediterranean coastal cities: 1) similarities in their urban design, in the form of port-city relations, historic centres and narrow streets, 2) high density of touristic attractions, cultural and natural heritage and proximity to the sea, which attract a high level of mobility, 3) islands and coastal zones are fragile ecosystems and are more vulnerable to environmental impacts, which can be exacerbated through additional tourism pressure. Modal share of cycling in Mediterranean and other Southern European cities is generally very low (<1% modal share) (EPOMM, 2018), having reached meaningful levels in only a few cities (Marqués et al., 2014), such as Seville and Barcelona (Spain), which have been recognised in the Copenhagenize Top 20 Bicycle Friendly Cities Index (Pucher & Buehler, 2017). Case studies of cities that have successfully managed to increase cycling modal share through investment in bicycle infrastructure and adoption of cycling-friendly policies can provide insight into the conditions that have sparked a growth in cycling numbers, and aid in understanding why some cities are so far ahead of others in their efforts to promote cycling (Handy et al., 2014). The city of Seville, Spain, has been dubbed the "cycling capital of Southern Europe" (Castillo-Manzano et al., 2015) and is presented as an example to emulate for cities with no existing cycling culture, such as most Southern European cities, for whom the model proposed by cities such as Amsterdam and Copenhagen have always seemed out of reach. Seville, a city of roughly 700,000 inhabitants, managed to increase the modal share of cycling from near zero to 6.6% in the period 2006-2011. The number of daily cyclists increased from 6,000 to 66,000 cyclists following the introduction of the BSS *SEVici*, and the creation of a 140km long cycling network (Castillo-Manzano et al., 2015). In addition to local residents and the university community, tourists are specifically targeted as a (potential) user group of the service (Castillo-Manzano & Sanchez-Braza, 2013).

The limited research that has focused on BSS in small and medium-sized cities in Southern Europe, consists of the following:

- Surveys with users of shared bicycles, e.g. to get an overview of the socio-demographic characteristics of users and the factors motivating BSS use in Seville (Spain) (Castillo-Manzano & Sanchez-Braza, 2013), in Palma de Mallorca (Balearic Islands, Spain) (Segui Pons et al., 2016), and in Rethymno (Crete, Greece) (Bakogiannis et al., 2019) and to understand the transition from public to private bicycle use in Seville (Castillo-Manzano et al., 2015);
- BSS trip data analysis to determine different usage types and travel behaviour in Santander, Spain (Bordagaray et al., 2016), and to spatially describe BSS use in general in Palma de Mallorca (Segui Pons et al., 2016) and in Rethymno (Bakogiannis et al., 2019);
- Stated preference surveys to quantify potential interest in BSS, e.g. with the general Greek population (Efthymiou et al., 2013), and specifically in the city of Drama (Greece) (Nikitas, 2018);
- Manual counts of cycling movements, including shared bicycles, to understand the impact of new cycling infrastructure and the introduction of the BSS in Lisbon (Portugal) (Félix et al., 2020);
- Pilot design for BSS in Piraeus (Greece) (Bakogiannis et al., 2018);
- Analysis of plans and guidelines for infrastructure, including the introduction of the BSS, and their impact on modal share and cycling safety in Seville (Marqués et al., 2014; Marqués et al., 2015).

The case studies for this research are cities that form part of the H2020 CIVITAS DESTINATIONS project, which is focused on piloting and testing a mix of mobility strategies and solutions in Southern European island cities that experience a significant influx of tourists, putting extra pressure on their transport systems. Of the cities participating in the project, three cities were selected to form part of the case studies in this research: Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta). Figure 1.1 shows their land use, existing and planned cycling paths and the locations of the bicycle sharing stations. The cities share similarities in terms of their urban design, are coastal cities, with historic centres and strong port-city relations, are medium-sized cities with comparable population sizes (Giffinger et al., 2007), and have a bicycle sharing system and are in the early stages of the creation of bicycle infrastructure and implementation of cycling policies (see Table 1.1). Different authors have put forward suggestions as to what characteristics could be acting as barriers to cycling in Southern European cities: e.g. hot summers and high humidity (Médard de Chardon, 2016), a challenging topography with hills and elevation differences (Heinen et al., 2010), car-oriented culture and infrastructure (Cavallaro et al., 2017), and economic and social peripheralization, even more so in the case of island cities, as a result of their insularity (Deidda, 2016). At the same time, there is also evidence to support the contrary: e.g. a more attractive climate for cycling, due to low rainfall and lack of sub-zero temperatures (Fishman, 2016; OBIS, 2011), the potential to increase cycling modal share through investment in cycling infrastructure and facilities, as evidenced by the example of Seville (Marqués et al., 2015), and increased availability and affordability of electric bicycles, which can neutralise the negative effect of hills and inclines (Handy et al., 2014; Shaheen et al., 2010).

The selected case study cities can be classified as ‘starter’ cycling cities. Thus far they have a low cycling modal share, and a high car dependence, as can be seen from the bicycle and car modal share in Table 1.1. On a national level, all three countries (Cyprus, Malta, Spain) have an above EU average car ownership (EU average was 507 cars per 1,000 inhabitants in 2019), with a level of 645 cars per 1,000 inhabitants in Cyprus, 519 in Spain and 597 in Malta, in 2019 (Eurostat, 2021). Car dependence has led to associated problems such as traffic congestion, air pollution and carbon emissions from the transport sector. There is some promotion of other modes of transport in all three case studies, including the promotion of cycling; all three cities have seen the introduction of a bicycle sharing system and are in the early stages of the creation of bicycle infrastructure and implementation of cycling policies. BSS have the potential to contribute to creating a more cycling-friendly culture, both for transport and for leisure (Nikitas, 2018). Providing access to bicycles can increase the normality of cycling (Goodman et al., 2014) and offer a solution to a lack of bicycle ownership, which has been identified as one of the barriers to cycling (Félix et al., 2019). Findings from ‘starter’ cycling cities in Southern Europe show that the main barrier for current and potential cyclists are issues related to actual and perceived road safety and a lack of a safe cycling network e.g. in Lisbon, Portugal (Félix et al., 2019), in Drama (Nikitas, 2018) and Rethymno, Greece (Bakogiannis et al., 2019), in Limassol (Maas et al., 2019) and Larnaca, Cyprus (Nikolaou et al., 2020), in Las Palmas de Gran Canaria, Spain (Maas, Attard & Caruana, 2020) and in Malta (Maas & Attard, 2020).



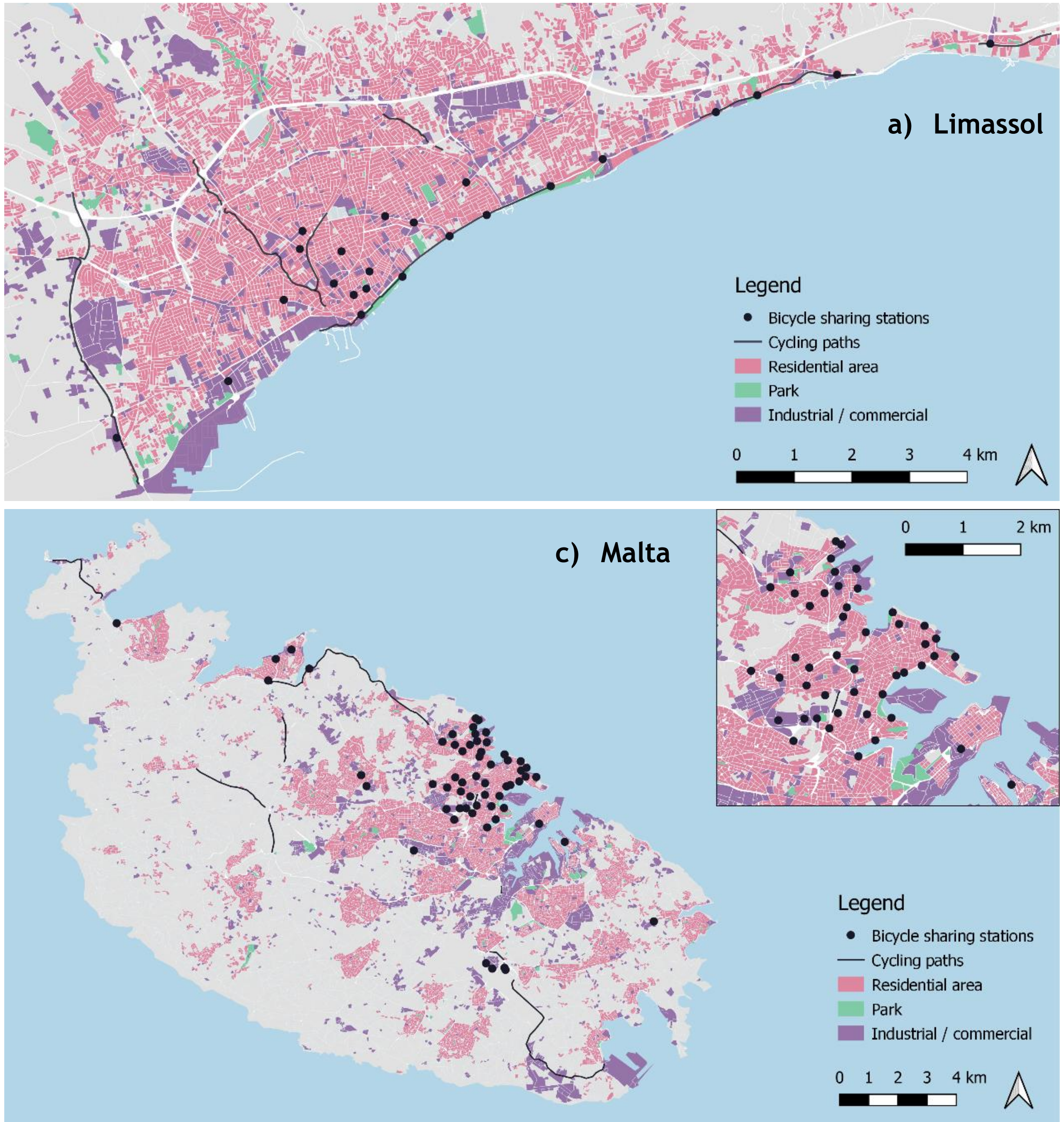


Figure 1.1: Land use, cycling paths and bicycle sharing stations in: a) Limassol, b) Las Palmas de Gran Canaria and c) Malta (adapted from Maas et al., 2020)

Table 1.1: Comparison of cycling attributes of three Southern European island cities

City (Country)	Population [1]	Modal split [2]	Bicycle sharing system [3]			Cycling context [4]	
			Operator	Bicycles and stations	Registered users	Urban cycling infrastructure	Cycling policy / legislation
Limassol (Cyprus)	207,000	Car: 92% PT: 1.5% Foot: 6% Bicycle: 0.7% (2017)	Nextbike Cyprus, Managed by private operator, introduced in 2012 nextbike.com.cy	170 bicycles, 23 stations (2019)	24,000 registered users (May 2018)	Fragmented bicycle paths measuring 14 km (2018), new bicycle infrastructure planned on several streets.	Bicycle Bill (2018); Limassol SUMP (2019)
Las Palmas de Gran Canaria (Spain)	378,998	Car: 63% PT: 13% Foot: 15% Bicycle: 0.5% (2012)	Sítycleta, Managed by SAGULPA (municipal parking authority), introduced in 2018 www.sitycleta.com	375 bicycles, 37 stations (2019)	22,000 registered users (January 2019)	Bicycle paths and lanes with a total length over 20 km, but it is planned to be enlarged to 52 km and connected to form a network (works started in 2019).	LPGC SUMP (2012); Bicycle Master Plan (Plan Director de la Bicicleta, 2016)
Valletta conurbation (Malta)	205,768 (South + North Harbour districts)	Car: 75% PT: 11% Foot: 7.5% Bicycle: 0.3% (2014)	Nextbike Malta, Managed by private operator, introduced in 2016 nextbike.com.mt	360 bicycles, 60 stations (2019)	11,000 registered users (January 2019)	In urban area only a few shared bus lanes. Outside of urban area some fragmented cycling paths and lanes.	*Draft* National Cycling Strategy (2018)

Sources:
[1] Population figures for Limassol (CyStat, 2019a); Las Palmas de Gran Canaria (INE, 2019); Malta (NSO, 2016).
[2] Modal split for Limassol (PTV, 2019); Las Palmas de Gran Canaria (Ayuntamiento de Las Palmas de Gran Canaria, 2015); Malta (Buijs et al., 2017).
[3] Information on BSS in Limassol (N. Ioannou, personal communication, May 18, 2018); Las Palmas de Gran Canaria (C. García, personal communication, January 15, 2019); Malta (A. Camilleri, personal communication, August 14, 2017; J. Gabarretta, personal communication, January 11, 2019).
[4] Information on cycling context in Limassol (M. Hatziioannou, personal communication, May 16, 2018; D. Demetriou, personal communication, May 17, 2018; PTV, 2019); Las Palmas de Gran Canaria (Ayuntamiento de Las Palmas de Gran Canaria, 2015; Estudio Manuel Calvo S.L., 2016); Malta (TM, 2016a; TM, 2018).

1.3 Aims and objectives

The aim of this research is to analyse the usage of Bicycle Sharing Systems (BSS) in Southern European island cities and their role in promoting cycling as a mode of transport, in order to formulate recommendations for accelerating a modal shift away from private car use towards sustainable urban mobility.

This aim can be further broken down in a number of research objectives (RO):

RO1 To understand the main characteristics of BSS and their role within sustainable urban mobility;

RO2 To identify the factors influencing travel behaviour for cycling and BSS use;

RO3 To understand the spatial and social context of cycling and BSS use in Southern European island cities;

RO4 To analyse BSS use and assess the factors influencing travel behaviour of BSS users in the case study cities;

RO5 To compare BSS use in the case study cities in order to make recommendations for promoting cycling.

1.4 Thesis structure

Building on this introduction, *Chapter 2* presents the findings of the literature review on transport planning and the urban transport problem, the concept of sustainable urban mobility, the emergence of cycling as a mode of transport in many cities around the world, and the rise and role of BSS in the transition to cycling. *Chapter 3* discusses the theoretical framework of travel behaviour underpinning this research, specifically the applications of socio-ecological models to understand the factors that influence cycling and BSS use. The chapter ends with a discussion of the research gap, linking the insights from the literature review and the theoretical framework, and sets the research agenda for this study. *Chapter 4* introduces the research design, including the research questions, as well as the data collection and data analysis techniques employed. The main findings of the study are subsequently presented: *Chapter 5* discusses the spatial and social context of cycling in the case study cities, *Chapter 6* presents the findings of the operation and use of the BSS in the case study cities, whereas *Chapter 7* and *Chapter 8* discuss the influence of individual and social environment factors, and physical environment factors, on BSS use respectively. A comparative analysis of the results from the case study cities is included in each of the results chapters, *Chapter 5* to *8*. *Chapter 9* contains the discussion, relating the findings to insights from the literature and presenting lessons learned and recommendations. The final chapter, *Chapter 10*, presents the conclusions of this research.

Annexes A to H contain background information to the literature review and the data collection and analysis. *Annex A* presents different standards and designs for cycling infrastructure and traffic calming. *Annex B* contains the interview guides, whereas *Annex C* details the BSS user survey questions. *Annex D* provides further background to the approaches used to collect the survey responses. *Annex E* presents the survey numerical codes used to prepare the data for analysis. *Annex F* contains the results from the correlation matrices showing the associations between the dependent variable and independent variables, whereas *Annex G* presents the parameter estimates for the binary logistic regression models. Lastly, *Annex H* visualises monthly BSS station use as origins and destinations in a series of maps for each case study city.

2. Literature review

This chapter addresses the first *research objective (RO1)* of this study, to understand the main characteristics of BSS and their role within sustainable urban mobility. The first section, 2.1, discusses the planning of cities, including land use and transport planning within urban areas, introducing concepts such as mobility and accessibility, as well as dominant urban transport problems. The second section, 2.2, introduces the concept of sustainable urban mobility, including the Avoid-Shift-Improve approach and planning tools for sustainable mobility. The third section, 2.3, focuses on cycling as a mode of transport, discussing different types of cyclists and cycling behaviour, as well as the benefits of cycling. The fourth section, 2.4, narrows in on the central topic of this study; bicycle sharing systems (BSS), their history and operation, as well as characteristics and benefits of their use. The final section, 2.5, summarises this chapter and looks ahead to the next chapter.

2.1 Urban transport planning

To understand why some cities have much higher levels of cycling than others, the first step is to look at their urban planning paradigm and transport system and patterns, as mobility behaviours are embedded in the context of urban space and the transport network and infrastructure (Gössling et al., 2016; Newman & Kenworthy, 2015). Urban planning, the policy making and management of urban change (Pacione, 2009a), has a large impact on transport planning and mobility behaviour. Urban planning comprises policies specifically targeted at the urban scale, such as zoning, land use planning or urban redevelopment, but is also influenced by social and economic policy at a larger scale; national housing and labour policies for example. The purpose of urban planning differs per country, but generally aims to regulate land use, to ensure the provision of goods and services, to balance competing interests and to ensure land is used to benefit the public interest (Pacione, 2009a; Thornley, 1991). European cities generally have higher densities than those in the US or Canada. This is due to stricter land use policies and a higher price of land, as well as a higher price of gasoline as a result of government tax policies, making car use in Europe much more expensive than in the US, thus making alternative transport options more attractive and resulting in a higher modal share of public transport and active modes (Pucher, 2004).

There has always been a close relationship between the predominant mode of transport and the structure of the urban form: from the distant past when walking was the main form of transport and cities were compact and densely populated, to the introduction of trains and streetcars, allowing travel over greater distances and the start of the separation of residential and commercial areas, to almost universal car ownership, which led to the establishment of an extensive road network, an increase in personal mobility and further spreading out of urbanization (Pacione, 2009b). Despite the strong interdependence between transport and urban form, the transport planning and land use and urban planning fields are not always viewed together in a holistic manner (Marshall & Banister, 2007). As Bertolini (2012) has noted, "urban planning still seems to see mobility as just one among many particular concerns, rather than a central, structuring perspective on the development of cities", while transport planning, on the other hand, "still seems to ignore the broader, long term implications for the quality of urban life" (Bertolini, 2012). Choices about transport are ultimately fundamental to the spatial design of cities and the comfort and liveability of urban spaces (Carmona et al., 2010).

2.1.1 Mobility and accessibility

Two core concepts in understanding transport are mobility and accessibility (Hanson, 2004). Whereas transport can be considered the means, mobility and accessibility are the end (Gaffron et al., 2007). Mobility refers to the ability to move between different locations of activities, so-called activity sites. Accessibility refers to the number of activity sites available within a certain distance or travel time (Handy & Niemeier, 1997; Hanson, 2004). The level of mobility and accessibility varies for different transport modes; the number of activity sites that are within your reach in half an hour when travelling on foot is lower than those that you can reach when travelling by car (Hanson, 2004). Accessibility can refer to the accessibility of a place, "how easily certain places can be reached", or the accessibility of people, "how easily a person or group of people can reach activity sites" (Hanson, 2004). Lower density settlements (e.g. larger residential plot sizes, urban sprawl), increased size of establishments (e.g. larger supermarkets and shopping malls in place of neighbourhood groceries), and car-centric planning (e.g. prioritization of vehicular transport network over the pedestrian network) mean that accessibility has come to depend more on mobility, and particularly, more on vehicular mobility than pedestrian mobility (Hanson, 2004).

The transport system is considered to be a "network comprising a series of nodes and links which connect origins and destinations", with different land uses (e.g. residential, commercial, industrial) generating trips from one zone to the other (Banister et al., 2007). In line with this understanding of transport, travel is generally considered as a derived demand; an activity undertaken in order to access desired activities in other places (van Acker et al., 2010). However, travel is not only a means to an end; it can also be undertaken for its own sake, e.g. walking or cycling for pleasure, sightseeing, or going shopping as a pastime (Banister et al., 2007).

Traditionally, transport planning has been very much focused on planning for automobiles, aimed at maximizing traffic speeds, minimizing congestion and reducing crash rates (Litman, 2017). Transport planning generally involves the analysis of current conditions and future projections for growth, through a traditional four-step urban transport model (see Table 2.1). Transport planners use traffic volume analysis, measured as the ratio between volume and capacity (the V/C ratio) during peak traffic, and Level-of-Service (LOS) ratings, an expression of the level of congestion on roads (ranging from A, best, to F, worst), to identify where additional capacity is needed and what possible projects and strategies can be employed to address this. These strategies are then evaluated and prioritised and adopted in short-term programs and long-term plans, and financial plans are developed for those strategies that are selected for execution (Johnston, 2004; Litman, 2017). Basing decisions on transport models with such a narrow focus has led to a 'transport bias'; transport planning predominantly focused on motorised vehicles, while overlooking the potential, the value and the needs of non-motorised modes within the transport system (Johnston, 2004). The allocation of space and investment in non-car infrastructure is essential to promote the use of active transport modes, including walking and cycling (Gössling et al., 2016; Kenworthy & Laube, 1999). Some cities have started adopting an alternative transport hierarchy, prioritising active, affordable and resource efficient modes over vehicular transport, by ranking the needs of pedestrians, bicycles, public transport, freight, taxis and multiple occupant vehicles as more important than single occupant vehicle travel (Bradshaw, 2004).

Table 2.1: Traditional four-step urban transport model (Johnston, 2004; Litman, 2017)

	Sub-model	Steps
1	Trip generation model	Determination of the number of trips per household based on characteristics such as household income and size.
2	Trip distribution model	Division of the region into different transport analysis zones, or transport model zones, from which the generated trips are calculated, within and between the different zones, based on origins and destinations.
3	Trip mode choice model	Calculation of predicted mode choice, based on the availability of different modes and routes, their associated generalised costs (including time and financial costs), and other factors such as travel speed per mode, congestion delays and parking costs.
4	Trip assignment model	Assignment of trips to the transport network, calculation of the resulting traffic volume on each route.

2.1.2 The urban transport problem

Urban transport, and the prevalence of the private car as the main mode of transport in particular, has led to a number of urban transport problems, as summarised in Table 2.2. The negative external effects of the transport system are present on different levels: they can have an immediate or a cumulative impact (e.g. noise pollution vs. CO_2 emissions), they can have a local or a global impact (e.g. lead emissions vs. greenhouse gas emissions), and they can manifest themselves differently across different areas in a city and levels of society (Geerlings et al., 2012).

Table 2.2: The seven dimensions of the urban transport problem (Thomson, 1977)

1	Traffic flow and congestion issues
2	Insufficient public transport capacity during peak demand
3	Off-peak inadequacy of public transport
4	Accessibility issues for pedestrians and cyclists
5	Environmental impacts
6	Accidents and road safety concerns
7	Parking difficulties and illegalities

Traffic congestion occurs as a result of a concentration of vehicles on the road greater than the infrastructure can support, generally during peak commuting hours (Thomson, 1977). While the traditional response in the 1950s and 60s was to focus on the supply side of the problem and build new infrastructure to increase the capacity in order to meet demand (Pacione, 2009b), analysis of this approach shows that when capacity is extended, additional vehicle traffic is attracted (Litman, 2017). This ‘induced demand’ is a result of a simple supply and demand curve; as congestion increases, traffic demand stops growing, while when capacity is extended, additional vehicle traffic is attracted. Transport can occupy up to a quarter or a third of a city’s land use: the spatial footprint of all streets, paths, car parks, petrol stations, (air)ports, etc. combined (Southworth & Ben-Joseph, 2013). In addition, cars are parked around 95% of the time, also taking up a lot of valuable public space when not in use (Shoup, 1997).

Exposure to air pollutants, including particulate matter (generally measured as PM_{10} and finer $PM_{2.5}$), hydrocarbons (e.g. BTEX: benzene, toluene, ethylbenzene and xylenes), carbon monoxide (CO) and nitrogen oxides (NO_x), has significant impacts on public health, such as a higher incidence of childhood asthma, impaired lung function, and increased cardiovascular mortality and morbidity (Giles-Corti et al., 2016). Transport is also a major contributor to CO_2 emissions and therefore to climate change. In the EU, transport accounts for a quarter of the EU's greenhouse gas emissions, and contrary to other sectors where emissions are being reduced, in the transport sector emissions are still growing (European Commission, 2019). As laid down in the EU 2030 framework for climate and energy, the goal is to reduce overall greenhouse gas emissions by 30% in 2030 and by up to 80-95% in 2050, compared to 1990 levels (European Commission, 2014). The European Green Deal (European Commission, 2019) and the proposed European Climate Law (European Commission, 2020b) raise the ambitions of these targets, to 50-55% GHG emission reduction in 2030, compared to 1990 levels, and to reach climate neutrality in 2050. These targets are also needed to meet the agreed targets under the Paris Agreement, ratified by the EU in 2016, to pursue efforts to limit the global temperature increase to 1.5°C. Finding alternatives to fossil fuel based transport becomes increasingly important to meet these European and global targets.

The transport bias of urban mobility – transport planning predominantly for private cars - has resulted in widespread investments in road infrastructure and urban sprawling, and increased energy use and carbon emissions, whilst overlooking the importance of providing equitable access to opportunities (UN Habitat, 2013). Transport equity concerns social and environmental justice issues related to the accessibility of transport: the distribution of both the benefits of the transport system, such as access to activities like work, education, healthcare, shopping and leisure; as well as the costs or burdens of the transport system, for example the impacts of noise and air pollution from transport on communities and exposure to risks from transport of hazardous materials (Deka, 2004; Golub & Martens, 2014). Transport inequality, or transport poverty, is the result of the interplay of transport disadvantages (e.g. high public transport fares, lack of access to information, no access to a private car, poor public transport service) and social disadvantages (e.g. low income, poor health, limited skills). Whereas these are not synonymous, they do often occur in unison and can reinforce each other, for example through lack of access to employment opportunities, or through limited skills to access alternative transport information (Lucas, 2012). Car-dependent development encourages social segregation through urban sprawl, the increase of distances and travel time for non-car users, and by severing access between communities and the services they need (Woodcock & Aldred, 2008). The risk of fatality on the road is also distributed unequally; in 2015, 71% of road fatalities in urban areas in the EU were vulnerable road users: pedestrians, cyclists and mopeds/motorcyclists (European Road Safety Observatory, 2017).

Approaches to overcome these urban transport problems have diversified since the standard supply-fix approach of the 1950s and 60s and include demand-side measures such as promoting the efficient and equitable use of infrastructure (e.g. through the use of traffic lights to improve traffic flow, reserved lanes for high-occupancy vehicles, and reversible traffic lanes), minimising the environmental impact of the car (e.g. by reducing demand through car-restraining policies such road pricing and reduced parking) and non-transport initiatives, such as staggering working hours, tele-working and reducing the need for travel by promoting higher density and mixed land use (Banister, 2011). However, despite the diversification of responses to the urban transport problem, many transport planners still rely on conventional transport models, which prioritise automobile travel and further lock in automobile dependency. This creates a self-fulfilling prophecy by directing resources primarily towards car-centric infrastructure, giving little consideration to infrastructural needs for other modes of transport (Johnston, 2004). Investment in infrastructure for public transport and active modes is only a fraction of the money spent on infrastructure for cars (Cass & Faulconbridge, 2016; Young & Caisey, 2010). Furthermore, traditional transport models are not fully representing and simulating all aspects of travel behaviour. Transport models use effects such as travel kilometres, hours of delay or total emissions to evaluate their performance, but do not take into account the wider impacts on the population (Golub & Martens, 2014) and often omit non-motorised mode choices, trip purposes and adaptive behaviour such as trip-chaining, changing travel time or even relocation of home or work (Johnston, 2004). To improve equity in transport planning, Martens (2012) suggests using accessibility, defined as the cumulative number of destinations that can be reached within a certain timeframe (for different transport modes), as the measure of benefits from transport plans (Golub & Martens, 2014; Martens, 2012).

2.2 Sustainable urban mobility

To counteract the legacy of the transport bias and its undesired side effects, the sustainable mobility concept proposes a better balance between social, economic and environmental goals; aiming for social well-being, economic vitality and environmental integrity (Pacione, 2009a). The term sustainable development was coined by the Brundtland Commission in 1987 and was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland, 1987). While recognizing that effective transport is essential for people's prosperity, the objective of sustainable mobility is the provision of a transport system that (Geerlings et al., 2012; Litman, 2008):

1. meets the basic access and mobility needs of people, including access to economic opportunities, now and in the future;
2. offers a choice of transport modes that provide equitable, affordable and efficient mobility options benefitting all members of the community; and
3. improves general quality of life by reducing environmental impacts from transport, such as emissions, noise, waste and land use change.

Sustainable mobility has been presented as the new, alternative paradigm to overcome decades of car-centric planning, shifting the focus from traffic to people. It is centred around actions that reduce the need to travel, encourage modal shift, and which encourage greater efficiency in the transport system (Banister, 2008).

2.2.1 An alternative approach: Avoid-Shift-Improve

New approaches to transport planning, such as transport demand management and multimodal transport planning, focus more on management approaches than on the construction of physical infrastructure (Johnston, 2004). The Avoid-Shift-Improve approach, presented in Figure 2.1, provides a hierarchy of priorities that can guide sustainable mobility policies (Ang & Marchal, 2013; Jonuschat et al., 2015).

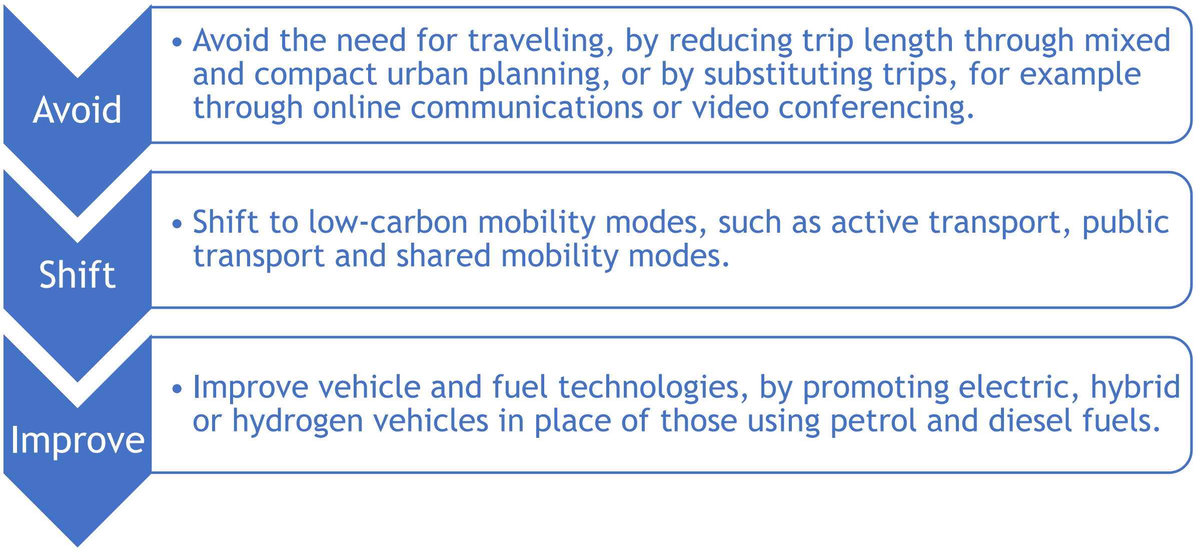


Figure 2.1: The Avoid-Shift-Improve approach for sustainable urban mobility (Ang & Marchal, 2013; Jonuschat et al., 2015)

Avoiding the need to travel, and thus avoiding the negative external effects of transport, can be achieved through different actions. Trips can be substituted, through online communications, tele-working or online shopping, in which case deliveries can be consolidated and optimised. Trips can be chained, combining several activities in one 'trip tour', that replaces several individual trips. Lastly, trips can be made shorter, by reducing the distance to essential needs, enabling accessibility via active modes of transport, such as walking and cycling (Ang & Marchal, 2013; Banister, 2011).

Modal shift, a change in the percentage of trips made using a particular mode of transport, is one of the tools to promote sustainable mobility. Modal shifts that promote sustainable mobility are shifts from private car use (particularly as a single occupant) to active transport, public transport, or shared mobility, including multimodal mobility; the flexible usage and combination of different transport modes, such as walking, cycling, automobile, public transport and shared mobility services, including the recent rise of micro-mobility solutions (Abduljabbar et al., 2021; Jonuschat et al., 2015; van Nes, 2002). Apart from the provision of a multitude of mobility services, multimodal mobility systems require seamless integration of transport networks, real-time mobility information and integrated payment options, as well as coordination of time-tables (van Nes, 2002). Mobility-as-a-Service (MaaS) is a relatively new transport approach that promotes multimodal and shared mobility, by putting the needs of the traveller at the centre of the service, creating a system in which easy access to the most appropriate transport mode or service – combining services from public and private transport providers – is included in a bundle of flexible travel service options for the end user. The integration of information provision, payment options and physical connection of modes offers increased flexibility and a door-to-door mobility service (Dotter, 2016).

A modal shift to active transport modes, such as walking and cycling, can reduce traffic related diseases and injuries, noise and air pollution and greenhouse gas emissions, while simultaneously providing individual health benefits and optimising the use of space, especially for shorter inner-city trips (Sallis et al., 2016). While not providing the same health benefits as active travel, micro-mobility solutions such as (electric) kickscooters, hover-boards, skateboards and Segways have seen a rapid rise in the urban environment in recent years. When used as an alternative to the private car for short-distance trips, a modal shift to micro-mobility solutions represents a reduction in noise and air pollution, as well as requiring much less road and parking space. At the same time, the rapid increase in micro-mobility usage has sparked concerns over road safety, littering of the public realm, and encroachment on pedestrian space (Abduljabbar et al., 2021). A modal shift to public transport, any type of publicly available high occupancy vehicles, provides benefits in terms of reduced occupancy of space and lower per capita greenhouse gas emissions. Public transport encompasses a wide range of transport modes, including buses, bus rapid transit (BRT), trams, light rail, metro, ferries, funiculars, cable cars and trains. Other forms of group transport, sometimes called paratransit, either operate for a special purpose, such as shared vans, (mini)buses or carpools for employee or school transport, or offer flexible scheduling and routing, for example in the case of (shared) taxis and other demand-responsive services (Pucher, 2004). Shared mobility, i.e. sharing a car, bicycle or ride, has spread rapidly in recent decades, and presents an important element in multimodal mobility, since such services can be instrumental in augmenting and connecting public and individual transport options, by providing alternative options on a specific route, and by providing a solution for the first- or last-mile leg of a journey (Jonuschat et al., 2015). Shared mobility is a growing segment of the sharing economy, which promotes the sharing of goods or the payment for a service, instead of private ownership (Shaheen & Chan, 2016), such as *Airbnb* (shared accommodation), *Blablacar* (shared rides) and *NeighborhoodGoods* (shared tools and equipment) (Shaheen & Chan, 2016).

Improvements in vehicle fuel use and efficiency, such as by replacing conventional vehicles with electric vehicles (cars, but also buses, ferries and railway engines), can help to reduce carbon emissions, although the emission reduction potential depends on the source of the electricity used to charge vehicles; whether this is from renewable sources, nuclear power or fossil fuels (EEA, 2018a). Although sales of electric vehicles have increased significantly in past years, in 2017 only 1.5% of all new vehicles sold in Europe were electric (EEA, 2018a), and zero- and low emission vehicles will need to gain significant market share by 2030 to reach the carbon emission targets adopted (European Commission, 2016). With the aim of incentivising and accelerating the uptake of electric vehicles, many European member states have started creating policy frameworks and economic incentives for the wider installation of electric charging points, as limited access to charging and maintenance infrastructure is one of the main barriers for increased electric vehicle uptake (European Commission, 2016).

2.2.2 Planning for sustainable urban mobility

In order to plan for sustainable urban mobility, transport planning needs to overcome the a priori prioritisation of the private automobile (Zipori & Cohen, 2015), and include active and public transport options, both in a unimodal and multimodal context, to better reflect reality and to be able to realistically compare different transport options (Litman, 2017). Transport planning models should therefore include a wider array of trip purposes, travel times and trip chaining of activities, the cost of congestion and parking, and the effect of generated and induced traffic (Johnston, 2004; Litman, 2017).

At the European level, Sustainable Urban Mobility Plans (SUMPs) are being promoted to plan urban mobility in a new way (European Commission, 2013; Wefering et al., 2014). The European Commission's 'European Strategy for Low-Emission Mobility' (European

Commission, 2016) states that cities and local authorities are at the forefront in the shift to low-emission mobility and that they should “encourage modal shift to active travel, public transport and shared mobility schemes such as bike- and car-sharing” as part of a comprehensive approach to sustainable urban mobility planning. In a SUMP, the focus of transport planning is shifted from traffic to people, and instead of having traffic flow control and speed improvement as its primary objectives, the main goals are to ensure accessibility, sustainability and quality of life. Urban mobility needs to be integrated across policy sectors such as transport and land use planning, and encompass economic, environmental and social policy goals (European Commission, 2013). The SUMP planning process adopts an integrated approach, longer timeframes, involvement of local stakeholders, and stresses the importance of co-creation, learning and evaluation as means to inform and improve planning strategies (Wefering et al., 2014). The shift in approach to transport planning represented by the SUMP process also demands a change in the modeling of transport flows and mobility needs, as traditional four-step models fail to adequately incorporate active modes, micro-mobility and shared mobility.

Experiences from different European cities prove that it is possible to decrease the modal share of private cars in favour of more sustainable transport through a combination of “mutually reinforcing transport and land-use policies that make car use slower, costlier and less convenient, while increasing the safety, convenience, and feasibility of walking, cycling, and public transport” (Buehler et al., 2017). This combination of ‘push’ and ‘pull’ factors, or ‘sticks’ and ‘carrots’, refers to a mix of measures to get people out of their car, either by pushing them out, through fiscal disincentives and physical restrictions, or by tempting them out, by providing alternatives, including information and incentives (Kenyon & Lyons, 2003; Nikitas, 2018). Evidence shows that enablers to active travel only modestly impact mode shift, whereas deterring car use appears more effective at changing behaviour (Piatkowski et al., 2019). Combining investment in public transport, cycling and walking with policies to reduce and restrict car use have had the greatest positive impact on increasing overall liveability and promoting sustainable mobility (Oldenziel et al., 2016) and on achieving modal shift towards active transport (Piatkowski et al., 2019). Recent efforts to rethink the approach to urban mobility and plan for people instead of traffic include the ‘15-minute city’ concept adopted in Paris and the ‘Superblocks’ idea from Barcelona. The ‘15-minute city’ is an urban planning concept emphasizing proximity of all basic services - living, working, commerce, healthcare, education and entertainment – within a 15-minute walk or cycle from people’s homes, thereby reducing the dependency on a car to access essential services (Moreno et al., 2021). The ‘Superblock’ concept, originating in Barcelona’s grid-based *Eixample* neighbourhood and covering areas of around 400x400m, bans through-traffic from the interior of the block, allowing only active transport and residential traffic at low speeds (<20km/h), while diverting other traffic to the roads framing the superblocks, including public transport connections every 400m at intersections. By removing traffic from the interior roads, road space can be reallocated to create public open and green spaces which prioritise pedestrian and cyclist movement (Mueller et al., 2020).

2.3 Cycling as a mode of transport

The archetype of the bicycle is considered to be the design of Karl von Drais, presented in 1817; a 'running machine' that features a bicycle frame and two wheels, but no pedals. Bicycle design developed further with the French *velocipede* and the 'penny-farthing', bicycles with an enlarged front wheel with pedals and a mechanical crank drive, in the mid-19th century. In 1890, the 'safety bicycle' was developed, with a diamond-shaped frame, chain-driven rear wheel and rubber tyres; the bicycle design we know today (Oosterhuis, 2016). The period between the First World War and the 1950s saw bicycles rise in popularity in many parts of the world (Oldenziel et al., 2016; Oosterhuis, 2016). The bicycle is also accredited with giving women unprecedented mobility, freedom and independence, contributing to female emancipation and liberation from corsets and long dresses (Herlihy, 2004). However, a bicycle is not always an emancipatory tool, and remains for many people the only available transport option; one that is not only associated with independence and enjoyment, but also with precarity, fears of harassment and insufficient road safety (Golub, et al., 2016; Soliz, 2021).

Around Europe, and the world, the 21st century has seen something of a cycling renaissance, with many cities moving away from the car-centric infrastructure, urban design and planning policies that became dominant since the 1950s. The interest in urban cycling and in promoting cycling as a viable means of transport has been spurred by the increasing recognition of the negative impacts of car use and the positive benefits of cycling. Cycling policies implemented in famous bicycle cities such as Amsterdam (the Netherlands) and Copenhagen (Denmark) during the 1980s and '90s caused the modal share of cycling to increase (Oldenziel et al., 2016), and triple fold increases in cycling have been observed in cities that did not previously have a strong cycling culture, such as Paris (France) and London (UK) in the last 3 decades (Pucher & Buehler, 2017). In more recent years, cities such as Seville (Spain), Bogotá (Colombia) and Buenos Aires (Argentina) have seen a dramatic growth in cycling numbers (Marqués et al., 2015; Pucher & Buehler, 2017). Cycling is not solely promoted as a mode of transport; urban cycling has also become a symbol of sustainability and public health and an engine of economic growth, and has been adopted by many cities as a branding tool (Oldenziel et al., 2016). Figure 2.2 shows the increase in cycling modal share in a number of cities in Europe, and North and South America.

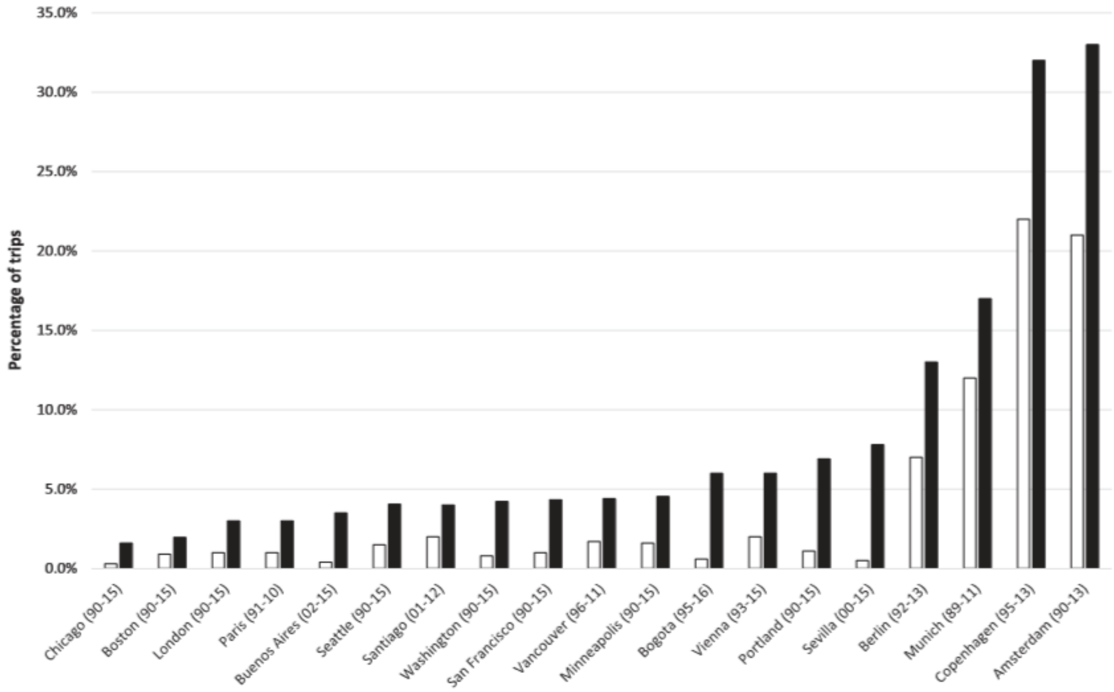


Figure 2.2: Increasing cycling modal share in European and American cities, 1990–2015 (Pucher & Buehler, 2017)

2.3.1 Types of cycling and cyclists

Travelling by bicycle is done for diverse purposes (Krizek et al., 2009). Cycling for utility, also termed transport or commuter cycling, refers to bicycle trips made for purposes related to work, education and shopping trips. Cycling is however not always a means to an end, and is also done for leisure purposes, including cycling for sport (e.g. road cycling, mountain biking, off-road cycling), cycling as exercise, and cycling for recreation, including for holiday and tourism purposes (Fuller et al., 2013b; Handy et al., 2014). Cycling trips can also be a combination of both, whether that means enjoying a leisurely ride on the way to a destination, or running errands while going cycling for fun (Handy et al., 2014; Krizek et al., 2009; Olafsson et al., 2016). As a transport behaviour study in Denmark highlights, cycling also forms an important part of multimodal travel, where a bicycle is used in conjunction with public transport, walking or the private car to cover the distance between origin and destination (Olafsson et al., 2016).

Cyclists come in different shapes and sizes. A common typology used to segment different types of cyclist is based on the Portland Office for Transportation paper 'Four Types of Cyclists', developed by their Bicycle Coordinator Roger Geller (2006): 1) strong and fearless; 2) enthused and confident; 3) interested but concerned; and 4) not interested: no way, no how. Based on initial findings from Portland, and later vetted with data from other cities, the distribution of the different categories has been found to be roughly as follows for cities in the US: <1-2% of strong and fearless cyclists, those that will cycle regardless of conditions, generally young, fit and male; ~7-10% enthused and confident, those who have been attracted to cycling by minimal construction of bicycle infrastructure; ~50-60% interested but concerned, those who are interested in cycling, but are concerned for their safety and afraid of cycling on roads with cars; and ~30-35% not interested, those who have a lack of interest in cycling or cannot for reasons of topography or physical inability (Dill & McNeil, 2013; Geller, 2006). In the academic literature, alternative approaches that have been used to categorise cyclists are based on cycling frequency, seasonality of cycling behaviour, and lifestyle typology of cyclists (Dill & McNeil, 2013).

The adoption and use of electric bicycles have grown substantially in recent years. Electric bicycles, also termed e-bikes, power-assisted bicycles or pedelecs, are bicycles with extra assistance provided by an electric motor, usually supporting speeds up to 25km/h and powered by a lithium-ion battery (EEA, 2018a). Electric bicycles are useful in assisting cyclists to overcome barriers such as steep hills, long distances and hot weather, and allow people to commute to work without breaking a sweat. E-bikes enable other groups of people to consider cycling, such as people with physical limitations, as well as older people (Dill & Rose, 2012). In the past decade, electric bicycles have also become more mainstream and are a rapidly growing phenomenon: in Northern Europe, e-bike numbers have grown fifteen-fold between 2006 and 2016 to a total of 1.5 million (CONEBI, 2016; Pucher & Buehler, 2017). In 2016, both in the Netherlands and Belgium, e-bike sales constituted 30% of all bicycle sales (Pucher & Buehler, 2017). Apart from overcoming longer distances and inclines, electric bicycles can also help cyclists feel more comfortable in faster moving traffic, as it assists with accelerating and keeping up with traffic. The faster speed can pose problems too though, as the difference in speed between e-bikes and regular bicycles can lead to conflict on bicycle lanes and paths (Dill & Rose, 2012). Concerns about a potential substitution effect – a loss of net physical activity because of a shift from bicycle to e-bike – have been proven unfounded in a study of the Norwegian cycling population: results showed the appeal of the e-bike is strongest for those with “little interest in, or level of, physical activity”, thus resulting in a net positive effect for public health (Sundfør & Fyhri, 2017). Further research with evidence from other countries and contexts is necessary to understand whether this effect is indeed non-existent or whether it depends on specific country characteristics.

2.3.2 Benefits of cycling

Cycling as a mode of transport is being promoted in cities around the world the globe as part of an effort to promote sustainable mobility, and particularly, more active transport, because of its potential to contribute to meeting environmental, climate, transport, public health, and other socio-economic policy goals (Goodman et al., 2013; Handy et al., 2014; Sallis et al., 2016).

Health benefits

An increase in physical activity, road safety and exposure to air pollution are the three most important factors for the health impacts of active transport (Schepers et al., 2015). In today’s society, most people live a sedentary lifestyle (Bélanger-Gravel et al., 2015). In 2008 over 30% of people over 15 years in the EU member states were insufficiently active (Bollars et al., 2013). Thirty minutes of cycling, the minimum amount of daily exercise recommended by the World Health Organisation (WHO), can contribute to a 50% reduction in risk of developing obesity and non-communicable diseases (NCDs), such as adult diabetes and coronary heart diseases, and improve overall fitness (Oja et al., 2011; Sallis et al., 2016; van den Noort, 2007). From their review of 16 cycling-specific studies on the health benefits of cycling, Oja et al. (2011) found a clear positive relationship between cycling and cardiorespiratory fitness in youth, improvements in fitness and cardiovascular risk in working-age adults, and a strong inverse relationship between cycling activity and mortality and morbidity in middle-aged to elderly people. Incorporating walking or cycling as a part of daily life is more sustainable in the long run as a physical activity than exercise regimes in a gym (Carnall, 2000). Cycling as a mode of transport is also associated with overall health, and has been shown to lead to significantly less work absenteeism, in a study in the Netherlands (Hendriksen et al., 2010). Apart from physical health benefits, physical activity also promotes mental well-being and reduces the risk of stress, depression and anxiety (van den Noort, 2007).

The benefits of increased physical activity are potentially offset by the risks that cyclists are exposed to, in terms of injuries or fatalities as a result of accidents and exposure to air pollutants (Handy et al., 2014). Research assessing the relationship between the benefits and risks of a shift from car to active transport shows that the ratio is overwhelmingly positive (Bauman & Rissel, 2009; de Hartog et al., 2010; Mueller et al., 2015; Schepers et al., 2015). Cycling-induced benefits for chronic disease prevention, obesity reduction, and improved mental health are substantial and supersede the risks of cycling-related injuries and fatalities and exposure to air pollution on a population level (Bauman & Rissel, 2009; de Hartog et al., 2010). Although physical activity outdoors increases exposure to air pollution, research has shown that exposure to air pollutants is generally higher for car occupants than those walking or cycling, as shown by evidence from Copenhagen, looking at particulate matter and exposure to BTEX for car occupants and cyclists travelling through the same environment (Rank et al., 2001), and from Barcelona for exposure to black carbon (BC), ultrafine particles (UFP), CO, $PM_{2.5}$ and CO_2 among pedestrians, cyclists, public transport and car users (De Nazelle et al., 2012). A study along a major commuting route in Leeds, comparing NO_2 and particulate matter exposure for those traveling on foot, by bicycle, by bus and by car, found that the cyclists experienced the least cumulative exposure to pollutants, due to their shorter journey time (Godward, 2018).

The net individual health benefits depend strongly on the context of cycling, and associated safety, in different cities (Handy et al., 2014). In cities where the modal share of active transport is low, pedestrians and cyclists face a greater risk of injury or death due to traffic accidents than car occupants (Elvik, 2009). However, as the modal share of active transport increases, research shows that the “safety in numbers” effect comes into play (Elvik, 2009; Jacobsen, 2003; Robinson, 2005). Safety in numbers describes the strong nonlinearity of the risks of active transport modes, where an increase in distance travelled by walking or cycling does not result in a proportional increase in the number of injuries, but instead in a decrease in the risk of road traffic injury (Doorley et al., 2015; Elvik, 2009). Cycling offers people a mode of transport that is healthy, highly autonomous, flexible and accessible (Efthymiou et al., 2013), although there are potential disadvantages in terms of the physical effort and fitness required, being at the mercy of the weather, and inability to carry heavy or large loads (Heinen et al., 2010).

Environmental, social, and economical benefits

Cycling is also encouraged for its contribution to ameliorating pressing urban environmental issues associated with private motorised transport, such as air and noise pollution, carbon emissions and uptake of land. Cycling consumes almost no non-renewable resources, far less than motorised transport, and hardly contributes to carbon emissions, air and noise pollution (Pucher & Buehler, 2008). In addition, cycling is far more space-efficient than the private car. In their update of the Transport Strategy for Melbourne, Fishman and colleagues visualise the space requirements of different modes of transport in terms of the area required for driving and parking, showing that travelling by bicycle requires an average 1.5 m^2 per person, in high contrast to the near 10 m^2 required for a person using a private vehicle (Institute for Sensible Transport, 2018). For parking purposes, a bicycle requires only one-twentieth of the space an average car occupies when parked (Richards, 1990).

Due to its relative low cost to users, cycling is also an economical choice, and because it is affordable to almost everyone, one of the most equitable forms of transport (Pucher & Buehler, 2008). Seville's bicycle infrastructure is estimated to have cost €0.27 million/km and caters for 70,000 trips per day. The estimated figure for the costs for metropolitan highways, carrying around 50,000 vehicles a day, is €30.8 million/km, which is 114x times higher (Marqués et al., 2015). Cycling proves to be a highly cost-effective solution to providing mobility, also in terms of public infrastructure costs (Pucher & Buehler, 2008). Although there is a paucity of peer-reviewed evidence on the impact of cycling on the local economy, the evidence available shows the potential of cycling friendly streets to contribute to higher turnover in shops. A review of studies in the US and Canada showed that creating or improving the conditions for walking or cycling generally has a positive or non-significant economic impact on nearby food and retail businesses (Volker & Handy, 2021). Focusing on the European context, the European Cyclists' Federation concludes that where streets are transformed from car-oriented to more inclusive for pedestrians and cyclists, contrary to often voiced fears of losing clients, there is an increase in clients coming on foot or by bicycle (Haubold, 2016).

2.3.3 Policies to promote cycling

While the context of a city, its history, culture, topography and climate, influences the level of cycling, an increase in active transport behaviour also depends on having the right policies and legal frameworks in place. These policies can include transport policies, land-use policies, urban development policies, housing policies, environmental policies, financial taxation and incentives and parking policies, as well as stricter enforcement of traffic regulations and restrictions on car use (Pucher & Buehler, 2008; Pucher et al., 2010; Sallis et al., 2006).

Governments can use encouraging measures such as tax incentives and priority lanes, as well as discouraging measures such as road pricing, stricter parking rules and speed restrictions, to make car ownership and use more expensive and difficult (Pucher & Buehler, 2008; Young & Caisey, 2010). Making cycling safe and convenient is essential for cities wishing to promote cycling as a mode of transport (Fraser & Lock, 2011; Pucher & Buehler, 2008). Road safety, and in particular perceived road safety, are paramount in enabling a shift to more active modes; in order for people to consider walking or cycling, road safety needs to be ensured either through traffic calming measures so that speed, volume and mass do not pose a significant risk to vulnerable road users, or by providing segregated cycling infrastructure (Mütze, 2018). The risk of fatality for road users involved in a collision with a vehicle increases exponentially with increase in speed (LaPlante & McCann, 2008; Mütze, 2018). Cycling standards and guidelines from different countries propose increased separation and protection of cyclists on roads with higher speed limits, in order to promote road safety and reduce the risk of conflict (Copenhagenize Design Co., 2013; CROW, 2016; Transport for London, 2014). The different types of cycling infrastructure (e.g. cycle paths, cycle lanes and mixed streets), design elements for traffic calming, and the application of concepts such as filtered permeability are presented in more detail in *Annex A - Cycling infrastructure and traffic calming designs*.

Another high level form of protection for cyclists is enshrining cyclists' vulnerability and safety in traffic legislation, through the concept of presumed liability such as applied in the Netherlands, Denmark and Germany. Such a legal framework places the onus on drivers to anticipate and avoid dangerous situations and creates safer cycling conditions, although accidents can still happen (Pucher & Buehler, 2008). Bicycle skills training and traffic education are essential to ensure all road users are educated about safe walking, cycling and driving practices (Pucher & Buehler, 2010). Some countries have adopted mandatory helmet laws or recommend their use (Olivier & Creighton, 2016), but helmets have been shown to discourage cycling, by making it less convenient, comfortable and fashionable (Pucher & Buehler, 2008). Evidence shows that while helmets and other personal protection devices may increase safety on a personal level, cycling safety on a societal level is created by creating safe infrastructure and making cycling as simple, carefree and normal as possible, so that more people start doing it (Reynolds et al., 2009). This is evidenced by the Netherlands, Belgium and Germany, with high levels of cycling and very limited helmet use, which have some of the lowest rates of bicycle injuries per cycling kilometres (Pucher & Buehler, 2008).

In recent decades, cities around the world have introduced BSS as part of a wider sustainable transport strategy and cycling promotion, e.g. in Seville (Marqués et al., 2015), Dublin (Murphy & Usher, 2015), Montreal (Fuller et al., 2013b), and London (Ricci, 2015). The rise of bicycle sharing systems has positively contributed to the promotion of cycling as a mode of transport. BSS contribute to lowered barriers for urban cycling and the physical provision of bicycles, because of the increased access to bicycles (Médard de Chardon et al., 2017) with the advantage of renting over owning (Efthymiou et al., 2013), as well as through normalising the image of cycling, by "increasing the number and diversity of cycling role models visible" (Goodman et al., 2014), and through "safety in numbers" (Elvik, 2009). BSS certainly play a role in carving out a space for cyclists and bicycles in the urban fabric, and therefore can contribute to the increase of cycling modal share within the urban mobility sphere. In the case of Luxembourg City's bicycle sharing system, this is even specifically mentioned as its purpose: "to serve as a transitional tool to private utility cycling" (Médard de Chardon et al., 2017).

2.4 The rise and role of BSS in sustainable urban mobility

A decade of BSS use has generated a wealth of knowledge on how BSS are operated, and who uses BSS, for what trip purposes, during which times of the day, month and year, and where. While keeping different city contexts in mind, with their varying geography, culture and socio-economic status, this chapter presents an overview of the research and insights on bicycle sharing systems worldwide – their history, operation, use and impacts – especially focusing on the last decade.

2.4.1 History of BSS

The concept of shared bicycles was first introduced in the 1960s in Amsterdam, the Netherlands, by means of the White Bike plan (*Witte Fietsenplan*). The idea has been revived a number of times, for example in the 1990s in Copenhagen, Denmark, with coin-operated shared bicycles. The Dutch and Danish experiments have been termed the first and second generation bicycle sharing systems respectively (DeMaio, 2009). However, bicycle sharing only reached its full potential during the digital age, now that user accounts and bicycles can be tracked and billed according to usage, whereas in the past, theft, disappearance and prolonged use marred the original ideals of these systems (Fishman, 2016; Médard de Chardon, 2016). Bicycle sharing systems are also referred to as BSS (Médard de Chardon, 2016), bikeshare (Buck et al., 2013; Fishman et al., 2013), shared bicycles (Jäppinen et al., 2013; Sarkar et al., 2015) or public bicycles (Beroud & Anaya, 2012; Fuller et al., 2013b; Ogilvie & Goodman, 2012).

Twenty-first century bicycle sharing systems are characterised by smart docking stations or smart bicycles, which can be unlocked using a monitor at the docking station or a mobile app, and are linked to the users' credit card. These are considered third generation bicycle sharing systems (Fishman, 2016), whereas some authors also speak of a fourth generation, a term which is being used to refer to systems which include new technological features such as solar powered docking stations, dockless bicycles, transit card integration and electric bicycles (Parkes et al., 2013; Shaheen et al., 2010). Some bicycles also contain a GPS (Global Positioning System) unit, allowing the operator to track its exact location and route (Fishman, 2016). Following the limited success of the first and second generation bicycle sharing systems, the introduction of IT-based shared bicycles has seen the number of cities offering bicycle sharing systems increase substantially over the past 2 decades, from only a handful in the late 1990s, to around 1,000 in 2016 (Médard de Chardon, 2016) and almost 3,000 active systems in 2020 (Galatoulas et al., 2020).

2.4.2 Operation of BSS

Bicycle sharing systems can be broadly classified in two different categories: those based on docking stations, where users rent and return the bicycles (most often at any available station, but in some cases bicycles have to be returned to the same station), and dockless free-floating systems, where users find, rent and return a bicycle through an app within a defined area (DeMaio, 2009; Fishman, 2016). Recent years have seen a wave of dockless bikesharing operators in cities in Europe and North America, such as *Ofo* and *Mobike*, overtaking cities around the world, but in many cases they were not successful and have had to withdraw and cease operations (Médard de Chardon, 2019; Nikitas, 2019), due to issues related to theft, abuse and public space littering. In general, dock-based BSS seem to fare better, especially those that are tailored to a city's needs, connected to the public transport system and which collaborate with local authorities and companies (Nikitas, 2019).

Bicycle sharing systems come in different shapes and sizes, depending on the city size, context, and operator, and range from small systems to those with tens of thousands of bicycles and hundreds of stations, such as the BSS of Paris, London and Hangzhou (Fishman, 2016; Médard de Chardon et al., 2017; Shaheen et al., 2011). General recommendations for the development of any BSS, as presented in *The Bikeshare Planning Guide* published by the Institute for Transportation and Development Policy (ITDP), are for the system to cover at least 10 km^2, with 10-16 stations per km^2, 10-30 bicycles per 1,000 residents, and a ratio of 2-2.5 bicycles per docking station (Gauthier et al., 2013). In a survey with BSS operators in the US, the majority of operators indicated that the preferred distance between stations for them is between 275m and 400m, with the upper limit being used as the maximum preferred distance to public transport hubs to facilitate multimodal transport (Shaheen et al., 2013). Docking stations consists of docking spaces, bicycles and at times a terminal or kiosk which facilitates bicycle rentals (Gauthier et al., 2013). Docking stations can be located on public or private land (Shaheen et al., 2012), with 19 North American operators indicating that in almost all cases, the use of the land was free (Shaheen et al., 2013). The majority of BSS worldwide operate with standard bicycles, although the deployment of e-BSS is on the rise in recent years (Galatoulas et al., 2020), including some systems that operate fully with electric bicycles, such as the BSS in Madrid, as well as some that offer a mix of both, for example Copenhagen's BSS (Fishman, 2016). Mandatory helmet laws, for example in Australia, present a barrier for BSS use, because of the lack of availability for spontaneous trips and hygiene concerns about shared use helmets (Fishman, et al., 2014; Shaheen et al., 2012). Most BSS use a tracking device to collect data on the location of their bicycles, either through a radio-frequency identification tag (which can locate the bicycle when entering or exiting a docking station), or by using smart bikes which have an on-board computer to record the exact route and location of the bicycle at all times through GPS (Shaheen et al., 2013).

Bicycle sharing systems are operated by different types of actors: privately owned and operated, publicly owned and operated (by either a local government or transport authority), publicly owned and contractor operated, companies (e.g. advertising agencies or dedicated bicycle sharing system provider), third-party operators with a street furniture contract, non-profit organisations, universities or vendor operated (DeMaio, 2009; Médard de Chardon et al., 2017; Shaheen et al., 2013). Even if the operator is not a public body, collaboration with local government is important in order to obtain the appropriate permissions for the use of public space and for the successful carrying out of their operations (Beroud & Anaya, 2012). Membership fees, usage fees, sponsorships and advertisement account for the majority of income for BSS operators. Four key factors impact profitability: 1) location of bicycle sharing stations, near tourist attractions and public transport hubs; 2) the ability to retain annual members; 3) providing a range of discounts; and 4) the ability to find new sources of revenue (Shaheen et al., 2012; Shaheen et al., 2014).

As shared bicycles are predominantly used for one-way trips between origins and destinations, the system can become spatially unbalanced, due to an imbalance in flows between trip generators and attractors (e.g. in systems mostly used for commuting), or between higher and lower elevation docking stations (Borgnat et al., 2011; Froehlich et al., 2009; Kaltenbrunner et al., 2010; O'Brien et al., 2014; Vogel et al., 2011). Rebalancing of bicycle sharing systems refers to the redistribution of bicycles across the system to maintain a reasonable balance of available bicycles and empty docking spots across the stations in the network, avoiding completely full or empty stations (Fishman, 2016; Médard de Chardon, 2016; Ricci, 2015). The rebalancing of BSS is usually performed using trucks (Fishman, 2016; Shaheen et al., 2013), but some BSS operators are experimenting with dynamic costing structures and incentives to positively influence usage patterns and reward users for redistributing bicycles from full stations to those with empty docks (Jurdak, 2013; Pfrommer et al., 2014; Shaheen & Guzman, 2011).

2.4.3 Characteristics of BSS use

Who uses BSS?

BSS are often presented as a public service, available to almost anyone, with the only real limitation being the necessity of using a bank card for payment (Beroud & Anaya, 2012). BSS typically offer registration for two different types of uses: subscription members who obtain a monthly, semester or year membership, and casual users, who use the system on a pay-as-you-go basis, or pay for a short term (e.g. for a day) (Gauthier et al., 2013; Jain et al., 2018). Some schemes do not allow for casual users, e.g. in Barcelona (Hampshire & Marla, 2012) and in London during the first months of operation (Lathia et al., 2012).

However, despite the premise of being accessible to (almost) all, evidence from a number of different cities show that bicycle sharing users tend to be predominantly white, male, with relatively high income and education, and engaged in full-time or part-time work (Fishman, 2016; Médard de Chardon et al., 2017), for example in London (Morton, 2018), Dublin (Murphy & Usher, 2015) and Chicago (Faghih-Imani & Eluru, 2015). This gender difference is primarily observed in cities with a low cycling modal share, where cycling is perceived as less safe. Men tend to represent the majority of cyclists where road safety concerns are high, as women are generally more risk-averse (Pucher & Buehler, 2008). In cities with a high modal share of cycling, women actually cycle more than men, such as in the Netherlands, where women make 55% of all bicycle trips (Pucher & Buehler, 2008). There are however also cities where BSS use is much more gender balanced, such as in Montréal (Fuller et al., 2011; Shaheen et al., 2012) and amongst students in Valencia (Molina-García et al., 2013). Furthermore, when assessing the difference between BSS users and regular cyclists in Washington DC, BSS users were found to be more likely to be female, younger and own fewer cars and bicycles when compared to regular cyclists in the same city, indicating that BSS in a city may be appealing to different user groups than private cycling (Buck et al., 2013).

In their study of the BSS in Lyon, Vogel et al. (2014) present a typology of the users, based on the intensity and frequency of their BSS use, from daily, occasional, and irregular users, to those who use BSS only on weekends, the "Sunday cyclists". A further distinction between users, especially relevant in cities receiving a lot of visitors and tourists, is between the residents and tourists. Some cities specifically target tourists as a (potential) user group of the service, e.g. in Seville (Castillo-Manzano & Sanchez-Braza, 2013) and Hangzhou (Shaheen et al., 2011). However, there are also cities that restrict BSS use to residents, and do not enable BSS use for tourists or other casual short-term users, such as Barcelona (Hampshire & Marla, 2012). Although many BSS operate in popular tourist destinations, most of the research about their use has focused on the usage by local residents, not by tourists (Kaplan et al., 2015).

Why?

BSS is used for a range of different purposes: for commuting (by professionals, students to travel to their place of work or study), for utilitarian purposes (by residents running errands), for leisure (for fun or exercise) and for sightseeing and recreational purposes (by tourists and visitors) (O'Brien et al., 2014). Subscription members most commonly use BSS for commuting purposes, whereas casual users are more likely to be leisure users or tourists, visiting points of interest, the city centre, or leisure areas such as parks and beaches (Buck et al., 2013; Fishman, 2016; O'Brien et al., 2014; Shaheen et al., 2012).

Where?

Areas with higher population density, indicating residential areas, are generally considered as trip origins, while areas with higher job density, retail density, tourist attractions and parks and leisure locations generally function as trip attractors (Krykewycz et al., 2010). In a Southern European context, high BSS use was found in areas with a high land use mix, with many Points-of-Interest (POI), including commercial and recreational activities, as well as places of historic interest, as shown by findings from Rethymno (Crete), Greece (Bakogiannis et al., 2019) and Barcelona and Seville, Spain (Faghih-Imani et al., 2017). Flows from predominantly residential to commercial areas are more common on weekday mornings, with the inverse flow occurring in the evening, reflecting commuter flows (Mateo-Babiano et al., 2016). BSS use is positively correlated with nearby bicycle lanes and paths (Buck & Buehler, 2012; Faghih-Imani et al., 2014; Mateo-Babiano et al., 2016; Rixey, 2013). The spatial coverage or extent of the BSS also influences the usage, as bicycle sharing systems are often geographically limited, focused on the city centre and destinations such as university campuses and business districts (Fishman et al., 2015; Ricci, 2015). The characteristics of the network, for example the distance between stations and the centre of the system, the distance to other stations and the number of stations within a certain radius, can influence system use, with findings showing higher BSS use at stations closer to the central business district (CBD) and those in proximity to other BSS stations (Faghih-Imani et al., 2014; Rixey, 2013; Wang et al., 2016).

Many BSS show marked concentrations of trips surrounding main public transport hubs, such as rail, metro and bus stations (Goodman & Cheshire, 2014; Nair et al., 2013; Zaltz Austwick et al., 2013), reinforcing the role of BSS to complement other forms of public transport, by acting as a feeder service for trip origins or destinations (Handy et al., 2014; Murphy & Usher, 2015), by providing a flexible first- or last-mile solution to expand the catchment area of public transport (Ricci, 2015; Shaheen & Chan, 2016), by reducing travel times (Jäppinen et al., 2013), and by reducing crowding on overburdened public transport services (Fishman et al., 2013; Gebhart & Noland, 2014). Results from a survey with BSS users in Dublin, Ireland, showed that 40% of trips are made in conjunction with another mode of transport, over 90% of which constituted public transport (Murphy & Usher, 2015). Findings from BSS use in Oslo, Norway, show that use is substantially higher on routes that either start or end with metro/rail connectivity (Böcker et al., 2020).

How much, how long?

Evidence from a number of cities – Melbourne, Brisbane, Washington DC, Minnesota and London - shows that the average BSS trip duration is between 16 and 22 minutes (Fishman et al., 2014; Mateo-Babiano et al., 2016). The pricing structure of BSS encourages short journeys (Beroud & Anaya, 2012; Pfrommer et al., 2014) and discourages users from locking bicycles away from docking stations (Wood et al., 2011). In most BSS, the flat fee interval (FFI) or free rental time for subscribed users, is 30 minutes (Bordagaray et al., 2016; Pfrommer et al., 2014). The impact of the FFI on BSS user behaviour is apparent from data collected in Boston and Washington DC: there is a clear cost-sensitivity, as users tend to either cut their journeys short just before reaching the 30-minute mark, or extend their trip further to make use of the extra time after starting payment for the next half hour (Jurdak, 2013). As a result, only a small percentage of trips (i.e. ~10-15%) last longer than 30 minutes (Mateo-Babiano et al., 2016), although casual users tend to make longer trips than subscription members (Buck et al., 2013). Some users have found a way to avoid incurring the extra fee by returning a bicycle within the flat fee interval and renting another bicycle immediately after (Bordagaray et al., 2016).

Trips per day per bicycle (TDB) is used as the most common metric to compare performance of bicycle sharing systems across cities (Fishman, 2016; Médard de Chardon et al., 2017). A TDB value of at least 1.0 was put forward by Médard de Chardon et al. (2017) as being psychologically important, seeing as that means that on average each bicycle is used at least once a day. In their *Bike Share Planning Guide*, Gauthier et al. (2013) advocate using an average TDB of 4-8 to determine system performance and further suggest a daily trip per 20-40 residents as a metric to determine market penetration. TDB values vary greatly between cities, from near zero to 8 or 9 trips per day per bike (Médard de Chardon et al., 2017). Barcelona and Paris have a yearly average TDB of around 6, New York City close to 4.5 and London an average of about 2.5 (Fishman, 2016; Médard de Chardon et al., 2017). Some cities see large variations in TDB over the span of the year, for example in Paris the monthly TDB in January 2013 was around 3.6, whereas it hit a peak monthly TDB of 8 in September of the same year (Fishman, 2016).

When?

BSS can be classified based on their temporal signature, with different patterns of aggregated diurnal hourly use signifying different dominant usage patterns (O'Brien et al., 2014), such as the 'weekday two peaks' characteristic of BSS dominated by commuter use for transport purposes, 'mainly weekend use' for leisure dominated BSS and 'single peak on all days', for BSS with high tourist usage. Commuter-based systems, such as London (Pfrommer et al., 2014), show strong weekday usage peaks between 7 and 9 am and 4 and 6 pm, with a more unimodal peak in the middle of the day on weekends, due to leisure use (Fishman, 2016; O'Brien et al., 2014; Zaltz Austwick et al., 2013). Some BSS, such as the one in Montréal, also show a peak on Friday and Saturday evenings, indicating BSS use for going out downtown (Faghih-Imani et al., 2014). Other cities clearly show BSS use during lunchtimes, indicating BSS use for visiting restaurants, e.g. in Lyon (Borgnat et al., 2011) and in Seville (Hampshire & Marla, 2012). Systems with more casual use are characterised by a single peak throughout the day and higher weekend use (Faghih-Imani & Eluru, 2016b). On weekend days, there are generally more trips originating from parks, reflecting leisure activities (Mateo-Babiano et al., 2016). Loop journeys, BSS trips beginning and ending at the same docking station, are associated with leisure and weekend trips (Mateo-Babiano et al., 2016).

When looking at average monthly TDB over the span of a year, BSS use has been shown to be generally higher in summer than in winter (Fishman, 2016). Different patterns can be observed for colder cities (with an average temperature <11ºC), which show larger seasonal variation with low demand in winter and a single peak in demand in summer, and for warmer cities (with an average temperature >11ºC), which show less seasonal variation, but exhibit a double peak in spring and autumn due to more favourable weather conditions, and show a drop in August at the height of summer (Fishman, 2016; OBIS, 2011). Potential explanations for the summer dip could be a decrease in commuting over the summer holidays, and/or the deterring effect of higher temperatures and higher humidity, but further research is needed to identify and understand the exact determinants of this phenomenon.

2.4.4 Impacts of BSS use

BSS use has the potential to offer a number of environmental, socio-economic, and transport-related benefits: economic benefits from cost savings from modal shifts, increased tourism, and lower implementation and operational costs, increased mobility options and convenience, a reduction in travel time, traffic congestion and fuel use, and an improvement in individual and public health and environmental awareness (Ricci, 2015; Shaheen et al., 2013).

Emission reductions as a result of modal shift

BSS have the potential to contribute to reductions in air pollution, traffic congestion and carbon emissions in cities as a result of decreased car use. However, it has to be established how many motorised vehicle trips BSS is replacing in order to make any claims about exact quantities (Fishman, 2014; Médard de Chardon et al., 2017). In addition to information about the substitution of trips, reliable quantitative data is needed on the frequency and magnitude of trips replaced, in order to truly understand the impact of modal shift on reduced car use and the benefits of more active transport (Ricci, 2015).

In terms of modal shift, from evidence from a number of cities (see Table 2.3), it appears bicycle sharing users are mainly substituting bicycle trips for public transport or walking trips, and not as much for car trips (Buck et al., 2013; Fishman et al., 2014; Murphy & Usher, 2015; Shaheen et al., 2011). As most BSS are primarily based in the city centre and used for short trips, this is not very surprising (Murphy & Usher, 2015).

Table 2.3: Modal shift to BSS in different cities

	Modal shift from:				
City (BSS)	**Private car / taxi / motorcycle**	**Public transport**	**Walking**	**Private bicycle**	**New trip**
Barcelona (*Bicing*)	10%	51%	26%	6%	*n/a*
Brisbane* (*CityCycle*)	24%	43%	23%	8%	1%
Dublin (*Dublinbikes*)	20%	35%	45%	-	-
London* (*Santander*)	6%	57%	26%	7%	4%
Lyon (*Vélo'V*)	7%	50%	37%	4%	2%
Melbourne* (*MBS*)	21%	41%	27%	9%	1%
Minnesota* (*Nice* Ride)	22%	20%	38%	8%	9%
Montréal (*BIXI*)	10%	34%	25%	28%	3%
Paris (*Vélib'*)	13%	65%	20%	*n/a*	*n/a*
Washington DC* (*CaBi*)	13%	45%	31%	6%	4%

* annual members only

Sources: Brisbane, London, Melbourne, Minnesota (Fishman et al., 2014), Dublin (Murphy & Usher, 2015), Washington DC (Buck et al., 2013), Barcelona, Lyon, Paris (Midgley, 2011), Montréal (Bachand-Marleau et al., 2012)

However, research does show that in cities with higher car use there is a higher rate of mode substitution for car trips (Fishman et al., 2014; Fishman et al., 2015). This is confirmed by the evidence collected in five cities, in Canada, the US and Mexico, on changes in transport behaviour as a result of BSS use, by Shaheen et al. (2012). BSS users report driving less, from 29% of respondents in Montreal up to 53% of respondents in Minneapolis-St Paul and Mexico City, and 55% in Salt Lake City. The general tenet appears to be that in cities with a higher modal share of public transport use and walking, and thus a lower car modal share, modal shift occurs mostly from the former categories, whereas in cities with higher car modal share, larger shifts from car to BSS use are observed.

The contribution of BSS to mode substitution or carbon emission reduction is often overstated (Médard de Chardon et al., 2017). The London BSS is even said to have caused increased emissions in London, because of very limited substitution for private car use and significant use of vehicles for rebalancing of bicycles (Fishman, 2016). The impact of BSS on emission reduction depends on the combined effect of mode substitution, and the frequency and magnitude of use of vehicles for redistribution and maintenance purposes (Ricci, 2015).

Health effects

Evidence from BSS from different cities show that generally there is a positive health outcome for BSS users. Only when BSS use replaces walking is there a net reduction in physical activity benefits (Fishman et al., 2015; Médard de Chardon et al., 2017). Multi-city analysis of the physical activity impacts of BSS in Melbourne, Brisbane, Washington DC, London and Minneapolis/St. Paul shows on average 60% of BSS trips replace sedentary modes (Fishman et al., 2015). Evidence from London (Woodcock et al., 2014), and Barcelona (Rojas-Rueda et al., 2011), also shows a positive health impact, when weighing up the overall impact of an increase in physical activity, and increased risk of road traffic injuries and exposure to air pollution.

A before-after study with students at the University of Valencia found that BSS use provided about an hour of physical activity on average among students who started using BSS, a significant increase from the baseline scenario of zero (Molina-García et al., 2013), although information about transport mode substitution was not provided, and thus net health benefits cannot be determined. A survey with over 3,000 BSS users in Washington DC showed a 31.5% reduction in reported stress, and 30% of respondents reported having lost weight since starting using the BSS (Shaheen et al., 2014). As Ricci's (2015) review of BSS points out however, no single BSS has been fully independently evaluated, and a full assessment of health impacts of BSS use is therefore still lacking. In their recent review, Bauman et al. (2017) formulate a framework for assessing the full health impacts of BSS use and subsequent changes in cycling at population level.

Improved cycling safety

BSS users appear to be less likely to be injured than regular cyclists on private bicycles (Fishman & Schepers, 2016; Gámez-Pérez et al., 2017). Potential explanations being offered to explain this phenomenon are the design of rented bikes, the policies that regulate bicycle sharing systems, lower riding speeds, a more upright riding position and car drivers behaving more respectfully around BSS users than around regular cyclists (Fishman, 2016; Gámez-Pérez et al., 2017). Drivers overtake cyclists differently depending on their appearance, e.g. leaving more space when passing someone appearing to be female or dressed like a police officer (Walker, 2007; Walker et al., 2014). Greater presence of bicycles on the road, has the potential to lead to increased awareness from car drivers and to provide benefits from safety-in-numbers (Martin et al., 2016; Murphy & Usher, 2015).

Economic benefits

Whereas the presence of shops, retailers and restaurants are being included as potential trip attractors (or destinations) in studies assessing the influence of land use on BSS use (Buck & Buehler, 2012; Faghih-Imani et al., 2014; Faghih-Imani & Eluru, 2015; Wang et al., 2016), there is a paucity of evidence on the economic benefits of BSS on local businesses and the economy. In two review articles on the topic of BSS, by Ricci (2015) and Fishman (2016), only Ricci identified two studies investigating this topic: Schoner et al. (2012) and Buehler & Hamre (2014). These studies both found that BSS can generate economic benefits at the neighbourhood level, especially for food-related businesses, and that BSS can generate additional economic activity in the vicinity of BSS stations.

Equity

Part of the observed demographic bias of BSS users can be explained by the limited geographic extent of many BSS, often focused on the city centre, and destinations such as business districts and university campuses' (Fishman et al., 2015; Ricci, 2015). A number of BSS studies have specifically looked into the equity and accessibility implications of BSS for different socio-economic groups. In an analysis of BSS membership in three US cities, Gavin et al. (2016) found that the gender, ethnicity and socio-economic status of BSS users did not reflect the population characteristics of the communities in which they are operating. A study from Glasgow showed how BSS stations are generally only found within walking distance for a limited number of a city's population; only 9% of Glasgow's population lives within a 400m radius of a BSS station (Clark & Curl, 2016). BSS often do not effectively serve other, and especially less affluent, parts of the city. Evidence from London showed that residents of more deprived neighbourhoods actually make more trips per month than those from wealthier areas, when adjusting for distance to the nearest BSS station (Ogilvie & Goodman, 2012). The extension of the London BSS towards the east of the city, into more deprived areas, demonstrated an increase in BSS use by residents of these parts of the city (Goodman & Cheshire, 2014). These findings show how providing good accessibility to the BSS, while ensuring affordability, can enable equal opportunities and improved mobility for everyone.

Contemporary city life demands a high level of mobility for people to meet their daily needs (Hanson, 2004). To ensure the introduction of BSS does not only encourage further mobility for the already hypermobile younger middle- and upper economic classes, it is important to design BSS with the mobility and accessibility needs of different groups of society in mind. Rixey (2013) pointed out that in Washington DC, for low-income communities with greater difficulties in acquiring the debit or credit card needed to access the system, additional outreach could assist in providing these potential BSS users with a discounted membership and/or access to a debit or credit card. In a study of the Dublin BSS, Murphy & Usher (2015) found that while modal shift among higher income earners was more likely to be from car or rail to bicycle, modal shift of people in lower income groups was more frequently a shift from using the bus or walking to bicycle, indicating increased mobility and efficiency for low income earners.

Increase of cycling uptake

The implementation of a BSS in a city has the potential to increase bicycle use as well as private bicycle ownership (Castillo-Manzano et al., 2015; DeMaio, 2009; Shaheen et al., 2010). In most cities, the introduction of a BSS has happened in conjunction with the creation, extension and improvement of bicycle infrastructure (DeMaio, 2009) as well as other bicycle promotion policies, making it difficult to attribute the overall growth of cycling to one specific factor. Ricci (2015) confirms that for BSS to contribute to an increase in cycling modal share, it “needs complementary pro-cycling measures and wider support to sustainable mobility”.

In Lyon, estimates of the increase in bicycle riding following the first year of the implementation of their BSS range from a 44% increase (Shaheen et al., 2010) to a tripling of bicycle use (Bouf & Hensher, 2007). In Paris, cycling increased by 70% after the launch of the BSS (Shaheen et al., 2010). Eight months after the introduction of the BSS scheme at the University of Valencia, cycling as a mode of transport rose from 6.9% to 11% among the students participating in a longitudinal survey, a statistically significant increase (Molina-García et al., 2013). In Seville, within 3 years of implementation of the BSS in 2007, cycling modal share had risen to 6.6% of total journeys, a 5x increase compared to the level when the system was introduced (Castillo-Manzano & Sanchez-Braza, 2013). Almost three quarters of respondents in a survey about BSS in four North American cities reported increased cycling levels (Shaheen et al., 2012). Evidence from a survey of BSS users in Washington DC confirms that BSS use can increase overall cycling modal share by encouraging new segments of society to cycle (Buck et al., 2013). This was also found by Ó Tuama (2015) in Dublin, where the BSS enabled new cycling experiences for people who have not recently cycled.

The adoption of bicycle sharing may happen differently for different user groups. In Washington DC, 77% of BSS annual users reported cycling trips for utilitarian purposes (work and errands). Over time, using the same survey, the share of utilitarian trips decreased as new members were less likely to make these types of trips (Buck et al., 2013). A potential explanation could be that utilitarian users are the early adopters of the scheme, whereas the later majority uses BSS for a wider range of purposes. In Hangzhou, 30% of BSS users use a shared bicycle regularly for their commute, with 70% using it on occasion for commuting purposes (Shaheen et al., 2011).

BSS can encourage different societal groups to start cycling, through social contagion (Schoner et al., 2016). From a survey with BSS users, aimed at understanding the shift from using BSS to private bicycles in Seville, it appeared that more than half of the users had not used private bicycles before, the majority because they did not own a bicycle, and started cycling because of the BSS. Just over 40% of the surveyed sample indicated they owned a bicycle before or purchased a private bicycle while still also using the BSS (Castillo-Manzano et al., 2015). The main obstacles to purchasing a private bicycle are fear of theft and a lack of proper parking space at origin or destination (Castillo-Manzano et al., 2015), highlighting the need for supportive bicycle infrastructure and facilities. Evidence from Lyon also shows a boom in private bicycle use and sales following the introduction of the BSS (Bouf & Hensher, 2007). In Dublin, 68.4% of respondents claimed not to have cycled for their current trip prior to the launch of the BSS in a survey about their BSS use and cycling habits, and

63.4% of respondents who now own a private bicycle said to have purchased it as a result of using the BSS (Murphy & Usher, 2015). These figures highlight the expansive effect of the implementation of the BSS on overall cycling.

2.5 Conclusion

In this concluding section, the key findings from the literature review presented in this chapter are summarised. The main research objective addressed in this chapter was to understand the main characteristics of BSS and their role within sustainable urban mobility. An overview of urban transport planning approaches and associated problems was presented, to provide history and context to the emergence of the sustainable mobility paradigm, which has been adopted in recent decades as the guiding principle for urban mobility planning in many cities, in Europe and beyond. Shared mobility services, including BSS, have emerged in recent years as new transport modes, complementing active and public transport modes, and offering new alternatives to private car use, especially in a multimodal transport approach.

The urban design and transport system of a city are key factors influencing mobility behaviours. The transport bias in urban mobility, basing decisions in transport planning primarily on private car use, has resulted in serious challenges for cities, including traffic congestion, issues with public transport capacity, environmental impacts and accidents and road safety concerns, particularly for vulnerable road users. Car-centric transport planning has persisted over many decades and has largely overlooked the potential, the value and the needs of active transport users, including pedestrians and cyclists. However, with the realisation that it is not possible to 'build a way out of traffic congestion', came different approaches to transport planning, focused more on the management of demand and multimodal approaches. One of the key components of sustainable mobility planning is the promotion of modal shift towards cleaner, healthier and more efficient modes of transport, including active transport modes such as walking and cycling, public transport and shared mobility modes, including BSS. In Europe, the promotion of Sustainable Urban Mobility Plans has shifted the focus of transport planning from traffic to people, placing higher value on accessibility, sustainability and quality of life, instead of on traffic flow and speed improvement. As a low-cost, low-polluting and active mode of transport, cycling has gained increased interest from policy makers and urban planners as one of the potential solutions in the move towards sustainable mobility in cities. As there is a need to transition to low-emission mobility, to meet European and global emission reduction targets, part of the solution lies in a modal shift to active travel, public transport and shared mobility schemes, including BSS.

Bicycle sharing systems, shared bicycle fleets allowing short-term public use, were first introduced way back in the 1960s in Amsterdam with free white bicycles distributed around the city, and revisited in the 1990s in Copenhagen with coin-operated bicycles. However, the idea only really took off globally in the digital age with third-generation BSS, which allow for user accounts and bicycles to be tracked and billed according to usage. BSS promises to enable cycling for a wider group of citizens, by lowering barriers for urban cycling, by providing access to bicycles (with the advantage of renting over owning), by normalising the image of cycling, by increasing the number and diversity of visible cycling role models and by providing safety in numbers. BSS can be an important component of multimodal trips because of their integration into the public transport network. When looking at previous research investigating who uses BSS, evidence from a number of different cities shows that bicycle sharing users tend to be predominantly white, male, with relatively high income and education, and in employment; thus not always reflecting the population characteristics of the communities in which they are based. Different BSS usage types can be distinguished, from leisure use on weekends and during the day, to commuting trips, predominantly on weekdays with morning and evening peaks, which can be identified from the diurnal temporal signature of BSS use. Frequent BSS use is generally found in areas with a high land use mix, with many Points-of-Interest (POI), including commercial and recreational activities. Commuter-based systems are characterised by morning flows from predominantly residential to commercial areas, and the opposite movements at the end of the day. Evidence from a number of cities shows that the average BSS trip duration is between 16 and 22 minutes, which is at least partially a result of the commonly used flat-fee interval of 30 minutes. To compare performance of bicycle sharing systems across cities, trips per day per bike (TDB) is being used as a common metric.

BSS use has the potential to contribute to reductions in air pollution, traffic congestion and carbon emissions in cities as a result of decreased motorised vehicle use, if the shared bicycle use replaces trips previously made by car or bus. BSS generally provide positive health benefits to users, based on an increase in physical activity, at least when the trip is a shift from motorised vehicles, which generally constitutes the majority of trips. BSS users appear to be less likely to be injured than regular cyclists on private bicycles, which can be explained by the design of the bicycles, lower riding speeds and more diverse user groups. BSS can generate economic benefits at the neighbourhood level, especially for food-related businesses in the vicinity of BSS stations. Demographic bias has been observed among BSS users in different cities, which is partially due to the geographic location and limitations of the system. Limited coverage of BSS, and in particular limited presence in more deprived areas of a city, mean that not all of a city's population is served by the BSS. However, extending the system to other areas has been shown to increase uptake by residents. The implementation of a BSS has increased shared bicycle use as well as private bicycle ownership in many cities. BSS can encourage different societal groups to start cycling, by enabling cycling through the provision of bicycles, by normalising cycling for different people, and through social contagion and changing social norms. The literature review confirms that the rise of BSS as a mode of transport can contribute to increasing cycling uptake in a city, and thereby contribute to a modal shift to cycling, which is an essential component in the promotion of sustainable urban mobility.

In the next chapter, *Chapter 3*, the theoretical framework guiding this research is presented. Socio-ecological models are used as the theoretical underpinning to understand the influence of different factors on travel behaviour; BSS use in this case. The state-of-the-art findings from the literature on this topic are reviewed, leading to the discussion of the research gap, which highlights how this research contributes to the body of knowledge. The methodology used for data collection and analysis, and a full overview of the research aim, the research objectives and the research questions are presented in *Chapter 4*.

3. Theoretical framework

This chapter addresses the *second research objective (RO2)* of this study, to identify the factors influencing travel behaviour for cycling and BSS use and provide the theoretical framework for this research. The first section, 3.1, introduces travel behaviour theory, which draws from economic utility theory, the theories of planned and repeated behaviour, and lifestyle and personal behaviours. It presents socio-ecological models that attempt to capture multiple levels of factors with an influence on travel behaviour. The second section, 3.2, presents the framework for factors influencing cycling and BSS use adopted in this research, based on socio-ecological models of travel behaviour and cycling in particular, and presents the findings of the influence of these factors on cycling and BSS use from the literature. The third section, 3.3, identifies the research gap addressed in this research and the contributions of this study. The final section, 3.4, summarises this chapter and looks ahead to the next chapter.

3.1 Socio-ecological models of travel behaviour

3.1.1 Travel behaviour: Time, cost and effort

Travel behaviour refers to the travel choices and decisions related to transport mode, number and linkage of trips, time of travel and whether to travel at all. Travel is generally considered to be a derived demand, a behaviour that follows decisions made with regard to location and activities (Dobson et al., 1978; van Acker et al., 2010); "people travel to participate in activities such as working, education, recreation, and social activities" (van Wee & Handy, 2016). Travel behaviour is the result of the intricate interplay between intrapersonal, interpersonal, socio-cultural and physical environment factors. The influence of multiple correlates, which may have positive or negative feedback effects, or reciprocal effects, makes it difficult to isolate the importance and impact of singular factors (Bauman et al., 2002).

From the perspective of economic utility theory, transport mode choices are based on maximization of the traveller's utility when comparing different travel options in terms of the time, cost and effort involved with travelling by a particular mode (Heinen et al., 2010). The generalised cost of travel is the sum of the different factors influencing travel behaviour: the direct monetary costs (fuel, fare, parking, insurance, etc.); travel time costs, the total time spent to complete a journey, including waiting time and time to search for parking; and travel impedance, in terms of (un)safety, (in)security and (dis)comfort (Hanson, 2004; Iseki & Tingstrom, 2014; Pucher & Buehler, 2006). The influence of these aspects is not fixed; it is their relative (dis)advantage in relation to other transport modes that matters in the mode choice. Any increase in time, cost or effort results in a decreased probability that that transport mode will be chosen (Heinen et al., 2010). When comparing the choice between cycling as a mode of transport and other modes, the cost, or changes in the cost, of other travel modes can make cycling more or less attractive (Handy et al., 2014).

Although cost, time and effort are undoubtedly important determinants of travel behaviour, there have been critiques on the utility maximization approach to travel behaviour: firstly, that travel behaviour is not solely driven by rational economic choices, but is also the result of individual and collective attitudes, perceptions and habits (Fishbein

& Ajzen, 1975; Ronis et al., 1989; Triandis, 1977; van Acker et al., 2010); and secondly, that travel time is not purely a disutility to be minimised, but that there is a certain amount of travelling people are willing to, and prefer to do (Mokhtarian & Chen, 2004; van Wee et al., 2006). Research into the factors influencing the choice of cycling as a mode of transport confirms that personal demographics, socio-economic status, and attitudes, perceptions and habits, which are also influenced by external social norms, play a role in travel behaviour (van Acker et al., 2010). While cycling is not necessarily a disutility to be minimised, as it can be used as a mode of transport for utility and for leisure, or a combination of both (Handy et al., 2014), an increase in travel time was found to decrease the perceived convenience of a trip by bicycle (Heinen et al., 2010). There is a clear distance decay in the likelihood to cycle; based on travel survey data from the UK the majority of cycling trips for commuting fall within a range of 1 - 10km distance (Lovelace et al., 2017).

3.1.2 The role of attitudes, social norms, habits and lifestyles

Travel behaviour is influenced by other factors than those identified in economic utility theory. At the individual level, behaviour is understood to be the result of the combination of three forces: 1) reasoned influences, 2) unreasoned influences, and 3) lifestyle and personal behaviours (van Acker et al., 2010).

Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA) forms the basis for the analysis of reasoned influences on behaviour. In their theory they believe behaviour to be the result of rational choices: intentions (or preferences) to perform a behaviour are influenced by a set of beliefs (or perceptions) collectively called attitudes, as well as by the subjective norm; normative beliefs and social pressure to perform a behaviour or not. This was later refined by Ajzen (1991) in his Theory of Planned Behaviour (TPB), in which he included a third dimension influencing behaviour: perceived behavioural control, the "perceived ability to perform a behaviour" (van Acker et al., 2010). The Theory of Repeated Behaviour (TRB) (Ronis et al., 1989) was developed in response to a common criticism of the TRA and the TPB that not all behaviour is reasoned and rational and rests on the premise that as behaviour is repeated, it becomes a habit. This theory is based on the idea that there is a trade-off between the influence of attitudes and habits on resulting behaviour, which was put forward by Triandis in the Theory of Interpersonal Behaviour (TIB) (Triandis, 1977). Muñoz et al. (2013) used the TPB to guide their study of factors influencing cycling commuting, including attitudes, subjective and descriptive social norms, perceived behavioural control, to understand attitudinal and behavioural differences between cyclists and non-cyclists and cycling habit in a case study in Madrid. Their findings show how non-commuting cycling habits strongly influence cycling for transport (Muñoz et al., 2013). Attitude can precede behaviour change, as shown in a study of commute change, where people with a pro-environment attitude were 1.3 times more likely to shift from using the car to other modes (Clark et al., 2016). However, the effect also occurs vice versa, with behaviour influencing attitudes, as people try to minimise dissonance between their attitudes and behaviour (Kroesen & Chorus, 2018). In fact, evidence from a panel study on travel behaviour shows that the effects from behaviour to attitudes are greater than vice versa (Kroesen et al., 2017). In a study on the effect of psychological determinants of mobility of older people in Malta, the TIB was used as a framework for analysis. Findings showed that the effect of personal intentions, influenced by social norms, had a stronger influence on mobility behaviour than a person's travel habits (Mifsud et al., 2019). Social norms have a strong impact on how cycling is perceived in a society; whether it is seen as a poor man's mode of transport, as a sport or exercise, or whether it is an accepted everyday activity and seen as something that anyone can do, without the need for special clothing or equipment (Daley & Rissel, 2011). Social interaction effects, including the opinions, choices and behaviours of other people and the general social environment of a decision maker, influence an individual's choices (Kamargianni et al., 2014).

The lifestyle of an individual is related to their socio-economic status and stage of life, which present opportunities and constraints, as well as their preferences for a way of living, influenced by beliefs, interests and attitudes. Lifestyle can have an influence on behaviour through its manifestation in preferences for location and activity behaviour (van Acker et al., 2010). Mobility patterns, and reliance on the private car specifically, are connected to life and lifestyle choices, such as "how households are provisioned, where children go to school, how work and leisure are conducted, and so on" (Cass & Faulconbridge, 2016). The perception of the car as a symbol of progress and marker of social differentiation is strongly tied with lifestyle too. The car is the most advertised commodity in the world and is sold with the promise of status, speed and control over the external environment. While the congested reality in urban areas shows the private car cannot deliver on these promises, many cities now find themselves locked into car-dependency after years of primarily investing in infrastructure for private vehicles (Woodcock & Aldred, 2008). Most daily journeys are not only work commutes but sequenced trips, involving a number of additional tasks, such as shopping, taking children to school and visiting healthcare centres or other service providers. To be able to promote sustainable transport modes as an alternative to the car for sequenced trips, non-transport strategies are needed too, such as changes to "the organization, timing and spacing of societal services and institutions" (Cass & Faulconbridge, 2016). Residential self-selection, residential choices based on housing, neighbourhood and travel preferences, can result in more or less sustainable behaviours. It is, to some extent, possible to persuade households to adopt more sustainable mobility behaviours, by providing housing and neighbourhoods with the preferred attributes, combined with excellent active travel and/or public transport facilities that meet their needs (Bohte et al., 2009). Transit-oriented development (TOD), the direct integration of public transport planning and land use planning, by concentrating urban development around transit stations, makes sustainable transport options convenient and efficient (Ibraeva et al., 2020). Car-reduced neighbourhoods, such as the examples of Vauban and Rieselfeld in the German city Freiburg, have been developed to encourage car-free lifestyles, by providing excellent cycling and public transport links, offering car-sharing services, and by limiting access for cars and parking (Hamiduddin, 2015).

3.1.3 Travel time budget

The spatial and temporal aspects of an individuals' activity pattern is central to the field of time geography (Hägerstrand, 1970). The accessibility of activity sites does not depend only on distance or travel time: the space-time prism is a measure that represents the possibilities in space and time open to a person, given certain constraints (Hanson, 2004), such as 1) the individual's time budget, 2) the location, opening hours and duration of activities, and 3) differences in travel velocities depending on different transport modes and the carrying capacity of the transport system (Hägerstrand, 1970).

Travel time budget (TTB) refers to the concept that the average individual time budget for travel is relatively stable across time and space (Mokhtarian & Chen, 2004). Increased speed and connectivity do not lead to a decrease in travel time, but an increase in travel distance covered (Hanson, 2004; Hupkes, 1982; Mokhtarian & Chen, 2004). Although there is variance in the estimations, also because they are often based on different assumptions or units of analysis, most estimations average a personal travel time budget of approximately 1.1 hours per day (Mokhtarian & Chen, 2004), or between 1 and 1.5 hours a day (EPOMM, 2018). Other researchers however, show that in certain cases they have observed an increase in travel time over the past decades, which can be explained by both the increased benefits of additional travel and from new opportunities to make better use of their travel time (van Wee et al., 2006). Therefore, instead of asking what the least possible amount of travel is to accomplish certain activities, it would be better to ask what is the most attractive way to visit a set of activities or destinations within a given travel time budget (Mokhtarian & Chen, 2004). Choosing cycling as a mode of transport would not only provide the required mobility to move from A to B, but also provides benefits for mental and physical health (Sallis et al., 2016; van den Noort, 2007). However, for cycling an increase in travel time also means an increase in effort required and as a result of this, longer trip distances, which take more time and effort, are associated with less frequent cycling. Depending on the person, the maximum acceptable trip distance to commute to work by bicycle lies between 6 and 12 km (Heinen et al., 2010). Based on an average speed of 15km/h this would translate to an average trip duration of 25-45 minutes for a single trip, and between 50 minutes to 1.5 hours for a return journey, in line with the findings about the personal travel time budget. The increased popularity and availability of e-bikes increases the distance that can be comfortably covered within the travel time budget, as speeds are higher and required effort is less (Sundfør & Fyhri, 2017).

3.1.4 Travel behaviour change and modal shift

Travel behaviour patterns are relatively fixed, but opportunities for change can arise out of changing conditions related to the different stages of life, locations and activities, for example a change in family composition (e.g. arrival of first child), a change in residential location (e.g. moving house), or a change in work location (e.g. change of employment) (Christensen et al., 2012; Savan et al., 2017; van Acker et al., 2010).

Clark et al. (2016) show that commute mode is most likely to change following a change of distance to work, related to work or home relocation, with evidence from a representative sample of the English working population. A switch from car to active modes becomes more likely as the distance between home and work drops below 3 miles (just under 5 km) and in areas with mixed land uses. High quality public transport links encourage switches from the private car to public transport (Clark et al., 2016). A number of authors have highlighted the possible confounding effects of the residential ‘self-selection’ mechanism, where preferences for physical activity or transport mode influence residential location choice, which could lead to a change in travel behaviour, instead of vice versa (Handy, 2005; Heinen et al., 2010; van Acker et al., 2010). Findings from studies on the direction of causation between attitudes and travel behaviour show that behaviour may have a stronger effect on attitudes than vice versa, indicating that rather than focusing efforts on changing attitudes, e.g. through educational and promotional campaigns, the desired behaviour should be made more attractive, e.g. through lower fares and improved service for public transport, and undesirable behaviour made less attractive, e.g. through road pricing or taxation (Kroesen et al., 2017; Kroesen & Chorus, 2018).

The Transtheoretical model, which highlights the temporal dimension of behaviour change, characterises the change as a process rather than an event and distinguishes different stages of change: precontemplation, contemplation, preparation, action and maintenance (Prochaska & Velicer, 1997). Initially, this 'stages of change' model was used in health psychology to examine behaviour change related to health risks such as smoking, obesity, and alcohol and substance abuse (Prochaska & Velicer, 1997; Warner, 2000). It has also been applied to study behaviour change and the promotion of physical activity (Marcus et al., 1992; Ronda et al., 2001) and cycling (Gatersleben & Appleton, 2007; Savan et al., 2017).

The desired modal shift towards more sustainable transport options, with the aim of providing better accessibility, improved equitability, and reduced environmental impacts, in practice generally means a shift from private car dependence to public transport, shared transport and active travel modes (Bae, 2004). Change in mode choice is influenced by a number of factors related to the different available alternative modes (e.g. their travel cost and time), individual characteristics (e.g. age, income, social status, household size) and the context (e.g. the trip purpose) (Di Ciommo et al., 2014). Different people have different motivations and biases that influence their behaviour; while some might respond to the call to choose a greener form of transport for environmental reasons, others are more interested in saving money, looking good, or reducing stress (Young & Caisey, 2010).

3.1.5 Socio-ecological models of active travel behaviour

Socio-ecological models build further on the legacy of the Theory of Planned Behaviour and Theory of Repeated Behaviour, and in addition to the psychosocial variables central to these theories, also includes people's interactions with their socio-cultural and physical surroundings (Pikora et al., 2003; Sallis et al., 2006). Socio-ecological models emphasise the multiple levels of influence – intrapersonal, interpersonal, socio-cultural, environmental and policy variables – that have an effect on human behaviour (Bauman et al., 2002; Saelens et al., 2003; Wood et al., 2011), and posit that interventions will be most successful when they operate on multiple levels (Sallis et al., 2006).

Conceptual travel behaviour models based on socio-ecological models suggest that individual behaviour is affected by multiple levels of factors, also termed determinants or correlates, ranging from individual factors to social and environmental factors (Handy et al., 2014; Heinen et al., 2010; Xing et al., 2010):

- Individual factors: socio-demographics, attitudes, habits, perceptions, and lifestyle;
- Social factors: social influences, cultural norms;
- Spatial factors: built environment (e.g. land use, infrastructure, design), and the natural environment (e.g. greenery, open spaces, and trees, but also elevation, scale, weather) and human use of public spaces.

These factors represent opportunities and constraints and together form the interlinked factors that influence the travel behaviour.

In their conceptual model of travel behaviour (see Figure 3.1), van Acker et al. (2010) integrate the opportunities and constraints that influence travel behaviour on these three levels: on the individual level, in the social environment, and in the spatial environment, after having examined different theories and methods of relating the built environment with individual travel behaviour and linking theories from transport geography and social psychology (van Acker et al., 2010).

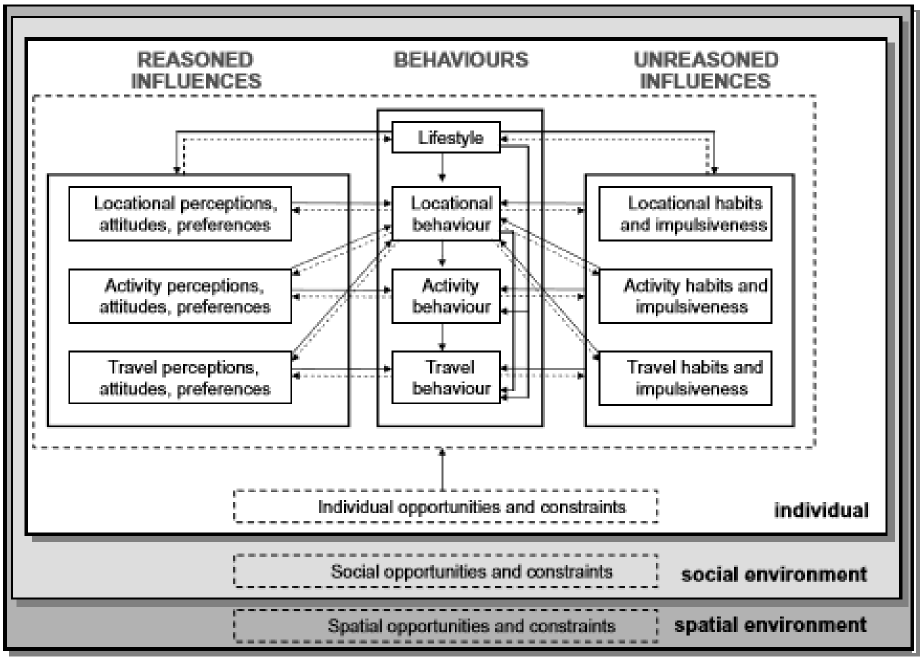


Figure 3.1: Travel behaviour model based on ecological models (van Acker et al., 2010)

Handy et al. (2010) applied the socio-ecological travel behaviour model to bicycling behaviour specifically (see Figure 3.2), highlighting individual factors such as age, gender, and self-efficacy, social environment factors such as other cyclists, drivers, and physical environment factors such as land use mix and bicycle infrastructure. A supportive built environment, based on high density development with a mix of land uses, with short distances, attractive design, and accessibility for pedestrians and cyclists, facilitates physical activity (Cervero & Kockelman, 1997; van Wee & Handy, 2016). Handy (2005) concludes however, that it is not enough on its own and that individual and interpersonal factors may be more important in explaining physical activity than built environment characteristics.

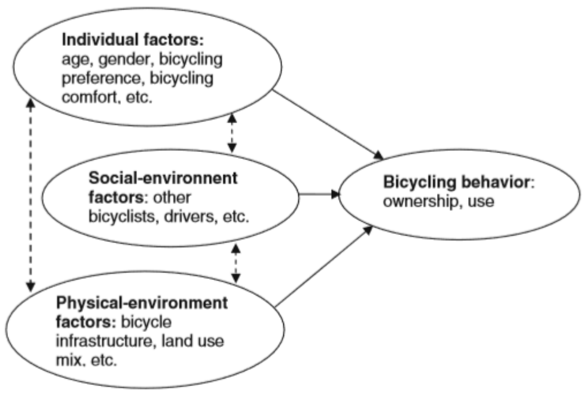


Figure 3.2: A socio-ecological model of bicycling behaviour (Handy et al., 2010)

The socio-ecological model presented by Sallis et al. (2006) draws upon the same basic concepts, but extends the model to explicitly feature the perceived environment and policy environment variables, in addition to the aforementioned levels (see Figure 3.3). Active transport behaviour, as described in their paper 'An Ecological Approach to Creating Active Living Communities', is influenced by factors on multiple levels of influence relative to this specific behaviour: weather, topography and air quality at the *natural environment* level; advocacy, social norms and social support at the *socio-cultural environment* level; transport and land use policies (such as zoning, development regulations, parking and transport demand management) at the *policy environment* level; active transport facilities, such as walking and cycling infrastructure, as well as provision of public transport options and traffic levels at the *behaviour setting* level; accessibility, safety, convenience, comfort and attractiveness at the *perceived environment* level; and psychological, demographic and biological factors, such as age, gender, socio-economic status, family situation, and attitudes and beliefs, at the *intrapersonal* level (Sallis et al., 2006).

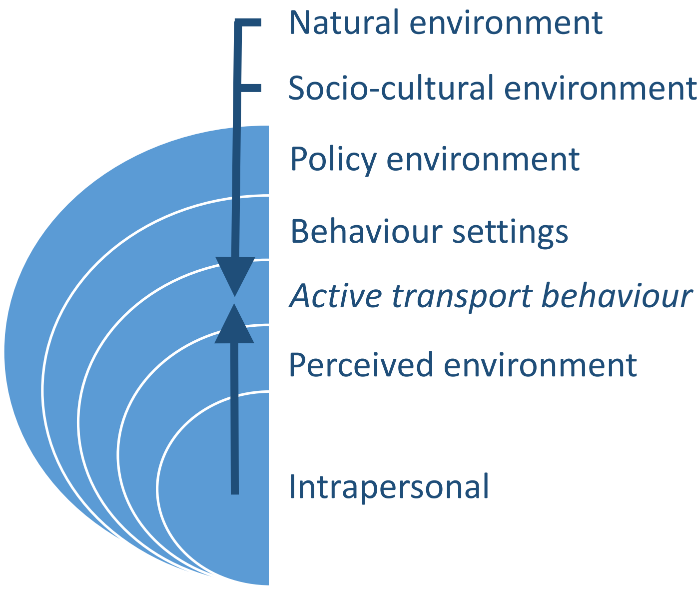


Figure 3.3: A socio-ecological model of active transport behaviour (Sallis et al., 2006)

In their literature review of factors influencing bicycle commuting, Heinen, van Wee & Maat (2010) confirm that there is a relationship between demographic and socio-economic factors and cycling, but highlight that the direction of causality is not clear and that there is potential collinearity between factors (e.g. age and income; income and level of education). They further posit that social values and attitudes may be more important than demographic and socio-economic factors (Heinen et al., 2010). Perceptions of the facilitators and barriers associated with a mode of transport have a strong influence on the resulting travel behaviour. Individuals' perceptions of the socio-cultural and physical environment (the natural and built environments), have been found to be associated with active transport behaviour (Alfonzo, 2005; Gebel et al., 2011; Sallis et al., 2006), with levels of cycling (Heinen et al., 2010), and BSS use (Liao, 2016). The importance of perception also emerges from the difference between perceived and objective measures of the environment. A person's subjective perception of their environment is not always in line with more objective measures of that environment. McCormack et al. (2004) and Gebel et al. (2011) showed that actual walking behaviour is correlated with the perception of a walkable environment, rather than with the objectively measured walkability score for that same area. It is therefore important that both subjective and objective measures of the environment are included as potential influencing factors (McCormack et al., 2004; Sallis et al., 2006). Differences in cycling levels and different social customs between cities and countries are to a certain extent self-reinforcing; in cities with a strong cycling culture, the habits and customs will foster cycling, but in cities with a low cycling modal share, the dominant habits and customs tend to deter cycling (Pucher et al., 2010).

Insights from socio-ecological models have been applied to behaviour change campaigns in two ways: 1) by combining interventions on multiple levels in order to seek synergies between them, and 2) by introducing and tailoring interventions specifically to different population segments (based on their 'stage of change') (Gatersleben & Appleton, 2007; Ronda et al., 2001; Warner, 2000). Socio-ecological models have been used to implement different public health strategies. To take tobacco control and cessation campaigns as an example, interventions have targeted smokers on multiple levels: through smoking cessation treatments, tobacco tax increases and prohibitions on smoking in public places, which helped in establishing a new non-smoking social norm and created a synergy between individual interventions (Warner, 2000). To promote physical activity, the following interlinked strategies are proposed: the creation of safe, convenient and attractive places for physical activity, the implementation of educational and motivational programs to encourage use of those places, and using mass media and community organization to change social norms and culture (Sallis et al., 2006).

3.2 A framework for analysing cycling and BSS use

This research builds on the socio-ecological models used in physical activity and travel behaviour research, as introduced in the previous section, and proposes the framework in Figure 3.4, which includes factors influencing cycling and BSS use as identified through the literature review. The framework will be used to analyse the relative influence of different factors on cycling and BSS use, to gain a deeper understanding of the opportunities and constraints they present and the interplay between them. The framework is presented at the beginning of each of the results chapters, *Chapters 5* to *8*, highlighting in blue which section of the framework is addressed in the specific chapter.

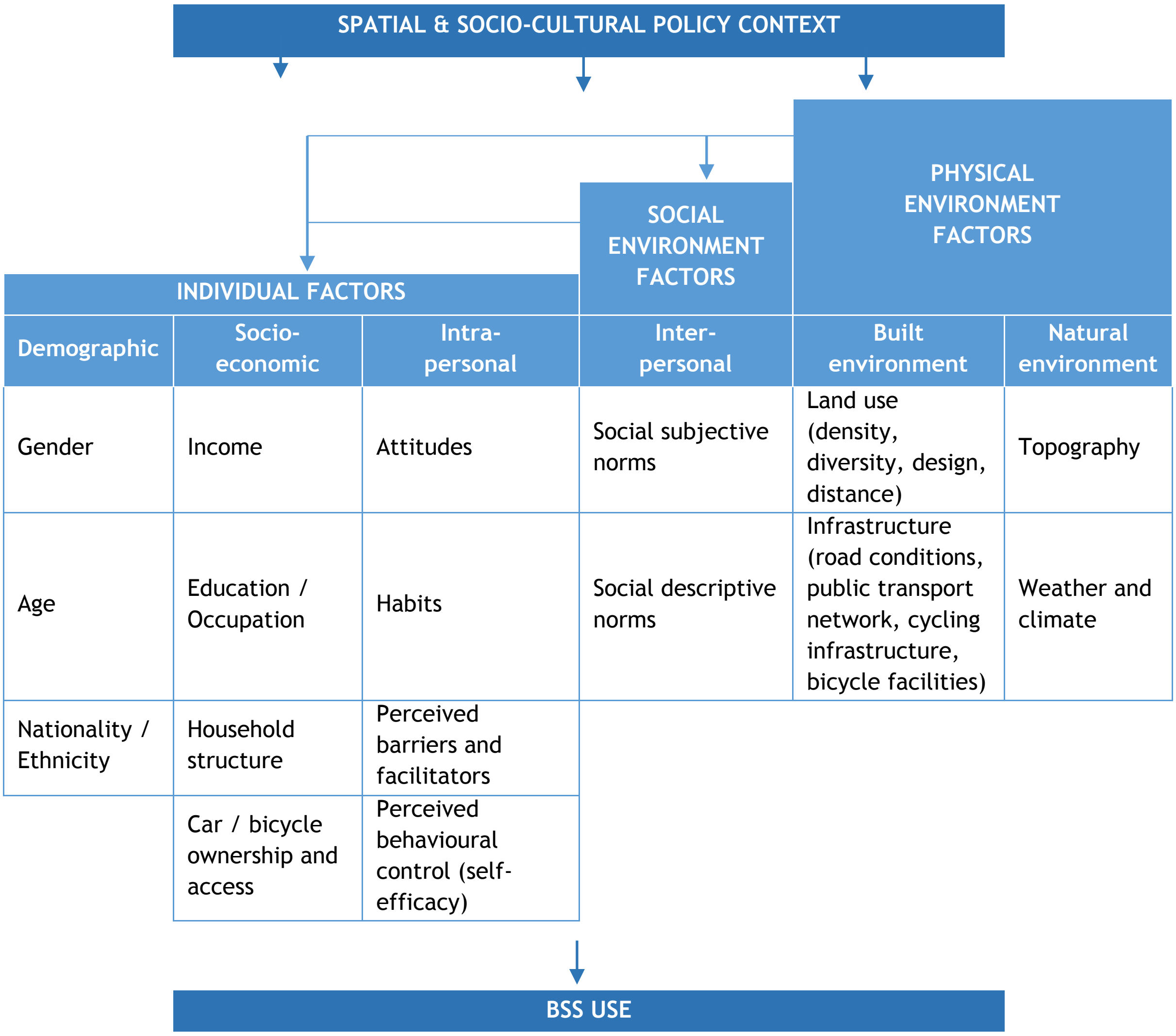


Figure 3.4: Framework for socio-ecological model of cycling behaviour and BSS use

Table 3.1 presents findings from the literature on the influence of the identified factors. The expected effect (direction) of the factors on the scale included in italics below the name of the factor is determined by the author based on a review of findings from the literature and is indicated using the following symbols to indicate a positive (+), negative (-), or inconclusive (+/-) effect. The findings for cycling as a mode of transport are primarily findings relevant to utilitarian cycling (for commuting or running errands) and for leisure use, but not for sports or long-distance recreational cycling, as these are not forms of cycling generally practiced on BSS.

Table 3.1: Expected influence of factors on BSS use

Factors		Findings	Effect
Individual factors			
Demographic factors	Age *(young - old)*	Cycling generally declines with age, but less so in countries with high cycling levels (Heinen et al., 2010; Pucher & Buehler, 2008). BSS users are generally younger than private cyclists, and are mostly between 18 and 34 years old (Fishman et al., 2015; Fuller et al., 2011; Murphy & Usher, 2015; Shaheen et al., 2012).	**-**
	Gender *(male - female)*	In countries with low cycling levels, males are more likely to cycle (Félix, Moura, & Clifton, 2019), whereas in countries with high cycling levels, females cycle as much, or more, as men (Fraser & Lock, 2011; Heinen et al., 2010; Pucher & Buehler, 2008). Most BSS have more male than female users, but the difference is less pronounced than in private cycling (Buck et al., 2013; Fishman, 2016; Fuller et al., 2011; Murphy & Usher, 2015).	**+/-**
	Nationality / ethnicity *(Caucasian - other ethnicities)*	Most findings on ethnicity are from the US, where BSS users are most commonly of Caucasian origin (Hyland et al., 2018; Rixey, 2013; Shaheen et al., 2012; Wang et al., 2016). A study of cycling levels between native and non-native Dutch residents showed higher cycling levels among native residents (Heinen et al., 2010).	**-**
Socio-economic factors	Income *(low - high)*	BSS users tend to be more affluent than the general population of the city (Fishman et al., 2015; Murphy & Usher, 2015; Shaheen et al., 2012), and BSS use was found to be higher in areas with a higher median income (Rixey, 2013).	**+**
	Education *(low - high)*	BSS users tend to have a higher than average level of education, as shown by findings from different cities in Canada and the US (Rixey, 2013; Shaheen et al., 2012) and Taiwan (Liao, 2016).	**+**
	Occupation *(unemployed - employed)*	BSS use is generally associated with higher employment rates, for example in Seville, and in Barcelona, where unemployment is negatively correlated with BSS use (Hampshire & Marla, 2012).	**+**
	Household structure *(single - couple - family)*	Singles, couples and students are more likely to cycle, while family expansion generally results in a reduced level of cycling (Heinen et al., 2010) or BSS use (Hyland et al., 2018).	**-**
	Car ownership and access *(no car - car)*	The relationship between BSS use and car ownership is not clear, as results from different cities are not consistent, indicating that other factors, such as income, cycling culture, and land use mix and density, may be confounding the relationship (Bachand-Marleau et al., 2012; Jain et al., 2018; Maurer, 2011; Shaheen et al., 2011).	**+/-**
	Bicycle ownership and access *(no bicycle - bicycle)*	BSS provides access to a bicycle without the burden of purchasing, maintaining and securely storing a private bicycle (Bachand-Marleau et al., 2012; Faghih-Imani & Eluru, 2016b; Murphy & Usher, 2015). Improved access to bicycles through the introduction of BSS has been associated with increased overall cycling (Pucher et al., 2010).	**+**

Factors		Findings	Effect
Individual factors			
Intra-personal factors	Attitudes *(negative - positive)*	People with a more positive attitude towards environment and sustainability are more likely to use BSS (Shaheen et al., 2011; Yin et al., 2018). The causality and direction of this relationship, whether a positive attitude towards cycling or the cycling habit comes first, is less clear (Heinen et al., 2010), with research finding a stronger influence of behaviour on attitude than vice versa (Kroesen & Chorus, 2018).	+
Intra-personal factors	Habits *(no cycling habit - cycling habit)*	People with a habit of cycling are more inclined to cycle (Willis et al., 2014). Decisions to cycle for transport are influenced by habit of cycling for non-commuting trips (Muñoz, Monzon, & Lois, 2013). However, people with a cycling habit are also more likely to own a private bicycle, so while the relationship between cycling habit and BSS use is generally positive, this is not always the case (Bachand-Marleau et al., 2012; Fishman et al., 2015).	+
Intra-personal factors	Perceived barriers *(no barriers - barriers)*	Common barriers to cycling include the lack of safe cycling infrastructure, road safety concerns, longer distances, hilliness and fear of arriving at a destination sweaty, and specifically for BSS, docking stations not being close enough to home and destinations (Félix et al., 2019; Fishman et al., 2014; Iwińska et al., 2018). In countries where helmet use is mandatory, this is also a strong barrier for cycling in general and for BSS in particular (Fishman et al., 2015).	-
Intra-personal factors	Perceived facilitators *(no facilitators - facilitators)*	Positive motivating factors for cycling include perceived health and environmental benefits, time and money savings, as well as access to the required facilities, i.e. access to a bicycle, parking facilities at home and destinations, showers at destinations (Félix et al., 2019; Fishman et al., 2015), although the first two facilities are included in the premise of dock-based BSS.	+
Intra-personal factors	Perceived behavioural control *(unable/unsure - able/confident)*	Confidence in one's ability to cycle has a positive influence on cycling (Handy et al., 2010; Willis et al., 2014). A person's perception of the social and physical environment has been found to be associated with levels of cycling (Heinen et al., 2010) and BSS use (Liao, 2016).	+
Social environment factors			
Social subjective norms *(no support - support)*		Friends' and family's encouragement and support of cycling, the general attitude to cycling in a country, information sharing and promotion of cycling, all contribute to a conducive social norm around cycling (Iwińska et al., 2018; Pucher & Buehler, 2008; Willis et al., 2014). Subjective norms are largely omitted in studies of BSS use, as found by Biehl et al. (2018).	+
Social descriptive norms *(no role models - role models)*		Having role models modeling the behaviour makes it more likely that someone will try out the behaviour for themselves (Bélanger-Gravel et al., 2015; Willis et al., 2014). Seeing others using BSS increases BSS users' confidence and willingness to use shared bicycles (Bélanger-Gravel et al., 2015; Fishman et al., 2012; Liao, 2016).	+

Factors		Findings	Effect
Physical environment factors			
Natural environment	Topography and elevation *(no physical barriers - physical barriers)*	The presence of slopes and steep inclines in general has a negative impact on the level of cycling (Fraser & Lock, 2011; Heinen et al., 2010). Data from BSS in cities with elevation differences confirms the negative effect of hilliness on cycling: BSS stations at higher elevations have significantly lower usage rates in Lyon (Tran et al., 2015), Brisbane (Mateo-Babiano et al., 2016) and Barcelona (Faghih-Imani et al., 2017).	**-**
	Weather and climate *(extreme weather - pleasant weather)*	Rain, snow, ice, and wind (or the chance thereof), darkness, and any type of extreme temperatures, whether cold or hot, can make cycling unpleasant and in general results in people cycling less (Fraser & Lock, 2011; Heinen et al., 2010; Pucher & Buehler, 2008). Data from BSS around the world confirms this (Borgnat et al., 2011; Corcoran et al., 2014; Faghih-Imani & Eluru, 2016a; Faghih-Imani & Eluru, 2016b; Gebhart & Noland, 2014), and shows that temperatures above 30˚C results in a decrease in BSS use (Corcoran et al., 2014; Gebhart & Noland, 2014).	**+**
Built environment	Land use *(sprawl - dense & mixed)*	Higher land use diversity and density have been positively correlated with cycling (Fraser & Lock, 2011; Heinen et al., 2010; Pucher & Buehler, 2008). BSS data from different countries shows a positive correlation between BSS use and land uses and points of interest such as city centres, restaurants, university campuses, tourist destinations, and parks and water bodies (Bordagaray et al., 2016; Faghih-Imani et al., 2017; Hampshire & Marla, 2012; Jain et al., 2018; Zaltz Austwick et al., 2013).	**+**
	Distances *(near - far)*	Shorter trip distances are positively associated with more cycling (Fraser & Lock, 2011; Handy et al., 2014; Heinen et al., 2010). BSS networks and pricing structures are designed to encourage short trips (Fishman et al., 2013). Proximity to BSS stations from a person's home and/or work location increases the likelihood of their use of BSS (Fishman et al., 2014; Fuller et al., 2013b; Molina-García et al., 2013; Ogilvie & Goodman, 2012).	**-**
	Road conditions *(quiet - busy)*	Levels of cycling are lower where there are busy roads, because of heavy traffic, air pollution, physical barriers and higher accidents risks (Fraser & Lock, 2011; Heinen et al., 2010; Pucher & Buehler, 2008). A higher incidence of major roads near BSS stations is negatively correlated with BSS use (Faghih-Imani et al., 2014; Faghih-Imani & Eluru, 2015).	**-**
	Public transport network *(near - far)*	BSS is generally understood to be a feeder service for public transport and a complementary form of mobility (Handy et al., 2014; Murphy & Usher, 2015), but there are also cases where a substitution effect is taking place, where BSS is competing with other forms of public transport (Shaheen et al., 2012).	**+/-**
	Cycling infrastructure *(limited - comprehensive)*	The provision of safe and connected bicycle infrastructure emerges as one of the main determinants of increased cycling from cities worldwide (Marqués et al., 2015; Pucher & Buehler, 2008). BSS use is positively correlated with nearby bicycle lanes and paths (Buck & Buehler, 2012; Faghih-Imani et al., 2014; Mateo-Babiano et al., 2016; Rixey, 2013).	**+**
	BSS network *(limited - comprehensive)*	The design and distribution of BSS stations, their capacity, and a continuous connection between stations are factors influencing overall BSS use (Rixey, 2013). No consistent correlation has been found to support a positive 'network effect' between system expansion and increased BSS use (Médard de Chardon et al., 2017).	**+/-**

3.3 Research gap

In the past decade bicycle sharing systems have evolved from a fringe phenomenon to a commonplace feature in the mobility mix of many cities. However, it is not always clear what exactly is the purpose of the BSS, what qualifies as success or failure of a system, how accessible and equitable they are, and to what extent BSS can deliver on their promise of providing an easy, flexible, low-carbon form of transport. These questions have spawned a wealth of research in conjunction with the growth in BSS worldwide. Some seminal papers on the topic of BSS are Fishman (2016) and Médard de Chardon et al. (2017), whereas for cycling research in general, Handy et al. (2014) and the work by Pucher & Buehler (2017) stand out.

Most studies on bicycle sharing systems, and cycling more in general, have been conducted in cities in European countries such as the Netherlands, Denmark, Germany and the UK (e.g. Goodman et al., 2014; Pucher & Buehler, 2008), North-America (e.g. Buck et al., 2013; Faghih-Imani & Eluru, 2016a), Australia (e.g. Fishman et al., 2012; Fishman et al., 2015; Mateo-Babiano et al., 2016) and China (e.g. Zhang et al., 2017; Zhao et al., 2014). As these cities are heterogeneous in terms of their urban design, infrastructure and transport modes and have diverse cultures and social norms, the use of cycling as a mode of transport and the role and use of the BSS vary to a great extent. To what extent do the geographical (e.g. topography, urban design, climate) and socio-cultural (e.g. car culture, social norms, perception of cycling) context matter in the promotion of cycling? Handy et al. (2014) identified the need for in-depth case studies to illuminate the different conditions that lead communities to efforts to promote cycling.

This research contributes to the literature on this topic by understanding in detail the usage of bicycle sharing systems in three case studies in a different subset of cities on Southern European islands: Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta). These medium-sized cities can all be classified as 'starter' cycling cities and share a set of common features due to their history and geography, such as their historic centres with narrow streets, port-city relations, relative smallness and remoteness, general flat political structures, high car modal share, dependence on imported fuel and energy, a strong influx of (seasonal) tourists and expat communities, hot summer climate and elevation differences between sea level and hinterland. The contribution of this research focuses on two main aspects of BSS usage in the case study cities; firstly, a characterisation of the BSS users and the motivators and barriers that influence their BSS use; the individual and subjective environment factors, and secondly, an analysis of the influence of objective environment factors, spatio-temporal factors such as land use, transport networks and weather, on BSS usage. This study builds and expands on previous research with BSS users and spatio-temporal analysis of BSS use, by assessing three bicycle sharing systems from both perspectives to understand both social and spatial influences, in a different context, where several identified barriers to cycling are present. The results provide insight into the behaviour and motivations of current users and to what extent the BSS serves the city's resident and tourist populations. The insights from this research are used to formulate recommendations for promoting BSS use and cycling, as part of a modal shift away from private car use towards more sustainable urban mobility, for these and comparable 'starter' cycling cities.

A question put forward in the literature, and one that is specifically relevant in cities with a minimal modal share of cycling and a budding bicycle sharing system, is "who uses bicycle sharing systems and why?” (Clark & Curl, 2016; Fishman, 2016). Are the users of BSS in Southern European island cities comparable to those in other geographic contexts or do they behave differently? What are the users’ motivations and preferences for using BSS? What is the influence of perceptions of their environment on BSS use? Mateo-Babiano et al. (2016) suggest surveying BSS users to investigate the impact of the built and natural environment on their BSS use. Liao (2016) adds that there is a paucity of studies that look at the associations between the perceived environment and BSS use. What has prevented or encouraged users to use the bicycle sharing system? Not all people who register with a BSS actually use the system, e.g. a bicycle sharing survey by Bikeplus (2017) showed that a number of respondents had not yet used the system, despite registering for it, as a result of stations not being conveniently located for them, or a preference to use their own bicycle, or for other reasons. While research has shown that the provision of safe cycling infrastructure is one of the main determinants for more cycling and BSS use (Médard de Chardon et al., 2017; Pucher & Buehler, 2017), it has also been proven that it is not the sole determinant, and that there have been cases where the modal share of cycling has grown despite minimal investment in cycling infrastructure (Savan et al., 2017). How important is the provision of safe cycling infrastructure for the BSS users in Southern European island cities, or to what extent is the lack of such infrastructure a reason to forgo cycling? This research aims to contribute to the research field by providing a better understanding of who the users of the BSS in the case study cities are, what their socio-economic characteristics are, what motivations they have for using BSS, and how their BSS use is influenced by their social environment and perceived physical environment.

In his landmark study of 75 bicycle sharing systems, Médard de Chardon (2016) compares the performance of BSS in cities across Europe, America and Australia and measures the influence of independent variables related to system attributes, station density, weather, geography, and transport infrastructure. While the methodology developed in his research proved suitable for the comparison of such a large number of systems, one of the future recommendations put forward by the author is to conduct “a similar study of fewer BSS case studies with higher quality data, such as cycling infrastructure and land use” (Médard de Chardon et al., 2017). Romanillos et al. (2016) put forward the idea of combining BSS data with complementary external datasets - demographic data, for example – to place BSS data within a wider context, including transport planning and behaviour change. In addition, analysing longitudinal usage trends of BSS is necessary to understand how temporal effects impact BSS use (Rixey, 2013), and what the impact is of new transport policies on BSS use (Jain et al., 2018). Rixey (2013) further suggests that researchers should expand analysis of BSS to smaller towns and cities, as much of the existing research focuses on BSS in large cities. To contribute to this field, this research includes a deeper, longitudinal analysis of BSS usage and the influence of objective environment factors, such as the influence of elevation differences, weather differences between mild winter and hot summer months, the impact of (new) cycling infrastructure, as well as the effect of tourist numbers on BSS use.

3.4 Conclusion

In this concluding section, the key components of the theories used to underpin this research are summarised. This chapter presented the framework that will be used for the analysis of cycling and BSS use, building on socio-ecological models developed to understand active travel behaviour, and discussed the reviewed literature critically to present the identified research gaps.

This research is based on socio-ecological models developed to analyse physical activity and travel behaviour. The theoretical basis for these models is underpinned by several theories emerging from the fields of economic and transport geography and social psychology, including economic utility theory, the theories of planned and repeated behaviour, and the transtheoretical model of behaviour change, which were discussed in the first section of this chapter. Economic utility theory postulates that travel behaviour is the result of the maximization of utility when weighing different travel options against each other in terms of the time, cost and effort involved. The Theory of Planned Behaviour builds on economic utility theory by including the influence of personal attitudes, social norms and perceptions in the set of factors that influence travel behaviour. The important role of habits in resulting travel behaviour is put forward by the Theory of Repeated Behaviour. The Transtheoretical model presents the different stages of change a person goes through when contemplating, taking action or reinforcing a behaviour change. The presented travel behaviour models based on socio-ecological models bring together the insights from the aforementioned theories and suggest that individual travel behaviour is affected by multiple levels of factors: individual factors, social environment factors and physical environment factors. The second section of this chapter presented the framework developed to analyse cycling and BSS use, including factors at multiple levels, as identified through the literature review and the theories underpinning this research. An overview was provided of the findings from the literature on the influence of the identified factors, including the expected direction (positive or negative) of the effect of the factors.

The third section of this chapter identified the research gaps that were addressed by this study. While much of the research on BSS has focused on large cities, in very heterogeneous contexts, this research contributes to the literature on this topic by understanding in detail the usage of bicycle sharing systems in three case studies in cities on Southern European islands, which can all be classified as ‘starter’ cycling cities: Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta). This research builds and expands on previous research with BSS users and spatio-temporal analysis of BSS use, by assessing the use of three bicycle sharing systems from both perspectives to understand both social and spatial influences, and by comparing and cross-validating results. This study provides a better understanding of who the users of the BSS in the case study cities are and how their BSS use is influenced by their social environment and perceived physical environment, from the analysis of BSS user surveys as well as through a deeper, longitudinal analysis of BSS usage and the influence of objective spatio-temporal environment factors.

The next chapter, *Chapter 4*, discusses the research design adopted for this study, including the presentation of the research questions. The methodologies used for data collection and analysis are also described in detail in the next chapter.

4. Methodology

The preceding chapters introduced the chosen research problem and selected case study cities (*Chapter 1*), presented concepts related to sustainable urban mobility, cycling and BSS use in the literature review (*Chapter* 2), the theoretical framework to understand travel behaviour, the factors influencing cycling and BSS use and the identified research gaps (*Chapter 3*). This research explicitly adopts a multiple-case study approach in three Southern European island cities. In doing so, it recognises the importance of the geographical and socio-cultural contexts in understanding the resulting travel behaviour and use of BSS.

This chapter presents the research design of the study. In section 4.1, the critical realism research paradigm, the multiple-case study design, and the quantitative research strategy adopted are described and discussed. The section ends with a presentation of the research questions and the data collection and analysis methods used. The second section, 4.2, details the data collection strategies used during the course of the research: secondary sources and interviews to describe the city context, the BSS user survey to collect user perspectives, and longitudinal BSS trip data and spatio-temporal datasets to understand the influence of physical environment factors on BSS use. The third section, 4.3, describes the data analysis methodologies in detail: the descriptive framework to present the context of the case study cities, the analytical tools used to analyse the survey results, and the modeling techniques used to analyse the trip data and spatio-temporal datasets. The section finishes with a discussion of techniques to compare the analysis of results between the case study cities. The final section, 4.4, concludes this chapter and looks ahead at the chapters presenting the results of this research.

4.1 Research design

4.1.1 Critical realism research paradigm

The way in which researchers gain and confirm understanding of some aspect of the world depends on which methodological tradition they adopt (Hart, 1998). The methodological tradition, or research paradigm (Bryman, 2016) is the approach taken on ontological and epistemological issues (Bryman, 2016; Easton, 2010; Hart, 1998). In this research critical realism is adopted as the research paradigm. Critical realism shares with positivism the belief that the natural and social sciences should apply the same kind of approach to data collection and analysis, and a view that there is an external reality separate from our descriptions of it. However, critical realism argues that the researcher's conceptualization of reality is only a way of knowing reality, and not actually directly reflecting that reality, as a positivist would believe (Bryman, 2016).

Critical realism's notion of causality differs from the positivist understanding of causation: the perception of cause (the independent variable) and effect (the dependent variable), which is dominant in natural sciences research and in the experimental research design. Instead, critical realism seeks out generative causal mechanisms that are responsible for observed patterns in the social world, and how they operate in a specific context. Context is at the core of the critical realism paradigm, as it sheds light on the contextual conditions that promote or impede the operation of the causal mechanism (Bryman, 2016).

Case studies are considered to be a fitting research approach within the critical realism tradition, as the intensive nature of the case study, and the attention paid to context enhance the researcher's ability to examine and understand the generative causal mechanisms (Ackroyd, 2009). This is even more relevant in multiple-case studies, as it allows the researchers to do this in contrasting or similar contexts (Bryman, 2016).

4.1.2 A multiple-case study design

A case study is an empirical inquiry, focused on "how" and "why" questions, about a contemporary phenomenon (the case) within a real-world context, where the boundaries between phenomenon and context are not always clear. A case study inquiry generally relies on multiple sources of evidence and bringing the insights from this data together to come to an understanding of causal mechanism, while being guided by a suitable theoretical framework in the data collection and analysis (Yin, 2014). A multiple-case study design includes more than one case, which can be an individual, organization, process, programme, institution, or event (Yin, 2014). In this research the case is the BSS, a novel transport system in each case study city. Selection of the case studies for a multiple-case study can be based on the differences or similarities between cases (Bryman, 2016). In this research, three similar cases – the introduction of BSS in the three Southern European island cities of Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta) - have been selected. Cross-national case research can be used to study two or more cases in an effort to gain insight into similarities or differences, and an understanding of the influence of different social and spatial contexts, and their structures and institutions (Hantrais & Mangen, 1996).

Some common concerns about case study research, and particularly a multiple-case design, are related to: 1) a potential lack of rigor and disregard of systematic procedures, as the methods of how to conduct a case study are sometimes perceived as a bit vague and unstructured; 2) difficulty gaining access to comparable datasets and achieving comparable conceptual and functional research parameters and units of analysis; and 3) an apparent inability to generalise from case study findings (Hantrais & Mangen, 1996; Yin, 2014). However, instead of criticising case studies as a weak attempt at statistical inference, Ruddin (2006) in his response to such critique, postulates that case studies are in fact the basic method of science, when they are seen as a tool for hypothetico-deductive theorising. To address the above-mentioned concerns, this research: 1) follows tested methods and procedures in case study research; 2) pays sufficient attention to the creation of a replicable research design, using the same concepts, units and parameters in each of the cases; and 3) uses insights from the data to expand and generalise theories, not to extrapolate probabilities (Hantrais & Mangen, 1996; Ruddin, 2006; Yin, 2014).

4.1.3 A quantitative research strategy

The multiple-case study follows a quantitative approach, collecting information from BSS users through surveys, revealed usage from BSS trip data provided by the operators, and external datasets providing insights about physical environment factors, such as weather and elevation. However, to better understand the context of the case study cities, the data collection starts off with a review of secondary sources and interviews with actors and stakeholders, to understand the social and spatial context, structures and institutions in the case study cities. Such an approach has been followed in a few other BSS studies, to get a deeper understanding of the context of different cities that have introduced BSS, i.e. how and why the system was introduced, what the role of local authorities and policy makers was, and how the system links to existing transport modes. In their research on the adoption and diffusion of BSS in Europe and North America, Parkes et al. (2013) held interviews with BSS operators, urban planners and policy makers, academics, public transport operators, and cycling groups. Shaheen et al. (2012) also collected qualitative data, through interviews with BSS operators, local authorities and experts in North America to obtain more insight in operational practices, business models, membership demographics, and the environmental and social impacts of BSS.

Analysing quantitative data, to understand the operation, use and impact of BSS is the most common approach in BSS research, either through the analysis of quantitative BSS trip data (provided by BSS operators or obtained through data-mining), or through BSS user surveys, as is outlined in the overview of quantitative approaches used in BSS research in Table 4.1 and Table 4.2.

Table 4.1: Quantitative approaches in BSS research: Analysis of BSS trip data

Analysis of BSS trip data	
Research objective	**Examples from the literature**
Obtaining insight in BSS user demand and travel behaviour trends	Analysis of BSS use, demand analysis and classification of usage types (Bordagaray et al., 2016).
	Analysis of origin-destination trip data to identify travel behaviour trends by casual users and long-term subscribers (Jain et al., 2018).
	Analysis of dockless BSS use through GPS data (Bakogiannis et al., 2019).
Quantifying the impacts of BSS use	Analysis of trip duration and distance from origin-destination trip data, to use in the quantification of mode substitution impacts (Fishman et al., 2014).
Visualising and characterising spatio-temporal dynamics of BSS use	Visualisation of origins, destinations and flows with origin-destination maps (Wood et al., 2010; Wood et al., 2011).
	Definition of spatio-temporal characteristics of BSS use in different cities based on origin-destination trip data (Zaltz Austwick et al., 2013).
	Definition of temporal dynamics, such as daily and monthly utilisation rates, trip duration and trip length, and comparison of neighbourhood performance, to understand the influence of resident population and number of stations on spatial trends in BSS use (Ahillen et al., 2015).
Understanding the influence of individual, social environment and physical environment factors on BSS use	Analysis of the influence of operator and system attributes, and physical environment factors (weather, geography and transport infrastructure), on BSS use in a regression model for 75 BSS (Médard de Chardon et al., 2017).
	Analysis of the influence of demographic factors and built environment factors (bicycle infrastructure and land use) on BSS users' destination station choice (Faghih-Imani & Eluru, 2015).
	Analysis of the influence of meteorological and temporal characteristics and built environment factors (such as bicycle infrastructure and land use), on BSS station-level arrival and departure figures obtained from BSS trip data (Faghih-Imani et al., 2014).
	Analysis of the influence of demographic and socio-economic status of registered and casual users on BSS use (Goodman & Cheshire, 2014).
	Analysis of the influence of weather conditions and calendar events (such as public holidays) on spatial and temporal trends in BSS use (Corcoran et al., 2014).

Table 4.2: Quantitative approaches in BSS research: Analysis of BSS user survey data

Analysis of BSS user survey data	
Research objective	**Examples from the literature**
Identifying the demographic, socio-economic and interpersonal factors and understanding their influence on BSS use	Identification of the motivators and barriers for joining BSS through an online survey with BSS members and non-members (Fishman et al., 2014).
	Identification of the factors facilitating and presenting barriers for BSS adoption through an intercept survey with BSS members and non-members (Shaheen et al., 2011).
	Identification of the BSS users' demographics, travel behaviour, modal shift, and the importance of helmet use and safety, through an online survey of BSS members and intercept surveys with casual users (Shaheen et al., 2012; Shaheen et al., 2014).
	Identification of BSS users' socio-economic characteristics, their satisfaction with the quality of service, and attitudes towards cycling in general and the BSS, through an online survey with BSS members (Morton, 2018).
	Analysis of the influence of demographics, intrapersonal factors (attitudes and habits), and BSS station proximity to home or destinations on (the frequency of) BSS use, through an online travel survey with a population-based sample (Bachand-Marleau et al., 2012).
	Identification of the BSS users' socio-economic characteristics, the purpose of their BSS use, and their perception of cycling, awareness of motorists, the integration with public transport and the role of BSS in promoting modal shift through an intercept survey (Murphy & Usher, 2015).
	Analysis of differences in demographics and travel patterns between BSS members, casual users and regular cyclists, through a comparison of results from a BSS member survey, BSS intercept survey and travel household survey respectively (Buck et al., 2013).
	Identification of the socio-economic characteristics of users, and their motivations for BSS use, through intercept surveys with BSS users (Buehler & Hamre, 2014).
	Identification of the prevalence of BSS use among the general population, and understanding the influence of socio-demographic factors, travel habits and BSS station proximity to home or destinations on BSS use, through a telephone survey (Fuller et al., 2011).
	Analysis of user perceptions of a dockless BSS, including differences between frequent and infrequent users (Bakogiannis et al., 2019).
Quantifying the impacts of BSS use	Estimation of the potential modal shift and health benefits from BSS use, through two cross-sectional telephone surveys with a population-based sample (Fuller et al., 2013a).
	Evaluation of the impact of exposure to the BSS on the likelihood of cycling, through a longitudinal analysis of telephone surveys with a population-based sample (Fuller et al., 2013b).
	Analysis of the spending behaviour of BSS users at local businesses, to understand the impact of BSS on economic benefits, through intercept surveys with BSS users (Buehler & Hamre, 2014).
	Examination of the effect of BSS use on intention and self-efficacy in relation to BSS use and cycling, while controlling for socio-economic status, through two cross-sectional telephone surveys with a population-based sample (Bélanger-Gravel et al., 2014).
	Evaluation of the impact of BSS use on, and the factors playing a role in, the choice to purchase a bicycle and transition to private cycling, through intercept surveys with BSS users (Castillo-Manzano et al., 2015).

Using BSS trip data enables a researcher to obtain a large dataset in an objective, cost-effective manner, and allows for analysis of the revealed usage data, such as "how", "how much", "where" and "when" shared bicycles are used, as well as analysis of the relationship between objective environment factors and BSS use (Bordagaray et al., 2016; Faghih-Imani & Eluru, 2015; Lathia et al., 2012). However, revealed usage data lacks the ability to answer "why" people use it and how users are influenced by intra- and inter-personal factors, such as their personal attitudes and motivations, their perception of the environment, and the influence of their peers and the dominant mobility culture (Fishman et al., 2015; Lathia et al., 2012; Murphy & Usher, 2015). These insights can be provided by the users themselves, through a self-reported questionnaire, in the form of an online survey, in-person intercept survey, or a telephone survey interview, as evidenced by the examples provided in the above tables (Table 4.1 and Table 4.2). In this research, quantitative analysis of self-reported usage data through a BSS user questionnaire allows for assessment of the influence of individual and social environment factors (including *perceived* environment factors) on BSS use, while quantitative analysis of longitudinal revealed BSS trip data provided by the BSS system operators enables assessment of the influence of physical environment factors (*objective* environment factors) on BSS use in the case study cities.

Combining insights obtained through different data collection and analysis methods has been adopted by a select number of researchers studying the use of BSS, e.g. a combination of insights from interviews with quantitative data obtained from BSS user surveys with members and casual users, or in combination with BSS trip data, as shown by the examples included in the above tables (Table 4.1 and Table 4.2). Using a combination of different data collection and analysis methods offers the ability to validate and triangulate results, adding to the breadth and depth of a research study (Johnson et al., 2007). Validation and triangulation of results via multiple sources of data allows for making more convincing and accurate case study conclusions (Eisenhardt, 1989; Yin, 2014).

4.1.4 Research questions

The theoretical framework presented in *Chapter* 3, in Figure 3.4 specifically, guided the formulation of the research questions. The research questions adopted in this study are presented in Table 4.3, and are connected with the relevant data collection methods, which are further expanded upon in Section 4.2, and the methods for data analysis, which are further explained in Section 4.3. For a schematic overview of how the research aim, objectives and questions relate to each other and to the research methods proposed, see Figure 4.1.

Research question 1 (RQ1) delves deeper in the geographical and socio-cultural characteristics of the case study cities, and the existing mobility practices in the cities. *Research question 2 (RQ2)* looks more closely at the relevant land use, transport and mobility policies, and will chart the entities governing and promoting cycling and BSS use. The results from the analysis of these two research questions are presented in *Chapter 5: Case studies context,* describing the spatial and socio-cultural policy context in the case study cities. *Research question 3 (RQ3)* answers how the BSS is used, and when, where, by whom and for what purposes. The results from the analysis of this research question are presented in *Chapter 6: BSS use in the case studies*. *Research question 4 (RQ4)* clarifies how user characteristics, their attitudes, habits and perceptions, encouraging and discouraging factors, social norms and perceived environment factors influence their BSS use. The results from the analysis of this research question are presented in *Chapter 7: The influence of individual and social environment factors on BSS use*. *Research question 5 (RQ5)* elicits what the influence of the natural and built environment is on BSS use, including factors such as weather, elevation, cycling infrastructure and urban form. The results from the analysis of this research question are presented in *Chapter 8: The influence of physical environment factors on BSS use*. *Research question 6 (RQ6)* compares the results across the case study cities, and brings forth the main similarities and differences between BSS use in the three cities. The results from the analysis of this research question are presented in dedicated sections focused on a comparative analysis of the results in each of the 'results' chapters: *Chapters 5 - 8*. *Research question 7 (RQ7)* wraps up the above and draws lessons learned from the different case study cities, and ways forward in the transition towards cycling as a mode of transport. The lessons learned and recommendations are presented in *Chapter 9: Discussion*.

Table 4.3: Research questions, data collection methods, and data analysis methods

		Research methods		
Research questions		Data collection	Data analysis	Chapter
RQ1	What are the spatial and socio-cultural characteristics in relation to cycling and BSS use?	• Secondary sources • Semi-structured interviews	Descriptive framework	5
RQ2	Which policies and entities exist that influence cycling and BSS use?			
RQ3	How is the BSS used, when, where, by whom and for what purposes?	• BSS user survey • Longitudinal BSS trip data	Descriptive statistics	6
RQ4	What is the influence of individual and social environment factors on BSS use?	• BSS user survey	Binary logistic regression analysis	7
RQ5	What is the influence of physical environment factors on BSS use?	• Longitudinal BSS trip data • Spatio-temporal datasets	Spatio-temporal regression analysis	8
RQ6	How do BSS use and influencing factors in the case study cities compare?	-	Comparative analysis, synthesis	5 - 8
RQ7	Which lessons can be learned from the promotion of cycling and BSS use in the case study cities?	-	Discussion	9

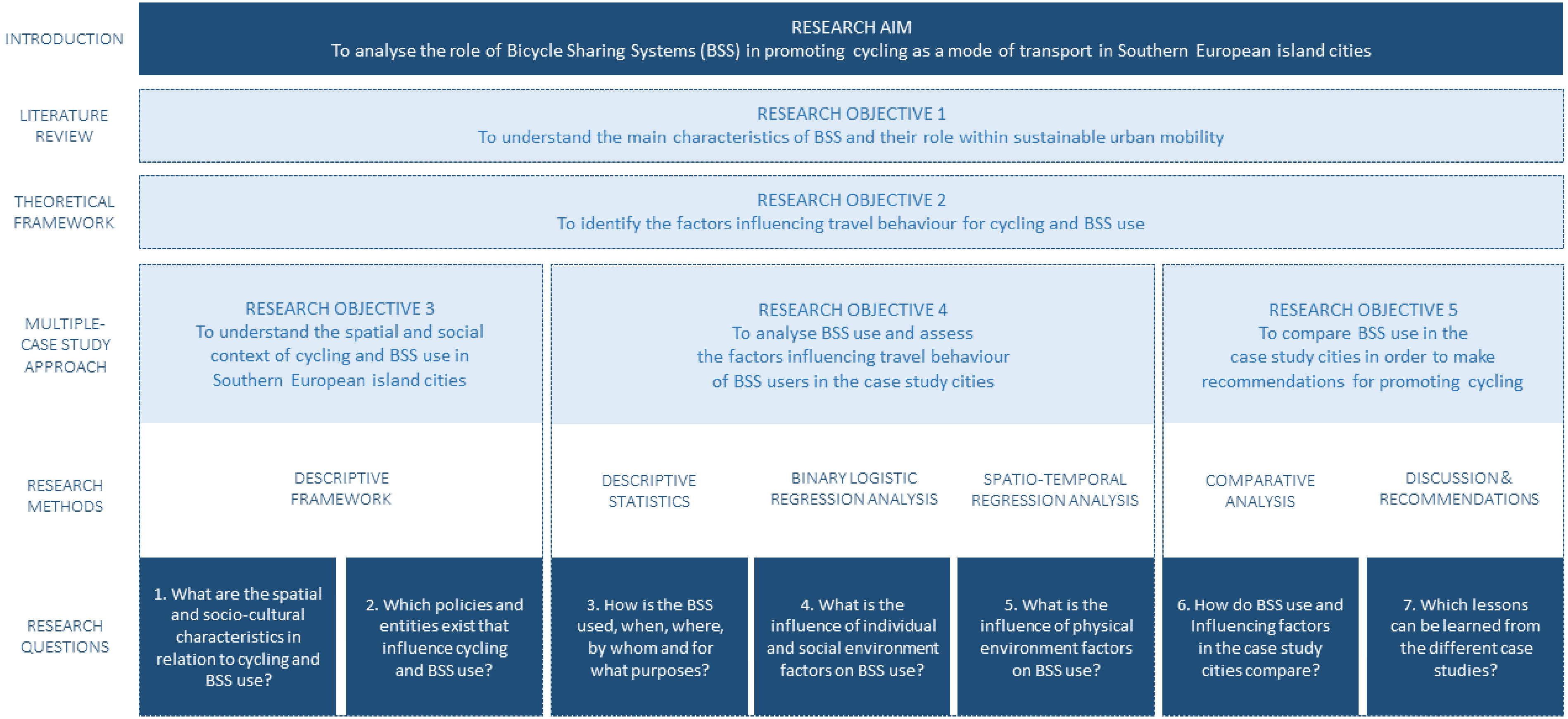


Figure 4.1: Research design

4.2 Data collection methodology

The different sources of data used in this research, and the strategies used to collect them, are presented here: in section 4.2.1, the secondary sources and interviews with experts and stakeholders; in section 4.2.2, the BSS user surveys; in section 4.2.3, the longitudinal BSS trip data; and in section 4.2.4, the spatio-temporal datasets.

The different data collection methodologies involved information from or pertaining to human participants: interviews with experts and stakeholders, respondents to the BSS user survey, and BSS users' anonymised trip data. Therefore, the data collection methodologies were subjected to a review by the Faculty Research Ethics Review of the University of Malta. Approval was received before commencing the data collection process (Unique Form ID: 524, year: 2019).

4.2.1 Secondary sources and interviews

Official government documents such as national statistics, legislation and reports, can be a useful source of information to understand context and policy direction in an area or city. Such documents are texts written with a distinctive purpose, and when analysing such texts, researchers should be aware of potential bias, the credibility of the information presented, and whether the document represents reality (Bryman, 2016). In order to better understand the cities' geographical and socio-cultural context, and the mobility practices and land use and transport policies influencing cycling and BSS use, a number of reports, policies and legislations, plans and guidelines, operating at the European, national, and district/city level were reviewed. Relevant documents were identified through literature search, online searches and via information provided by the interviewed stakeholders and experts. Table 4.4 presents the relevant documents that were included in the analysis.

Semi-structured interviews, guided by a list of questions on specific topics (Bryman, 2016), were conducted with selected governmental, non-governmental, experts and academics and (public-)private stakeholders with a relation to the transport and mobility context, with a specific focus on cycling and bicycle sharing, in the case study cities. The objective of the semi-structured interviews was to speak to at least the operator of the BSS, a local expert/academic, one representative of the local authority, one representative of the regional/national government authority responsible for transport and/or land use planning, and a representative of one local NGO or action group working on the theme of cycling and/or sustainable mobility, in order to gain a broad understanding of the context in each city, and to request information that is not available in published documents and datasets. Table 4.5 presents an overview of the experts and stakeholders that participated in the interviews.

Table 4.4: Overview of relevant documents at EU, national and city level

Document	European Union		
Reports	• DG MOVE (2013) Special Eurobarometer about Urban Mobility • ETSC (2015) Making Walking and Cycling in Europe Safer		
Policies & Legislation	• European Commission (2011) White Paper on Transport • European Commission (2013) Urban Mobility Package • European Commission (2016) A European Strategy for Low-Emission Mobility		
Document	**Conurbation around Valletta, Malta**	**Limassol, Cyprus**	**Las Palmas de Gran Canaria**
Reports	• National Household Transport Survey 2010 • Tourism in Malta 2016 • Transport Statistics 2016	• Tourism Statistics 2016	• Population census 2011 • Cuenta Satélite del Turismo de Canarias 2002
Policies & Legislation	• Transport Master Plan 2025 • Transport Strategy 2050 • Strategic Plan for Environment and Development • Draft National Cycling Strategy (2018) • North Harbours Local Plan (2006) • Grand Harbour Local Plan (2002) • National Electromobility Action Plan • Guidelines for Bicycle/Pedelec Sharing System • Low-Powered Vehicles and Pedal Cycles Regulations S.L.65.26	• Structure Plan - Central Area • Limassol Local Plan (2013) • Limassol Cycling Masterplan (2013) • City Centre Plan • Bicycle Bill (2018)	• Spanish Bicycle Strategic Plan (PEEB) (2019) • Plan General de Ordenación LPGC (2012) • Ordenanza de Trafico LPGC • Plan Director Bici Las Palmas (2016)
Plans & Guidelines	• Strategy for Valletta • SUMP Valletta harbour (*in preparation)*	• Streetscape Manual Cyprus • SUMP Limassol (2019)	• SUMP Las Palmas de Gran Canaria (2012)

Table 4.5: Interviewed experts and stakeholders in the transport and mobility field

Stakeholders	Valletta conurbation, Malta	Limassol, Cyprus	Las Palmas de Gran Canaria
Government entities	• Transport Malta • Planning Authority • Infrastructure Malta	• Limassol Municipality • Ministry of Transport, Communication and Works • Limassol Tourism Board	• Ayuntamiento de Las Palmas de Gran Canaria (municipality)
Bicycle sharing operators	• Nextbike Malta • Malta Public Transport	• Nextbike Cyprus	• SAGULPA (Sítycleta BSS management)
Non-governmental Organisations (NGOs)	• Rota (bicycle advocacy group)	• Cyprus Cycling Federation • KmEaters (cycling club) • Friends of the Earth Cyprus • Cyprus Scientific and Technical Chamber	• Las Palmas en Bici (bicycle advocacy group)
Expert / Academic	• Urban planner, University of Malta • Transport policy expert, University of Malta	• Environmental engineer, Cyprus University of Technology, Limassol	• Urban planner, Observatorio de Movilidad (mobility observatory) • Architecture firm (design of cycling infrastructure)

The interview guides used in the semi-structured interviews can be found in *Annex B – Interview guides* and focus on: a) the land use and transport planning process; b) specific plans and policies for cycling; and c) the introduction and use of BSS. The semi-structured interview questions were tested during the first case study site visit to Limassol in May 2018 in a series of scoping interviews with urban and transport planners, representatives of cycling organisations and the BSS operator *Nextbike Cyprus*. Interview participants were informed about the purpose of the study and were asked to sign a consent form prior to the interview, to give permission to be audio-recorded, and for the information provided to be used in the research and to be attributed to them in their professional capacity.

4.2.2 BSS user survey

Data was collected through BSS user surveys to understand "who" the BSS users are, and "why" they use the BSS, and to assess how intra- and inter-personal factors, such as socio-demographic characteristics, personal attitudes and perceptions, and the influence of their peers and wider social norms influence their use of the BSS.

The survey design

The BSS user survey is a self-administered revealed preference survey with a cross-sectional design, made available on Google Forms, a web-based platform to conduct questionnaire surveys. Adopting a cross-sectional design, meaning the data was collected at a single point in time (Bryman, 2016) implies that insights from the survey can be used to detect patterns of association, and understand which factors are associated with travel behaviour, but that they cannot be used to determine causality between influencing factors and BSS use (Liao, 2016). The BSS user survey was designed as a web-based, self-administered questionnaire. In line with recommendations for self-administered questionnaires, the survey consisted of mostly closed-ended questions, and had an easy to follow design (Bryman, 2016). The survey was based on the same format and questions for each city, to allow for aggregation and cross-site comparison. However, in certain instances, where the survey referenced the specific city location, there were differences in the surveys (e.g. in the introductory text, in questions related to residence in the city, and with reference to the subscription types, which differ between the cities). The surveys for Limassol and Malta were in English, which is widely spoken in both Cyprus and Malta, as both were under British rule in the past (English is the second official language in Malta). The survey for Las Palmas de Gran Canaria was made available in both English and Spanish. The surveys could be accessed via a purposely created webpage: www.survey.bike (see Figure 4.2).

Figure 4.2: The portal to the online surveys on www.survey.bike (no longer active)

Using a web survey, through Google Forms, allowed for central collection of all data entries online and facilitated data cleaning and pre-processing before data analysis. There are potential pitfalls associated with web surveys: 1) the need for respondents to have an internet connection and online skills, and 2) a lower response rate than through other survey methods, such as telephone and face-to-face surveys (Bryman, 2016). However, as identified through the literature review, the main user group of BSS fall within the 18-35 age range, and the use of a BSS is generally accessed through a smartphone or sign-up process online. Therefore, an online survey was deemed a good fit, as it could be assumed that the majority of BSS users are internet users and would have no issues filling in an online survey.

The survey structure and questions

The survey contained three sections: 1) demographic and socio-economic characteristics; 2) mobility practices and travel habits; and 3) attitudes and perceptions. In order to limit the time needed to complete the survey and increase the willingness of BSS users to participate, to enable a higher response rate, the survey consisted of 34 questions and could be completed in around 10 minutes. This follows similar intercept BSS user surveys, which have between 25-35 questions (Buehler & Hamre, 2014; Castillo-Manzano et al., 2015; Murphy & Usher, 2015). The complete BSS user survey can be found in *Annex C - BSS user survey*. The survey questions were primarily closed-ended questions, which allowed for easy understanding and a quick progression through the survey. Closed-ended questions included binary yes/no questions, multiple choice questions, and questions scored on a Likert scale (Bryman, 2016). Questions about frequency of use of different transport modes (e.g. walking, cycling, public transport, car) and frequency of use of BSS for different purposes (e.g. commuting, shopping, fun) were measured through a five-point Likert scale ranging from ‘daily’ to ‘never’. Attitudes and perceptions, e.g. motivating factors, satisfaction with the service, encouraging and discouraging factors, were measured through five-point Likert scales ranging from ‘completely agree’ to ‘completely disagree’.

The survey included questions about individual factors; the demographic, socio-economic and intra-personal factors, as well as inter-personal factors; the social subjective and descriptive norms that are part of the socio-cultural environment, as described in *Section 3.2: A framework for analysing cycling and BSS use*. As the survey is a self-reported questionnaire, all the answers represent the respondent's perceptions, e.g. in the case of trip duration this is the perceived duration. The survey questions were designed to answer the "who", "when", "where", and "why" questions about BSS use posited in *Research question 3*, and to assess the influence of individual and social environment factors on BSS use, as set out in *Research question 4*. The survey structure, questions and measurement scales used are presented in Table 4.6.

Table 4.6: Survey structure: sections, questions and measurement scales

Survey section		Survey question		Measurement scale
1.	**Demographic and socio-economic characteristics**	Gender		Nominal
		Age		Discrete
		Nationality		Nominal
		Education		Nominal
		Occupation		Nominal
		Income		Ordinal
		Household structure		Nominal
		Residency		Nominal
2.	**Mobility practices and travel habits**	Vehicle ownership		Nominal
		Frequency of use of transport modes		Ordinal
		Cycling habits	Helmet use	Nominal
			Joined BSS	Ordinal
			Membership type	Nominal
			Most recent trip	Ordinal
		Distance to BSS	To residence	Ordinal
			To most frequent destination	Ordinal
		Frequency of BSS trip purposes		Ordinal
		BSS trip frequency and duration	Week/weekend	Nominal
			Location most frequent trip	Open-ended
			Duration most frequent trip	Ordinal
		Modal shift		Nominal
		Trip infrastructure		Nominal
		Multimodal trips		Nominal
3.	**Attitudes and perceptions**	Motivations for BSS use		Ordinal (Likert scale)
		Satisfaction with BSS service		Ordinal (Likert scale)
		Bicycle types: electric vs standard		Nominal
		Opinion on statements (attitudes, norms, perceptions)		Ordinal (Likert scale)
		Perceived behavioural control	Cycling skill	Ordinal
			Perceptions of cycling safety	Ordinal (Likert scale)
			Encouraging factors (attitudes, norms, perceptions)	Ordinal (Likert scale)
			Discouraging factors (attitudes, norms, perceptions)	Ordinal (Likert scale)

The survey sample and response

In order to obtain responses from a sample that is representative of the entire population of BSS users in a particular city, probability sampling would have been the preferred sampling strategy. Random probability sampling is the most common form, where everyone in the population has an equal chance to be selected to be a part of the sample (Bryman, 2016). Fishman et al. (2015) for example, sent a survey via e-mail to a randomly selected sample from the population of BSS users for their study. However, because the BSS operators in the case study cities collect no or very limited personal data from users (e.g. it is not mandatory to include an email address when registering for the BSS in Limassol and Las Palmas de Gran Canaria), it was not feasible to select BSS users for participation in the survey through random probability sampling. As an alternative, several researchers conducting BSS user surveys have used on-street intercept surveys at stratified locations and times to reach a random sample (Buck et al., 2013; Buehler & Hamre, 2014; Castillo-Manzano et al., 2015; Murphy & Usher, 2015; Shaheen et al., 2011). In addition, adopting an intercept survey approach means both registered and casual users have a chance to be included in the sample, whereas the random probability sample of BSS users employed by Fishman et al. (2015) resulted in almost only receiving responses from members of the scheme.

Different approaches have been used by other researchers to select BSS stations for intercept surveys: ranging from random selection (Castillo-Manzano et al., 2015; Murphy & Usher, 2015), to selection based on intensity of use (Buck et al., 2013) or geographical spread of the stations (Buehler & Hamre, 2014). Drawing on these experiences, sampling BSS users from five to six stations appears to be the most common approach, and was therefore adopted in this research. Whereas random sampling, used for example by Castillo-Manzano et al. (2015) in Seville or Murphy & Usher (2015) in Dublin, would be the preferred strategy to minimise bias, the BSS in the case study cities are smaller and have lower levels of daily use in comparison to Seville (260 stations and 2,650 bicycles) and Dublin (58,000 registered users, and an average of 9 trips per day per bicycle). In the case study cities, smaller BSS and lower average trips per day per bicycle (TDB) means that some stations have very few arrivals or departures. For example, while average weekday TDB was 2.4 in Las Palmas de Gran Canaria after only a few months of operations, the intensity of use between different stations varies greatly, with up to a factor of 60 difference between the least and most intensely used stations (SAGULPA, 2018). Randomly selecting stations in the case study cities could have jeopardised reaching the target number of respondents. Therefore, stations were selected on the basis of intensity of use and geographical spread, as proposed by Buck et al. (2013) and Buehler & Hamre (2014).

Initial sample size targets were based on the number of registered users of the BSS in the case study cities: around 24,000 registered users in Limassol *(*N. Ioannou, personal communication, May 18, 2018), around 22,000 registered users in Las Palmas de Gran Canaria (C. García, personal communication, January 15, 2019), and around 11,000 registered users in Malta (J. Gabarretta, personal communication, January 11, 2019). The actual population size was determined once the BSS trip data covering a one-year period from April 2018 to March 2019 was obtained, and was based on the total number of active users over the span of that year, as presented in Table 4.7. Based on the total population size of 16,158 active users, with a margin of error of 4% and a confidence level of 95%, the total sample required was determined to be 579 respondents. Following the principle of stratified sampling, the sample size per case study was weighted according to their relative contribution to the total population. However, in order to capture the greatest possible variation in the population of BSS users in the different cities, and to be able to extend the analysis to the individual cities (in addition to comparing the results across cities), an attempt was made to collect more responses per case study. Across the three cities, a total of 759 survey responses were collected.

Table 4.7: Sample size calculation for BSS user surveys using stratified sampling

Case study	BSS	Active users	Target weighted sample size*	Actual sample size	Margin of error**
Limassol	Nextbike Cyprus	3,070	110	140	8.1%
LPGC	Sítycleta	9,006	323	491	4.4%
Malta	Nextbike Malta	4,082	146	128	8.5%
Total		**16,158**	**579**	**759**	**3.5%**

* confidence level 95%, margin of error 4%, based on https://www.surveysystem.com/sscalc.htm
** margin of error calculation based on active users (population) and actual sample size (sample)

In order to reach both registered users that have a subscription, as well as casual users using the pay-as-you-go tariff, the survey was distributed in different ways: through intercept surveys at the stations, on social media, through the operators' newsletter and notifications in the app. Using a variety of different media, such as mailing lists, newsletters and social media, to distribute an online survey allows for broader exposure and can aid the minimization of bias associated with these types of surveys (Bachand-Marleau et al., 2012). Data from such a convenience sample can result in response bias as a result of self-selection, and may not represent the population. However, the insights from the results can provide a stepping stone for further research and be linked with existing findings in the same field of study (Bryman, 2016), for example in comparison with the results from the other case study cities, and the results of similar BSS user surveys.

The survey dissemination

During a 2 to 3-week fieldwork period in each of the case study cities (in Limassol in May 2019, Las Palmas de Gran Canaria in July 2019, Malta in September 2019), BSS users were approached in person at the selected BSS stations, introduced to the research, and asked to fill in the survey on-site by using a tablet to access the web survey, or at a later stage by following a web link (www.survey.bike). The intercept surveys were done at different times and days (peak/off-peak hours, and week/weekend days), to ensure representation of different types of users. Reflective wristbands, a cycling gadget to increase visibility on the road, printed with the link to the web survey (see Figure 4.3), were left on parked bicycles at different BSS stations across the cities, to address a wider range of users. They were also handed out as a token of thanks to those who filled in the survey, and to users who indicated they preferred to fill in the intercept survey at a later point in time, so they had the details to fill in the survey in hand. Furthermore, posters were hung up at the BSS stations and small flyers were attached to the bicycles to alert BSS users at the stations to the survey (see Figure 4.4).

Figure 4.3: Reflective wristband with link to the BSS user survey

Figure 4.4: Posters and flyers at BSS stations with link to the BSS user survey

The intercept survey approach was complemented with additional means to reach out to BSS users to take part in the survey online. In the case study cities, in discussion and collaboration with the BSS operators, different approaches were used to share the survey online with their users (see *Annex D – Survey data collection*):

- Limassol: The survey was shared on social media, including as a paid advert, and was also shared as a news item on the website and on the app.
- Las Palmas de Gran Canaria: The survey was shared on social media and with all registered users via a dedicated e-mail.
- Malta: The survey was shared on social media and in the newsletter.

As an incentive for participation, respondents were offered a reward for completing the survey: a 120-minute free ride in Limassol, a gift pack from the Sítycleta brand in Las Palmas de Gran Canaria, and a 30-minute free ride in Malta.

To prepare the BSS survey data for analysis, survey responses were imported from Google Forms into Microsoft Excel and were checked and cleaned. In suspected cases of double-entries, all answers to the questions were compared and identical copies were removed. The question about nationality was open-ended, so entries were corrected to ensure each nationality was written in the same way (e.g. from 'Spain' and '*España*' to 'Spanish'). Since all questions in the survey were marked as mandatory in the online survey form, there were no issues related to missing or incomplete responses. Nominal and ordinal data was numerically coded for further statistical analysis and modeling in R, an open-source software for statistical computing and graphics. Coding of nominal data, such as gender, was done by assigning a (1) to male and a (2) to female, whereas coding of ordinal data followed the measurement scale, e.g. for a Likert scale: completely agree (5), slightly agree (4), neither agree nor disagree (3), slightly disagree (2) and completely disagree (1) (Bryman, 2016; Burt & Barber, 1996). The codes used to translate from text-based survey responses to numerical codes are listed in *Annex E – Survey numerical codes*.

4.2.3 Longitudinal BSS trip data

To analyse and classify BSS usage, trip and station data were used in this study. Third generation dock-based BSS, in Limassol, Las Palmas de Gran Canaria and Malta, produce different forms of data (Zhang et al., 2016): trip, or flow data (time varying origin-destination matrices); point, or stock, data (station locations and statuses); and in certain cases, routing data (GPS routes). As GPS data was not available for the BSS trips in Limassol, Las Palmas de Gran Canaria or Malta, it was not considered. Trip data of the three BSS was obtained from the operators, *Nextbike Cyprus*, SAGULPA (*Sítycleta*) and *Nextbike Malta*, after negotiating and signing a data sharing agreement. Station location data was extracted from the BSS operators' websites[1].

The trip data describes the bicycle trips, from a station origin (O) to a station destination (D), including the location data of the stations, the date and time when the bicycle was rented and returned, the bicycle number and an anonymised user ID. The datasets used for the analysis in this research cover a one-year period, from 1 April 2018 until 31 March 2019, for the Limassol and Malta datasets. The dataset from Las Palmas de Gran Canaria starts on 8 April 2018, the day the BSS was inaugurated.

[1] All three BSS are operated by Nextbike or using Nextbike bicycles and software. Station locations were extracted from: https://nextbike.net/maps/nextbike-live.xml

To prepare the trip data for analysis, entries with a missing origin or destination station, as well as those pertaining to a temporary station or to a station outside of the city were removed. Any trips with a duration under 2 minutes were removed, as the literature identifies these as likely errors or malfunctioning of the bicycle (Fishman et al., 2014), as well as trips with a duration of longer than 500 minutes (Bordagaray et al., 2016). Data cleaning resulted in the removal of 12.3% of the initial 19,991 trips in the Limassol dataset, with 17,532 trips remaining. In Las Palmas de Gran Canaria, 7.8% of the initial 176,731 trips were removed in the data cleaning process, leaving 162,871 trips. Data cleaning saw the removal of 10.7% of the initial 41,763 trips in the Malta dataset, with 37,306 trips remaining.

A second year of data was obtained for the BSS in Las Palmas de Gran Canaria to be able to study the influence of the creation of new cycling infrastructure on BSS use. The second year period covered 1 April 2019 until 31 March 2020. In the initial dataset, there were 232,537 trips, an increase compared to the first year. After data cleaning, following the same procedure as described above, 8.0% of the trips were removed, leaving a total of 213,941 in the second year dataset.

4.2.4 Spatio-temporal datasets

Land use, socio-economic, network and temporal variables that may influence BSS use were identified through the literature review. Physical environment factors with a spatial character that can potentially have an influence on BSS use are hilliness, in terms of elevation differences between stations (Faghih-Imani et al., 2017; Mateo-Babiano et al., 2016; Médard de Chardon et al., 2017), the presence of cycling infrastructure (Buck & Buehler, 2012; Mateo-Babiano et al., 2016; Rixey, 2013), land use types, including their density, distance and diversity, and the location of retail shops, restaurants and other Points-of-Interest (POI), water bodies and trails, and public transport infrastructure (Faghih-Imani et al., 2014; Hampshire & Marla, 2012; Wang et al., 2016; Zaltz Austwick et al., 2013). Further factors that showed a significant correlation with the use of shared bicycles in specific studies are socio-economic variables such as age (Wang et al., 2016), population density (Buck & Buehler, 2012) and income (Rixey, 2013), network variables such as distance to the city centre / business district and proximity to other BSS stations (Wang et al., 2016), and temporal variables such as weather (Borgnat et al., 2011; Corcoran et al., 2014; Faghih-Imani & Eluru, 2016a; Faghih-Imani & Eluru, 2016b; Gebhart & Noland, 2014). Assessment of the influence of POI and tourism destinations within a buffer zone around BSS stations, e.g. in Barcelona and Seville (Faghih-Imani et al., 2017), Melbourne (Jain et al., 2018) and Santander (Bordagaray et al., 2016), showed that many POI and a high land use mix positively influence BSS use. However, the direct influence of tourism numbers has not been evaluated in BSS regression models before. Because of the touristic nature of the case study cities, the influence of seasonal tourism, was included in the temporal regression analysis, by including the monthly total of visiting tourists.

The spatial dataset used for analysis contained variables for the three case study cities: Limassol (LIM), Las Palmas de Gran Canaria (LPA) and the Valletta conurbation in Malta (MAL) (see Table 4.8). Two dependent variables were included: the total counts of trip origins (COUNTO) and trip destinations (COUNTD) respectively at a station location, to assess the influence of factors on the use of a station as a trip origin and as a trip destination, as stations may fulfil different roles, either predominantly used as an origin, or as a destination, or both.

Table 4.8: Yearly station use and land use, network and socio-economic variables (adapted from Maas et al., 2020)

Variables	Definition (unit)	Range of values		
Dependent variables		LIM	LPA	MAL
COUNTO	Aggregated yearly count of station as a trip origin (discrete number)	0 - 3,881	32 - 12,529	0 - 2,398
COUNTD	Aggregated yearly count of station as a trip destination (discrete number)	25 - 4,020	17 - 13,862	8 - 3,359
Land use variables		LIM	LPA	MAL
LU_RES	Percentage of residential land use in 300m buffer (percentage points)	0.06 - 0.83	0.00 - 0.81	0.00 - 0.82
LU_COM	Percentage of commercial/industrial land use in 300m buffer (percentage points)	0.00 - 0.73	0.00 - 0.73	0.00 - 0.70
LU_PARK	Percentage of park land use in 300m buffer (percentage points)	0.00 - 0.21	0.00 - 0.28	0.00 - 0.22
LU_TOUR	Count of hotels/hostels within 300m buffer (discrete number)	0 - 7	0 - 15	0 - 17
LU_CAFE	Count of cafes/bars/restaurants in 300m buffer (discrete number)	0 - 28	0 - 134	0 - 61
LU_SHOP	Count of clothes shops in 300m buffer (discrete number)	0 - 13	0 - 40	0 - 11
LU_UNI	Count of university faculty buildings in 300m buffer (discrete number)	0 - 9	0 - 3	0 - 14
LU_BEACH	Presence of beach/promenade in 300m buffer (dummy variable)	0 - 1	0 - 1	0 - 1
LU_BUS	Presence of bus station in 300m buffer (dummy variable)	0 - 1	0 - 1	0 - 1
LU_CYCLE	Presence of cycling path in 300m buffer (dummy variable)	0 - 1	0 - 1	0 - 1
LU_NODES	Count of nodes in transport network in 300m buffer (discrete number)	123 - 712	114 - 550	24 - 634
LU_DISTBUS	Distance from station to nearest bus stations (distance in meters)	98 - 11,588	69 - 2,540	36 - 5,859
LU_DISTCYC	Distance from station to nearest cycling path (distance in meters)	1 - 1,819	1 - 770	33 - 5,007
LU_DISTSEA	Distance from station to nearest coastline (distance in meters)	10 - 1,716	34 - 928	2 - 3,310
LU_DISTUNI	Distance from station to nearest university building (distance in meters)	31 - 11,559	109 - 4,183	22 - 13,275
LU_LENCYC	Length of cycling path in 300m buffer (length in meters)	0 - 672	0 - 1,486	0 - 639
ELEV	Elevation above sea level at station location (meters)	1.36 - 22.90	2.25 - 66.15	0.24 - 116.65
Network variables		LIM	LPA	MAL
DIST_MEAN	Station distance from centre of the BSS (distance in meters)	98 - 9,878	73 - 4,318	64 - 13,184
COUNT_STAT	Number of stations in 600m buffer around station (discrete number)	1 - 5	2 - 12	1 - 9
COUNT_STA2	Number of stations in 1,200m buffer around station (discrete number)	1 - 10	2 - 18	1 - 20
Socio-economic variables		LIM	LPA	MAL
POP_DENS	Population density at station location (inhabitants/km^2)	107 - 7,805	372 - 64,032	394 - 11,509
PERC_EDU3	Percentage of residents with tertiary education at station location (percentage points)	0.11 - 0.32	0.02 - 0.60	0.07 - 0.14
GEND_RATIO	Percentage of M in M/F quotient at station location (percentage points)	0.82 - 1.00	0.83 - 1.00	0.90 - 1.11
AGING_POP	Percentage of population over 65 years of age at station location (percentage points)	0.08 - 0.22	0.07 - 0.25	0.15 - 0.21
FORGN_POP	Percentage of foreign population at station location (percentage points)	0.12 - 0.54	0.02 - 0.22	0.02 - 0.21

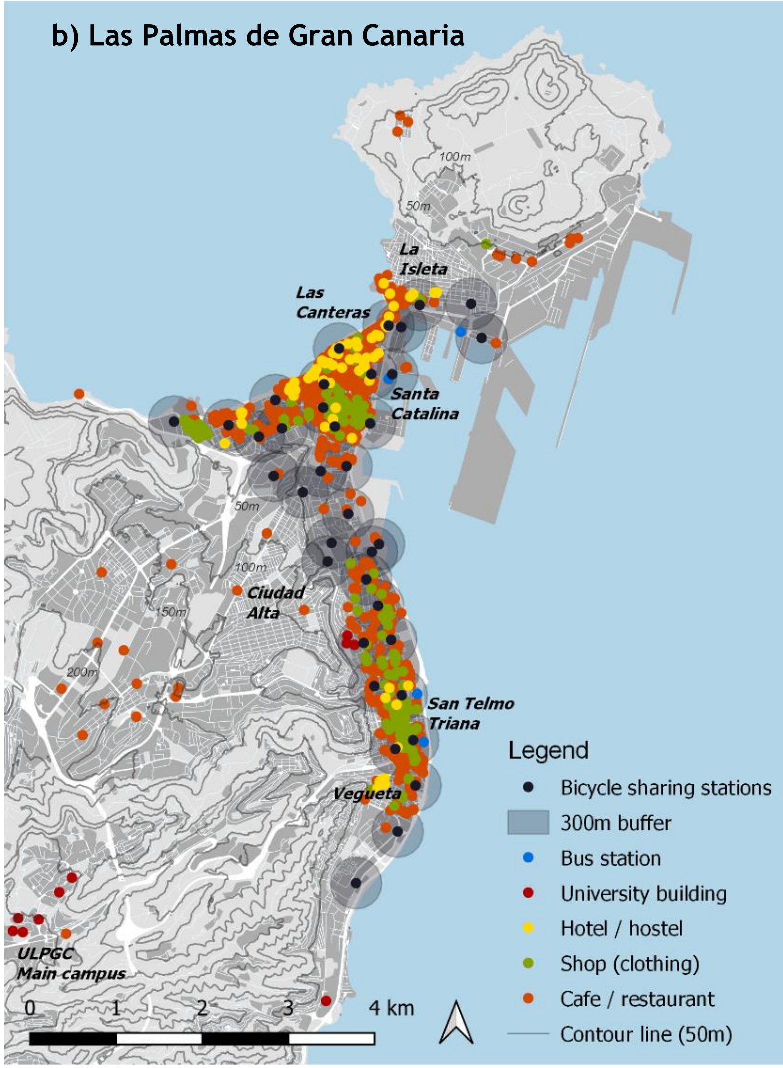
To construct the independent variables, spatial data was collected from secondary sources based on the location of the stations. Data on land use and network variables was extracted from the Copernicus Land Monitoring Service - Urban Atlas (UA) 2012 dataset (EEA, 2018b) and the OpenStreetMap (OSM) dataset (OpenStreetMap contributors, 2019).

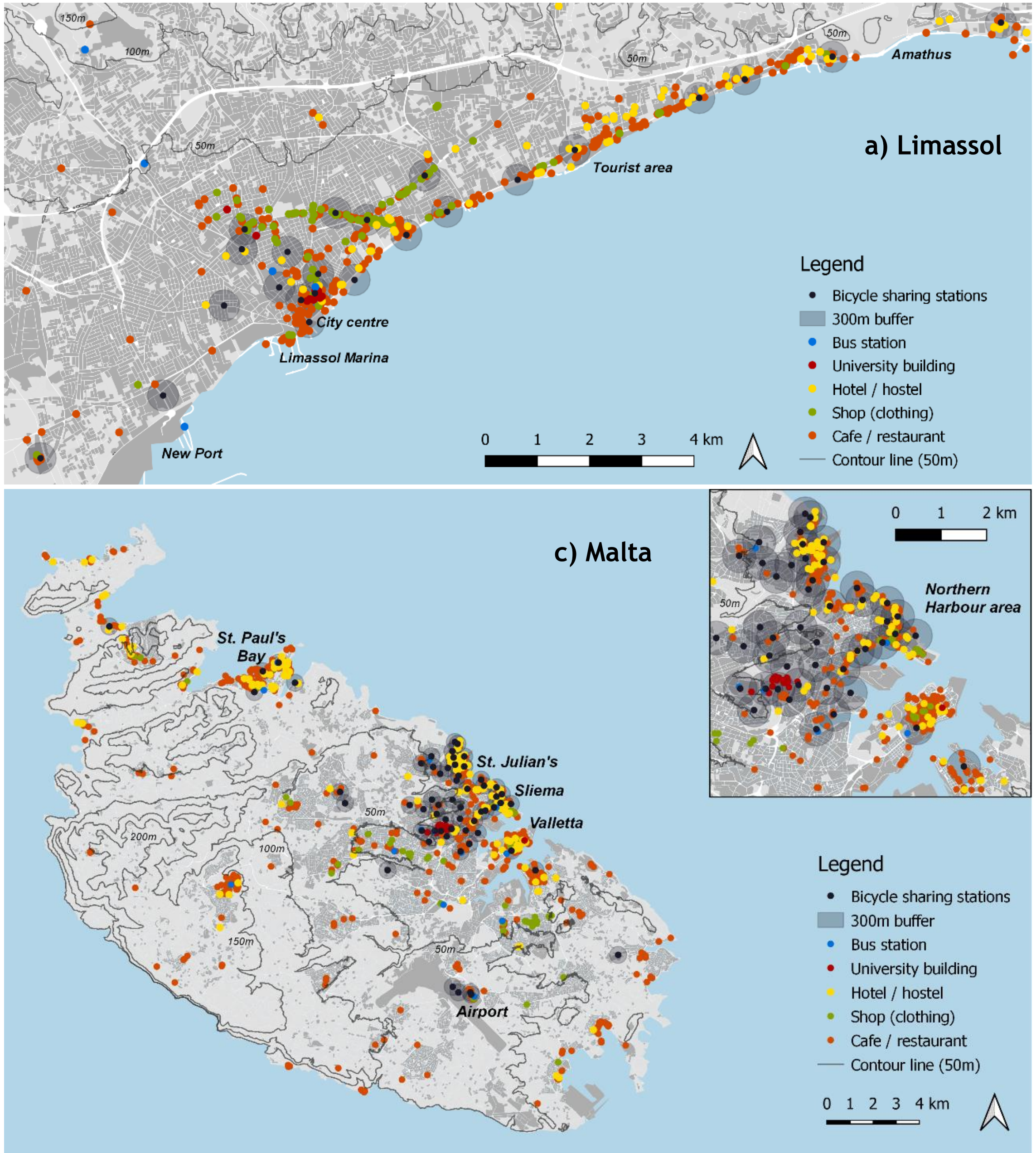
Elevation data was extracted from the Digital Terrain Models (DTM) of Cyprus (MOI, 2019), the Canary Islands (IGN, 2018) and Malta (MEPA, 2012). Socio-economic data was obtained and values calculated at neighbourhood, census tract or local council level, for Limassol from the 2011 Population Census with data on neighbourhood level (CyStat, 2012), for Las Palmas de Gran Canaria from statistical data on census tract and neighbourhood level (Ayuntamiento de Las Palmas de Gran Canaria, 2018; INE, 2011; INE, 2016), and for the Valletta conurbation in Malta from the 2011 Population Census and the 2014 Demographic Review at local council level (NSO, 2014; NSO, 2016). Other variables were considered, for example the average age of the population of the neighbourhood, the availability of parking spaces, as well as accident data, but these were not included as no reliable data sources were found to quantify them accurately and consistently between the case study cities.

QGIS, the open source Geographic Information System (GIS) mapping software, was used to calculate the values for the spatial variables. The value of a variable was determined based on the specific location of a station, either by taking the value at the point location (e.g. the population density in the neighbourhood or locality, or the elevation) or by using a 300m buffer around the station locations, the most commonly used measure for a walkable distance to BSS stations (e.g. Jain et al., 2018). Based on the UA dataset, the percentage of land use (e.g. residential, commercial/industrial, park) within the station buffer was calculated by using the 'geometry' and 'intersect' tools in QGIS. The presence of recreational establishments (restaurants/cafes), hotels, university buildings, city centres, parks, cycling paths, promenades/beaches and bus stations within the buffer were obtained from the OSM dataset, using the 'QuickOSM' tool in QGIS to select the relevant variables (e.g. cafes/restaurants, hotels/hostels, clothes shops, bus station, university buildings), the number of which in the buffer was then counted using the 'count points in polygon' tool. The location of existing cycling infrastructure was extracted from relevant documents, from the SUMP document in Limassol (PTV, 2019), from the Bicycle Master Plan for Las Palmas de Gran Canaria (Estudio Manuel Calvo, 2016) and from the Malta Transport Master Plan 2025 (TM, 2016a) for Malta, as well as from the OSM dataset. The distance between the station point location and the nearest cycling path, coastline, bus station and university building was calculated using the 'distance to nearest hub' tool in QGIS. The road network was extracted from the OSM dataset. The number of nodes in the road network (as a measure of network density) within the buffer around the stations was calculated, using the 'count points in polygon' tool. Elevation data was sampled at the point locations of BSS stations using the 'raster values to points' tool in the SAGA toolbox in QGIS. The land use types and cycling infrastructure were presented in *Chapter 1*, in Figure 1.1. The other land use variables included, the POI and elevation, are presented in Figure 4.5.

Network variables were included to control for the influence of the system design and interaction. The distance between each station location and the centre of the BSS was computed, as well as the number of stations within a 600m and 1,200m buffer around each station was calculated (Rixey, 2013). Socio-economic variables, such as population density, the percentage of population with a tertiary education level, the gender quotient, and the percentage of the population over 65 years, were obtained by intersecting the point location of the station with the datasets containing these socio-economic variables at the census tract, neighbourhood or locality level.

Figure 4.5: Points-of-Interest, elevation, BSS stations and 300m buffers in: a) Limassol, b) Las Palmas de Gran Canaria and c) Malta (Maas et al., 2021a)





The temporal variation of BSS use is presented for the three cities in Figure 4.6. The temporal analysis assesses the influence of temporal variables – in addition to the spatial variables discussed above – on a monthly level. The included variables are presented in Table 4.9. The dependent variables COUNTO and COUNTD used in this analysis were aggregated on a monthly basis, instead of annually. To incorporate the effect of any system expansion, the BSS operators were asked to indicate if and where stations were added during the one-year period covered by the datasets. In Limassol, there was no change in the number or location of the stations. In Las Palmas de Gran Canaria, one station was added in May 2018, one in September 2019, one in October 2018, and one in February 2019. In Malta, two stations were added in October 2018. Monthly values for these new stations were added to the dataset from the month of their installation onwards.

Data on tourist arrivals and weather were included as temporal variables. The temporal variables were collected either on a monthly basis (visitor numbers) or averaged (temperature) or aggregated (rainfall) over the period of a month. The datasets cover the period from 1 April 2018 until 31 March 2019. The months are abbreviated as follows: 1804 – April 2018, 1805 – May 2018, […], 1903 – March 2019. Tourism data was collected from the Cyprus national statistical service (CyStat, 2019b) for Limassol, from the statistical institute for the Canary Islands (ISTAC, 2020) for Las Palmas de Gran Canaria, and from the National Statistics Office (NSO, 2019) of Malta. Since there was no data available specifically for the number of tourists staying in or visiting Limassol, monthly figures of tourist arrivals in the Republic of Cyprus (TOT_TOUR) were used as a proxy for the number of tourists visiting Limassol (CyStat, 2019b). Weather variables were extracted from reports of the relevant meteorological institute, to collect values of average monthly maximum temperature (AVG_MAXC) and total monthly precipitation (TOT_RAIN). Weather variables for Limassol were extracted from reports of the Department of Meteorology for the weather station at Limassol New Port (MOA, 2019), from the Meteorological Office at the Las Palmas de Gran Canaria airport (AEMET, 2019) and from the Met Office for Malta (Met Office, 2019).

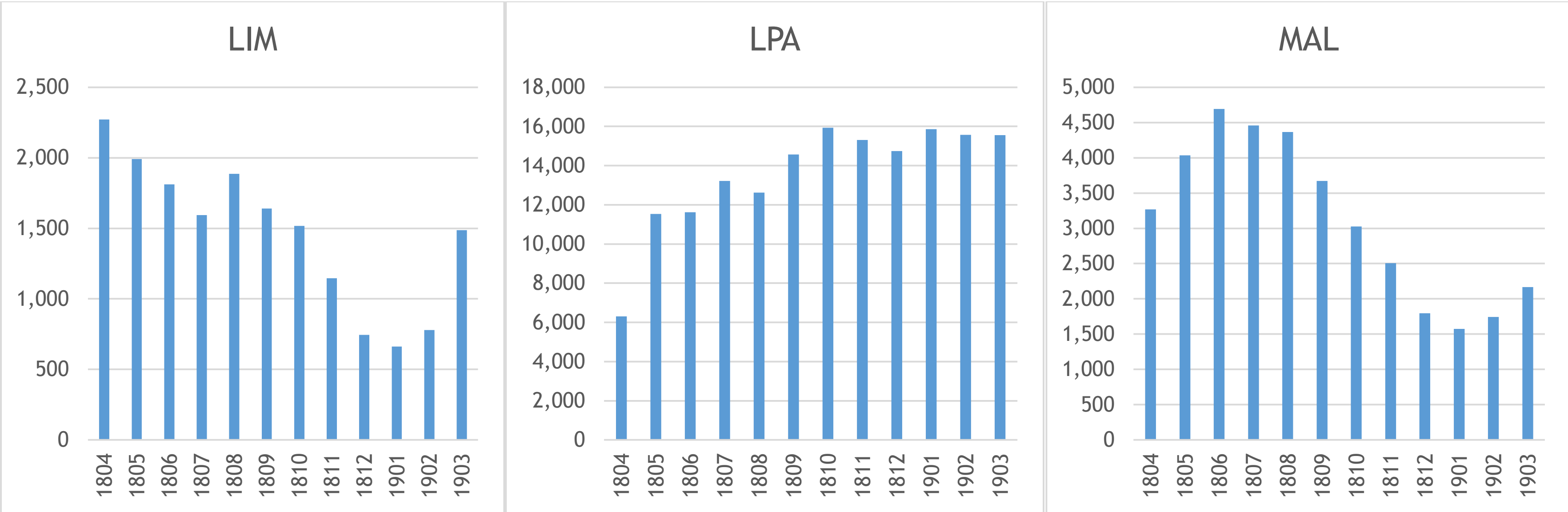


Figure 4.6: Monthly variation in BSS use in Limassol (LIM), Las Palmas de Gran Canaria (LPA) and Malta (MAL)

Table 4.9: Monthly station use and temporal variables

Variables	Definition (unit)	City	1804	1805	1806	1807	1808	1809	1810	1811	1812	1901	1902	1903
			Range of monthly values											
Dependent variables														
COUNTO	Aggregated monthly count of station as a trip origin (discrete number)	LIM	0-475	0-515	0-415	0-324	0-405	0-387	0-330	0-250	0-170	0-143	0-168	0-323
		LPA	0-425	0-895	0-830	0-1,015	0-1,013	0-1,216	0-1,187	0-1,229	0-1,228	0-1,199	6-1,318	26-995
		MAL	0-237	0-270	0-309	0-273	0-268	0-234	0-208	0-184	0-107	0-117	0-122	0-138
COUNTD	Aggregated monthly count of station as a trip destination (discrete number)	LIM	2-523	1-529	1-393	1-337	0-380	0-383	0-320	0-254	0-162	0-152	0-186	0-401
		LPA	0-428	0-944	0-934	0-1,106	0-1,212	0-1,352	0-1,391	0-1,349	0-1,343	0-1,288	3-1,351	14-1,165
		MAL	0-376	0-394	0-481	0-387	0-430	0-317	0-303	0-209	0-168	0-142	0-162	0-214
Variables	**Definition (unit)**		Monthly values											
Temporal variables		**City**	**1804**	**1805**	**1806**	**1807**	**1808**	**1809**	**1810**	**1811**	**1812**	**1901**	**1902**	**1903**
AVG_MAXC	Average monthly maximum temperature (˚C)	LIM	25.2	29.0	30.8	33.1	33.1	32.4	26.5	24.4	19.9	17.4	18.5	19.8
		LPA	22.6	23.6	25.3	26.9	27.5	27.2	26.2	24.2	22.2	20.8	21.2	22.3
		MAL	19.9	24.5	29.0	31.7	32.1	28.3	24.8	20.7	17.2	15.7	15.5	17.2
TOT_RAIN	Total monthly precipitation (mm)	LIM	1	0	9	0	0	0	24	29	189	181	128	77
		LPA	6	1	0	0	0	9	16	22	31	25	24	12
		MAL	26	9	6	5	9	68	76	90	90	89	83	41
TOT_TOUR	Total monthly tourist arrivals at destination *	LIM	314,143	450,495	511,073	539,626	534,847	520,138	433,617	158,685	106,563	81,970	105,571	169,934
		LPA	10,638	8,163	6,103	7,092	8,244	8,363	11,137	13,921	12,425	11,480	13,915	13,626
		MAL	234,488	262,205	265,823	290,041	317,490	279,010	270,702	177,000	122,759	127,723	125,198	172,971

Note: * data not available for Limassol, only for the Republic of Cyprus as a whole

4.3 Data analysis methodology

The data analysis tools and methodologies used in this research to answer the research questions posited in *Section 4.1.4* are presented here:

- The descriptive framework used to organise information obtained from secondary sources and the interviews, to address *research questions 1* and *2*, in *Section 4.3.1*;
- The descriptive statistics used to describe BSS use in the case study cities, based on the BSS user survey results and the longitudinal BSS trip data, to address *research question 3*, in *Section 4.3.2*;
- The correlation and regression analysis used to analyse the influence of individual and social environment factors on BSS use, using BSS survey results, to address *research question 4*, in *Section 4.3.3;*
- The spatio-temporal regression models constructed to analyse the influence of physical environmental factors on BSS use, using longitudinal BSS trip data and spatio-temporal datasets; to address *research question 5,* in *Section 4.3.4*;
- The comparative analysis of the results of the descriptive statistics and regression models across the case study cities, and a synthesis and discussion of the results, to address *research questions 6* and *7,* in Section *4.3.5*.

4.3.1 Descriptive framework

Organizing a case study according to a descriptive framework is a general analytical strategy used in case study research, in which the findings are organised according to topics relevant to describing the case study (Yin, 2014). In this research, relevant topics to structure the case studies were identified through the literature review and theoretical framework: 1) the spatial context, 2) the socio-cultural context, 3) the policy and legislative framework, and 4) the influence and interest of actors and stakeholders. National and local policies, contextual factors and cultural traditions, norms and attitudes are important for explaining the success (or lack thereof) of cycling promotion in different cities (Lanzendorf & Busch-Geertsema, 2014). *Research questions 1 (RQ1)* and *2 (RQ2)* address the spatial and socio-cultural contextual factors present in the case study cities, as well as policies and stakeholders relevant in the promotion of cycling. The results are presented in *Chapter 5*.

In their multiple-case study of cycling policies in four German cities, Lanzendorf & Busch-Geertsema (2014) "gathered and analysed documents relating to each city's cycling policy" and "searched additional, mostly unpublished information and documents both from practitioners and researchers". A similar approach was adopted in this research for the descriptive framework. In order to understand the spatial and socio-cultural context, as well as the policies and entities that influence cycling policies in the three case study cities, information in reviewed secondary sources and the semi-structured interviews was collated and analysed. The relevant identified secondary sources (which were listed in Table 4.4) were searched specifically to identify passages related to bicycle sharing, cycling, as well as references to more generic active transport and sustainable mobility policies. To describe the legislative and regulatory framework, relevant passages from policy and legislative documents were presented in a table format, following the example of Beroud & Anaya (2012). The information provided through the interviews was used to gain a deeper understanding of the history and current status of cycling and bicycle sharing systems, within the context of the case study cities, to identify local actors and stakeholders, and to identify further relevant policies and reports. Taking a wider perspective on the case studies being examined also assisted in identifying potential rival explanations for the phenomenon under study, e.g. where the observed results are influenced by another intervention (fully or partially), by a force larger than the intervention, or by broader social trends (Yin, 2014).

4.3.2 Descriptive statistics

In order to address *research question 3 (RQ3)*, understanding the “who”, “why”, “when”, “where” and “how much” of BSS use, the BSS user survey results and the BSS trip data were explored through descriptive statistics. Numerical and graphic techniques are used to describe and visualise the data, and understand the basic characteristics of the datasets. The results are presented in *Chapter 6*.

Descriptive statistics of the survey results are used to gain an understanding of the “who” and the “why” of BSS use. Other studies analysing BSS use have used descriptive statistics to characterise system users and their use of shared bicycles, e.g. in Dublin (Murphy & Usher, 2015), in Seville (Castillo-Manzano et al., 2015), in Hangzhou (Shaheen et al., 2011), and Brisbane and Melbourne (Fishman et al., 2014). The frequency distribution of nominal and ordinal variables such as gender, education, and income were defined to provide insight in the main characteristics that describe the BSS users. Age, the only continuous variable, was defined through the range (the difference between the lowest and highest observation) and the mean (the average of the observations) as well as through percentages after grouping the ages into classes (e.g. ages 18-24; 25-34; 35-44; etc.) (Burt & Barber, 1996). Nominal variables were visualised as bar charts. Results for ordinal variables based on a Likert scale were described through their frequency distribution, and visualised using the ‘plot.likert function’ in R, to create diverging stacked bar charts (Robbins & Heiberger, 2011). The outputs of Likert scale questions were also presented through the mean response and standard deviation (SD).

Descriptive statistics of the revealed usage of the BSS are used to gain a basic understanding of the BSS trip patterns and dynamics, in terms of travel time, speed, direction and distance (Mateo-Babiano et al., 2016). Analysis of the BSS trip data gives insight into “when”, “where” and “how much” the bicycle sharing system is used. Firstly, the location and number of stations, bicycles and unique users are used to characterise the BSS (Médard de Chardon et al., 2017). In order to understand the timing of BSS use, BSS use was characterised through measures of trip duration, using histograms to visualise the frequency distribution, as well as through time series, showing the sequence of observations at equal time intervals, e.g. per hour and per month (Burt & Barber, 1996). BSS trips were aggregated hourly and plotted over the course of a day to show the distribution of daily use (Jain et al., 2018), including typical weekday and weekend temporal usage patterns (Bordagaray et al., 2016; O’Brien et al., 2014; Wood et al., 2011). Trips were also plotted as monthly time series to understand temporal and seasonal variation, including potential influence of increased visitors as a result of seasonal tourism (Bordagaray et al., 2016; Jain et al., 2018; Wood et al., 2011). The location of the stations was used to compute the population coverage of the system, based on a 300m and 400m buffer around the stations, two widely used metrics to determine the walkable distance to a BSS station (Clark & Curl, 2016; Jain et al., 2018). The frequency of trips between different Origin-Destination (OD) pairs was visualised in matrices of origin-destination flow volumes (Guo et al., 2006; Wood et al., 2011), showing the total trips from all different origin stations to all different destination stations, with the diagonal indicating circular trips with the same origin and destination station (Zaltz Austwick et al., 2013). Dominant OD flows were visualised using lines between the origin and destination station, using varying line thickness to indicate the relative weight of the flow, based on Euclidian distance between stations (Wood et al., 2011). The top flows between origin (O) and destination (D) were identified, so as to find out what characterises these stations in terms of land use, socio-economic and network variables. To understand how much BSS use there is, the number of trips per day per bicycle (TDB), a widely used metric to classify system use overall (Médard de Chardon et al., 2017), was computed as a yearly and monthly value for each BSS.

4.3.3 Correlation and regression analysis

As highlighted in the literature review in *Chapter 2* and the theoretical framework in *Chapter 3*, socio-ecological models conceptualising travel behaviour identify a number of factors (independent variables) that can influence travel behaviour (the dependent variable). The dependent variable being studied in this research, BSS use, can be influenced by individual factors such as age, income and attitudes, by social environment factors, such as social subjective and descriptive norms, and by physical environment factors. In *research question 4 (RQ4)*, the influence of individual and social environment factors on BSS use are analysed. The results are presented in *Chapter 7*.

As the survey is a self-reported survey, measurement of the physical environment is limited to *perceived* environment factors, such as the perception of the influence of safe cycling infrastructure, the perceived effect of distance, weather and hilliness, and attitudes towards cycling in different road environments. These perceptions were included in the survey as questions about perceived behavioural control (self-efficacy) and as perceived barriers and facilitators (discouraging and encouraging factors). Not all variables measured through the survey questions were considered in the correlation and regression models, as some of the variables, such as frequency of BSS use for different trip purposes and trip duration, are not variables that can be used to explain travel behaviour, but are different measures of the same behaviour. These variables were used as input for the descriptive statistics to describe BSS use, which are presented in *Chapter 6*. The dependent and independent variables measured through the survey questions that were used in the correlation and regression analysis are presented in Table 4.10.

Correlation analysis

To find out which independent variables showed a significant association with the dependent variable 'Use_bikeshare', Chi-Square tests (for nominal/ordinal variables) and a Kruskal-Wallis test (for the continuous variable 'age') were used to assess the associations between the dependent and independent variables. The Chi-Square test assesses the relationship between two qualitative variables, analysing if there is a significant difference between the expected and observed frequencies in the categories of the variables. The null hypothesis is that there is no difference; the alternative hypothesis that there is a significant difference. Where the *p*-value of the Chi-Squared test is <0.05 the null hypothesis is rejected and a significant association is present. The Kruskal-Wallis test is a method to test the equality of population mean ranks between more than 2 groups. The null hypothesis is that the median is equal across the groups; the alternative hypothesis is that there is a significant difference. If $p<0.05$, the null hypothesis is rejected. Where an association was confirmed for binary and nominal independent variables, the relationship between the dependent and independent variables was explored through boxplots and comparison of the median. To understand the strength and direction of the relationship between the dependent variable and ordinal independent variables, Spearman's correlation test was used to further explore the relationship. This test quantifies the relationship between two quantitative variables, with values between -1 and 1, with the former showing a negative correlation and the latter a positive correlation. Near 0 values mean there is little to no correlation between the two variables (Wheeler et al., 2013).

Table 4.10: Variables considered in correlation and regression analysis

Dependent variable		Definition (scale)
Use_bikeshare		Frequency of use of BSS (ordinal)
Independent variables		**Definition (scale)**
Demographic and socio-economic characteristics	Gender	Gender (nominal)
	Age	Age (discrete)
	Native	Native or non-native to country of BSS (binary)
	Education	Highest level of education (nominal)
	Occupation	Main occupation (nominal)
	Household	Household structure (nominal)
	Income	Gross annual income (ordinal)
	Residency	Resident or visitor of city of BSS (nominal)
	License	In possession of a driving license (binary)
Independent variables		**Definition (scale)**
Mobility practices and travel habits	Vehicle ownership (Own_car / Own_motor / Own_bike)	Private car / motorcycle / bicycle ownership (binary)
	Frequency of use of transport modes (Use_walking / Use_bicycle / Use_motor / Use_PT / Use_cardriver / Use_carpass / Use_taxi)	Frequency of use of walking (more than 5 minutes) / private bicycle / motorcycle / public transport / private car (as a driver) / private car (as a passenger) / taxi (ordinal)
	Helmet	Helmet use (nominal)
	Distance to BSS (Dist_home / Dist_dest)	Walking distance from residence / frequent destination to nearest station (ordinal)
	Trip_before	Modal shift from other transport mode (nominal)
	Environment	Road environment in which users most frequently cycle (nominal)
	Multimodal trips (Multimod_no / Multimod_walk / Multimod_PT / Multimod_car	Multimodal transport combination, BSS with: no other mode / with walking / with public transport / with car (binary)
Attitudes and perceptions	Motivations for BSS use (Mot_money / Mot_conv / Mot_time / Mot_health / Mot_env / Mot_fun)	Money-saving / convenience / time-saving / health benefits / environmentally friendly / having fun as a motivating factor (ordinal)
	Satisfaction with BSS service (Sat_regist / Sat_price / Sat_loc / Sat_avail / Sat_rent / Sat_comf / Sat_brand	Satisfaction with: sign-up/registration process / price / location of stations / availability of bicycles / renting and returning a bicycle / comfort of the bicycles / branding of the BSS (ordinal)

Independent variables (*continued*)		Definition (scale)
Attitudes and perceptions (*continued*)	Electric	Preference for standard or electric bicycle (nominal)
	Opinion on statements: attitudes, norms, perceptions (Like_cycling / Conv_cycling / Need_car / Cycle_rain / Cycle_sun / Appear / Uphill / Friends / Busy_road / Road_users / Cycle_accept)	Attitude towards: liking cycling as a mode of transport / convenience of cycling as a mode of transport / the need for using a car for daily tasks / cycling when it is rainy and windy / cycling when it is hot and sunny / worrying about appearance after cycling / cycling uphill is difficult / support of cycling behaviour by friends and family / busy roads being barriers / other road users respecting cyclists / cycling being an accepted mode of transport in the city (ordinal)
	Skill	Cycling skill level (ordinal)
	Perceptions of cycling safety (Safe_path / Safe_lane / Safe_road / Safe_pave)	Perceived safety on: a separated bicycle path / a bicycle lane on the road / the road (without cycling infrastructure / the pavement/promenade (pedestrian space) (ordinal)
	Encouraging factors: attitudes, norms, perceptions (Enc_paths / Enc_speed / Enc_aware / Enc_route / Enc_people / Enc_friends / Enc_home / Enc_work / Enc_PT / Enc_carprice	'More cycling paths' / 'Roads with lower vehicle speeds' / 'Greater cycling safety awareness' / 'Information about safe and direct routes' / 'Seeing more people cycling' / 'Friends/family members who cycle' / 'Stations closer to home' / 'Stations closer to place of work/education' / 'Better integration with public transport' / 'Making driving more expensive/difficult' as an encouraging factor (ordinal)
	Discouraging factors: attitudes, norms, perceptions (Disc_carconv / Disc_PTconv / Disc_safe / Disc_cost / Disc_people / Disc_friends / Disc_home / Disc_work / Disc_PT)	'Driving a car is more convenient' / 'Public transport is more convenient' / 'Concerned for safety in traffic' / 'Too costly' / 'Not seeing many other cyclists' / 'No friends/family members who cycle' / 'Stations not close enough to home' / 'Stations not close enough to place of work/education' / 'Lack of integration with public transport' as a discouraging factor (ordinal)

Binary logistic regression analysis

To study the influence of multiple independent variables on a dependent variable, regression analysis techniques are used. Regression analysis includes techniques to explain variation in a dependent variable, BSS use in this case, by several independent variables (Burt & Barber, 1996). As pointed out by Buck et al. (2013), using regression analysis to control for the influence of multiple variables, instead of relying on a bivariate comparison of independent variables, can help clarify the interrelation between different socio-demographic characteristics, such as the correlation between age, car ownership and income. Bachand-Marleau et al. (2012) used a binary logistic regression model to analyse the influence of independent variables on the likelihood of using BSS, and found socio-economic characteristics, transport habits, and spatial characteristics (such as proximity of BSS stations to home and work locations) to be significant explanatory variables. Martin & Shaheen (2014) applied an ordinal multiple regression model to their dataset of modal shift as a result of BSS use and found age, gender, income, and population density, amongst others, to be independent variables with a significant effect on the dependent variable.

In this research, binary logistic regression (BLR) models were employed to understand the influence of a combination of independent variables on a binary dependent variable: the frequency of BSS use. In binary logistic regression, a model is determined for a binary dependent variable, a dichotomous variable with only two outcomes (1 or 0, or in this case, 'frequent' or 'infrequent'). The general form of a binary logistic regression equation is

$$Logit(P) = ln[P/(1-P)] = b_0 + b_1X_1 + b_2X_2 + b_nX_n$$

The logit(P) represents the dependent variable, where the odds ratio of 1 vs 0 for P at any value for X is P/(1-P). The constant, or intercept, is represented by b_0, while X_1 and X_2 represent independent variables (up to *n* independent variables), and b_1 and b_2 are the coefficients (Bryman & Cramer, 1994). The coefficients indicate the extent and direction of the influence, i.e. the relative contribution of each independent variable, and whether this is a positive or a negative influence (Burt & Barber, 1996).

In order to construct the binary variable 'frequency of BSS use', the variable was re-coded from an ordinal five-point Likert scale into two classes: frequent and infrequent users. This approach has been utilised in other BSS research, to create models that can explain and predict potential BSS use in a more straightforward manner than multiple regression models, with only two instead of multiple separate classes for the dependent variable (Bakogiannis et al., 2019; Barbour et al., 2019). Barbour et al. (2019) divided shared bicycle users into frequent and infrequent users depending on whether they used the BSS more or less often than once a month, whereas Bakogiannis et al. (2019) used the 'at least weekly' use as the cut-off point. In this analysis, the dependent variable 'frequency of BSS use' (an ordinal five-point Likert scale variable with possible answers ranging from 'never' to 'daily') was re-coded to a binary variable, including 'frequent' users, who use the BSS at least once every two weeks, and 'infrequent' users, who use the BSS less often than that.

The datasets were analysed using R and SPSS. In order to define the binary regression models, several steps were taken to determine which variables should be included in the model for each dataset (pertaining to each of the three case study cities):

- The association between the binary dependent variable and the independent variables was assessed through Chi-Square tests (for nominal/ordinal variables) and a Kruskal-Wallis test (for the continuous variable 'age').
- Independent variables that showed association with the dependent variable were then assessed for multicollinearity. The commonly used value of +/- 0.7 (Dormann et al., 2013) was adopted to determine variables that exhibit multicollinearity. In the case where multicollinearity between independent variables was present, the independent variable with the strongest association with the dependent variable was retained, while the other independent variable(s) was removed from the dataset. The inclusion of multicollinear variables is avoided as it can result in over-fitted models, which are too specific for the dataset and not useful for predictions using other datasets.
- The datasets were split in a training (80%) and testing dataset (20%), maintaining the same balance between binary classes. Since the number of observations in the Malta dataset was quite small it was decided not to split the data into the training and testing sets.

- The balance of the dependent variable was assessed for each training dataset, aiming for a share of 45-55% for each binary class. Reasonably balanced datasets are required for classification techniques to work adequately. To remedy imbalanced data, synthetic data was created for the training datasets using the Python tool SMOTE-NC (Synthetic Minority Oversampling Technique), which creates new synthetic examples for the minority class, based on the existing examples from the minority class.
- The best model fit was then determined, using forward stepwise variable selection, ensuring the *p*-value of independent variables in the model showed significance (<0.05) and limiting the size of the standard errors. Forward stepwise variable selection was chosen because of the large number of independent variables in the dataset. Model fit was confirmed through Goodness-of-Fit tests and a confusion matrix.
- To determine the accuracy of the model, the model developed using the training dataset was then fitted on the testing dataset, to see how well it performed. The accuracy of the model prediction was assessed from cross-tabulation of the observed versus predicted values.
- The outputs of the Binary Logistic Regression Models were then compared to another modeling technique, neural networks, to determine the model with the best predictive power and interpretation. Neural networks are a series of algorithms that mimic the way the human brain works, using complex prediction functions to solve classification problems. The neural network is organised as a number of nodes in different layers. Each node in the input layer represents one of the independent variables. The single node in the output layer represents the predicted classification. In between the input and output layer there are one or more hidden layers of nodes, which are calculated based on weighted connections of combinations of the input variables to explain and predict variation in the outcome (Zantalis et al., 2019).

Aggregated analysis

In order to understand which factors encourage or discourage BSS use across the board in the three case study cities, as well as potentially in similar city contexts, the datasets with the survey responses from the three cities were aggregated. However, while ideally the collected samples of survey responses perfectly mirror the population in the city, and the number of survey responses per city would reflect the real sizes of their populations, or at least represent an equal fraction of the total responses, this is rarely the case in reality. Effort was made to collect as many responses as possible per city and to reach a certain amount of responses per city following the principle of stratified sampling (as described in section 4.2.2), but the sample collected is not entirely representative of the population of BSS users in the case study cities.

To correct for potential bias in the analysis based on the unweighted aggregated dataset, as there is a larger sample from Las Palmas de Gran Canaria than from Limassol and Malta, two post-stratification weighting adjustments were applied (see Table 4.11). Post-stratification weighting refers to adding a value to each observation in a dataset to indicate how much it will count, and is used to make a sample more representative of a population (Johnson, 2008). The first weighting criterion ('Weight1') was based on the proportion of the active BSS users in the city as a percentage of the total of the three case study cities. This weight was computed by dividing the population percentage ('population %') by the actual sample percentage ('sample %'), to better reflect the proportional contribution of the city's BSS user population to the whole (the total of the three case study cities considered). The second weighting criterion ('Weight2') was based on equal representation of the three case study cities; a contribution of a third (33%) each to the total. This weight was computed by dividing the even sample percentage ('even sample %') by the actual sample percentage ('sample %') (Johnson, 2008). The weighting adjustments were applied using the 'survey' package in R (Lumley, 2020).

All the included results of associations emanating from the statistical analysis, presented in section 7.4 of *Chapter 7,* showed significant results in the unweighted dataset as well as in the two weighted datasets, unless noted otherwise. Including the two weighted datasets in the analysis ensures the presented results are robust and representative of the aggregated dataset, and not dominated by the results from one city.

Table 4.11: Weighting criteria used for weighting the survey results in the aggregated dataset

	LIM	LPA	MAL	Total
Actual population size (active BSS users)	**3,070**	**9,006**	**4,082**	**16,158**
Population %	19%	56%	25%	100%
Actual sample size	**140**	**491**	**128**	**759**
Sample %	18%	65%	17%	100%
Even sample %	33%	33%	33%	100%
Weighting of datasets	**LIM**	**LPA**	**MAL**	
Unweighted (sample %)	1	1	1	
Weight1 (population % / sample %)	1.05	0.86	1.47	
Weight2 (even sample % / sample %)	1.83	0.51	1.94	

4.3.4 Spatio-temporal regression models

Apart from individual and social environment factors, travel behaviour can be influenced by physical environment factors. In *research question 5 (RQ5)*, the influence of physical environment factors, both spatial and temporal variables, on the dependent variable BSS use is analysed. The results are presented in *Chapter 8.*

In order to understand the influence of spatial and temporal variables on the dependent variables COUNTO (use of a BSS station as origin) and COUNTD (use of a BSS station as destination), different analyses and modeling techniques were employed. The starting point was to understand the influence of the spatial variables, as these are characteristic of the station use and are stationary over time. First, a bivariate correlation analysis was performed to get an understanding of the associations between the dependent variables and individual independent variables. Thereafter, Ordinary Least Squares (OLS) models were constructed, to understand the interplay between independent variables and their collective influence on the dependent variables. Whereas spatial variables vary between stations, but not over time, the temporal variables vary over time, but not between stations. In order to understand the combined effect of the influence of spatial and temporal variables on BSS use, several approaches were used. OLS models were constructed on a monthly basis, and the varying influence of spatial independent variables was assessed based on the outputs of the monthly models. Finally, to be able to incorporate both spatial and temporal variables in one model, linear mixed models were employed. One of the assumptions for linear regression models is independence of observations. When introducing the temporal observations, this assumption is violated. Instead, linear mixed models can be used to analyse the influence of fixed effects while having multiple observations per subject, the stations in this case, and multiple observations for every time period, the twelve months in the one-year period being studied. The stepwise procedure followed in the data analysis and model development is visualised in Figure 4.7.

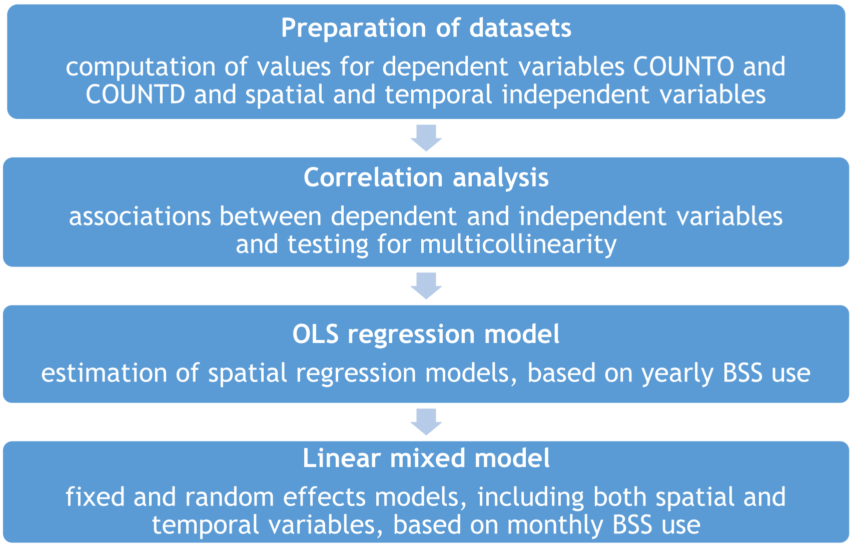


Figure 4.7: Step-by-step analytical framework for data analysis and model development (adapted from Maas et al., 2021b)

Bivariate correlation analysis

The first step to determine the influence of independent variables on dependent variables COUNTO and COUNTD was bivariate correlation analysis. Using the Pearson correlation coefficient *r*, the strength and direction of the relationship between the dependent variable and the spatial independent variables was determined. Values of *r* can range from -1 to 1, with a stronger relationship the further away from 0. Where *r* is positive, as one variable increases, the other increases as well. If *r* is negative, then as one variable increases, the other decreases. The land use, socio-economic and network variables presented in Table 4.8 and the temporal variables presented in Table 4.9 were included in the correlation analysis.

OLS models

Based on the variables identified as showing an association with the dependent variables, Ordinary Least Squares (OLS) models were constructed for the three case studies to estimate the effects of the independent variables on the BSS use and explain variation in BSS use. OLS regression models follow this general form:

$$y = \alpha + \beta_1\chi_1 + \beta_2\chi_2 + \beta_n\chi_n + \varepsilon$$

where y is the dependent variable, a is the intercept, x_1 and x_2 represent two independent variables (up to n independent variables), β_1 and β_2 are the regression coefficients, and ε is the error term, referring to a portion of variance in y that remains unexplained after accounting for the intercept and the influence of the independent variables (Bryman &

Cramer, 1994). The coefficients indicate the extent and direction of the influence, i.e. the relative contribution of each independent variable, and whether this is a positive or a negative influence (Burt & Barber, 1996).

A correlation matrix was created to examine the collinearity between independent variables – to avoid including two or more multicollinear variables in the regression model - before settling on the best model fit. A threshold of ±0.7 was assumed to indicate multicollinearity (Dormann et al., 2013). Backward Stepwise Regression Analysis (BSRA) was used to omit non-statistically significant variables, for both the COUNTO and COUNTD models. Backward stepwise variable selection was opted for to be able to consider the effects of all variables simultaneously, before reducing the model to include only the variables at the selected level of significance. Effort was made to balance maximum predictive power of the model (as measured by Adjusted R^2) with a parsimonious design, while ensuring variables follow the expected direction of influence and were statistically significant at least at the $p < 0.1$ level (or support the model to maintain significance of other variables). R-squared (R^2) provides a measure of strength of relationship between the dependent and independent variables; it quantifies the level of variance explained by the model on a scale from 0 to 1. Adjusted R^2 is adjusted to take into account the number of independent variables used in the model (Winter, 2013). The *p*-value of the overall model indicates the conditional probability of either accepting the null hypothesis (the independent variables do not have a significant effect on the dependent variable, when $p > 0.05$) or rejecting the null hypothesis (the independent variables do have a significant effect on the dependent variable, when $p < 0.05$). To confirm the assumptions for an OLS model were met, regression diagnostics were run on the fitted models, to confirm normality and homoscedasticity of the residuals, linearity in the coefficients and error term and absence of influential data points (Frost, 2019).

Linear mixed models

Multiple observations per station and per months mean that these observations are not independent from each other (as they pertain to the same station, or the same month) (Winter, 2013). To this end, linear mixed models (LMM) can be used to include both spatial and temporal factors, as demonstrated by Faghih-Imani et al. (2014) in their study of the BSS in Montréal, where they analysed the influence of temporal variation on an hourly basis, while controlling for the influence of spatial variables. In a mixed model, there is a mix of fixed effects and random effects. To account for the multiple observations per station and per month, in the linear mixed models, the station ID ('Station_Nu') and the month ('Month') were included as random effects; they were assigned a specific error term (per station, and per month) in addition to the generic error term in the model. The linear mixed models were constructed using the 'lmerTest' package in R (Kuznetsova et al., 2017).

Determining whether the model overall is significant, and therefore whether the null hypothesis is rejected or accepted, is not as straightforward in mixed models as it is for general linear models. To obtain the *p*-value of the mixed models, the constructed linear mixed model can be compared to the null-model (an intercept only model, without any independent variables included), after which the Likelihood Ratio Test results can be compared, to determine whether the constructed mixed model has superior explanatory power over the null-model (Winter, 2013).

Linear mixed models for longitudinal analysis

This research took advantage of planned changes to cycling infrastructure in Las Palmas de Gran Canaria, to study the effect of the new cycling lanes and paths on BSS use in the stations in close vicinity to the new infrastructure. A quasi-experimental design, as suggested by Handy (2005), can be used to measure changes in physical activity associated with changes in the built environment, which can range from small changes such as the installation of traffic calming devices or significant redevelopment projects. In a more recent discussion of key research themes concerning the relation of land use policies and sustainable urban mobility, van Wee & Handy (2016) concluded that “panel-based before-and-after studies into the impacts of different options for urban renewal on travel behaviour are especially scarce”, and that there is an urgent need for deeper research into the impacts of changes in the built environment on behaviour change. In the specific context of BSS use and cycling infrastructure, Mateo-Babiano et al. (2016) corroborated the need for further research into this relationship.

In the summer of 2019, nearly 10km of new cycling lanes and paths were created in Las Palmas de Gran Canaria. Using the two years of BSS trip data to create two datasets to study the before and after effect, BSS station use was aggregated over a six-month period before the implementation of new infrastructure (September 2018 – February 2019) and the same six-month period a year later (September 2019 – February 2020), following the creation of the new cycling lanes and paths. Linear mixed models were used to assess the difference between stations that were impacted by the change, and those that were not. Stations were classified as belonging to either the ‘treatment’ group (stations with new cycling infrastructure within a set buffer around the station) or ‘control’ group (stations without new cycling infrastructure in the buffer). Different sizes of buffers around the stations were tested in the analysis, to see which distance measure best captures the effect of the new cycling infrastructure. The dependent variable was the overall station use (COUNTOD): the aggregated usage of the station as an origin (COUNTO) and a destination (COUNTD). The independent variables are the factor TIME, a dummy variable indicating the ‘before’ period (six months during the baseline year 0) and the ‘after’ period (year 1) and the factor GROUP, a dummy variable indicating whether the station in question was impacted by the new cycling infrastructure or not, separating stations in the ‘treatment’ and the ‘control’ group. The analysis aids in understanding and quantifying the effect of the extension of cycling infrastructure on the use of a dock-based BSS.

4.3.5 Comparative analysis of results

In order to put the results from the three case study cities in perspective and analyse their similarities and differences, *research question 6 (RQ6)* focuses on how the BSS use and influencing factors in the case study cities compare. The identified similarities and differences enable a deeper understanding of the importance of the specific contexts in the different cities and allows for drawing lessons applicable to cities with a comparable geographical and/or socio-cultural context. Following Eisenhardt’s (1989) framework for building theory from case study research, in multiple-case studies data analysis starts with the ‘within-case’ analysis, to gain familiarity with the data and start preliminary theory generation, and is thereafter analysed ‘cross-case’, to search for patterns and see the evidence through multiple lenses. The results of the comparative analysis are presented at the end of each 'results' chapter: *Chapters 5 – 8*. The outputs of the comparative analysis are further discussed in relation to findings from the literature and translated into recommendations for BSS operators and policy makers in the discussion in *Chapter 9*.

Comparing the results from the research across the cities can aid in getting a deeper understanding of the importance of the specific planning and policy contexts in the different cities, and where possible, to draw broader conclusions generalizable to cities with a comparable spatial and/or social context (Hantrais & Mangen, 1996). Other studies have compared insights related to the uptake of cycling and BSS use across cities, e.g. the comparative analysis of cycling policies and modal share in four large German cities (Lanzendorf & Busch-Geertsema, 2014), a comparison of BSS' spatial and temporal dynamics in Washington DC and Brisbane (Ahillen et al., 2015), a comparison of BSS use in three US cities (Rixey, 2013) and a comparison of the impact of BSS use on car use based on BSS trip data across five cities in Australia, Europe and the US (Fishman et al., 2014).

The results of the policy and stakeholder analysis in *Chapter 5* provide for an understanding of the differences and similarities in the spatial and social context of the cities and their mobility system. Descriptive statistics of the BSS use, based on the survey results with BSS users and obtained from the observed trip data presented in *Chapter 6*, was used to compare the BSS use between the three case study cities. The results of the correlation and binary logistic regression analyses, found in *Chapter 7*, based on the BSS user survey results from Limassol, Las Palmas de Gran Canaria and Malta, were compared with each other through statistical tests, to determine whether there are significant similarities and differences in the factors that influence BSS use in the different cities. The results of the spatio-temporal regression models, presented in *Chapter 8*, based on the BSS trip data and external datasets for Limassol and Las Palmas de Gran Canaria, were summarised for each case study to identify the main factors influencing BSS use in each city. The comparison of the findings from the 'results' chapters was used to contribute to expand and generalise theories on what encourages and discourages BSS use in these cities and similar city contexts, to come to tangible policy recommendations for encouraging and increasing BSS use and cycling as a mode of transport.

4.4 Conclusion

In this concluding section, the research design and the data collection and analysis methodologies used in this research are summarised. Critical realism was adopted as the research paradigm. In the critical realism view, social sciences adopt the same approach to data collection and analysis as the natural sciences apply in their research. Case studies are considered to be a fitting research approach within the critical realism tradition, as the intensive nature of the case study, and the attention paid to context enhance the researcher's ability to examine and understand the generative causal mechanisms, even more so within a multiple-case study. Selection of the case studies for the multiple-case study was based on the similarities between cases: the introduction of BSS in the three Southern European island cities of Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the conurbation around Valletta (Malta). In case study research, multiple sources of evidence are combined and compared, for purposes of validation and triangulation.

This chapter presented an overview of the research aim, objectives and research questions of the study, and how these were addressed through appropriate data collection and analysis techniques. The multiple-case study follows a quantitative approach, collecting data from BSS user surveys, revealed usage from BSS trip data and external spatio-temporal datasets capturing social and physical environment factors. This was combined with qualitative data from secondary sources and interviews with stakeholders, to understand the social and spatial context in the case study cities. The data analysis tools and methodologies presented include a descriptive framework to analyse and organise the insights from the interviews and secondary sources, descriptive statistics and binary logistic regression models to analyse the BSS user survey results, spatio-temporal regression models to analyse the influence of physical environmental factors on BSS use, and the approach for the comparative analysis of the insights from the different case study cities.

The following chapters present the results from the data analysis. The spatial and social context of cycling in the case study cities is presented in *Chapter 5*. *Chapter 6* discusses the findings of the operation and use of the BSS in the case study cities. The influence of individual and social environment factors on BSS use on the one hand, and physical environment factors on the other, are found in *Chapter 7* and *Chapter 8* respectively. A comparative analysis of the results from the case study cities is included in each of the results chapters, *Chapter 5 to 8*.

5. Case studies context

This chapter introduces the context of the case study cities, by addressing research question 1 (RQ1): *What are the spatial & socio-cultural characteristics in relation to cycling and BSS use?* and research question 2 (RQ2): *Which policies and entities exist that influence cycling and BSS use?* Spatial factors and socio-cultural contextual elements related to mobility in the case study cities are presented, as well as relevant legislation, policies and stakeholders in the field of mobility and cycling. A comparative analysis of the cities' spatial and socio-cultural context and their land use, transport and mobility laws and policies is also included, addressing research question 6 (RQ6): *How do BSS use and influencing factors in the case study cities compare?* The positioning of the spatial and socio-cultural policy context in the theoretical framework guiding this research is highlighted in Figure 5.1. As outlined in *Chapter 3*, BSS use, as a form of active travel behaviour, is influenced by multiple levels of factors: from individual factors to social and physical environment factors. These factors are further shaped by the spatial and socio-cultural context of a city, the focus of this chapter, including the influence of transport and land use policies, such as zoning, development regulations, parking and transport demand management.

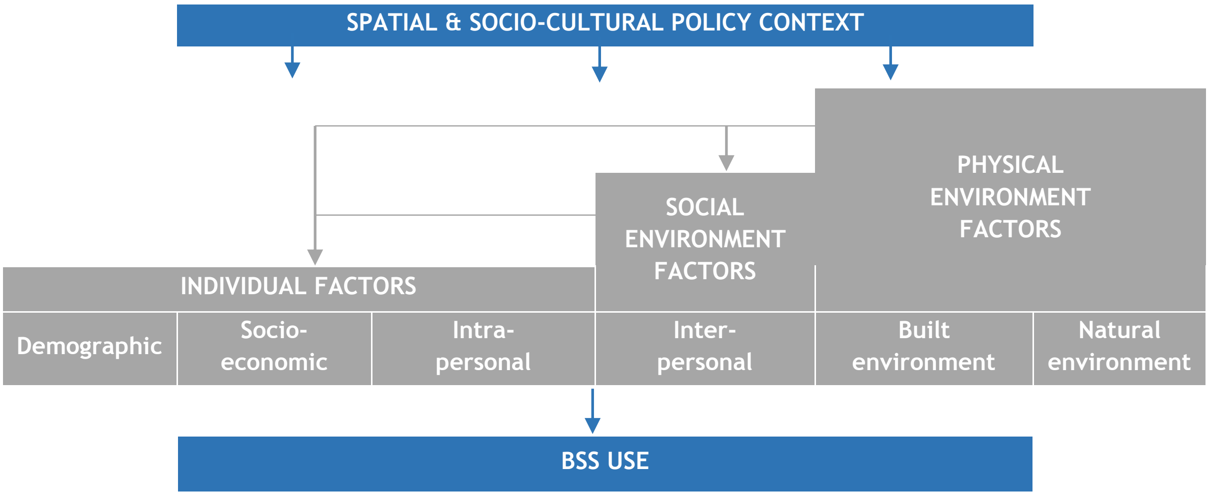


Figure 5.1: Position of the spatial and socio-cultural policy context in the theoretical framework

In the following sections, 5.1, 5.2 and 5.3, the spatial and socio-cultural characteristics of the cities, as well as the relevant land use, transport and mobility policies and stakeholders, are discussed for Limassol, Las Palmas de Gran Canaria and Malta respectively. The spatial and socio-cultural context of the case study cities is described, including their geographic form, location and position in the country, and factors related to land use and transport planning, as well as existing mobility practices and social norms around cycling. Aerial images of the three case study cities are included in Figure 5.2, to get an impression of their form and character. Relevant land use, transport and mobility laws and policies are presented in the policy and legislative framework, and entities and stakeholders active in the governance and promotion of cycling and BSS use are introduced. In section 5.4, the insights from the three case study cities are discussed in a comparative analysis, to understand differences and similarities in the spatial and socio-cultural context of the cities and their mobility systems. In the final section, 5.5, the results from this chapter are summarised and the next chapter is introduced.



Figure 5.2: Aerial images of (left) Limassol, with the promenade and coastal road in the foreground; (middle) Las Palmas de Gran Canaria, with the Avenida Marítima along the city's eastern coastline and the port and La Isleta; (right) the main urban area of Malta, with St Julian's in the foreground and Valletta and its harbours in the back (sources: Flickr: (left) Sio, (middle) muelle6, (right) Patrick Müller)

5.1 Context of cycling in Limassol

This section presents the spatial and socio-cultural characteristics of Limassol, its land use, transport and mobility policies and legislative framework. The insights below are based on the analysis presented in the Limassol SUMP (Demetriou, 2018; PTV, 2019), as well as a number of personal communications and interviews with representatives of the Limassol Municipality, the Public Works Department and Sustainable Mobility section of the Ministry of Transport, Communication and Works, the Cyprus University of Technology (CUT), the Limassol Tourism Board, the operator of the bicycle sharing system (Nextbike Cyprus), and non-governmental organisations, such as the Cyprus Scientific and Technical Chamber (ETEK), the Cyprus Cycling Federation and Friends of the Earth Cyprus.

5.1.1 Spatial and socio-cultural characteristics of the city

Introduction

Limassol is the second largest city in Cyprus, located on the island's southern coast (see Figure 5.3), with 100,000 inhabitants in Limassol municipality, and over 200,000 inhabitants living in the greater urban conglomeration surrounding Limassol (CyStat, 2019a). The average population density in greater Limassol (including surrounding municipalities) is around 921 inhabitants/km^2 (PTV, 2019). Limassol is home to the largest port in Cyprus, used for shipping and cruise liners (Limassol New Port), it is one of the main industrial hubs and it is also a well-known tourist destination (Bizakis, 2018). Cypriot cities in general have an organic structure, following a long historical and cultural development process. Limassol's urban structure shows some characteristics of radial structure (with the port as the nucleus), but also exhibits an orthogonal grid, because of urban development along the six highway interchanges which provide access to the city (Dimitriou & Savvides, 2019). The city experienced rapid economic development in recent years, evidenced by the sharp growth in high-rise buildings and commercial facilities. Increased industrial and commercial activity, along with growth in tourism have contributed to a number of issues in Limassol, such as urban sprawl, congestion and traffic problems, increase in energy consumption, carbon emissions and pollution, and degradation of the traditional town and city centres, as well as decreased road safety for vulnerable road users (Bizakis, 2018; Michael, 2019). In the past two decades, the city centre has been revitalised, with pedestrianisation of streets around Limassol Castle, the development of a promenade and seafront park and new developments around Limassol Marina providing the main impetus for change (S. Stylianides, Limassol Municipality, personal communication, May 18, 2018). However, in more recent years, development and planning of several high-rise buildings along the seafront, aimed at occasional and wealthy residents, which include underground car parking, is further incentivising private car transport in and near the city centre (PTV, 2019).

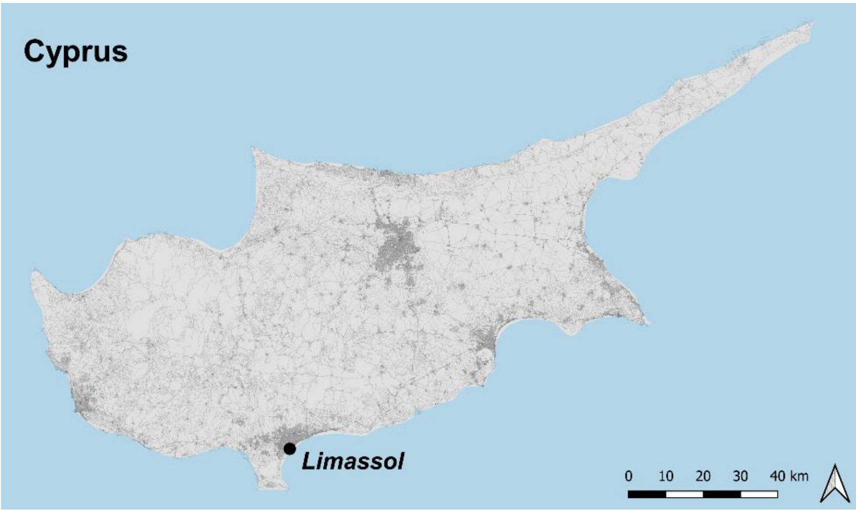


Figure 5.3: Map of Cyprus with location of Limassol

Topography and weather

The city measures approximately 18km in length following the coastline from west to east, and 6km from the city centre to the suburbs to the north of the highway, covering in total an area of around 34km^2 (Bizakis, 2018), with the larger Limassol area measuring around 222km^2 (PTV, 2019). The city centre is relatively flat, with elevation differences at the bicycle sharing station locations between 1 and 23 meters above sea level. However, the elevation increases further inland, with elevation profiles over 100m above sea level in some of Limassol's suburbs (MOI, 2019). Limassol has a Mediterranean climate, characterised by hot, dry but humid summers and mild, wet winters, with an average daily high temperature of 33˚C in summer (July/August) and 18˚C in winter (January/February). The majority of rainfall takes place in the months between November and March, with an average yearly rainfall of around 500mm (MOA, 2019). Total tourist arrivals were just under 4 million for all of the Republic of Cyprus in 2018, with around 13% of those visiting Limassol. The majority of tourist arrivals (84%) in Cyprus are between April and October (CyStat, 2019b).

Road network and transport system

Limassol has an extensive road network, historically focused on the coastal road (28th October avenue), but with the opening of the A1 Nicosia-Limassol highway in the early 1980s and associated interchanges, arterial roads from the highway to the city centre and port increased in importance (Dimitriou & Savvides, 2019). These arteries suffer from congestion during peak hours (Bizakis, 2018). The modal share of private car use in Cyprus is high (PTV, 2019); in 2016 there were 595 cars per 1,000 people (CyStat, 2018). Research done for the Limassol SUMP found a modal split of 92.1% private car, 1.5% public transport, 5.8% walking, and 0.7% cycling (Demetriou, 2019), as well as the fact that 95% of Cypriot households own 2 or 3 vehicles (Bizakis, 2018). Efforts to improve the public transport system are underway, with new contracts for public transport on a national level (for service within and between the major cities in Cyprus) being implemented in 2020 (M. Lambrinos, Sustainable Mobility section, personal communication, May 24, 2019). The upgrading of the public transport system includes the provision of real-time information at bus stops and the introduction of smartcard payment. A proposal for the reorganisation and upgrading of the bus system in Limassol city was also included in the Limassol SUMP (PTV, 2019). There are also new plans for upgrading and extending the road network, including the creation of a new northern bypass to ease congestion on Limassol's existing highway (Y. Kakoullis, ETEK, personal communication, February 15, 2020). Parking is generally available for free or cheaply and where this is not the case, car parking on pavements is common, presenting barriers and dangers to pedestrians (PTV, 2019).

The existing cycling infrastructure is made up of around 14 km of segregated bicycle lanes, most notably the stretches along the promenade from the city centre and Limassol Marina towards the eastern part of the city, where most of the hotels and the touristic zone are located and the cycling paths along parts of the *Garyllis* Linear Park. However, the cycling infrastructure is mainly used for recreational cycling and does not form a continuous and comprehensive network (PTV, 2019). A comprehensive network of bicycle infrastructure has been presented in the Limassol SUMP. The SUMP was finalised in June 2019 but no practical arrangements have been made for the proposed measures in the SUMP, nor for the design and implementation of the proposed cycling network. However, a number of urban development projects which include cycling infrastructure are currently underway, including the extension of the *Garyllis* Linear Park to connect the park with the seafront (Limassol Municipality, 2019). There are also plans for joining the fragmented cycle paths along the seafront to create a connected cycle path from the new port to the cluster of hotels just east of *Amathus*, where the easternmost stretch of currently existing cycle paths is found (Y. Kakoullis, ETEK, personal communication, February 15, 2020). Figure 5.4 presents a map of the road network in Limassol, with prominent locations referred to in the text and the locations of the existing cycling infrastructure. Figure 5.5 and Figure 5.6 highlight some positive and negative examples of streetscapes in Limassol. The fact that the implementation of new cycling infrastructure does not always go according to plan can be seen in images of cycling lanes haphazardly painted on the road and pavement by private contractors (see Figure 5.6). A municipal enquiry revealed serious omissions and errors at various stages of the implementation of the project (Hadjioannou, 2019).

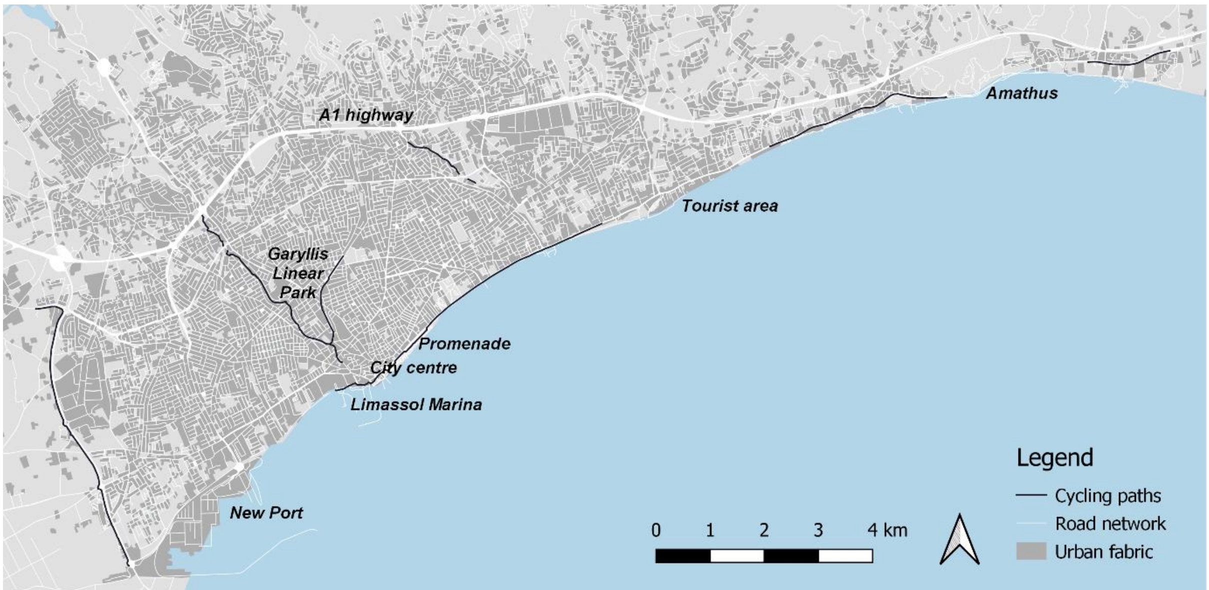


Figure 5.4: Limassol's road network and prominent locations

Figure 5.5: Positive examples of streetscapes in Limassol: Garyllis Linear Park cycling and foot path, pedestrianised area in Limassol city centre, bicycle path along the promenade (photos by author)

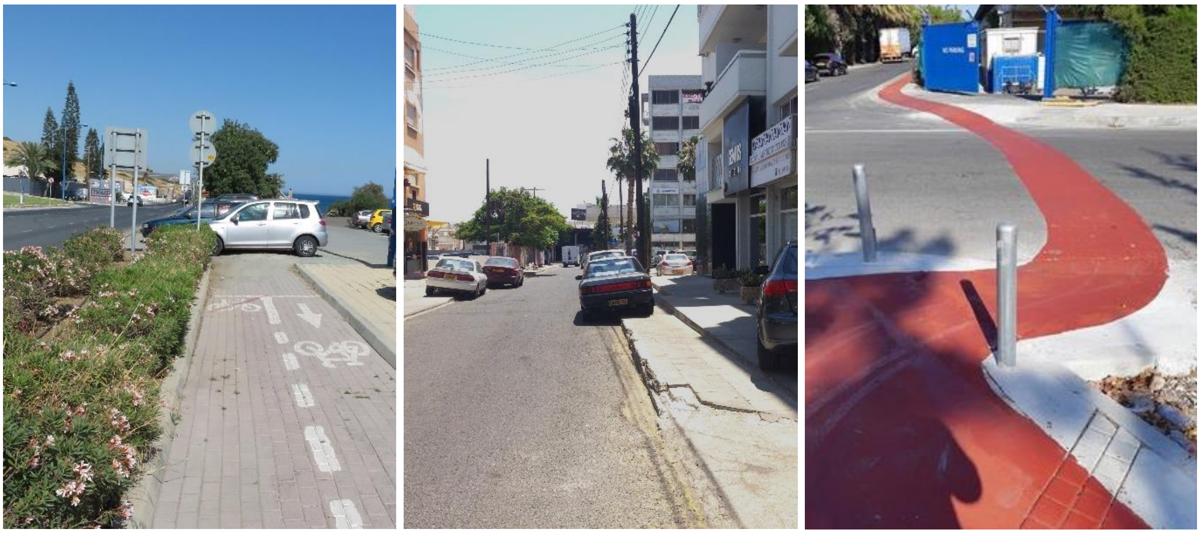


Figure 5.6: Negative examples of streetscapes in Limassol: abrupt end to cycling path, illegal parking on pavement, implementation of bicycle lanes gone wrong (left and middle photos by author; right photo: Hadjioannou, 2019)

Mobility practices

Car dependence in Cyprus is very high (Demetriou, 2018). The car is perceived as the only mode of transport providing freedom, access and flexible mobility (PTV, 2019). Socially it is the norm that youth get a car as soon as they come of age. In the past, up to 40 years ago, there were bicycles everywhere and people used to cycle to school, to the cinema and other places of leisure (M. Lambrinos, Sustainable Mobility section, personal communication, May 24, 2019). However, in the past few decades, limited investments were made in active modes of transport and both car ownership and infrastructure grew. The bicycle as a mode of transport is now associated with the past, or with being poor. Conversely, the car is a status symbol and is associated with affluence, and people cannot imagine another way of life (M. Hatziioannou, Cyprus Cycling Federation, personal communication, May 16, 2018; Y. Kakoullis, ETEK, personal communication, May 17, 2018). Car imports are also an important business sector, with most ministers of Transport having operated as businessmen in this sector before (Y. Kakoullis, ETEK, personal communication, May 17, 2018). Recent years have seen a slight shift in the attitude towards cycling with more people cycling for sport and leisure, but less so as a daily means of transport. “There is a need for safe infrastructure to encourage cycling, before expecting or investing in a culture change” (D. Demetriou, Sustainability Mobility section, personal communication, May 17, 2018). Although in urban areas there are many streets that may not need separated cycling infrastructure, as vehicle speeds are low, roads with higher speeds and traffic volumes will need dedicated infrastructure. There is a perception that it is dangerous to walk or cycle in the streets. “Whereas in the past children used to cycle (or walk) to school, nowadays there is more fear of traffic and of other dangers children might encounter if they would travel to school alone” (M. Lambrinos, Sustainable Mobility section, personal communication, May 24, 2019). Apart from a lack of safe infrastructure, there are other barriers to cycling, such as the heat in summer. This can be addressed in different ways, by providing showers at workplaces and other destinations, as well as by promoting electric bicycles, and by using trees and green infrastructure to provide adequate shading along foot- and cycle paths (M.

Hatziioannou, Cyprus Cycling Federation, personal communication, May 16, 2018; T. Zachariadis, Environmental Technology, CUT, personal communication, May 27, 2019). The introduction of the bicycle sharing system has contributed to the visibility of cycling in Limassol. Although the primary use seems to be for leisure, the extension of the system into other parts of the city enables the use of the system for commuting as well (Y. Kakoullis, ETEK, personal communication, May 17, 2018). As part of the CIVITAS DESTINATIONS project, the Limassol Tourism Board has promoted cycling through cycling education activities at primary schools, an extension of the bicycle sharing system, cycling to work schemes with local employers, the development of a sustainable mobility planning app, and cycling events and an e-bicycle showcase during European Mobility Week (M. Stylianou, Limassol Tourism Board, personal communication, May 17, 2018).

5.1.2 Relevant stakeholders, legislation and policies in the mobility sector

Stakeholders

Stakeholders on different levels are involved in the planning, promotion and management of cycling in Cyprus. On a national level, the main relevant entities are the Ministry of Transport, Communication & Works (including the Public Works department, the Sustainable Mobility section, Road Transport department and the Road Safety unit), the Ministry of Interior (Town Planning & Housing department and District administration), and the Ministry of Agriculture, Rural Development and Environment (Environment department). On an urban scale, the Municipality of Limassol, as well as the neighbouring municipalities and communities are relevant stakeholders. In addition, there are non-governmental entities and organisations that are active in the field of cycling and mobility: the Cyprus Cycling Federation, local cycling clubs (KMeaters, Limassol Cycling Club) and NGOs such as Friends of the Earth Cyprus, the Cyprus Scientific and Technical Chamber (ETEK) and the association for people with a disability. Cycling is also closely tied to tourism in Cyprus and thus the Cyprus Tourism Organisation (which is also the national member of the European Cyclists Federation, ECF) and the Limassol Tourism Board play an active role. Lastly, there are local bike-based businesses such as cycling shops, rental companies and bicycle sharing companies present in the city as stakeholders.

There are no metropolitan authorities dealing with topics such as land use and mobility, and local authorities have too few responsibilities to be effective in land use and mobility planning (Lambrinos, 2015). Most municipalities (with the exception of Nicosia) do not have a transport planner, they only have an urban planner. Transport planning falls under the remit of the Ministry of Transport, Communication and Works. There is currently no national authority for transport, although plans are in the works for the creation of such an entity and the development of a national strategic transport plan (Lambrinos, 2015). In 2019 the procurement process for this plan was expected to start shortly (M. Lambrinos, Sustainable Mobility section, personal communication, May 24, 2019). Planning for cycling and sustainable mobility is the responsibility of the Sustainable Mobility Unit within the same ministry, which has been working on creating cycling policy and legislation, as well as the creation of SUMPs for all Cyprus' major cities (D. Demetriou, Sustainability Mobility section, personal communication, May 17, 2018). However, in the absence of a regulator in the transport planning field, there is little to no monitoring of policies as set out in the Local Plans, and no strategic policy guidance or standards. Finally, as Cyprus is a small country, "many things depend on the person occupying a certain position" and their personal beliefs and connections (D. Demetriou, Sustainability Mobility section, personal communication, May 17, 2018).

The Council for the Promotion of Cycling (*Συμβούλιο Προώθησης Χρήσης Ποδηλάτου*) was established on January 18th 2016 after a Ministerial Decision. It acts as an advisory body for the Minister for all plans regarding cycling. Its representatives come from ministries and government departments, municipalities, semi-governmental organisations, cyclist groups and universities. The Council's vision is for the bicycle to be a credible choice as a means of transport, contributing to improvements in the quality of life, public health, the environment and the economy. Under their guidance, the Bicycle Bill, the main cycling legislation, was revised in 2018 and a campaign to promote cycling and cycling safety was launched in 2019 (M. Lambrinos, Sustainable Mobility section, personal communication, May 24, 2019). In line with the official position of the Union of Municipalities, which states that all new road projects and road restructuring projects must be "bicycle friendly", the Council also reviews such plans to ensure these include either cycling paths/lanes or other measures to ensure cycling safety, such as traffic calming measures (S. Stylianides, Limassol Municipality, personal communication, May 18, 2018). As the bicycle sharing system is managed by a private operator, they need to seek permission from the relevant municipality for the placement of stations and pay a fee for the use of public space (N. Ioannou, Nextbike Cyprus, personal communication, May 18, 2018).

Legislative and policy framework for mobility

Cycling and mobility are regulated by a number of laws and regulations in Cyprus, most notably the Motor Vehicles and Road Traffic Regulation and the associated Highway Code, setting out the framework for the use of the road by different road users, and the Town and Country Planning Law and the Local Plans, which set out the framework for urban and spatial planning. An overview of relevant laws, regulations and policies, including their general contents and specific clauses pertaining to cycling, can be found in Table 5.1.

The transport sector is the largest energy consumer in Cyprus, responsible for 60-70% of all energy consumption in 2016 (Achilleos, 2019; Mesimeris & Kythreotou, 2019). In terms of greenhouse gas emissions (in CO_2 equivalent), in 2016 transport was responsible for 31% of all emissions from the energy sector and 23% of all national emissions (including all sectors: energy, industrial processes, agriculture, land use change and waste) (Kythreotou & Mesimeris, 2018). In order to meet the EU energy and climate targets, Cyprus had the following targets for 2020: reduction of greenhouse gas emissions by 20% (from 2005 levels), 20% improvement in energy efficiency, 13% share for renewable energy, and 10% share for renewable energy (including biofuels) in transport (Achilleos, 2019; Mesimeris & Kythreotou, 2019). In their draft 'National Energy and Climate Plan' for the period 2021-2030, the Government of Cyprus admitted that "the achievement of the national GHG reduction target requires considerable effort and investment, especially in the field of transport" (Mesimeris & Kythreotou, 2019).

Table 5.1: Legislative and policy framework: Sustainable mobility and cycling in Limassol

Law/regulation	Year	Contents
Motor Vehicles and Road Traffic Regulation	1984	• Provides the framework for use of the road by different road users. • Definition of electric bicycle (25 kW), speed up to 25 km/h.
Town and Country Planning Law	1990	• Provides the framework for urban and spatial planning.
Cyprus Highway Code	2013	• Cyclists have to follow the same road rules as car drivers, they are not allowed to cycle on pavements. • Four different types of cycleways: cycle paths, cycle lanes, cycle corridors and cycle routes. • A functioning bell, lights and reflectors are mandatory. Helmets are not mandatory, but their use is advised.
Limassol Local Plan	2013	• Building heights, volume and density. • Provision of public amenities. • Parking requirements. • Limassol bicycle master plan 2013 (not implemented).
Bicycle Bill	2018	• Minimum bicycle equipment: two sets of brakes, a front and back light, reflector and a bell. • Four different types of cycleways: cycle paths, cycle lanes, cycle corridors and cycle routes. • Offenses and penalties.

Policy/guidance	Year	Contents
Streetscape manual *(Nicosia)*	2010	• Urban design requirements and guidelines to be used to design streets to serve all road users in Nicosia. • For urban areas, provision for shared road space (speeds <50km/h) and separated cycle lanes (speeds >50km/h).
Strategic Road Safety Plan for 2012-2020	2012	• Improved safety for vulnerable road users. • Road safety education. • Goals for safer roads and mobility.
Cyprus National Energy and Climate Plan 2021-2030 (draft)	2019	• Greenhouse gas emission reduction in the transport sector requires considerable effort. • Renewable energy in transport target 10% by 2020. • Promote energy efficient and alternative transport through promotion of public transport, improvement of walking and cycling infrastructure, low emission zones, parking policy and restriction of car use. • Target: increase of active transport modal share to 20% of all trips by 2030.
Limassol Sustainable Urban Mobility Plan (SUMP)	2019	• Promotion of sustainable mobility, including active modes. • Proposal for a bicycle network, as well as associated bicycle facilities such as parking and rental systems. • Proposal to establish regulations and guidelines for infrastructure, and include cycling requirements in the Local Plan.

Urban planning is based on the British discretionary planning system, as Cyprus was a British colony until independence in 1960. A discretionary planning system allows for considerable negotiation and discretion at a late stage in the planning process, with decisions made by a Planning Board, in contrast with a regulatory planning system, in which decisions are based more strictly on compliance with the local plans (Oxley et al., 2009). The Department of Town Planning and Housing, under the Ministry of Interior, is the national directorate responsible for the implementation of the 1990 Town and Country Planning Law and therewith, urban policy, spatial planning and development control. Local Plans have been developed for the main urban areas in the Republic of Cyprus, including for the urban area around Limassol (Lambrinos, 2015). Although Local Plans are legally binding documents, they contain rather generic guidelines and policy objectives and lack a monitoring framework. There is a prevalence of sectoral policies and a lack of strategic and holistic planning. As a result, there is a lack of clear policy direction for sustainable mobility planning. This has resulted in ad-hoc project planning, working with too many stakeholders without a clear direction, and a number of studies and plans that are never implemented (Lambrinos, 2015; Michaelides, 2017). In terms of urban development, recent years have seen urban sprawl and linear development along roads, which makes the urban environment more dispersed and car-centred and less suitable for walking or cycling (PTV, 2019).

The Bicycle Bill, the law for the regulation of bicycles and bicycle use (N. 19(I)/2018), was approved by parliament and came into force on 31 October 2018. The bill contains provisions about bicycle equipment, regulations for motor vehicle drivers and cyclists, rules for different types of cycling infrastructure (cycle paths, lanes, corridors and routes), and a list of offenses and penalties (Stylianou, 2019). Cyclists are allowed to make use of any street, except for highways (Chrysostomou, 2018). A communication campaign was implemented to explain the Bicycle Bill (2018) through TV and radio spots and participation in TV and radio shows, ads on buses, leaflets, and support for cycling clubs and cycling activities (including European Mobility Week) (Stylianou, 2019).

The Ministry of Transport, Communication and Works decided to develop Sustainable Urban Mobility Plans (SUMPs) for all Cyprus' major cities, including Limassol (Lambrinos, 2015; PTV, 2019). The 'Sustainable Urban Mobility Plan for the Greater Urban Area of the City of Limassol', was developed between 2017 and 2019 and officially published on 13 June 2019. The Limassol SUMP covers six municipalities and eleven communities together making up the greater Limassol urban area, covering a total area of 222.5 km^2 and a population of around 205,000 (PTV, 2019). The main findings of the SUMP confirm the current car-dependency and low usage of public transport and walking and cycling as modes of transport. People who do rely on public or active transport for their daily mobility needs are primarily captive users, i.e. those who do not have another option, who do not have access to a private vehicle (Bizakis, 2018; PTV, 2019). The Limassol SUMP recognises the need to step away from the vicious circle of car-dependence and the need for a paradigm shift. The SUMP objectives are to improve the efficiency and cost-effectiveness of the transport system, while minimising pollutants and emissions, and ensuring accessibility, safety and security for all road users, in order to enhance the attractiveness of the city and the quality of life of its citizens and society as a whole (PTV, 2019).

5.2 Context of cycling in Las Palmas de Gran Canaria

This section presents the spatial and socio-cultural characteristics of Las Palmas de Gran Canaria, and its land use, transport and mobility policies and legislative framework. The insights below are based on the analysis presented in the Las Palmas de Gran Canaria Mobility in Transformation document (Ayuntamiento de Las Palmas de Gran Canaria, 2015), the Bicycle Master Plan (Estudio Manuel Calvo, 2016) and other policies and plans. The analysis also incorporates a number of personal communications and interviews with representatives of the Las Palmas de Gran Canaria Municipality and SAGULPA, the municipal parking and bicycle sharing company, the engineers and architects working on the Bicycle

Master plan, a mobility expert from the Mobility Observatory *(Observatorio de Movilidad)* of the city and a representative of *Las Palmas en Bici* (Las Palmas by bicycle), a non-governmental organisation promoting and advocating for cycling in the city.

5.2.1 Spatial and socio-cultural characteristics of the city

Introduction

Las Palmas de Gran Canaria (LPGC) is the largest city and capital of Gran Canaria (see Figure 5.7) and joint capital of the Canary Islands autonomous community (together with Santa Cruz de Tenerife). The city is home to 379,925 inhabitants (INE, 2019). Population growth has mostly occurred in the neighbourhoods on the western side of the city, such as *Tamaraceite* and *Los Torres* (Ayuntamiento de Las Palmas de Gran Canaria, 2015). The average population density in the municipality of Las Palmas de Gran Canaria is around 1,848 inhabitants/km^2 (Ayuntamiento de Las Palmas de Gran Canaria, 2019). The city has two main city centres: firstly, the area around *San Telmo*, its bus station, the shopping district around *Triana* and the historic city centre in and around *Vegueta* and secondly, the area around *Las Canteras* and *Santa Catalina*, including the bus station there. This area is also near the port, with shipping services, a cruise liner terminal and inter-island ferries, and an industrial zone in the northeast section of the city. These parts of the city and the transport network that connects them are located in the littoral zone of the city and are relatively flat. Moving further inland, the direction in which the city has expanded, the terrain rises over slopes and terraces towards the upper city. The lower part of the city is home to the city's main public services and commercial activities, and sees 75% of the total transport movements, even though it is home to only 36% of the city's inhabitants (Ayuntamiento de Las Palmas de Gran Canaria, 2015). The upper city is more residential in nature. The main university campus (*Universidad de Las Palmas de Gran Canaria*, ULPGC) is located in the hills outside of the city boundary, although there are a few university buildings found within the southern part of the city.

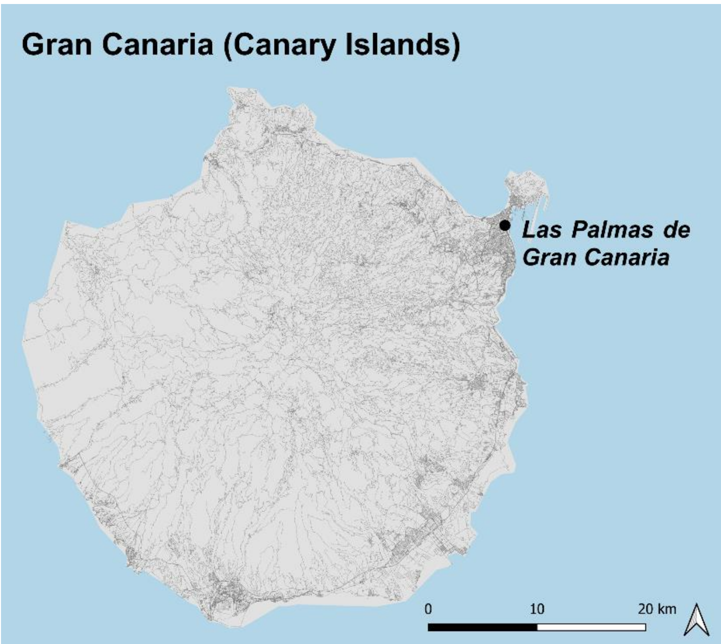


Figure 5.7: Map of Gran Canaria (Canary Islands) with location of Las Palmas de Gran Canaria

Topography and weather

The city measures approximately 12km in length following the coastline from north to south, and 5km in width. The entire municipality covers an area of around 205 km^2. The city has a challenging topography, due to its linear development along the coast, the presence of an isthmus and peninsula within the urban perimeter and elevation differences of up to 300 meters between sea level and the highest located neighbourhoods. The city is colloquially divided into the lower city (*Ciudad Baja*) and the upper city (*Ciudad Alta*). The presence of elevation differences and valleys and ravines cutting through the city creates difficulties for the transport network, especially for active modes such as walking and cycling (Ayuntamiento de Las Palmas de Gran Canaria, 2015). Apart from connecting roads, there are a few vertical connections available, including public elevators and escalators at *Canódromo* and *Parque de las Rehoyas*. Las Palmas de Gran Canaria has a desert climate mediated by the impact of the Gulf stream and the trade winds. Temperatures are relatively stable throughout the year, with an average daily high temperature of 27˚C in summer (July/August) and 21˚C in winter (January/February). Yearly rainfall is around 150 mm, with the majority of rainfall between October and March (AEMET, 2019). The city of Las Palmas de Gran Canaria received around 125,000 tourists in 2019, with the majority of tourist arrivals (70%) occurring in the winter season, between October and April (ISTAC, 2020).

Road network and transport system

Las Palmas de Gran Canaria and its metropolitan area are the hub for the island's motorway network. The city is linked with three highways: the GC-1 to the south, the GC-2 to the west and GC-3 to the centre of the island. The GC-1 is the main thoroughfare into the city and to the port; the *Avenida Marítima* (Maritime Avenue) runs along the city's eastern coastline up to the port and the peninsula *La Isleta*. In 2017, Las Palmas de Gran Canaria was found to be the third most congested city in Spain, with an average level of 27% extra time spent in traffic relative to a situation of optimal traffic flow, which increases up to 38% additional time during peak hours (El Diario, 2017). In a study as part of the city's SUMP, modal share in the city was determined, which found that of all trips, 67% are done by private car, 13% by bus, 15% on foot and <1% by bicycle. The rate of motorisation is relatively high in Las Palmas de Gran Canaria, with 531 cars per 1,000 people; above the average for Spain (Ayuntamiento de Las Palmas de Gran Canaria, 2015). Public transport is managed by *Guaguas Municipales*, the municipal company for public transport, who are also leading the implementation of a Bus Rapid Transit (BRT) system for the city, *MetroGuaguas*, which will run a 11.7km trajectory from *Hoya de la Plata* at the southern end of the city, to the port in the north[2].

The parking management of Las Palmas de Gran Canaria was changed after 2012, to include specific paid parking types on-street and off-street, with 'green' and 'blue' parking spaces, the former reserved to residents and only available for other use for a maximum of 1 hour, and the latter available for a maximum of 2 hours, for anyone. Users can pay at a parking meter or through an app *LPA Park*, which also allows users to search for and reserve a parking spot (M. Morales, Engineer bicycle network, personal communication 12/07/2019). The parking locations and payments are managed by SAGULPA, the municipal parking

[2] https://www.guaguas.com/lineas/metroguagua

company, who are now also responsible for the new bicycle sharing system *Sítycleta*, which is in fact partly funded by the income from parking management. There is currently one large P&R (*El Rincón*) at the northern entrance to the city, where the payment for parking includes a free ticket for the bus to reach the city centre (M. Morales, Engineer bicycle network, personal communication 12/07/2019). The P&R also includes a bicycle sharing station, with future plans to include a free trip by bicycle in the parking payment as there is for the bus (C. García, SAGULPA, personal communication, 24/07/2019). Several of the interviewees recommend the creation of P&Rs at the southern and central entrances to the city too, and to improve intermodal connections, with better bicycle parking at the bus stations and stops and full integration of payment for parking, public transport and bicycle sharing services. The existing cycling paths and lanes, just under 20km in total, are found predominantly along the main GC-1 road into the city along the eastern coastline. The existing cycling infrastructure has contributed to the use of bicycles primarily for recreational or exercise purposes (Ayuntamiento de Las Palmas de Gran Canaria, 2015). Figure 5.8 presents a map of the road network in Las Palmas de Gran Canaria, with prominent locations referred to in the text and the locations of the existing cycling infrastructure. Figure 5.9 and Figure 5.10 highlight some positive and negative examples of streetscapes in Las Palmas de Gran Canaria.

Figure 5.8: Las Palmas de Gran Canaria's road network and prominent locations

Figure 5.9: Positive examples of streetscapes in Las Palmas de Gran Canaria: bicycle parking near the beach of Las Canteras, newly created cycling infrastructure in the city centre, 30km/h zones in narrow streets (photos by author)

Figure 5.10: Negative examples of streetscapes in Las Palmas de Gran Canaria: cars parked illegally on the pavement, a van occupying the cycling lane, a person cycling on the pavement in a section where cycling infrastructure is (still) lacking (photos by author)

Mobility practices

Las Palmas de Gran Canaria has a high rate of motorisation and incidences of traffic congestion. While there is a reasonable share of trips made by public transport and on foot, movements by bicycle are limited thus far. However, several interviewees commented on the fact that cycling as a mode of transport has grown in the past few years; there are more cyclists in the street, including more cycling for transport and commuting, as evidenced by the attire of people on bicycles. The last two municipal legislative periods have contributed to this change, with attention for and investment in cycling infrastructure (M. Palacios, Las

Palmas en Bici, personal communication, 17/07/2019). The theme of cycling paths featured quite prominently in the most recent municipal elections, as works had just commenced at the time of the elections, and it was a central, divisive, topic in debates and on social media (H. Dávila, LPGC Municipality, personal communication, 29/07/2019; J. Tantalean, Mobility expert, personal communication, 29/07/2019), including several memes about cycling paths going viral on social media platforms (La Provincia, 2019). There is still some division between different parts of the population, with some applauding the efforts of the municipality to promote sustainable mobility through their investment in the BRT and active modes, and a more conservative segment who state this is not possible in Las Palmas de Gran Canaria, due to their different culture, topography and narrow streets (H. Dávila, LPGC Municipality, personal communication, 29/07/2019). There is a change in mentality in younger people, who are less interested in private car ownership, partly because of their more precarious economic situation, and partly because of increased environmental awareness and different values in life. This is happening globally and in Las Palmas de Gran Canaria too, albeit with a bit of delay. There are, however, also still people for whom a private car is a status symbol (M. Palacios, Las Palmas en Bici, personal communication, 17/07/2019). A large barrier to cycling is the fear of cycling in the street. Previously, there were some streets with sharrows to indicate where to cycle, but without any further intervention (such as traffic calming) this does nothing to protect cyclists. Now, there is more investment in separated cycling infrastructure, which will offer more safety for people of all ages on bicycles (M. Palacios, Las Palmas en Bici, personal communication, 17/07/2019).

There is also a need for investment in active mobility from a health perspective; in Las Palmas de Gran Canaria, 43% of the population is classified as obese and more than 39% of people suffer from diabetes (P. Conde Martín, LPGC Municipality, personal communication, 30/07/2019). In the past there was some investment in cycling paths, but in isolated streets or squares, not as part of a connected network. Some of these, notably the cycling path along the GC-1, were used for leisure or sports, but such isolated paths did not provide the connectivity for people to use them to cycle to work, to go shopping or to run errands (M. Palacios, Las Palmas en Bici, personal communication, 17/07/2019). The key to promoting cycling as a mode of transport, is that the infrastructure is not isolated from the city along the coastline, but entering into the city; connecting trip origins with destinations (H. Dávila, LPGC Municipality, personal communication, 29/07/2019). Infrastructure alone is not enough though; while the creation of cycling infrastructure and the investment in a new bicycle sharing scheme can amplify the use of bicycles, there is also a need for strong promotional campaigns, to change the culture and mentality (J. Tantalean, Mobility expert, personal communication, 29/07/2019).

5.2.2 Relevant stakeholders, legislation and policies in the mobility sector

Stakeholders

Stakeholders at different levels are involved in the planning, promotion and management of cycling in Las Palmas de Gran Canaria. The Canary Islands, as an autonomous community of Spain, has its own government. Each of the seven major islands have an island council (*Cabildo insular)*, with the Gran Canaria *Cabildo* having a department of public works, infrastructure, transport and mobility (*Consejería de Obras Públicas, Infraestructuras,* *Transportes y Movilidad*), as well as providing the framework for land use and spatial planning through the Island Land Use Plan (*Plan Insular de Ordenación*). While this plan does make some reference to cycling infrastructure in the major urban areas on the island, as well as to corridors for cycling tourism in rural areas, the main planning for cycling infrastructure takes place at the municipal level. Within the municipality, transport planning is organised in two different sections, the mobility department, who focus on developing plans (such as the Bicycle Master Plan) and are responsible for road safety and education, and the urbanism department, who have more executive powers and implement such plans (P. Conde Martín, LPGC Municipality, personal communication, 30/07/2019).

While the politicians and management level may now have become convinced about the need to move towards sustainable mobility, there are still challenges at the level of implementation, where technical staff may not be educated about suitable design and measures to meet the specific needs of different mobility users (P. Conde Martín, LPGC Municipality, personal communication, 30/07/2019). Mobility provision and management is in the hands of two municipal companies: *SAGULPA*, responsible for parking management and the bicycle sharing system, and *Guaguas Municipales*, the public transport operator. In addition, there are non-governmental entities and organisations that are active in the field of cycling, in the city of Las Palmas de Gran Canaria primarily *Las Palmas en Bici*, advocating for urban cycling and organising a monthly critical mass. *Las Palmas en Bici* is a member of *Ben-Magec*, the local arm of *Ecologistas en Acción*, a major Spanish confederation of environmental organizations, as well as of *ConBici*, the Spanish confederation of cycling associations and member of the European Cyclists Federation, ECF. Other local cycling organisations primarily target sports cycling and competitions, such as the Gran Canaria Cycling Federation (*Federación Insular de Ciclismo de Gran Canaria*) and the Canarian Cycling Federation (*Federación Canaria de Ciclismo*). Lastly, there are local bike-based businesses, such as cycling shops, rental companies and the bicycle sharing company present in the city as stakeholders.

In recent years, a bicycle roundtable (*Mesa de la Bicicleta)* was created. This group of stakeholders includes representatives from the municipality, companies and providers working in the mobility sector, and non-governmental organisations such as citizen groups and the Gran Canaria cycling federation, who get together to discuss any plans related to cycling, such as the Bicycle Master Plan and the location of ancillary services such as bicycle parking (H. Dávila, LPGC Municipality, personal communication, 29/07/2019). The different stakeholders who signed the Sustainable Mobility Pact included political parties, the public transport providers, taxi associations and *Las Palmas en Bici*, the organisation advocating for cycling. Other stakeholders, most notably the association of car importers, which have strong ties with one of the main political parties, were not in favour of this pact. They are also not in agreement with the Bicycle Master Plan and the creation of bicycle paths on what they deem to be space for cars (former on-street parking or driving lanes) (M. Palacios, Las Palmas en Bici, personal communication, 17/07/2019). In general, there are powerful economic interests from companies that import fossil fuels and cars, which strongly oppose the transition towards more sustainable mobility and renewable energy as it impacts their business negatively (J. Tantalean, Mobility expert, personal communication, 29/07/2019).

Legislative and policy framework for mobility

Cycling and mobility are regulated by a number of laws and regulations in Las Palmas de Gran Canaria, most notably the General Vehicle Regulations and the Traffic Ordinance, setting out the framework for the use of the road by different road users, and the Gran Canaria Island and LPGC urban and land use planning documents, which contain the framework for urban and spatial planning. An overview of relevant laws, regulations and policies, including their general contents and specific clauses pertaining to cycling, can be found in Table 5.2.

The Traffic Ordinance (*Ordenanza de Tráfico*) regulates the movement of vehicular and active modes of transport, and includes specific objectives to promote sustainable mobility, including public and active transport, in order to create a friendlier, sustainable and safe city. In the same year, a Sustainable Mobility Pact (*Pacto por la Movilidad Sostenible)* was signed between different stakeholders in the field of mobility, agreeing on a new transport hierarchy, stating the city and its public space is foremost for pedestrians, cyclists, public transport users and lastly for private vehicles. In 2012, a Sustainable Urban Mobility Plan (SUMP) was developed for the city of Las Palmas de Gran Canaria, setting out strategic goals and practical measures to discourage private car use and encourage public transport and active mobility in the city (EDEI & EPYPSA, 2012).

Table 5.2: Legislative and policy framework – Sustainable mobility and cycling in Las Palmas de GC

Law/regulation	Year	Contents
Reglamento General de Vehículos (General Vehicle Regulations)	1998	• Brakes and a functioning bell on a bicycle are mandatory. • Front and back lights and reflectors are mandatory for use at night, in tunnels, and situations with limited visibility. • Bicycles may not be used to tow another person.
Plan Insular de Ordenación de Gran Canaria (Gran Canaria Land Use Plan)	2000/ 2017	• Provides the framework for urban and spatial planning (2000). • Annex with analysis of mobility situation, including references to cycling infrastructure and future plans (2017).
Ordenanza de Tráfico de Las Palmas de Gran Canaria (Traffic Ordinance)	2011	• Regulation of traffic circulation, including non-motorised vehicles such as bicycles. • Includes regulations for pedal-assist bicycles (up to 0.5 kWh). • Where there is cycling infrastructure (shared paths on the pavement, dedicated cycling paths on the road), cyclists are required to use it. Where there isn't, cyclists are allowed on the road. Maximum speed is 25km/h. It is allowed to cycle in pedestrian zones and 30km/h zones, but pedestrians have priority. • Bicycles are not allowed to use highways or motorways, but are allowed to cycle on hard shoulders. • Minimum passing distance for vehicles to overtake cyclists is 1.5m. • Creation of a municipal registry to voluntarily register a bicycle to prevent theft or track a bicycle in case of theft. • Provisions for dedicated bicycle traffic lights.
Plan General de Ordenación de Las Palmas de Gran Canaria (General Land Use Plan LPGC)	2012	• Urban regulations • Urban development zone • Spatial planning • Mobility and transport planning

Policy/guidance	Year	Contents
Pacto por la Movilidad Sostenible (Sustainable Mobility Pact)	2011	• States that "the city is for people": the priority should be living in the city, rather than on vehicular movements. • Establishes a hierarchy for the use of different modes of mobility: 1) pedestrians, 2) cyclists, 3) buses and taxis, 4) private cars and motorcycles.
Plan de Movilidad Urbana Sostenible (*PMUS*; SUMP, Sustainable Urban Mobility Plan)	2012	• Promotion of sustainable mobility, including active modes. • Proposed measures to promote cycling include: traffic calming measures, improvement of cycling infrastructure, provide bicycle parking at locations of trip attractors, the creation of a cycling traffic code including legal protection for cycling and the implementation and promotion of the bicycle sharing system. • Proposes a separated cycling network as the best way to promote cycling as a mode of transport, to enable safe connections between trip origins and destinations.
Plan Director de la Bicicleta (Bicycle Master Plan)	2013	• *Superseded by 2016 Bicycle Master Plan.*
LPA_GC Movilidad en Transformación (Mobility in Transformation)	2015	• Target: to triple the daily movements in the lower city by bicycle from 3,000/day (0.4% modal share) to 9,000/day (3.8%) in 5 years (by 2020). • Cycling education and organisation of events to encourage 8,000 inhabitants of the city (school children, adults, police) to learn how to cycle. • Proposals for the creation of 30km/h zones, a dedicated cycling network and an improved bicycle sharing system. • Proposal for the creation of a transport smart card that integrates payments for all mobility services (parking, public transport, shared bicycles).
Plan Director de la Bicicleta (Bicycle Master Plan)	2016	• Aims to facilitate cycling to become a real alternative mode of transport. • Proposes a safe and connected cycling network for the city, including specific routes and design principles. • General design is based on bi-directional cycling paths with a minimum width of 2.3-2.5m, while minimising the length and occurrence of steep inclines and the number of intersections with other traffic.
Plan Insular de la Bicicleta (Bicycle Plan for the Island, Gran Canaria)	2018	• Aims to create technical and management criteria to promote the use of bicycles. • Proposes the creation of regulatory frameworks and sectoral plans for the promotion of cycling as a mode of transport, both on the urban and metropolitan scale, as well as cycling for leisure, tourism and as a sport. • Proposes coordination between different stakeholders and local/regional authorities.

The 2015 Mobility in Transformation policy document (*Movilidad en Transformación*) (Ayuntamiento de Las Palmas de Gran Canaria, 2015), building on the Traffic Ordinance, Sustainable Mobility Pact, and SUMP documents, sets out the key mobility changes that need to be made in the city in order to create a balanced mobility system: a modern public transport system, a parking management system, a revised road hierarchy for better traffic flow, and empowerment of soft modes, such as cycling and walking. One of the main proposed interventions was the creation of a BRT system, which started being implemented in 2019. In addition to the improvement of public transport, the policy seeks to promote active mobility, walking and cycling, through pedestrianisation, wider pavements, safer crossings, the creation of 30km/h zones with priority for pedestrians and cyclists (*Zonas 30*), a dedicated cycling network and an improved bicycle sharing system (Ayuntamiento de Las Palmas de Gran Canaria, 2015). While the Gran Canaria island and Las Palmas de Gran Canaria urban land use plans make reference to sustainable mobility, these are provided as guidelines, not as rules. It depends on the development whether the principles of sustainable mobility are taken into account at the planning stage. There are still new developments, such as residential complexes or commercial centres, where provisions for public transport and active modes are not sufficiently considered, therewith further encouraging private vehicle use (J. Tantalean, Mobility expert, personal communication, 29/07/2019).

In 2016, the municipality published the Bicycle Master Plan (Plan Director de la Bicicleta) (Estudio Manuel Calvo, 2016), an updated version of a previously issued plan in 2013, which proposes a plan for promoting cycling as a mode of transport, defines a cycling network for the city and sets out design principles for the proposed cycling infrastructure. The Bicycle Master Plan identifies five main axes that together will create an integrated bicycle network, adding over 20km of new cycling paths to the existing network, the first parts of which started being implemented in summer 2019. The main guiding design principles are the creation of bi-directional segregated cycling paths, with a minimum width of 2.3 to 2.5m, while avoiding streets with steep or long inclines and minimising the number of intersections with other traffic. The space for the new cycling paths is primarily taken from on-street parking lanes, from traffic lanes, or by narrowing lane widths. While the main focus of the Bicycle Master Plan is the lower city, there are some provisions for extending the network to the upper city, including potential vertical connections such as elevators or escalators and an analysis of the road connections with the least steep inclines (Estudio Manuel Calvo, 2016). In the stakeholder engagement process as part of the creation of the Bicycle Master Plan, the reaction of the general public was in general positive. However, when works started and on-street parking was removed in front of people's doorstep, there was a negative response and controversy about the 'right to park' (which does not exist legally). People are used to parking right in front of where they want to go, or at least on the nearest corner. Nonetheless, in the latest municipal elections, the political parties promoting cycling and the implementation of the Bicycle Master Plan were voted in, so the planned works went ahead (M. Morales, Engineer bicycle network, personal communication 12/07/2019). Changes to the priorities and implementation of a different mobility system take some time to get used to, but it is the direction the city has taken; "the city's residents will see the benefits and the use of the new bicycle paths" (C. García, SAGULPA, personal communication, 24/07/2019).

Thus far, the investment in cycling infrastructure and the new bicycle sharing system have focused on the lower city. There are some existing vertical connections between the lower and upper city, but better connections would need to be installed to overcome the steep inclines. This can be either through more such vertical connections, but also through the investment in electric bicycles. This will also be addressed through a foreseen master plan for the upper city (C. García, SAGULPA, personal communication, 24/07/2019). While there is financial support for the purchase of electric vehicles from the Canarian government this does not, as yet, include electric bicycles, even though bicycles are considered to be vehicles as per the General Vehicle Regulations (P. Conde Martín, LPGC Municipality, personal communication, 30/07/2019). There is a need to change the local legislation to include rules on the use of electric kickscooters, Segway's and other forms of micro-mobility. Currently, they are allowed to use the pavement, but this creates dangerous situations for pedestrians (M. Morales, Engineer bicycle network, personal communication 12/07/2019). New legislation for micro-mobility and other forms of shared mobility (e.g. scooter- or car-sharing) will be proposed as a revision to the 2011 Traffic Ordinance. The idea is to allow e-kickscooters and other micro-mobility as well as electric wheelchairs to use cycling infrastructure, as long as they are limited to a maximum of 25km/h (H. Dávila, LPGC Municipality, personal communication, 29/07/2019; P. Conde Martín, LPGC Municipality, personal communication, 30/07/2019).

5.3 Context of cycling in Malta

This section presents the spatial and socio-cultural characteristics of the Valletta conurbation in Malta, and its land use, transport and mobility policies and legislative framework. The insights below are based on the analysis presented in the Transport Master Plan (TM, 2016a), the National Transport Strategy (TM, 2016b) and other policies and plans, as well as a number of personal communications and interviews with representatives of government authorities, such as Transport Malta (TM), the Planning Authority and Infrastructure Malta, the general manager of Malta Public Transport, the public transport operator, academics with expertise in urban planning and transport policy from the University of Malta (UoM), the operator of the bicycle sharing system (Nextbike Malta) and a representative of the bicycle advocacy group *Rota*, a non-governmental organisation promoting and advocating for cycling.

5.3.1 Spatial and socio-cultural characteristics of the city

Introduction

Malta, a Mediterranean island state, is the smallest EU member state with a total population of 460,297 in 2016 (NSO, 2018). The Valletta conurbation in Malta refers to the urban area around the capital city Valletta (see Figure 5.11), encompassing the Northern and Southern Harbour districts, which together are home to a population of 205,768 inhabitants (NSO, 2016). The Northern Harbour district is the most densely populated area on the Maltese Islands, home to over a quarter of the population. The average population density in the Northern Harbour district is 5,014 inhabitants/km^2, whereas in the Southern Harbour district this is 3,035 inhabitants/km^2. Population density for the Maltese Islands as a whole is 1,457 inhabitants/km^2 (NSO, 2018). The Northern and Southern Harbour districts consist of a collection of cities and villages that over the years have merged together into one main urban area, albeit still retaining their own distinct character and community, with their own Local Council and traditions such as the local feast (*festa*) (Boissevain & Bear, 1965). The area includes the tourist town of *St Julian's*, residential, commercial and employment centres in *Msida*, *Gżira* and *Sliema*, which have a relatively large share of foreign populations as well, and the University of Malta (UoM) in *Msida*. The Southern Harbour district includes Valletta, the capital city and a main employment and entertainment hub, as well as the site of the main bus terminus. The Grand Harbour is both a touristic port, with cruise liners berthing in *Floriana* at the *Valletta Waterfront,* and a commercial and industrial port, with operations in *Marsa* and *Kordin*. *Paola* is the main commercial hub of the Southern Harbour district. The 'Three Cities', *Birgu*, *Bormla* and *L-Isla*, are historic harbour cities, and together with Valletta are the main tourist attraction of this part of the island.

Topography and weather

The conurbation around Valletta measures around 9km from north to south and 9km across. The Northern Harbour and Southern Harbour districts together cover an area of 50km^2. The total surface area of the Maltese Islands is 316 km^2 (NSO, 2014). Malta, the main island of the Maltese archipelago, is a limestone plateau with a north-western tilt, with high cliffs (up to 253m) along the western coast of the island, giving way to the southeast, with its natural harbours and lower elevations, where the main developed area of island is found. In the conurbation, elevation varies from sea level to around 60-70 meters, with elevation differences most prominent in the many (dry) valley systems running from higher grounds to the harbours (PA, 2015). Valletta itself was built on a peninsula; it is surrounded by two natural harbours and on the land side by bastions, creating challenges for access to and from the city (TM, 2016a). Malta has a Mediterranean climate, characterised by hot, dry but humid summers and mild, wet winters, with an average daily high temperature of 31˚C in summer (July/August) and 16˚C in winter (January/February). The majority of rainfall takes place in the months between October and January, with an average yearly rainfall of around 550mm (Galdies, 2011). Total tourist arrivals to the Maltese Islands were just over 2.7 million, with the vast majority of visitors staying in or visiting the Valletta conurbation. The majority of tourist arrivals (73%) in Malta are between April and October (NSO, 2020).

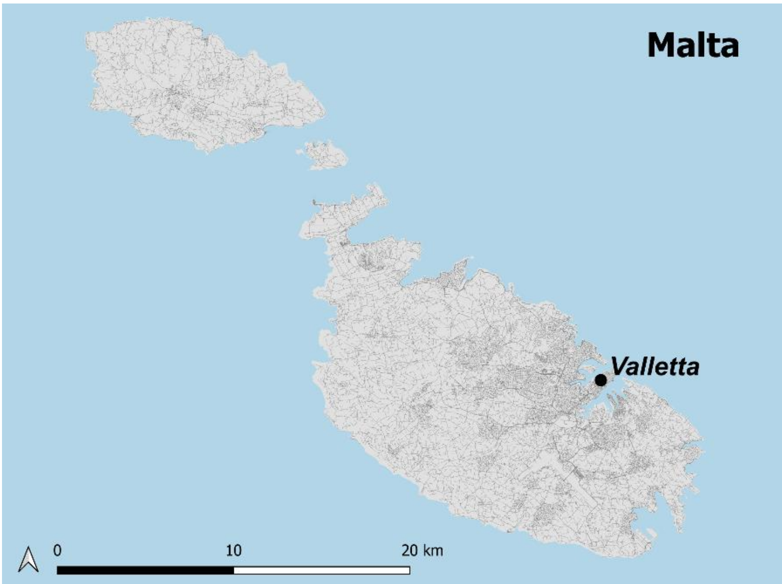


Figure 5.11: Map of Malta with location of Valletta

Road network and transport system

The main arterial road is 'Route 1', which runs along the entire length of the island of Malta, from the port in *Birżebbuġa* in the south, past the airport, towards the conurbation, and up north along *Regional Road* and the *Coast Road* to *Ċirkewwa*, from where the ferry to Gozo departs. Other important roads are ‘Route 5’, from the University of Malta to *Mosta* via *Birkirkara Bypass*, and ‘Route 7’, from the conurbation towards the cities of *Rabat* and *Mdina* in the centre of the island via *Mrieħel Bypass*. Road design in Malta is generally car-oriented and lacks dedicated lanes for public transport and cycling and pedestrian friendly infrastructure (TM, 2016a). Malta has a high car dependence. During the latest National Household Travel Survey (NHTS) in 2010, the modal share by private car was 75%, by bus 11%, on foot 7.5% and by bicycle 0.3% (TM, 2016a). Car ownership is at an all-time high with 799 cars per 1,000 residents (NSO, 2017). Car dependence has led to congestion and parking issues, deteriorating air quality, noise pollution, excessive carbon emissions and accessibility problems for pedestrians and cyclists. The external costs associated with traffic congestion, air and noise pollution, climate change and accidents as a result of private and commercial vehicle use in Malta was calculated to amount to €274 million per year in 2012 (Attard et al., 2015).

Private operator Malta Public Transport has been running the national bus service since 2015, following a national bus reform in 2011, which saw a modernisation of buses, routes and service (Bajada & Titheridge, 2016). Since then, they have introduced an app with route and real-time information, improved customer care, and introduced smartcard payments with the *tallinja* card and Wi-Fi on buses (T. Bajada, Transport Policy, UM, personal communication, 17/02/2020). While public transport patronage had been in decline in the period 1990 – 2010, as of 2015 public transport users exceeded 1990 levels (TM, 2016b). However, the National Transport Strategy document notes that it is unlikely that this is due to modal shift from car use, but rather indicative of more mobility overall. Mobility is changing around the world, as are people’s expectations of the offering, so Malta Public Transport is also including other mobility solutions, for example through offering a demand responsive transport service, *TD Plus,* as well as a bicycle and moto-scooter sharing service. A BRT line is being planned to be able to provide a more reliable and faster service with higher capacity, but the implementation depends on political will to get accepted as a mass transit solution (K. Pulé, Malta Public Transport, personal communication, 21/02/2020). The natural harbours around Valletta, at the heart of the conurbation, present both a barrier for the road network and an opportunity for sea transport. Harbour ferry connections between Valletta and Sliema on the one side and the Three Cities on the other were introduced in 2013, operated by *Valletta Ferry Services,* with increasing patronage ever since (TM, 2016a). On the Three Cities side, the ferry landing site is connected to the Valletta city centre through a public elevator, but on the Sliema side, a steep hill presents a barrier for the connection with the city centre. While the ferry service is not part of the national public transport service operated by Malta Public Transport, payment options have been integrated so ferry users can also pay with the *tallinja* card and new bus routes have been introduced to connect the ferry landing sites (K. Pulé, Malta Public Transport, personal communication, 21/02/2020).

The majority of on-street parking provision is free and unrestricted. There are some paid private off-street car parking facilities and residential parking schemes in certain localities (TM, 2016a). In Valletta, a fixed annual charge for access and parking in the city was transformed into a road user charge in 2007 through the Controlled Vehicular Access (CVA) scheme. As part of the same transport strategy, a P&R was created in Floriana on the access road to Valletta, with 750 parking places and a shuttle service to the capital, and the main shopping streets of Valletta were pedestrianised (Attard & Ison, 2015; TM, 2016b). While the CVA system contributed to a modal shift in trips to and from Valletta (Attard &

Ison, 2015), it has not been revised since 2007. To be more impactful, the terms and payment conditions would need to be revised and extended to a wider area, or to other urban cores (T. Bajada, Transport Policy, UM, personal communication, 17/02/2020). Two other P&R areas were introduced in recent years on the periphery of the conurbation: one in Marsa, towards the south and one in Pembroke, on the northern edge of the urban area. The rates of utilisation of the latter two P&Rs are low however (TM, 2016b). During the past years, a number of shared mobility services, bicycle, car and scooter (moto) sharing, have been introduced in Malta, including bicycle sharing by Nextbike Malta, car sharing by *GoTo*, moto-scooter sharing by *ioscoot, GoTo* and *Whizascoot*, electric kickscooter sharing by *Bolt* and an electric bicycle sharing service at certain locations in Valletta, by Malta Public Transport, with payment integrated through the same smartcard, as well as several ride-sharing and ride pooling operators, such as *Bolt* and *Cool* (Maas & Attard, 2020; Maas, Attard & Bugeja, 2021). In 2019 the Mobility-as-a-Service (MaaS) platform *Meep* launched their app in Malta, which provides a multimodal journey planner, incorporating public transport options as well as selected shared mobility providers, and an integrated payment platform (K. Pulé, Malta Public Transport, personal communication, 21/02/2020). To promote the uptake of electric vehicles, for the past few years, TM has offered grants on the purchase of electric vehicles, including electric bicycles and cargo-bicycles through their 'Transport Schemes'[3], for individuals and for up to 20 bicycles for companies. The Ministry of Finance also offers a VAT rebate[4].

The first cycling paths were introduced in Malta in the mid-2000s, primarily outside the urban area, where there was some space to add them in road reconstruction projects; either as a painted lane on the road or as a shared path with pedestrians. At that time, they were more of an afterthought, whereas in more recent years cycling infrastructure has been included at the design stage for the first time (D. Sutton, Transport Malta, personal communication, 31/01/2020). However, the cycle paths and lanes that exist are fragmented and do not penetrate the main urban area (TM, 2016a). Many recent infrastructural projects have included some kind of cycling infrastructure, but these remain fragmented and inconsistent in style, from sharrows and 'share the road signs' to painted cycling lanes on the road and roundabouts, bridges and lifts to cross large junctions and arterial roads, as well as separated cycling paths in certain locations (Farrugia & Maas, 2020; TM, 2018). Figure 5.12 presents a map of the road network in Malta, with prominent locations referred to in the text and the location of the existing cycling infrastructure. Figure 5.13 and Figure 5.14 highlight some positive and negative examples of streetscapes in Malta.

[3] https://www.transport.gov.mt/news/transport-schemes-2019-2772
[4] https://www.servizz.gov.mt/en/Pages/Tax-and-Finance/Taxation/Tax/WEB439/default.aspx

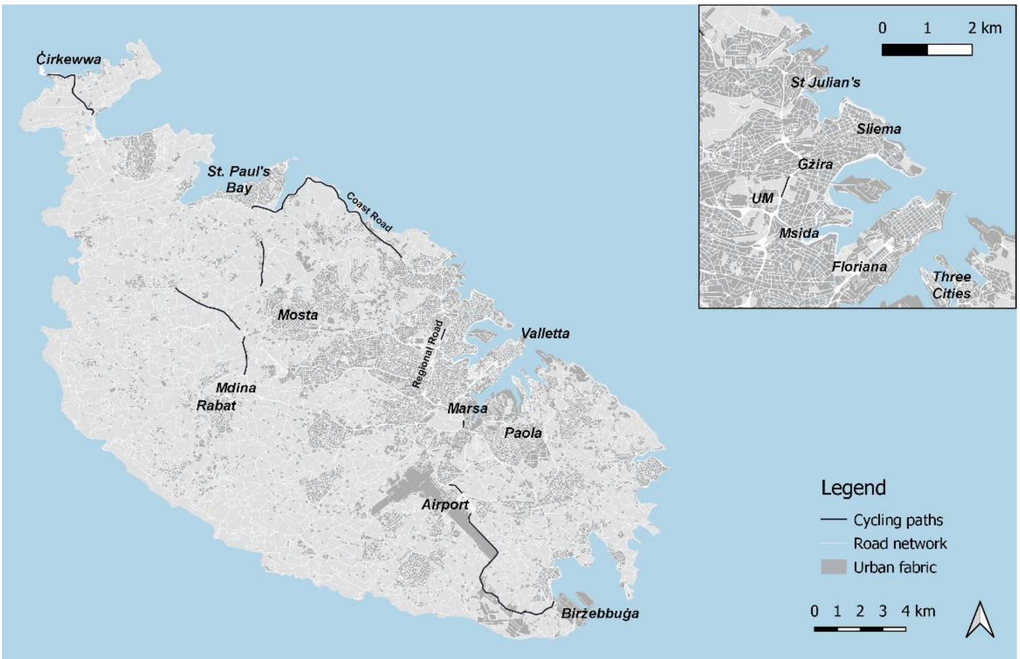


Figure 5.12: Malta's road network and prominent locations

Figure 5.13: Positive examples of streetscapes in Malta: dense urban fabric suitable for traffic calmed and shared streets, pedestrianisation in the main street of Valletta, a segregated cycling and foot path (left photo TM, 2018; middle and right photos by author)

Figure 5.14: Negative examples of streetscapes in Malta: unconnected cycling path next to arterial road, painted green cycling lanes on roundabout perimeter, illegal parking on cycling path (left and right photos by Paolo Cassar Manghi; middle photo: Farrugia & Maas, 2020)

Mobility practices

There is high car dependence in Malta, as evidenced by the high rate of motorisation and modal share of private car use. There is a strong car mentality, where the car is seen as an absolute necessity in order to achieve daily needs, such as going to work and running errands (M. Farrugia, *Rota*, personal communication, 08/01/2020). However, traffic congestion, as well as poor compliance with road traffic rules, such as illegal or double parking hampering free movement, on or near the strategic road network are frequently observed occurrences, and diminish the convenience of the private car (TM, 2016a). The main challenge for transport planning is to reduce car dependency and make alternative modes of transport more convenient and attractive (M. Farrugia, *Rota*, personal communication, 08/01/2020; S. Scheiber, Urban Planning, UM, personal communication, 16/01/2020). To promote sustainable mobility there is a need for both ‘carrots’ (incentives for sustainable transport modes) and ‘sticks’ (disincentives for private motorised vehicles). Interviewed government officials confirm that there is a need for a change in mentality, but the current approach is predominantly focused on providing ‘carrots’, not on using ‘sticks’. A representative of the national infrastructure authority stressed how road users (mainly vehicle drivers) need to understand that the road is not only for vehicles; that the road should also serve pedestrians, cyclists and other road users (F. Azzopardi, Infrastructure Malta, personal communication, 13/07/2020). The approach of the transport ministry is to focus on a voluntary culture change, rather than on placing limitations on private car use. Just after being elected, the current transport minister insisted the government would not disincentivise driving, e.g. by placing restrictions on registered cars or by introducing paid parking (Pace, 2017). It is clear that before politicians are willing to take ‘unpopular’ decisions such as the introduction of congestion charges or the removal of parking spaces, they want to be certain that there is public support for such measures. To this end, the general public needs to understand and speak up about the need for improvements to their health, the public realm and a better quality of life (D. Sutton, Transport Malta, personal communication, 31/01/2020). If on-street parking would be reduced or shifted elsewhere (underground or communal parking), this could create the required space for pedestrian infrastructure, cycling infrastructure and green infrastructure (S. Scheiber, Urban Planning, UM, personal communication, 16/01/2020).

Cycling within the built up areas is considered by many to be dangerous, given the congested streets, lack of safe crossings at junctions and the possibility of 'dooring' from parked vehicles (TM, 2016a). The Local Plan for the most densely populated urban area in Malta (the North Harbours Local Plan) highlights that the promotion of cycling is "inhibited by the physical condition of many roads, the number of motor vehicles, competing uses and driver behaviour" (PA, 2006). Lack of (perceived) road safety is the major barrier for cycling, as evidenced by the results from surveys with the local population (Maas & Attard, 2020). There is also a large percentage of the population who do not know how to cycle. From results of the same study, based on three surveys with representative samples of the Maltese population, 34-49% of respondents indicated not being able to cycle (Maas & Attard, 2020). With 58% of the adult population classified as overweight or obese, there is a need for more active lifestyles (Superintendence of Public Health, 2012). However, lack of fitness is also a barrier for people to take up cycling; "many locals can't even imagine walking for 10 minutes, let alone take up cycling as a mode of transport" (S. Scheiber, Urban Planning, UM, personal communication, 16/01/2020). There are some efforts to teach cycling, such as Nextbike's *Bikeability* course, local cycling groups and shops who offer classes, as well as cycling skills activities organised by TM as part of European Mobility Week (M. Farrugia, *Rota*, personal communication, 08/01/2020). There is a need for teaching such skills in schools, as part of a wider road education programme, where children and youths learn how to behave on the road, what traffic signs mean, and how to safely use the road, e.g. on foot, on a bicycle or using a kickscooter. These modes of transport could give youths more independence and teach them life skills, but in general parents are too afraid to let children or youths take part in traffic independently (T. Bajada, Transport Policy, UM, personal communication, 17/02/2020). Malta's Road Safety Strategy also identified that social norms, including peer pressure and youth rebellion, can influence irresponsible or unsafe behaviour of youths on the road as drivers, as passengers, as cyclists or as pedestrians (MTI, 2014). Better education on the rules of the road could aid in addressing this.

Most interviewees commented that in recent years, there has been an increase in cyclists on the road. Part of this increase is due to non-Maltese residents who cycle, including both expats from countries with a stronger cycling culture as well as migrants for whom it is an affordable means of transport. There is however a paucity of recent data on the modal share of cycling, so quantitative evidence of an increase in cycling is lacking. The latest National Household Travel Survey, which took place in 2010, has a follow-up survey planned to take place shortly (D. Sutton, Transport Malta, personal communication, 31/01/2020). Other interviewees confirm that the observed growth in the use of shared mobility services (such as shared bicycles) and an increased uptake of public transport can be partly explained by the increased segment of foreign residents, who generally have a more multimodal mindset. It is still a challenge to get the local resident population to get used to the concepts of multimodality and intermodality. However, the modelled multimodal transport behaviour is slowly also influencing the local population, who are becoming more willing to try out using the bus, cycling and new mobility services (K. Pulé, Malta Public Transport, personal communication, 21/02/2020). As a result, some change in mentality appears to be occurring. Although the general mentality is still pro-car, there has been a surge in the reference to cycling in political discourse. As cycling is becoming a buzzword, it is becoming more normal for people to hear about it, and to think of it as a serious mode of transport (M. Farrugia, *Rota*, personal communication, 08/01/2020). As part of the CIVITAS DESTINATIONS project, Transport Malta developed campaigns to promote road safety, with guidelines for safe cycling for cyclists and drivers, as well as a campaign to promote bicycle and car sharing. While creating promotional campaigns and providing shared bicycles can be part of measures to encourage cycling, there is also the need to address road safety concerns and provide safe and connected infrastructure. Additionally, there is a need for disincentives for the use of the private car, through taxation and parking management, to reclaim public space for active modes of transport (S. Scheiber, Urban Planning, UoM, personal communication, 16/01/2020).

5.3.2 Relevant stakeholders, legislation and policies in the mobility sector

Stakeholders

Stakeholders at different levels are involved in the planning, promotion and management of cycling in Malta. At the national government level, there is the Ministry for Transport, Infrastructure and Capital Projects and the Ministry for Environment, Climate Change and Planning, as well as the main government authorities responsible for spatial planning, transport and infrastructure: Transport Malta (TM), the transport regulator, the Planning Authority (PA), the planning regulator, and Infrastructure Malta (IM), the body implementing infrastructure and road works on a national level. Within TM, the Sustainable Mobility Unit and the Integrated Transport Strategy Directorate are the bodies working predominantly on active modes. The PA has a dedicated Transport Planning unit, to address cross-cutting issues between urban and transport planning, such as Traffic Impact Assessments, Road Safety audits and Green Travel Plans (A. Falloon, Transport Planning unit, PA, personal communication, 18/02/2020). The PA's Planning Board is the highest decision-making body at the authority. At the local level, there are the Local Councils, responsible for local road works and improvements, and the Regions, promoting collaboration and communication between neighbouring councils as part of 6 regions on the Maltese Islands. The Local Councils Association (LCA) is the national body representing the 68 Local Councils, promoting their interests and coordinating collaboration. There is a national Commission for the Rights of Persons with a Disability (CRPD) who aim to work towards a more inclusive society, and in infrastructural projects provide feedback on the accessibility for persons with limited mobility.

Malta Public Transport is the primary public transport operator, responsible for the national bus network. Inner harbour ferry services are provided by Valletta Ferry Services. There are several companies offering shared mobility services, including bicycle, electric kickscooter, moto-scooter and car-sharing, as well as ride-sharing and ride pooling. There are a number of non-governmental entities and organisations that are active in the field of cycling and active mobility, such as *Rota* (the Maltese word for bicycle/wheel), the national bicycle advocacy group, also a member of the European Cycling Federation, Project Aegle Foundation, a non-profit promoting sustainable mobility, and Walking Malta, a community organisation advocating for pedestrian needs and collecting data about the walkable environment. There are also other environmental and social NGOs that have been vocal about transport and infrastructure projects, promoting sustainable mobility concepts and criticising virgin land uptake, tree cutting and social equity issues. There are several local cycling groups, promoting sports cycling and competitions, such as the Malta Cycling Federation, the Mosta Cycling Club and the Gozo Cycling Club. Further stakeholders are local bike-based businesses, such as cycling shops and bicycle rental companies. On the other hand, there are the car importers and fuel stations, which are a very strong lobby with vested interests in the car-based transport system (K. Pulé, Malta Public Transport, personal communication, 21/02/2020).

Both governmental and non-governmental stakeholders stress the need for better cooperation on the topic of transport planning and the promotion of cycling and cycling infrastructure. The Transport Planning unit, currently under the auspices of the Planning Authority, in the past used to be part of Transport Malta. There is a need for integration and communication, as transport planning has to do with both urban and spatial planning (the remit of the Planning Authority) and policy and regulation of transport (the remit of Transport Malta). The recent creation of another authority, Infrastructure Malta, has complicated matters, with a lack of real discussion on the design of new roads they are implementing (A. Falloon, Transport Planning unit, PA, personal communication, 18/02/2020). From the start of the creation of the bicycle advocacy group *Rota*, there has been animosity between the NGO and government authorities implementing transport projects, with the NGO being accused of being too negative and critical. The representative of *Rota* indicates that one of their targets is to repair this relationship, to work together and collaborate, but that they need the freedom to criticise and disagree on the content of plans, as that is their role as an organisation advocating for cyclists (M. Farrugia, *Rota*, personal communication, 08/01/2020). They further stress that there is a need for proper stakeholder consultation; that relevant organisations and bodies are informed and consulted as key stakeholders and can have a say and propose alternatives when an infrastructural project is being proposed (M. Farrugia, *Rota*, personal communication, 08/01/2020). A representative from Infrastructure Malta indicates they feel there is too much negative feedback from groups such as *Rota*, and suggests there is a need to speak with a common voice, to show they are working together towards the same goal (F. Azzopardi, Infrastructure Malta, personal communication, 13/07/2020). In order to facilitate communication and cooperation, the draft National Cycling Strategy proposed the creation of a stakeholder forum 'Cycling Malta' to promote cycling and oversee the implementation of the National Cycling Strategy and Action Plan (TM, 2018). This proposal is echoed by the bicycle advocacy group, which suggests the creation of a commission that would protect the rights of cyclists and scrutinise new infrastructural proposals and projects (M. Farrugia, *Rota*, personal communication, 08/01/2020). However, in the absence of the finalised National Cycling Strategy, the formation of this stakeholder forum has not (yet) materialised.

There are further needs and opportunities related to collaboration. A university lecturer stressed the lack of communication and coordination between academia and government authorities, and noted that if that is improved, evidence that is produced in academic research can be used and implemented in actual projects (T. Bajada, Transport Policy, UoM, personal communication, 17/02/2020). Collaboration between transport operators is a relatively new phenomenon in Malta. The public transport operator explained how in creating the Mobility-as-a-Service app *Meep,* Malta Public Transport sought collaboration with other transport providers, such as shared mobility providers and the inner harbour ferry service. Even though these are technically competitors, Malta Public Transport took the decision to collaborate rather than to compete; an approach that was taken to serve the user and to promote multimodal mobility (K. Pulé, Malta Public Transport, personal communication, 21/02/2020).

Legislative and policy framework for mobility

Cycling and mobility are regulated by a number of laws and regulations in Malta, most notably the Low-Powered Vehicles and Pedal Cycles Regulations, detailing the traffic rules for cycling, and the main planning documents, the Strategic Plan for Environment and Development (formerly the Structure Plan) and the Local Plans, which contain the framework for urban and spatial planning. An overview of relevant laws, regulations and policies, including their general contents and specific clauses pertaining to cycling, can be found in Table 5.3.

Promoting a modal shift towards more sustainable modes of transport, including public transport, active and shared mobility options, is one of the guiding principles of the National Transport Master Plan 2025 and the National Transport Strategy 2050 (TM, 2016a; TM, 2016b). The National Transport Strategy recognised that the design of new roads following the 'predict and provide' approach is expensive, short-sighted and not effective in tackling peak demand and car dependence (TM, 2016b). The strategy document highlights that cycling, if it was seriously developed as a mode of transport, could offer a "faster, more environmentally-friendly alternative to the car for many commuters". The strategy recognises how active mobility is a key component of inter-modal travel, and the need for safe infrastructure to connect to public transport services (buses and ferries). Safer infrastructure can also encourage active modes as a mode of transport from an early age, changing the mobility culture and creating sustainable travel habits (TM, 2016b). As part of a set of measures proposed for the short term in the Transport Master Plan, Transport Malta proposed the creation of a National Cycling Policy, the creation of pilot cycling corridors, and the implementation of a national bicycle sharing scheme (TM, 2016a).

While these documents are generally applauded for their accurate identification of issues and solutions for the transport system and a move towards sustainable mobility, several interviewees expressed their concern that these documents were just prepared as a requirement for EU accession and are not actually guiding transport policy and the implementation of new infrastructural projects. Even though Malta is not meeting its GHG emissions reductions targets as part of the EU Climate and Energy Package, and road transport is one of the major contributors to national GHG emissions (MRA, 2019), the EU is still funding new road infrastructure in Malta. These days, there are requirements to show that this investment promotes sustainable mobility, by including infrastructure for public transport, cycling and pedestrians (D. Sutton, Transport Malta, personal communication, 31/01/2020). However, several interviewees comment that this is seen more as a check-box, and without scrutiny or on-the-ground audits by the EU, any type of cycling infrastructure can be included to satisfy the requirement; this doesn't mean it is part of a safe and connected network.

Table 5.3: Legislative and policy framework - Sustainable mobility and cycling in Malta

Law/regulation	Year	Contents
Structure Plan	1992	• *Superseded by Strategic Plan for Environment and Development*
Grand Harbour Local Plan	2002	• Urban planning guidelines and policies for the Grand Harbour area. • Transportation section proposes that efforts should be made to promote alternative forms of transport: public transport (bus, ferry), taxis and cycling.
Low-Powered Vehicles And Pedal Cycles Regulations	2004	• Anyone on a bicycle needs to observe and abide by all traffic regulations. • Cycling is not allowed on promenades, pedestrian subways, footpaths and in tunnels (except for children under 12 and along footpaths in tunnels, at max. 6 km/h). • Cyclists should keep to the left of the road, apart from at intersections and when overtaking. • Bicycles need to be fitted with a bell, front and rear lights and a rear reflector. • It is mandatory to wear a helmet on any motor assisted bicycle, including pedelecs, with an output of more than 250W.
North Harbours Local Plan	2006	• Indicates there is scope to encourage walking, cycling and ferries as an alternative to the private car and to maintain accessibility to the main town centres.
Strategic Plan for Environment and Development (SPED)	2015	• Aims to facilitate modal shift through the provision of an integrated transport network and a parking framework.
Micromobility Regulations	2019	• Rules for the registration, use and circulation of micro-mobility modes, such as e-kickscooters. • A maximum speed of 10km/h when driving a micro-mobility device on a cycle path, footpath or shared path.
Policy/guidance	**Year**	**Contents**
Valletta and Floriana: A Strategy to Improve Access	2006	• Project proposals to address transport challenges in Valletta and Floriana: a P&R in Floriana, CVA road user charging in Valletta, pedestrianisation in Valletta and alternative transport solutions such as ferries and electric minicabs (Attard & Ison, 2010).
The Malta National Electromobility Action Plan	2013	• Establishes the electrification of transport as one of the main pillars of transport policy and as a contribution to achieving Malta's energy and environment targets. • Targets: 5,000 EVs on the road by 2020; 500 public charging points by 2020; 10% of transport fuels from renewable sources by 2020; total phasing out of ICE vehicles by 2050. • No specific targets or aims for electric bicycles.
Road Safety Strategy Malta 2014-2024	2014	• Action plan to reduce traffic injuries and fatalities. • Objectives for vulnerable road users: to reduce injury and fatalities; to ensure safe design for pedestrians and cyclists is included in new transport schemes, particularly at junctions; to provide a safe road environment for pedestrians and cyclists of all ages; to change the mentality of vehicle drivers to vulnerable road users; to promote safe routes to school; […]
National Transport Strategy 2050	2016	• Vision and strategic goals for transport strategy for Malta: provide a sustainable transport system which is efficient, inclusive, safe, integrated and reliable for people and freight […]. • Aims to work towards making urban areas conducive for active mobility, public transport use and inter-modal travel to reduce car dependency and its negative effects.

Policy/guidance (*continued*)	Year	Contents
National Transport Master Plan 2025	2016	• Sets out the framework and the overall priorities which will guide transport investment in air, sea and land transport until 2025, as part of an ex-ante conditionality for accessing EU funding. • Aims to deliver a safer, secure, more sustainable and healthier transport system over the short-medium term. • Specific measures proposed to promote and plan for cycling include: the creation of a National Cycling Policy, the creation of pilot cycling corridors, implementation of a national bicycle sharing scheme.
Draft A Strategy for Valletta	2016	• Aims to optimise public transport access (bus and ferries) and improve management of vehicular access and parking in the city. • Aims to incentivise new eco-friendly transportation modes, such as bicycle sharing, car sharing and carpooling. • *To date not published as a final document.*
Draft National Cycling Strategy	2018	• Vision: cycling to become accepted as a part of everyday life and a highly-valued transportation mode. • Targets: Double the number of people who choose cycling as a mode of transport for trips less than 5km, by 2050 as compared to 2010; Reduce injuries involving cyclists by 50% by 2050. • Proposes the creation of Cycling Malta, a stakeholder platform, and the development of Cycling Design Standards and Guidelines. • *To date not published as a final document.*
Guidelines for Bicycle/Pedelec Sharing System	2018	• Guidelines and procedures for the application for a bicycle sharing system, operating license, minimum requirements of service and placement rules. Systems already in place are informed of the need to regularise their operations accordingly. • Only docking-station based systems are allowed.
Micromobility in the Maltese Transport System	2020	• E-kickscooters have to be insured, registered and licensed. • Only persons with a driving license may ride an e-kickscooter. • E-kickscooter users need to have a head and tail lamp, and need to wear a high visibility vest when it is dark. A helmet is recommended. • The maximum speeds are 10km/h in pedestrian zones and 20km/h on the road. The use of arterial and distributor roads and tunnels is not allowed. Other roads and the safe cycling network may be used.
Slow Streets: Rethink mobility	2020	• Action plan to promote safe, sustainable, healthy and efficient mobility, focused on urban cores and town centres

As early as the 1990s, when the Structure Plan was drawn up (the predecessor to the SPED), the unsustainable growth of private vehicles was already identified as an issue. Unfortunately, as the recommendations of the plan were not heeded (investment in mass public transport, active mobility); in fact, the observed growth of car ownership has exceeded the forecast maximum growth (S. Scheiber, Urban Planning, UoM, personal communication, 16/01/2020). The Structure Plan contained a major section on Transport, addressing topics such as planned new roads, traffic management schemes and public transport infrastructure. While cycling was included in the Structure Plan and the more specific Local Plans, there was a push to promote cycling for leisure and tourism, while efforts to include cycling as a mode of transport were sidelined (A. Falloon, Transport Planning unit, PA, personal communication, 18/02/2020). Up until 2003, there was no legal or policy framework for cycling, which created problems for the regulators and enforcement. To address this, the Low-Powered Vehicles and Pedal Cycles Regulations were introduced (D. Sutton, Transport Malta, personal communication, 31/01/2020). While the SPED, the replacement of the Structure Plan, was marketed as holistic, it comes nowhere near the former document in terms of scope and depth of the analysis and proposed measures (A. Falloon, Transport Planning unit, PA, personal communication, 18/02/2020). In reality it is just a document that allows for a lot of loopholes. The original Structure Plan had very specific policies and objectives, whereas the SPED directs to other policies and does not contain specific objectives, leaving space for mis-interpretation (T. Bajada, Transport Policy, UoM, personal communication, 17/02/2020). In general, the discretionary planning system in place in Malta, based on the British system, allows for negotiation and interpretation of the policies, and more importantly, political influence in the decisions of the Planning Board (A. Falloon, Transport Planning unit, PA, personal communication, 18/02/2020).

While the National Transport Strategy, the Transport Master Plan and the draft National Cycling Strategy (TM, 2018) identify the need for standards and guidelines for designing urban streets, home zones and cycling infrastructure in the Maltese context, to date, no publicly available design guidelines and standards have been published. The National Transport Strategy underlines how important it is that "regulations on cycling facilities design and driving rules are developed prior to the implementation and use of such facilities" (TM, 2016b) and that these should consider different typologies of cyclists, whether or not space will be shared, the safety requirements, continuity of the network and speed limits. Connectivity and consistency have been recognised as key elements of successful cycling infrastructure. However, as the Ministry for Transport and Infrastructure recognises themselves in the Road Safety Strategy, in Malta there is a "tendency for the provision of on-road facilities for pedestrians and cyclists to be piecemeal with the result that there is no continuous network of safe and convenient routes for travel" (MTI, 2014). A representative from Infrastructure Malta explains that this is a chicken-and-egg situation, where they can either start building sections where works are ongoing, or opt to do nothing; it is not possible to create a complete cycling network in all of Malta from today to tomorrow (F. Azzopardi, Infrastructure Malta, personal communication, 13/07/2020). However, several interviewees express their belief that standards and an overall plan to connect the fragmented sections should have been developed first, and that the lack of standards and guidelines in the implementation of cycling infrastructure is resulting in a lack of consistency, connectivity and safety, e.g.:

- "Designs suitable for low traffic roads (e.g. sharrows, in international standards advised for streets with up to 30km/h speeds) are implemented on main roads with speeds of 60km/h" (M. Farrugia, *Rota*, personal communication, 08/01/2020);
- "There are signs on the road that say 'end of cycle path' and 'cyclists re-join the carriageway', as if a segregated cycling path is only required in certain parts of the same road" (S. Scheiber, Urban Planning, UoM, personal communication, 16/01/2020);
- "The green cycle lanes on the roundabouts are not safe for cyclists, as it is not clear who has to give way and whether a driver should stop for the cycle lane or in the middle before exiting the roundabout" (T. Bajada, Transport Policy, UoM, personal communication, 17/02/2020).

Malta's Road Safety Strategy also recognises that on roads with high volumes of traffic and/or high speeds (defined as >60km/h) where the potential of conflict is likely, it is considered safer for cyclists to be provided with separate routes" (MTI, 2014). Malta is one of the few European countries, including Cyprus as well, where the system of 'presumed liability' is not adopted. This legal provision assumes drivers to be at fault in case of an accident with a vulnerable road user, unless proven otherwise, and is considered to be an integral part of encouraging safer roads for cyclists (K. Pulé, Malta Public Transport, personal communication, 21/02/2020).

The draft National Cycling Strategy identifies the limited available road space as a major challenge in the Maltese context (TM, 2018). On the other hand, land use and transport plans also identify that the dense urban form can provide opportunities for walking and cycling (PA, 2006), as distances are short, and improvement of the quality of the pedestrian and cycling facilities within and around town centres can ensure daily needs are accessible within walking or cycling distance (TM, 2016a; TM, 2016b). The Slow Streets concept, developed by the Local Council's Association, puts forward the idea that, in town centres where the urban fabric is fine-grained and well connected, there can be shared use of urban streets, with priority for people (pedestrians, cyclists) over motorised traffic (LCA, 2020). This requires reducing the speed limits and educating the drivers, because of issues with speeding and illegal parking. Where sharing the road is not possible due to vehicle speeds or volumes, there is a need for dedicated cycling infrastructure, which can be created by removing on-street parking (S. Scheiber, Urban Planning, UoM, personal communication, 16/01/2020).

5.4 Comparative analysis

The three case study cities share similarities in their urban form, in terms of their historic centres with narrow streets, the port-city relations in their metropolitan area, and pressures on their mobility system from tourism. However, even though the population sizes of the cities are reasonably comparable, from around 200,000 in Limassol to just under 400,000 in Las Palmas de Gran Canaria, there is a stronger difference in population density, with a lower population density and more dispersed and sprawling urban form in Limassol, compared to higher population density in Las Palmas de Gran Canaria, including some neighbourhoods with extremely high population density as a result of residential tower blocks, and Malta, where the harbour regions around Valletta, with their dense urban form, have the highest population density of the conurbation and the country.

The weather and climate characteristics of the three cities, while all in Southern Europe, are somewhat different. Limassol and Malta show similar weather patterns: warm and dry summers and mild, wet winters, with slightly higher average temperatures in the former. In Las Palmas de Gran Canaria temperatures are more stable throughout the year, with the island receiving less than a third of the rainfall observed in Limassol and Malta. The influence of temperature and rainfall on cycling is thus expected to be less severe in Las Palmas de Gran Canaria than in Limassol and Malta, where hot summer days can act as a deterrent, as well as rainy winter days. In terms of elevation, the city centre in Limassol is relatively flat, although it slopes upward in the suburbs to the north of the city. In Las Palmas de Gran Canaria, there is a stark difference between the predominantly flat lower city and the upper city with elevation levels over 200 and 300m. This is also evident from the development of their cycling network and bicycle sharing system, which thus far focus on the lower city. In Malta, the urban area is located on the relatively low-lying side of the island, but there are steep inclines on valley sides when crossing from one locality to another. There are several solutions that can address the challenges brought on by weather and elevation factors, such as electric bicycles (including financial support for their purchase), physical interventions in the urban fabric, such as elevators, escalators or bridges to overcome elevation differences, shower facilities at destinations, as well as the use of green infrastructure to shade and cool active transport infrastructure.

While all three case studies cities have a relatively high rate of motorisation and high car modal share, the modal share is especially high in Limassol, with almost all trips made by private car. Although less extreme in Las Palmas de Gran Canaria, with a higher share of public transport and pedestrian movements, the city is still the third most congested city in Spain. In Limassol and Malta, car parking is largely unrestricted and unmanaged. In Las Palmas de Gran Canaria, a new parking system has been implemented in recent years, including the provision of residential and timed parking, and a dedicated app to reserve and pay for parking. Revenues from parking management are used to subsidise the bicycle sharing system, while on-street parking was removed in certain locations to create space for cycling infrastructure, while offering residential parking nearby. The relationship between public transport and cycling can be strengthened in all cities. The use of public transport, to cover larger distances, and cycling, to complete the journeys, is a powerful combination. The investment in the upgrading of the public transport systems, happening in all three cities, provides opportunities for the physical and financial integration of different mobility services and offering multimodal mobility.

The lack of safety for cyclists, on the road and on junctions, is the major barrier for cycling. Although all three cities already had fragmented sections of cycling paths and lanes, to promote cycling as a mode of transport, there is a need for cycling infrastructure to be connected, so that people can move between different origins and destinations. In Las Palmas de Gran Canaria, this is being addressed through the creation of a Bicycle Master Plan and the rollout of cycling infrastructure that will create a safe cycling network in the lower city. However, in both Limassol and Malta, the lack of design standards and an overall plan for the development of their cycling infrastructure has led to some piecemeal implementation of cycling paths and lanes. In certain cases, these are sub-standard, when compared to the overview of cycling standards and guidelines from different European countries, as presented in Annex A. Furthermore, Cyprus and Malta are both among the few European countries that have not adopted the system of 'presumed liability', which provides strong legal protection for cyclists and promotes careful driving by other road users. While the creation of a safe, continuous and consistent cycling network is considered one of the key factors to promote cycling, it is not enough on its own. There is a clear need to combine this with the provision of ancillary infrastructure (provision of bicycles, bicycle parking, repair stations, lockers, showers) as well as promotional campaigns to influence social norms around cycling (Kroesen et al., 2017; Pucher et al., 2010). Managing this transition is difficult for stakeholders, as they receive criticism for allocating space to dedicated cycling infrastructure when the number of cyclists is seen as very low, while they cannot seriously promote cycling until there is a safe cycling network.

The need for a change in mentality to cycling is evident in all three cities. Cycling is often still seen as something from the past, as something for poor people, or only as a sport or leisure activity (Aldred & Jungnickel, 2014). There is a clear segment of the population that is still car-oriented, and the strong industry and commercial interests behind the car-oriented transport system (car importers, fuel importers, fuel stations, contractors) and their political influence became evident from discussions with stakeholders in all three cities. However, there is also some evidence that attitudes are changing, whether through the influence of visiting tourists or foreign residents who bring with them a different mobility culture, or through younger generations less interested in material ownership and more concerned about environmental issues. To promote cycling for children and youths, who can benefit from more active and independent modes of transport and the potential creation of lifelong active transport habits, there is a clear need for a safer road environment, through infrastructure, education for all road users, enforcement of illegal and irresponsible driving behaviour, and targeted interventions, such as 'safe routes to school'.

The extent to which government entities and local authorities 'walk the talk' varies between the three cities. Policy documents may contain aims and visions of the promotion of safe, sustainable and active modes of transport; whether these are actually prioritised and implemented according to accepted standards on the ground is another matter. Decisions to invest in different forms of mobility, particularly concerning the reallocation of road space are politically sensitive. It is only in Las Palmas de Gran Canaria where a real commitment to a shift to sustainable mobility is evident, from their investment in a BRT, the creation of a parking management system, investment in a cycling network and prioritising vulnerable road users through traffic calming in 30km/h zones and the creation of segregated cycling infrastructure instead of on-street parking. A concerted effort, based on a plan, is in place, although it is still limited to the lower part of the city thus far, when a large share of the city's residents lives in the upper city. In Limassol, while the SUMP provides a detailed analysis of the mobility situation and proposals for sustainable mobility measures, not much has happened since the finalisation of the report, while new road projects and high-rise developments further encouraging private car use are being proposed and built. In Malta, while the Transport Strategy and Master Plan contain a strong vision for sustainable mobility, the major infrastructural works of the past few years have still been car-oriented, and where they do include cycling infrastructure, this is not necessarily up to standard or part of an integrated network. The discretionary planning system, inherited from former British rule in both Cyprus and Malta, allows for negotiation and discretion of planning decisions. Local Plans, while legally binding, are generally interpreted as guidelines with a certain degree of flexibility, making it difficult to set strict standards.

5.5 Conclusion

In this concluding section, the results found through the analyses described in this chapter are summarised. This chapter focused on the spatial and socio-cultural context of the three case study cities, as well as relevant legislation, policies and stakeholders in the field of mobility and cycling.

While sharing similarities in their urban form, weather and elevation characteristics, each city presents its own challenges and idiosyncrasies. To promote cycling, there is a need to address the major barrier to cycling – lack of road safety – through dedicated cycling infrastructure and traffic calming, together with investment in ancillary facilities, educational and promotional campaigns and integration with other modes of transport. While sustainable mobility is presented as the guiding framework for future investment and development in the transport system in all three cities in relevant policy documents, the actual implementation of necessary infrastructure and changes to the road environment is done to varying degrees. The need for a holistic plan for a cycling network, including implementation and monitoring frameworks, and standards and guidelines for cycling infrastructure is evident.

In the following chapter, *Chapter 6*, the three BSS being investigated in this research are introduced, and the *"who"*, *"why"*, *"where"*, *"when"* and *"how much"* of BSS use is analysed and described. *Chapter 7* and *Chapter 8* then investigate the associations between BSS use and individual and social environment factors, and physical environment factors, respectively. The results presented in this chapter and the following chapters will be discussed in relation to findings from the literature in *Chapter 9*.

6. Use of BSS in the case studies

This chapter addresses the third research question (RQ3) of this study: *How is the BSS used, when, where, by whom and for what purposes?* The chapter starts with an introduction of the three BSS being investigated in this research; *Nextbike Cyprus* in Limassol, *Sítycleta* in Las Palmas de Gran Canaria, and *Nextbike Malta* in Malta. The *"who"*, *"why"*, *"where"*, *"when"* and *"how much"* of BSS use is then analysed, through descriptive statistics of the results from the BSS user survey and the BSS trip data. A comparative analysis of the BSS use is also included, addressing research question six (RQ6): *How do BSS use and influencing factors in the case study cities compare?* The positioning of the active travel behaviour addressed in this research, BSS use, in the theoretical framework guiding this research is highlighted in Figure 6.1. As outlined in *Chapter 3*, BSS use is influenced by multiple levels of factors; from individual factors to social and physical environment factors, which are in turn shaped by the spatial and socio-cultural context of a city.

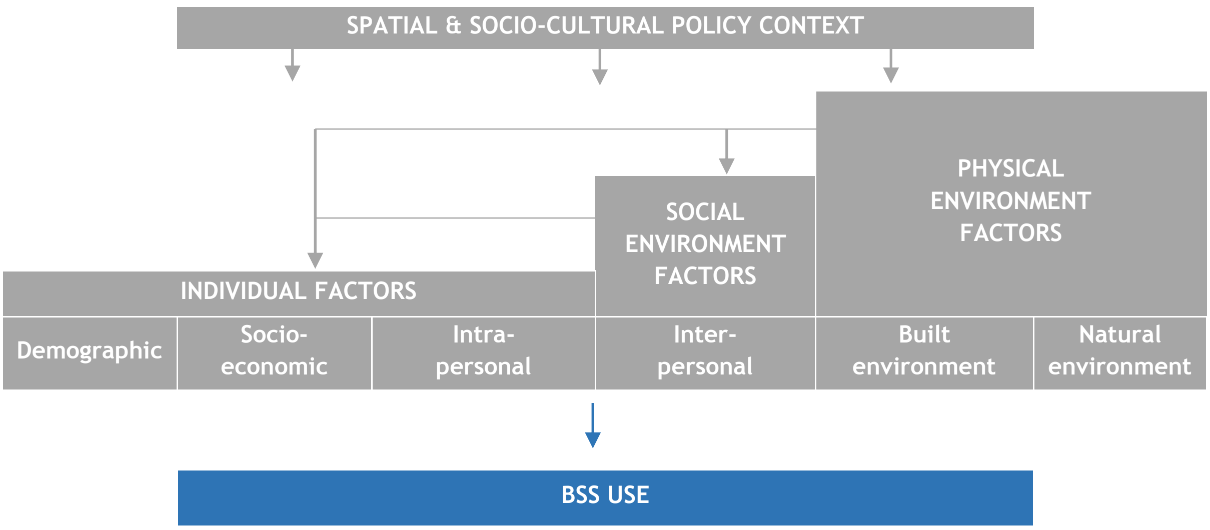


Figure 6.1: Position of BSS use in the theoretical framework

Section 6.1 introduces the BSS and describes their implementation and current operation. In section 6.2, the use of the BSS is described according to *"who"* the BSS users are, by describing their socio-economic characteristics and travel habits based on the survey results. Section 6.3 looks into the *"why"* of BSS use; the trip purposes, usage types and motivating factors (facilitators and barriers). Section 6.4 details *"where"* the BSS is used, based on the location of origins and destinations of trips made, and the road environment that BSS users indicate to use. In section 6.5, the *"when"* of BSS use is discussed, looking at the timing and temporal variation of trips. Section 6.6 describes *"how much"* BSS use there is, by looking at trip frequency and duration. In section 6.7, the results from the three case study cities are discussed in a comparative analysis, to understand differences and similarities in their BSS use. The final section, 6.8, presents the conclusions of this chapter and links to the following chapter.

6.1 BSS implementation and operation in the case studies

In this section the three BSS in the case study cities are presented in order to better understand the history and characteristics of the BSS under study. The BSS are introduced using some general characteristics: operator type and name, year of system launch and moments of system change or expansion, membership structure and cost, the number of stations and bicycles, and number of registered users (Médard de Chardon et al., 2017). The location of the stations and the land use characteristics of the city, including existing and planned cycling infrastructure, can be seen in the maps presented in Figure 1.1 and Figure 4.5. The information presented in this chapter is based on the situation of the BSS during the period researched, from April 2018 – March 2019, and is obtained from the operators' websites[5] and from information obtained through the semi-structured interviews and follow-up communications as part of the data collection process for this research *(Nextbike Cyprus:* N. Ioannou, personal communication, May 18, 2018; January 11, 2019*; Sítycleta:* C. García, personal communication, January 15, 2019, July 24, 2019; *Nextbike Malta:* A. Camilleri, personal communication, August 14, 2017; J. Gabarretta, personal communication, January 11, 2019).

6.1.1 Nextbike Cyprus in Limassol

In Limassol, there is currently one dock-based BSS in operation. *Nextbike Cyprus* introduced a BSS in Limassol in 2012, with 24,000 registered users, 170 bicycles and 25 stations in 2018. Around 85% of the users are local residents, with most of the marketing also targeting the local market. The system is available to users 24/7. The 23 active Nextbike Cyprus stations (excluding one station located outside of the city, and one temporary station, from the aforementioned 25 stations) are concentrated along the coastal promenade and the city centre. The BSS started as a very small system, with just 4 stations along the promenade bicycle path. In recent years, more stations have been added, in the city centre near the Technical University of Cyprus campus and the bus station, towards the east of the city where the main tourist areas and hotels are, at strategic locations in the west of the city (near the New Port and next to a shopping mall), as well as further inland along the main avenue around the city centre, lined with shops and restaurants. Users can opt for a subscription at €120/year paid in monthly €10 instalments, with a flat fee interval (free daily use) of 120 minutes per day, or use the pay-as-you-go rate, which is €2 for the first hour, €1 for every subsequent hour, and capped at €8/day. Bicycles can be rented and returned through a dedicated app, via telephone and at selected stations via a kiosk (see Figure 6.2a). Subscription users register their bank card for monthly payments, whereas casual users can either register and be billed on their linked bankcard or pay via a customer card that can be obtained from the operator. Using the code on the bike (manually typed or via QR code), the user obtains a four-digit lock code to open the lock. One user can rent up to four bicycles at the same time, enabling shared rides with friends or family. While docks are provided at the stations, it is possible for users to return a bicycle to a full docking station, by locking the bicycle nearby and indicating the return of the bicycle via the app, telephone or kiosk. Re-balancing is done on a near-daily basis, using a truck or by moving

[5] Nextbike Cyprus: https://www.nextbike.com.cy/el/limassol; Sítycleta: https://www.sitycleta.com; Nextbike Malta: https://www.nextbike.com.mt/en/malta

bicycles from one station to another. The operator, *Nextbike Cyprus,* is a private company. Part of the business model relies on advertising on the bicycles and rental kiosks. Advertisements include local companies such as supermarkets, restaurants, diving schools and other services. In summer months, the operator organises a free weekly cycling activity for Nextbike users and other cyclists in the city ("Get Up and Ride" on Friday evenings).

6.1.2 Sítycleta in Las Palmas de Gran Canaria

In Las Palmas de Gran Canaria, the bicycle sharing system *Sítycleta* was introduced in April 2018, following previous bicycle sharing systems LPA ByBike and BiciAmbiental. There was a desire to introduce a modern, third-generation BSS, following the previous experience with a second-generation BSS, which was available for free, but badly maintained and poorly perceived by the city's inhabitants. The *Sítycleta* dock-based system has around 375 smart bikes and 37 stations operational in the first year, all located within the lower part of the city, including the area around Las Canteras and the bus station at Santa Catalina in the north of the city, and the area around the bus station of San Telmo and main commercial streets around Triana. After the first year of operation, in March 2019, the BSS had close to 24,000 registered users and nearly 11,000 active users (SAGULPA, 2019). Registered users include everyone who signs up online or through the app, whereas active users are only those who connect their credit card to be able to use the service. In April 2019, the system expanded with the opening of the first e-bike station in the upper part of the city, and one station where e-bikes can be rented and returned in the lower part of the city, as part of a planned extension into the upper city. The dedicated e-bike stations are not considered in this research, as they were added after the period of data collection. The system is closed during the night, in an effort to minimise abuse and vandalism; it is open daily throughout the year from 07:00 until 23:00. There are weekly (€15), monthly (€20), and yearly memberships (€40 for one person, €72 for a two-person membership and €102 for a three-person membership), which give a user unlimited free 30-minute use of the system, and a pay-as-you-go rate of €1.50 for every 30 minutes. Bicycles can be rented and returned through the dedicated app, by tapping the public transport smartcard (*LPA Movilidad* card) on the bike computer, or at selected stations, via a kiosk. Smartbikes contain an on-board computer and an integrated lock, and therefore need to be properly returned to a docking station (see Figure 6.2b). For this reason, users of *Sítycleta* cannot return a bicycle to a full station; a common issue for BSS which requires attentive and adequate rebalancing to ensure that there are always bicycles available, but also space to return a bicycle. Users can only rent one bicycle per person. The BSS is operated by SAGULPA, the municipal company responsible for parking management. While the BSS is subsidised through income generated from municipal parking fees, this is supplemented with income from the subscription and user fees and increasingly, through sales of advertising space on the bicycles, for example through sponsorship by a major shopping mall. Re-balancing is done throughout the day, using constant monitoring via an online application and two vehicles for bicycle redistribution.

a) *Nextbike Cyprus bicycles docked at a station with a rental kiosk along the promenade in Limassol (photo by author)*

b) *Sítycleta smartbikes with integrated locking system (photo from www.sitycleta.com)*

c) *Bikeability bicycle skills course offered to aspiring cyclists by Nextbike Malta (photo from www.nextbike.com.mt)*

Figure 6.2: Images of BSS in Limassol, Las Palmas de Gran Canaria and Malta

6.1.3 Nextbike Malta in Malta

In Malta, *Nextbike Malta* introduced a bicycle sharing system in late 2016, with 58 stations and over 400 bicycles. It was the first BSS in Malta, although a smaller electric BSS was added the year after by the public transport operator Malta Public Transport, predominantly in the capital Valletta. The majority of the *Nextbike Malta* stations are located around the central urban area stretching from Valletta to the tourist area of St. Julian's, including stations at the University of Malta (UoM) campus in Msida and stations in the residential, commercial and employment centres around Gżira and Sliema. There are also some single and small clusters of stations in other parts of the island, for example a cluster of 4 stations around St. Paul's Bay in the north of the island, two stations at the airport, and a handful of single stations (e.g. near a hotel, marina). At the start of 2019, *Nextbike Malta* had around 11,000 registered users. Pricing is €1.50 for the first half hour, and €1 for every consecutive half hour for pay-as-you-go users, in addition to weekly (€15), monthly (€25), quarterly (€35) and yearly (€80) memberships, which include a free first half hour ride. The stations in St. Paul's Bay also offer electric bicycles in addition to standard bicycles, for rent at a higher pay-as-you-go rate (€3 for first half hour, €2 for every consecutive half hour). Registration is required to rent a bicycle, after which the bicycles can be rented through an app or by phone through an automated system. A single user can rent up to four bicycles at the same time. *Nextbike Malta* is a private company, with part of their income coming from the subscription and pay-as-you-go fees, as well as income from advertising on the bicycles and kiosks and a dedicated scheme targeting employers (*Business Bike)*, to offer a station at their offices and subscriptions to their employees. A few times a year they offer a *Bikeability* course to teach people how to cycle and gain confidence on the road (see Figure 6.2c), which is offered complementary with membership.

6.2 Who uses the BSS?

In this section, the use of the BSS is described by looking at "*who*" are the BSS users, by describing their demographic and socio-economic characteristics and travel habits based on the survey results.

6.2.1 Demographic and socio-economic characteristics of BSS users

As discussed in the literature review in *Chapter 2*, studies of BSS in cities around the world have found that BSS users are usually not representative of the general population of a city; they are more likely to be younger, in employment, with higher income and education levels, and especially in 'starter' cycling cities, more likely to be male. The demographic and socio-economic profile of the BSS user survey respondents in the three case study cities are presented in Table 6.1 (Limassol: LIM; Las Palmas de Gran Canaria: LPA; Malta: MAL).

In terms of gender, the results show some disparities. In Limassol, the majority of the survey respondents are female, whereas in Las Palmas de Gran Canaria and Malta the majority are male. As mentioned earlier, and especially in cities without a strong cycling culture, an initial predominance of male users is expected (Murphy & Usher, 2015; Faghih-Imani & Eluru, 2015). The mean age of respondents in Limassol is 31 (min. 12; max. 63), 39 in Las Palmas de Gran Canaria (min. 17; max. 73) and 29 in Malta (min. 12; max. 62). In line with findings from the literature (Murphy & Usher, 2015; Fishman et al., 2015) where the majority of BSS users are between 18 and 34 years of age, in Limassol, 68% of respondents fall within the 18-24 and 25-34 age brackets, and in Malta 58%. However, the age distribution in Las Palmas de Gran Canaria shows a more evenly distributed picture, with the main age groups of BSS users being in the 25-34, 35-44 and 45-54 age brackets, and remarkably less users in the younger age categories. Whether respondents are native or not to the country in which the BSS is located varies widely between the cities. In Las Palmas de Gran Canaria, the vast majority of respondents are native residents (85%), whereas in Limassol (53%) and Malta (48%) that figure is much lower. However, the majority of these respondents are permanent residents of the cities (and to a lesser extent temporary residents), indicating that they primarily represent foreign residents, not visitors to the cities.

Table 6.1: Demographic and socio-economic characteristics of BSS user survey respondents in LIM, LPA and MAL

		Sample specifics		
		LIM (*n*=140)	LPA (*n*=491)	MAL (*n*=128)
Gender	Female:	51.4%	37.3%	39.8%
	Male:	48.6%	62.3%	59.4%
	Non-binary:	0.0%	0.04%	0.8%
Age	< 18:	0%	1%	15%
	18-24:	29%	9%	24%
	25-34:	39%	29%	34%
	35-44:	19%	29%	17%
	45-54:	9%	23%	5%
	55-64:	4%	7%	4%
	65+:	0%	2%	0%
Nationality	Native:	53%	87%	48%
	Non-native:	47%	13%	52%
Residency	Permanent resident (1 year +):	76%	85%	75%
	Temporary resident (< 1 year):	8%	6%	5%
	Visitor (for work/education):	5%	4%	5%
	Visitor (for leisure/tourism):	11%	5%	15%

		Sample specifics		
		LIM (*n*=140)	LPA (*n*=491)	MAL (*n*=128)
Highest completed education	None:	0%	0%	2%
	Primary school:	6%	1%	0%
	Secondary school:	10%	12%	25%
	Undergraduate degree (college, bachelor degree):	42%	49%	45%
	Postgraduate level (Master's degree, PhD):	42%	38%	28%
Gross annual income	Less than €10.000/year:	25%	20%	30%
	Between €10.000 and €20.000/year:	34%	27%	18%
	Between €20.000 and €30.000/year:	13%	21%	16%
	Between €30.000 and €40.000/year:	8%	15%	11%
	Between €40.000 and €50.000/year:	7%	7%	8%
	More than €50.000/year:	14%	10%	17%
Employment status	Full-time employed:	70%	71%	54%
	Part-time employed:	11%	6%	7%
	Housewife/husband:	1%	1%	2%
	Retired/pensioner:	1%	4%	1%
	Student:	12%	10%	34%
	Unemployed:	3%	8%	2%
	Other:	1%	1%	0%

In terms of education level, the BSS users in all three cities are generally highly educated: in Limassol 84% of the respondents have an under- or postgraduate level education; compared to 87% in Las Palmas de Gran Canaria and 73% in Malta. Looking at employment status, it can be noted that the majority of respondents in all three cities are in full-time employment, part-time employment or are students. That the figures for Malta are slightly lower for education level and full-time employment can be attributed to the lower age of the respondents, as can be observed also from the higher percentage of students. Overall the results paint a very similar picture between the three cities, in line with user characteristics of other BSS, where the majority of users are highly educated and in employment (Fishman, 2016; Médard de Chardon et al., 2017). Income levels are generally on the low to average side, with most respondents falling in the first three income bracket levels (from <€10.000 to €30.000/year): 72% of respondents in Limassol, 68% in Las Palmas de Gran Canaria and 64% in Malta.

Access to personal transport modes, including the ownership of private vehicles and being able to drive, is presented in Figure 6.3. The results show that the majority of respondents have a driving license: 86% in Limassol, 87% in Las Palmas de Gran Canaria and 75% in Malta. Respondents in Limassol have the highest car ownership; 73% of respondents, versus 69% in Las Palmas de Gran Canaria and 49% in Malta. Motorcycle or scooter ownership is much lower in all of the cities, with 13% of respondents in Limassol and Las Palmas de Gran Canaria and 11% of respondents in Malta owning a motorcycle or scooter. Private bicycle ownership ranges from 43% in Limassol, to 48% in Las Palmas de Gran Canaria and 52% of respondents in Malta.

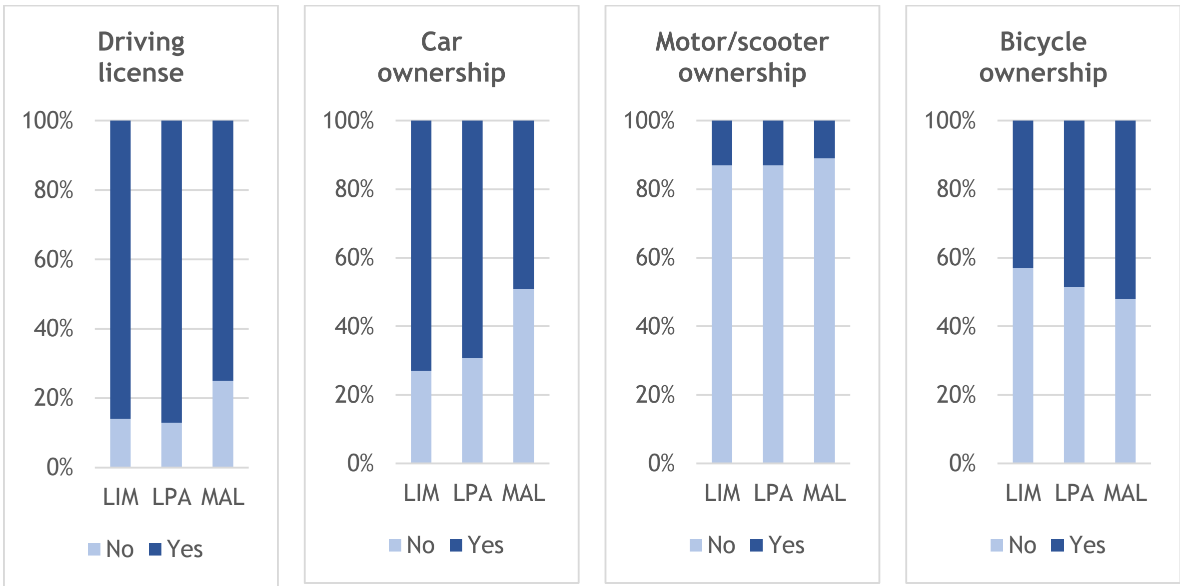


Figure 6.3: Access to transport modes in LIM, LPA and MAL

6.2.2 Travel habits of BSS users

In the survey, BSS users were asked about their travel habits, using different modes of transport. The frequency of use of different modes of transport in Table 6.2 shows that the frequency of shared bicycle use is higher in Las Palmas de Gran Canaria than in Limassol and Malta. In Las Palmas de Gran Canaria, 62% of respondents use the BSS at least once every 2 weeks ('daily', 'often' or 'sometimes'), versus 38% of respondents in Limassol and 45% in Malta. In all three cities, the majority of respondents walk on a daily basis, although again that percentage is higher in Las Palmas de Gran Canaria (70%) than in Limassol (50%) and Malta (63%). Public transport use is more frequent in Las Palmas de Gran Canaria and Malta than in Limassol. While 66% of respondents in Las Palmas de Gran Canaria and 68% of respondents in Malta use public transport at least once every 2 weeks ('daily', 'often' or 'sometimes'), in Limassol only 36% of respondents use public transport that frequently. Notably, the percentage of respondents that use a private car is much higher in Limassol than in Las Palmas de Gran Canaria and Malta; 61% of respondents in Limassol use a private car as a driver on a daily basis, while that figure is 30% in Las Palmas de Gran Canaria and 24% in Malta.

Respondents were also asked about multimodal transport use; whether they combine the use of the BSS with other modes of transport to complete their trips. Respondents could select that either they do not combine BSS use with any other mode of transport ('No'), or if yes, select which mode of transport they combine it with, where multiple answers were possible, e.g. combining BSS use with walking (more than 5 minutes) ('Multimod_walk'), with public transport ('Multimod_PT') and/or with private car use ('Multimod_car'). As can be seen from Figure 6.4, around 30-40% of respondents in the three cities do not use the BSS in combination with another mode of transport. The majority of those who do use BSS as part of multimodal transport do so in combination with walking, ranging from 34% of respondents in Limassol to 50% in Las Palmas de Gran Canaria and 55% in Malta. There is more complementarity with public transport in Las Palmas de Gran Canaria and Malta (20% of respondents in both cities) than in Limassol, where just 6% uses the BSS in combination with public transport. This is partially explained by the overall lower share of public transport use in Limassol. In Limassol there is a higher combination with private car use, which can be either use of the private car to arrive at a place of leisure to use the BSS (i.e. the promenade or park) and/or private car use into the city and BSS use as a last-mile solution to arrive at a destination.

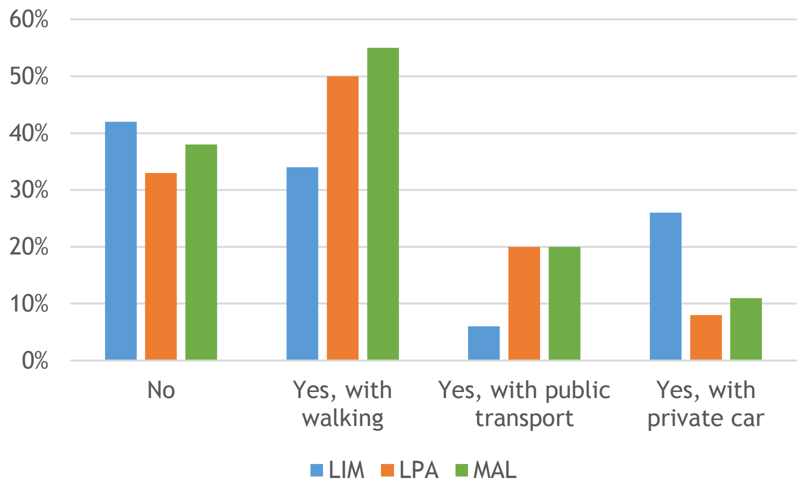


Figure 6.4: Multimodal transport: BSS use in combination with other modes of transport

To understand the modal shift as a result of BSS use, respondents were asked what mode of transport they used to use for their most frequent BSS trip. Figure 6.5 presents the percentages of modal shift from the different transport modes: a shift from walking, cycling (private bicycle), motorcycle/scooter, public transport, car (driver), car (passenger), taxi, or a new trip. The dominant category across the three cities is a shift from walking: 43% in Limassol, 31% in Las Palmas de Gran Canaria and 34% in Malta. Compared to walking, BSS use provides increased speed and convenience. The shift from the private car – primarily as drivers and only a small percentage as passengers – is 21% in Limassol, 20% in Las Palmas de Gran Canaria and 17% in Malta. In the case of modal shift from private car use, BSS use contributes to emission reductions and reduced air pollution, as well as an increase in physical activity. Modal shift from public transport shows more divergent results, with 28% of respondents in Las Palmas de Gran Canaria indicating this was how they previously made their most frequent BSS trip, compared with 18% of respondents in Malta and just 7% of respondents in Limassol. These results show that in Las Palmas de Gran Canaria and Malta, with more public transport use in general, there is also higher competition between public transport and BSS use, whereas in Limassol, where the modal share of public transport is lower, this is less apparent. Compared to public transport, the BSS can provide more flexibility and freedom, and its use contributes to an increase in physical activity. In the three cities there are similar shifts from private bicycle use (around 10%), motorcycle/scooter or taxi (both categories <5%). In Limassol, 14% of the respondents indicated this was a new trip, versus 5% of respondents in Las Palmas de Gran Canaria and 11% of respondents in Malta.

To understand more about the BSS users' cycling habits, respondents were asked about their cycling skills and helmet use. Around half of the respondents assess themselves as 'experienced' cyclists; 52% of respondents in Limassol and Malta and 49% in Las Palmas de Gran Canaria. Around 10% of respondents in each city call themselves 'inexperienced', with the remainder considering themselves 'moderately experienced'. The majority of respondents in Limassol and Las Palmas de Gran Canaria indicate that they 'never' wear a bicycle helmet while using the BSS; 62% in Limassol and 61% in Las Palmas de Gran Canaria. In Malta, this figure is lower, with 42% indicating they 'never' wear a helmet, 30% 'sometimes' and 27% 'always' wearing a helmet when using the BSS. In both Limassol and Las Palmas de Gran Canaria, only 14% of respondents indicate they 'always' wear a helmet. This difference between Limassol and Las Palmas de Gran Canaria on the one hand and Malta on the other, can be explained by better provision of cycling infrastructure near the BSS in Limassol and Las Palmas de Gran Canaria, whereas cycling infrastructure in the urban area in Malta is lacking, implicating more BSS use in mixed traffic, and therefore a likely higher (perceived) risk by BSS users. Respondents were also asked about their BSS subscription type and when they started using the service. The majority of respondents in Limassol (61%) and Malta (62%) indicated to be pay-as-you-go users, with the remainder of users either having a membership or using the BSS with a member (as in these cities, registered users can rent bicycles for up to 4 people at a time). In Las Palmas de Gran Canaria, a larger share of respondents indicated being a subscribed user with a membership (50%). This can potentially be explained by the more economical membership offers in Las Palmas de Gran Canaria, and shows how this encourages people to become a subscribed member rather than a casual user. Memberships are also more associated with BSS use for commuting purposes, whereas casual users more often use the BSS for leisure or for exercise (Fishman, 2016; O'Brien et al., 2014).

Table 6.2: Frequency of use of different modes of transport by BSS users in LIM, LPA and MAL

	Daily			**Often** *a few days per week*			**Sometimes** *about once every 2 weeks*			**Rarely** *less than once a month*			**Never**		
	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL
Shared bicycle (Nextbike/Sítycleta)	7%	14%	12%	14%	29%	20%	17%	19%	13%	44%	31%	35%	17%	7%	20%
Walking (more than 5 minutes)	50%	70%	63%	31%	20%	8%	11%	7%	30%	5%	2%	0%	3%	1%	0%
Private bicycle	9%	6%	16%	13%	12%	16%	14%	13%	9%	15%	21%	18%	50%	48%	41%
Motorcycle / scooter	4%	5%	5%	7%	4%	11%	6%	10%	9%	6%	4%	5%	76%	76%	70%
Public transport (bus)	10%	17%	23%	10%	25%	25%	16%	24%	20%	24%	28%	21%	40%	6%	10%
Private car (driver)	61%	30%	24%	11%	24%	24%	6%	17%	13%	4%	9%	6%	17%	21%	32%
Private car (passenger)	17%	8%	11%	34%	17%	28%	25%	25%	23%	15%	27%	22%	9%	23%	16%
Taxi	3%	3%	3%	9%	8%	13%	11%	19%	20%	29%	49%	38%	48%	21%	27%

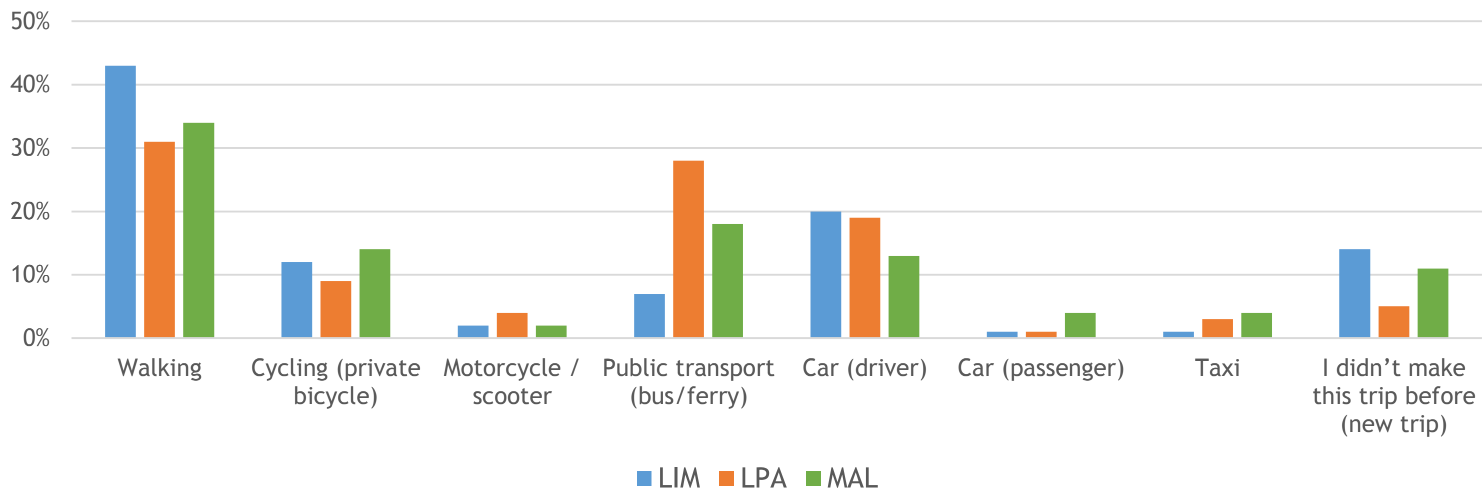


Figure 6.5: Modal shift: previous transport mode for most frequent BSS trip

Distance is an important factor in the decision for a mode of transport and resulting travel habits (Handy et al., 2014; Hanson, 2004). The survey included two questions related to the individual's distance from the BSS; the walking distance from the respondents' residence to the nearest BSS station and the walking distance from their most frequent destination to the nearest BSS station, expressed in walking minutes. The results are presented per city in Figure 6.6. It can be noted that Las Palmas de Gran Canaria has the shortest distances to the nearest BSS station, and Limassol the longest, with Malta falling in the middle, for both distance from residence and distance from most frequent destination. As an example, in Las Palmas de Gran Canaria, 60% of the respondents live within a 5-minute walk from the nearest BSS station; compared with 46% of the respondents in Malta and just 26% in Limassol. The differences between the cities can be partly explained by differences in population density and urban form, with more densely populated neighbourhoods in Las Palmas de Gran Canaria and a more low-density urban form in Limassol, but also with the spatial coverage of the BSS. This will be further discussed from a spatial perspective in section 6.3, which discusses "where" the BSS use is taking place and how well the BSS serves the population in the city.

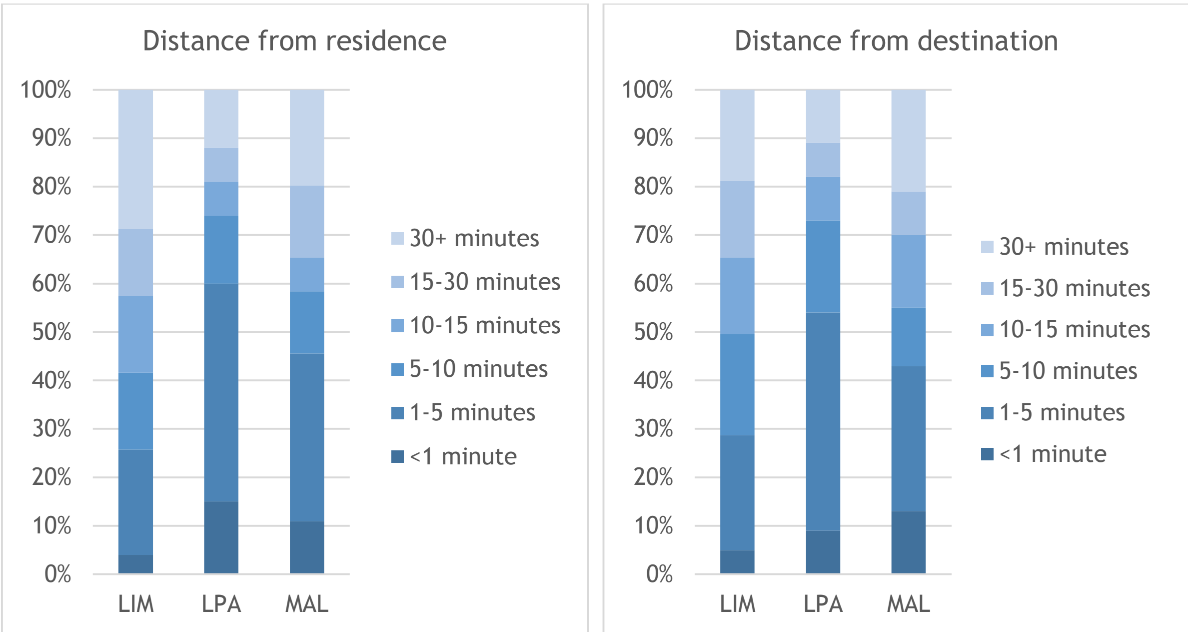


Figure 6.6: a) Distance from residence (home/hotel) to nearest BSS station; b) Distance from most frequent destination to nearest BSS station.

6.3 Why is the BSS used?

This section looks at the "*why*" of BSS use, examining the different trip purposes and usage types from the survey responses and BSS trip data, as well as the motivating factors for BSS use contributed by the survey respondents, including both facilitators and barriers for BSS use.

6.3.1 BSS trip purposes and usage patterns

BSS can be used for different trip purposes: for commuting (to work or school), for business travel, for shopping or errands, to go out for food or drinks, to visit a touristic site, for leisure or fun, for exercise or to visit friends or family. The frequency of using the BSS for these different trip purposes is presented in Table 6.3. Whereas in Las Palmas de Gran Canaria and Malta the most frequently mentioned trip purpose for daily use is 'for commuting' (14% of respondents in Las Palmas de Gran Canaria; 13% in Malta), the most frequent trip purpose for daily use in Limassol is 'for exercise'. Using the BSS 'for business travel' is the least frequent trip purpose across the three cities, with 72% (Limassol), 69% (Las Palmas de Gran Canaria) and 65% (Malta) of respondents never using the BSS for this purpose.

The mean responses for the frequency of the use of the BSS for different trip purposes was statistically assessed using the Dunn test, to see if there is a significant difference (at *p*-value <0.05** or <0.01***) between the three cities. The frequency of the BSS use for the different trip purposes was measured on a five-point Likert scale, from 1 ('never') to 5 ('daily). While the mean value in itself does not represent a category on the Likert scale, it provides insights in the distribution of the frequency of the provided answers, and is useful to understand which city has a higher or lower mean value; i.e. more or less frequent use for the different trip purposes. The results are presented in Table 6.4 and show that there are statistically significant differences in the BSS use for:

- 'Use_commute' (to commute to/from work/school): the mean value of responses in Las Palmas de Gran Canaria is significantly higher than in Limassol;
- 'Use_business' (for business travel): no significant differences between the mean value of responses per city;
- 'Use_shopping' (for shopping or errands): the mean value of responses in Las Palmas de Gran Canaria is significantly higher than in both Limassol and Malta;
- 'Use_food' (to go out for food or drinks): no significant differences between the mean value of responses per city;
- 'Use_fun' (for leisure or fun): no significant differences between the mean value of responses per city;
- 'Use_exercise' (for exercise): the mean value of responses in Limassol is significantly higher than in both Las Palmas de Gran Canaria and Malta;
- 'Use_friends' (to visit friends or family): the mean value of responses in Las Palmas de Gran Canaria is significantly higher than in both Limassol and Malta.

From the BSS trip data, usage types can be inferred based on the characteristics of trips. Round trips, starting and ending at the same station location, are generally considered to be indicative of leisure use (Bordagaray et al., 2016), whereas single trips, between different origins and destinations, are typically understood to be for transport purposes. Of the total 17,532 trips in Limassol, 42% constitute round trips. In Las Palmas de Gran Canaria, of the total 162,871 trips, only 5% constitute round trips. In Malta, of the total 37,306 trips, 13% are round trips. In comparison, Bordagaray et al. (2016) found that around 19% of total trips with the BSS in Santander (Spain) were round trips. In Cork (Ireland), only 4% of trips constituted round trips (Caulfield et al., 2017). The higher percentage of round trips in Limassol confirms the BSS trip purpose findings from the survey: that BSS use in Limassol is more motivated by use for leisure or exercise, whereas the BSS in Las Palmas de Gran Canaria, and Malta to a lesser extent, are dominated by use for transport; for commuting, shopping or errands.

Table 6.3: Frequency of use of BSS for different trip purposes in LIM, LPA and MAL

	Daily			**Often** *a few days per week*			**Sometimes** *about once every 2 weeks*			**Rarely** *less than once a month*			**Never**		
	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL	LIM	LPA	MAL
To commute to/from work/school	5%	14%	13%	11%	15%	12%	6%	12%	10%	15%	12%	13%	63%	48%	52%
For business travel	3%	2%	4%	9%	6%	13%	5%	9%	7%	11%	13%	12%	72%	69%	65%
For shopping or errands	4%	4%	4%	14%	17%	12%	6%	22%	13%	13%	23%	16%	64%	34%	55%
To go out for food or drinks	4%	5%	2%	11%	13%	13%	11%	19%	16%	17%	23%	20%	57%	40%	49%
To visit a touristic site	4%	5%	2%	10%	10%	13%	17%	17%	12%	13%	26%	17%	56%	42%	56%
For leisure / fun	8%	8%	6%	17%	19%	20%	24%	20%	8%	26%	30%	35%	25%	23%	31%
For exercise	11%	8%	5%	16%	14%	16%	22%	16%	11%	23%	24%	20%	28%	38%	48%
To visit friends or family	4%	6%	4%	10%	17%	10%	8%	18%	12%	10%	23%	16%	68%	36%	59%

Table 6.4: Significant differences from Dunn Test between mean values of responses per city

Variable	LIM mean	LPA mean	*p*-value	LIM mean	MAL mean	*p*-value	LPA mean	MAL mean	*p*-value
Use_commute	1.8	2.3	***	1.8	2.2	-	2.3	2.2	-
Use_business	1.6	1.6	-	1.6	1.8	-	1.6	1.8	-
Use_shopping	1.8	2.3	***	1.8	1.9	-	2.3	1.9	***
Use_food	1.9	2.2	**	1.9	2.0	-	2.2	2.0	-
Use_tourist	1.9	2.1	-	1.9	1.9	-	2.1	1.9	-
Use_fun	2.6	2.6	-	2.6	2.3	-	2.6	2.3	-
Use_exercise	2.6	2.3	**	2.6	2.1	***	2.3	2.1	-
Use_friends	1.7	2.3	***	1.7	1.9	-	2.3	1.9	***

Note: - not significant; significant at ** <0.05; *** <0.01 level

6.3.2 Motivating factors for BSS use: facilitators and barriers

In the survey, respondents were asked about factors that motivate their BSS use, their satisfaction with the service provided by the BSS, and factors that may act as facilitators and barriers. The results from these questions in the survey are discussed here.

When asked about what motivates respondents to use the BSS, the top three motivating factors are consistent among the three cities: health, being environmentally friendly and fun (Figure 6.7). The difference between these three factors and the motivating factors more associated with commuting - 'money-saving', 'convenience' and 'time-saving' – is largest in Limassol. In Las Palmas de Gran Canaria 'convenience' and in Malta 'convenience' and 'time-saving' are also important motivating factors for the BSS users. The latter two factors are identified as the strongest motivating factors in other BSS research (Fishman, 2016). Saving money appears as the least important motivating factor in the three cities.

Respondents were also asked about their satisfaction with aspects of the BSS, in terms of the registration process, the price, the location of the stations, the availability of bicycles, the ease of renting and returning bicycles, the comfort of the bicycles and the branding and marketing of the BSS. In Las Palmas de Gran Canaria an additional question was asked, regarding the opening hours of the BSS, as it is not available 24/7 like the BSS in Limassol and Malta. The mean responses and their standard deviations (SD) are presented in Table 6.5. Overall, satisfaction with the BSS is high, with values around 4 (a mean response of 'slightly satisfied') across the board. Aspects that receive the highest mean response in terms of satisfaction are the sign-up process and the availability of bicycles.

Lower mean responses are obtained for the price and the comfort of the bicycles. It is somewhat surprising that Las Palmas de Gran Canaria receives the lowest mean response for the satisfaction with the price, when it is in fact the most affordable system (in terms of memberships; pay-as-you-go rates are similar to the other two BSS). This could potentially be explained by the fact that previously there was a free BSS in Las Palmas de Gran Canaria, even though that system was not operating at the same level of service and with nowhere near the same intensity of use as the current system. The comfort of the bicycles received a relatively lower mean score in Limassol and Malta. In these cities, the BSS has been around for a few years (at the time of the survey around 7-8 years in Limassol and 3-4 years in Malta), potentially reflecting long-term wear and tear on the bicycles, despite being frequently serviced by the operators. In Malta, the satisfaction with the location of the stations also receives a relatively lower mean response. While the BSS is present in one of the main urban areas on the island, as well as in other specific locations, there are also other urban areas that are currently not served by the BSS. In Las Palmas de Gran Canaria, the mean score for their operating hours is the lowest score for any aspect of the service, indicating that the choice to close the system overnight may not be satisfying all of their users. The overall high satisfaction with the BSS confirms the efforts made by the operators to provide a high level of service, maintenance of the system and bicycles, and customer service to deal with queries and issues. Satisfaction with the operation of the BSS, a user-centric design, and a high level of service to users have been identified as important contributors to BSS usage and scheme longevity (Morton, 2018; Nikitas, 2019).

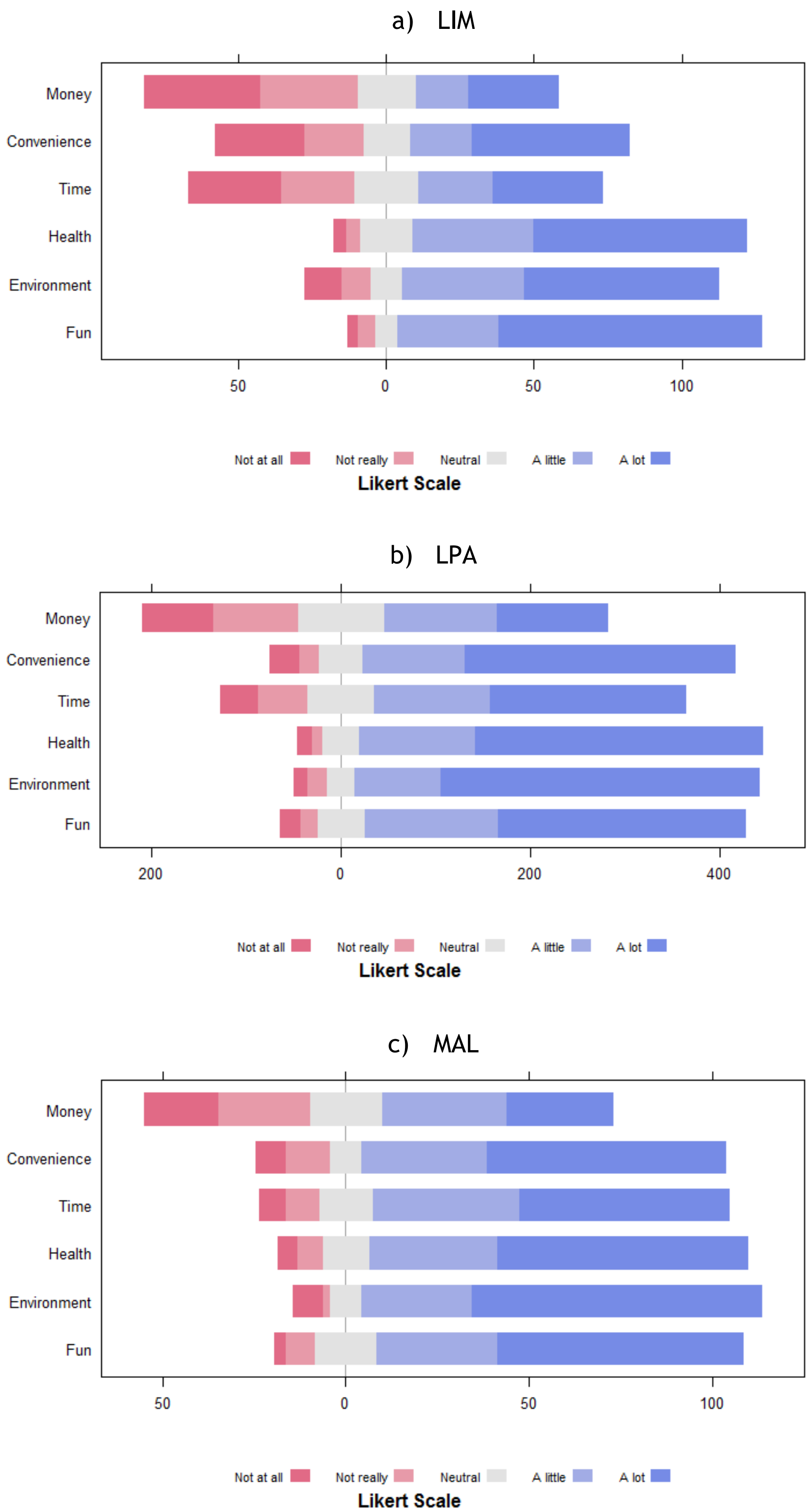


Figure 6.7: Motivating factors for BSS use in: a) LIM, b) LPA, c) MAL

Table 6.5: Satisfaction with aspects of the BSS in LIM, LPA and MAL

Satisfaction with aspects of the BSS	*Mean response 5-point Likert scale (SD)*		
	LIM	LPA	MAL
"Sign-up process to become a user"	3.97 (1.13)	4.00 (1.07)	4.13 (0.94)
"The price"	3.74 (1.06)	3.32 (1.40)	3.39 (1.21)
"The location of stations"	3.87 (1.04)	3.94 (1.09)	3.42 (1.28)
"The availability of bicycles"	4.24 (0.96)	4.18 (1.02)	4.04 (0.94)
"Renting and returning a bicycle"	4.11 (1.06)	3.90 (1.21)	3.94 (0.97)
"The comfort of the bicycles"	3.64 (1.09)	3.84 (1.07)	3.44 (1.11)
"The branding and marketing of the BSS"	3.82 (1.04)	3.65 (1.03)	3.70 (1.02)
"Operating hours of the BSS"	*N/A*	3.17 (1.34)	*N/A*

Notes: SD: standard deviation; *N/A*: not applicable; Likert scale: 1= Very unsatisfied, 2 = Slightly unsatisfied, 3 = Neither satisfied nor unsatisfied, 4 = Slightly satisfied, 5 = Very satisfied.

In the survey, respondents were asked about their attitude towards factors that have been identified in the literature as potentially impacting cycling and BSS use, such as personal attitudes, aspects of the transport network and mobility system, the behaviour of other road users, weather factors and social norms around cycling in their city (Fishman et al., 2014; Iwińska et al., 2018). The responses are presented in Table 6.6. In all three cities there is high agreement with the statement 'liking cycling' (score near (5), '*completely agree*'); a positive attitude towards cycling. This is also seen, although to a slightly lesser extent, in their perception of the convenience of cycling, which is rated higher in Las Palmas de Gran Canaria and Malta than in Limassol. There is more disagreement in regard to the need for a car for daily tasks, whereas this is scored highly in Limassol, concurrent with higher daily use of the car as seen in Section 6.2, this figure is much lower in Las Palmas de Gran Canaria and Malta. In terms of respondents' attitude to weather, overall respondents agree not to like cycling in rainy and windy weather, with the strongest negative response in Limassol. In terms of hot and sunny weather, there is a slightly stronger positive response in Las Palmas de Gran Canaria, which is expected as temperatures are not as extreme as in Limassol and Malta, where summer temperatures can make it uncomfortable to cycle. Worrying about one's appearance after cycling does not show a strong response in any of the cities, with the mean hovering around the neutral value of 3 ('*neither agree nor disagree*'). There is greater agreement with the statement that cycling uphill is difficult. Busy roads are considered a barrier, especially in Malta. In terms of respect from other road users, the mean value is generally quite low (<3, towards '*slightly disagree*'), again with the strongest response in Malta. These values give an indication of the barriers presented by the road environment and of the importance of the creation of safe cycling infrastructure for increasing BSS use and cycling. Support from family and friends, and feeling that cycling is an accepted form of transport scores higher in Limassol and Las Palmas de Gran Canaria than in Malta, where the social norm around cycling seems less supportive of cycling. The normality of cycling, both in terms of it being an accepted form of transport by an individual, as well as by wider society, is an important driver for cycling behaviour (Goodman, Green, & Woodcock, 2014).

Table 6.6: Attitudes towards facilitators and barriers for BSS use in LIM, LPA and MAL

Attitudes towards facilitators and barriers for BSS use	*Mean response 5-point Likert scale (SD)*		
	LIM	LPA	MAL
"I like cycling"	4.67 (0.58)	4.68 (0.72)	4.68 (0.56)
"Cycling is a convenient way to get to work or school"	3.86 (1.19)	4.44 (0.89)	4.36 (0.95)
"I need a car to perform my daily tasks"	4.10 (1.11)	2.89 (1.41)	3.02 (1.44)
"I don't like to cycle when it is rainy and windy"	4.28 (1.04)	4.03 (1.07)	3.84 (1.26)
"I like to cycle when it is hot and sunny"	3.41 (1.42)	3.78 (1.09)	3.43 (1.23)
"I worry about my appearance after cycling"	3.08 (1.41)	3.18 (1.33)	3.07 (1.39)
"Cycling uphill is difficult"	3.84 (1.19)	3.89 (1.15)	3.94 (1.08)
"Busy roads are a barrier to cycling"	4.07 (1.00)	4.00 (1.04)	4.31 (1.05)
"Other road users respect cyclists"	2.86 (1.35)	2.70 (1.21)	2.46 (1.32)
"My friends and family support my cycling behaviour"	3.94 (0.99)	4.02 (1.03)	3.49 (1.27)
"Cycling is an accepted form of transport in [city]"	3.59 (1.20)	3.39 (1.25)	2.50 (1.37)

Notes: SD: standard deviation; Likert scale: 1= Completely disagree, 2 = Slightly disagree, 3 = Neither agree nor disagree, 4 = Slightly agree, 5 = Completely agree; [city]: LIM/LPA/MAL.

The respondents were also asked to rate their attitude towards the influence of encouraging and discouraging factors influencing their BSS use and cycling habits. The results are presented in Table 6.7.

Table 6.7: Encouraging and discouraging factors for BSS use in LIM, LPA and MAL

Encouraging factors	*Mean response 5-point Likert scale (SD)*		
	LIM	LPA	MAL
"More cycle lanes/paths"	4.78 (0.55)	4.39 (1.00)	4.85 (0.40)
"Roads with lower vehicle speeds"	4.14 (0.98)	3.91 (1.15)	4.23 (0.94)
"Greater cycling safety awareness"	4.56 (0.77)	4.43 (0.90)	4.57 (0.73)
"More information about safe and direct routes"	4.44 (0.82)	4.30 (0.95)	4.43 (0.82)
"Seeing more people cycling"	4.13 (1.03)	4.04 (1.08)	4.41 (0.91)
"Friends or family members who cycle"	4.21 (0.89)	3.89 (1.10)	4.09 (1.03)
"Having BSS stations closer to home"	4.30 (1.01)	4.15 (1.03)	4.16 (1.04)
"Having BSS stations closer to work or school"	4.19 (1.03)	4.19 (1.01)	4.22 (1.00)
"Better integration with public transport"	4.11 (1.08)	4.25 (0.97)	4.41 (0.87)
"Making driving a car more expensive or difficult"	3.32 (1.46)	3.25 (1.45)	4.00 (1.22)
Discouraging factors	*Mean response 5-point Likert scale (SD)*		
	LIM	LPA	MAL
"Driving a car is more convenient"	4.20 (0.92)	2.64 (1.29)	3.45 (1.40)
"Public transport is more convenient"	2.99 (1.37)	3.32 (1.16)	2.92 (1.37)
"Concerned for safety in traffic"	4.06 (1.01)	3.84 (1.04)	4.40 (0.79)
"Using BSS is too costly"	3.05 (1.30)	3.05 (1.38)	3.48 (1.16)
"Not seeing many other cyclists"	3.04 (1.29)	2.83 (1.20)	3.38 (1.19)
"No friends or family members who cycle"	3.12 (1.29)	2.67 (1.22)	3.16 (1.31)
"BSS stations are not close enough to home"	3.63 (1.31)	3.33 (1.32)	3.66 (1.31)
"BSS stations are not close enough to work or school"	3.49 (1.34)	3.38 (1.26)	3.56 (1.28)
"Lack of integration with public transport"	3.48 (1.28)	3.52 (1.18)	3.82 (1.21)

Notes: SD: standard deviation; Likert scale: 1= Completely disagree, 2 = Slightly disagree, 3 = Neither agree nor disagree, 4 = Slightly agree, 5 = Completely agree.

Factors that were considered as encouraging are potential changes in the social and physical environment that could make cycling and BSS use more attractive, as found in the literature (Fraser & Lock, 2011; Pucher & Buehler, 2008). In terms of encouraging factors, all factors but the last receive a strong positive response in Limassol. 'Making driving a car more expensive or difficult' is not rated as high as the other factors in Limassol and Las Palmas de Gran Canaria; understandable as the majority of BSS users also drive a car themselves frequently, and would thus be impacted by such a policy measure. This is less apparent in Malta, where a lower percentage of the respondents use a private car. 'More cycle lanes or paths' received the strongest positive response in Limassol and Malta as a factor that would encourage more cycling and BSS use, highlighting the importance of dedicated infrastructure for cycling. The need for 'greater cycling safety awareness' also scored high in both cities. In Las Palmas de Gran Canaria these factors also scored positively, although to a slightly lesser extent, which is to be expected considering that this city has the most extensive cycling network of the three.

The results for discouraging factors are more discordant between the cities. Considering 'driving to be more convenient' is agreed with much more in Limassol than in Malta, and receives more disagreement in Las Palmas de Gran Canaria. Public transport on the other hand is considered to be somewhat more convenient than BSS in Las Palmas de Gran Canaria, but not particularly in Limassol and Malta. In terms of concerns for one's safety in traffic, this is the strongest discouraging factor in Malta, and is also discouraging to respondents in Limassol and Las Palmas de Gran Canaria, albeit less so. Cost does not appear to be a serious discouraging factor, with mean responses around the neutral value. The effect of the social norm is divergent: in Las Palmas de Gran Canaria there is less agreement that a positive social subjective and descriptive norm is lacking; from the respondents' answers it seems there are more cyclists around and they have more friends and family members that cycle, when compared to Limassol and Malta. There is slight agreement with not having stations close enough to home or work/school in Limassol and Malta, but less so in Las Palmas de Gran Canaria. There is also moderate agreement with the BSS not being integrated with public transport, most strongly in Malta.

6.4 Where is the BSS used?

This section looks at the "*where*" of BSS use: where are trips taking place and what characterises the most popular stations, to what extent does the BSS serve the city's population, and what is the relation of BSS use with the road environment? To understand where BSS trips are taking place, flows between origin (O) and destination (D) stations were examined and visualised for each city. The most frequently used stations (as origins and destinations) were identified, and their spatial characteristics were analysed to understand what characterises them in terms of land use and nearby Points-of-Interest, as well as the relationship with the presence of dedicated cycling infrastructure. The spatial coverage of the BSS, based on a 300m and 400m buffer around the stations as metrics to determine the walkable distance to a BSS station, was used to calculate what percentage of the city's population is served by the BSS. The road environment with BSS use was assessed from the survey data, using respondents' answers to where they most frequently cycle and how they assess the perceived safety of different types of road infrastructure.

6.4.1 Location of origin and destinations of BSS use

The OD flows between stations in: a) Limassol, b) Las Palmas de Gran Canaria and c) Malta, are visualised in Figure 6.8 with lines of varying thickness indicating the relative strength of the flows (Leaflet © OSM, Carto). Circles around a station indicate round trips, with the same origin and destination. The OD flows represented on the maps were created using the total number of BSS trips over the 1-year period under consideration, from April 2018 to March 2019, with total trips per city: Limassol (n = 17,532), Las Palmas de Gran Canaria (n = 162,871), Malta (n = 37,306). From the map of BSS flows in Limassol, the strong concentration of the OD flows near the bicycle paths along the city's promenade is evident, as well as a large number of round trips from the westernmost station on the promenade. In Las Palmas de Gran Canaria, the strongest OD flows are associated with the city centre in the north of the city, around the beaches near Las Canteras and Santa Catalina bus station and park, as well as further south near San Telmo park and bus station and Triana. In Malta, the highest concentration of OD flows is found in the urban area north of the capital city Valletta, which has a high population density, as well as some of the main employment and entertainment centres on the island. All stations are close to or on the coastal promenade.

To understand what influences the usage of the most frequented stations (as origins and destinations), the spatial characteristics of the top 5 stations (O+D) are presented in Table 6.8. The median value and standard deviation (SD) of the values of all stations per city are provided for comparison, and the locations of the stations are indicated in Figure 6.8. Almost all stations have a relatively high percentage of residential land use (LU_RES); at or above the median figure for each city. The percentage of commercial/industrial (LU_COM) land use varies, but averages out around the median for each city; it does not show a specific relationship. The positive influence of parks (LU_PARK) is primarily clear in Limassol, where 3 of the 5 stations have a higher than average percentage of park land use in the buffer around the station, which can be indicative of leisure use. The presence of cafes and restaurants (LU_CAFE), indicative of entertainment and leisure areas, is important for BSS use in all three cities, although hotels (LU_TOUR) only to a lesser extent; they are not present in all top stations' buffer zones. The influence of the beach or promenade (LU_BEACH) on cycling in these coastal island cities is very evident, as well as the provision of cycling paths (LU_CYCLE). All top 5 stations Limassol and Las Palmas de Gran Canaria are in close proximity to cycling paths. This same effect is not observed in Malta, because there are essentially no cycling paths in the urban area where the BSS is present. The presence of public transport connections (LU_BUS) shows importance in Las Palmas de Gran Canaria and Malta: in both cities, 2 out of the 5 most frequented stations are found in the vicinity of a public transport hub. In Limassol, none of the top 5 OD flows stations are in the vicinity of the bus station, which can be explained by the very low modal share of public transport in the city. The presence of the university (LU_UNI) has shown positive associations with BSS use in other cities, e.g. in Seville (Castillo-Manzano & Sanchez-Braza, 2013). However, it does not show any association with the most frequented stations in any of the three case study cities. While the university campus in Las Palmas de Gran Canaria is located outside of the city and the area covered by the BSS, the university campuses in Limassol and Malta are covered by the BSS.

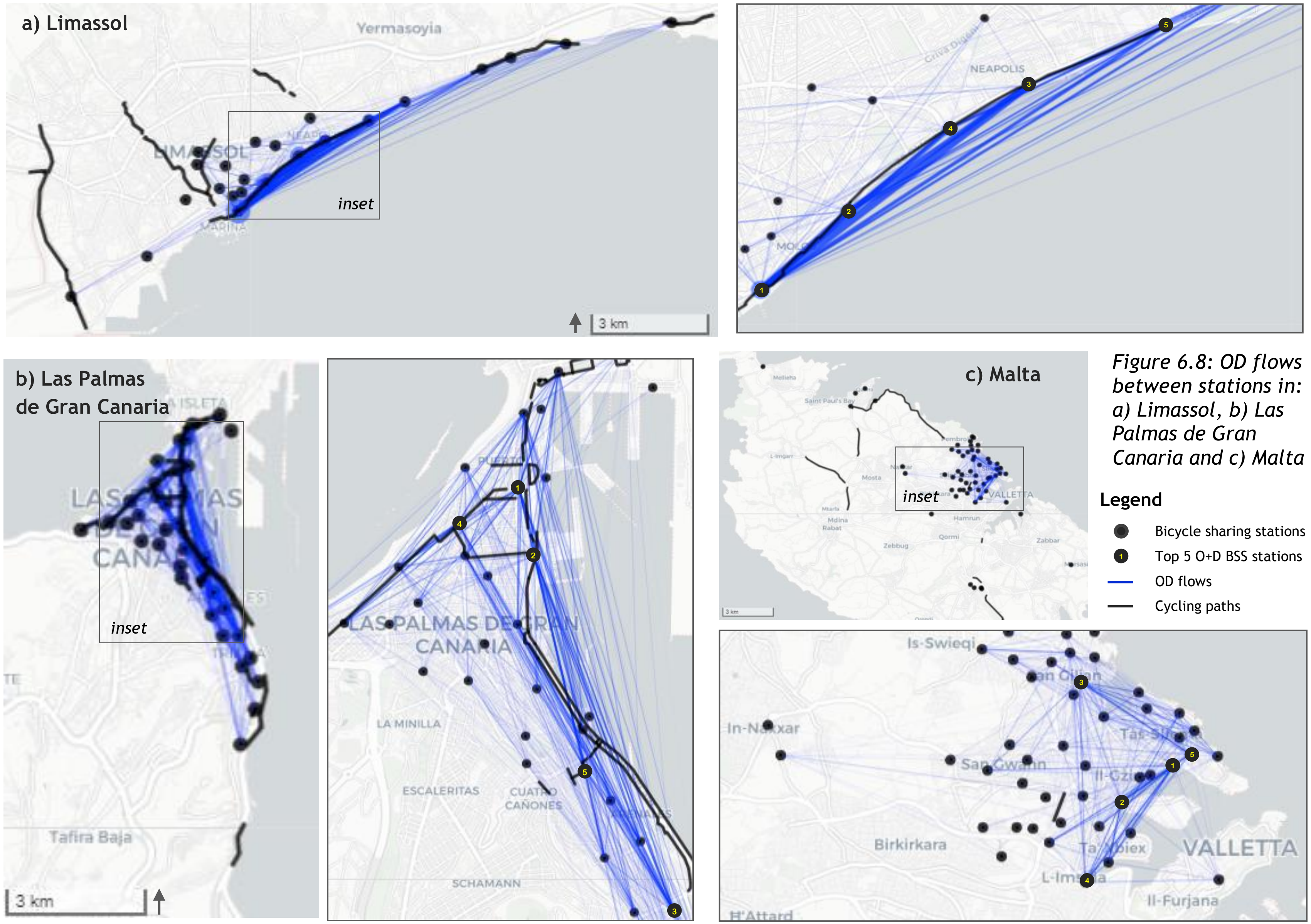


Figure 6.8: OD flows between stations in: a) Limassol, b) Las Palmas de Gran Canaria and c) Malta

Legend

- Bicycle sharing stations
- Top 5 O+D BSS stations
- OD flows
- Cycling paths

(adapted from Maas et al., 2020)

(Leaflet © OSM, Carto)

Table 6.8: Spatial characteristics of the top 5 stations (O+D) in LIM, LPA and MAL (adapted from Maas et al., 2020)

	LU_RES	LU_COM	LU_PARK	LU_TOUR	LU_CAFE	LU_SHOP	LU_UNI	LU_BEACH	LU_BUS*	LU_CYCLE	LU_NODES	ELEV	POP_DENS	PERC_EDU3	GEND_RATIO	AGING_POP	FORGN_POP	DIST-MEAN	COUNT_STAT
LIM																			
Median BSS stations (SD)	*0.46 (0.20)*	*0.16 (0.15)*	*0.01 (0.05)*	*1 (1.8)*	*6 (8.5)*	*1 (3.6)*	*n/a*	*n/a*	*n/a*	*n/a*	*362 (189)*	*5.70 (6.74)*	*3,866 (2,429)*	*0.28 (0.07)*	*0.92 (0.05)*	*0.16 (0.05)*	*0.33 (0.14)*	*2,149 (2,457)*	*1 (1.4)*
LIM O+D 1	0.42	0.33	0.09	0	26	1	-	✓	-	✓	608	1.44	1,583	0.15	0.90	0.19	0.48	2,149	3
LIM O+D 2	0.38	0.22	0.17	3	5	0	-	✓	-	✓	297	1.36	4,619	0.18	1.00	0.16	0.49	1,175	2
LIM O+D 3	0.83	0.00	0.01	0	6	3	-	✓	-	✓	176	1.95	7,805	0.25	0.95	0.12	0.54	653	1
LIM O+D 4	0.43	0.09	0.00	3	21	1	-	✓	-	✓	241	1.97	7,805	0.25	0.95	0.12	0.54	98	1
LIM O+D 5	0.44	0.09	0.21	0	4	0	-	✓	-	✓	150	3.55	1,871	0.32	0.94	0.08	0.46	1,872	1
LPA																			
Median BSS stations (SD)	*0.57 (0.22)*	*0.11 (0.17)*	*0.04 (0.06)*	*0 (3.8)*	*20 (30.5)*	*3 (11.7)*	*n/a*	*n/a*	*n/a*	*n/a*	*324 (111)*	*6.69 (12.04)*	*13,998 (13,548)*	*0.32 (0.13)*	*0.91 (0.05)*	*0.21 (0.03)*	*0.09 (0.06)*	*1,556 (979)*	*7 (2.5)*
LPA O+D 1	0.45	0.09	0.23	8	70	3	-	✓	✓ (B)	✓	486	4.74	5,562	0.36	0.96	0.21	0.22	1,602	9
LPA O+D 2	0.30	0.31	0.04	1	31	13	-	✓	-	✓	324	6.55	5,115	0.37	0.87	0.22	0.15	1,035	8
LPA O+D 3	0.59	0.14	0.07	4	40	32	-	✓	✓ (B)	✓	542	5.16	4,504	0.44	0.83	0.22	0.07	2,209	6
LPA O+D 4	0.70	0.00	0.01	14	134	14	-	✓	-	✓	484	7.00	38,953	0.25	0.96	0.21	0.22	1,511	9
LPA O+D 5	0.72	0.08	0.03	0	20	5	-	✓	-	✓	296	6.69	27,150	0.25	0.85	0.18	0.09	806	9
MAL																			
Median BSS stations (SD)	*0.53 (0.24)*	*0.13 (0.16)*	*0.01 (0.04)*	*0.5 (4.0)*	*5 (13.5)*	*0 (1.9)*	*n/a*	*n/a*	*n/a*	*n/a*	*240 (142)*	*19.97 (29.92)*	*4,981 (3,434)*	*0.14 (0.02)*	*0.98 (0.06)*	*0.20 (0.01)*	*0.16 (0.07)*	*1,683 (2,552)*	*4 (2.2)*
MAL O+D 1	0.66	0.00	0.01	6	23	7	-	✓	✓ (B,F)	-	368	0.57	11,509	0.14	0.93	0.20	0.19	1,891	6
MAL O+D 2	0.53	0.19	0.05	3	13	0	-	✓	-	-	340	0.24	7,779	0.14	0.98	0.20	0.16	1,317	6
MAL O+D 3	0.68	0.13	0.01	3	29	1	-	✓	-	-	204	2.19	5,638	0.14	1.11	0.20	0.18	1,225	6
MAL O+D 4	0.62	0.12	0.01	0	8	0	-	✓	✓ (B)	-	370	0.79	4,981	0.14	1.03	0.20	0.17	1,750	2
MAL O+D 5	0.68	0.05	0.01	9	22	6	-	✓	-	-	432	12.1	11,509	0.14	0.93	0.20	0.19	2,120	6

Notes: O+D: yearly aggregated count of use of a BSS station as origin (O) and destination (D); *n/a*: not applicable; * B = bus station, F = ferry landing site.

As all most frequented stations in the three cities are located near the coast, the elevation (ELEV) is generally low. In Malta in particular, the elevation of the top stations is notably lower than the median. In terms of socio-economic variables, the population density (POP_DENS) at the station locations varies. Certain stations have a higher population density than the median, but this is not the case for all stations. There is no clear influence of higher education level (PERC_EDU3), the gender quotient (GEND_RATIO), or aging population (AGING_POP) at the station location. The percentage of foreign population (FORGN_POP) at the station location however, is significantly higher than the median in all three cities, especially in Limassol. However, this may be (at least partially) confounded by the prominent seaside use of the BSS, which is likely a preferred location for foreign investors and expats. The importance of network connectivity is evident from the values for the distance to the centre of the BSS (DIST_MEAN) and the count of other BSS stations within a 600m buffer around the station (COUNT_STAT); in all cities the top 5 stations are relatively close to the centre of the BSS, with a higher number of surrounding stations than the median.

When comparing these results with findings from other BSS in Southern Europe, the role of bicycle infrastructure, areas with a high land use mix and Points-of-Interest (POI) and the location of recreational areas, especially near the sea, become evident. From their analysis of the BSS in Santander (Spain), Bordagaray et al. (2016) found that symmetrical trips, indicative of commuting BSS use, were most likely to originate from residential areas, whereas round trips, indicative of leisure BSS use, were found more at stations in open areas, near parks or the sea, or with panoramic views. The BSS station located in the city centre, close to shops, cafes/restaurants and POI, was the most popular station in their analysis. The presence of bicycle lanes also stimulated usage of BSS stations found in the vicinity of such infrastructure. In their analysis of BSS use demand in Rethymno (Crete, Greece), Bakogiannis et al. (2019), found that the highest usage of the BSS was found in the city centre and the eastern part of the urban area, adjacent to the seafront, with touristic and commercial activities. Research into BSS usage in Seville and Barcelona shows the association of BSS use with areas with a high land use mix, many POI, including commercial and recreational activities, as well as places of historic interest (Faghih-Imani et al., 2017).

6.4.2 Spatial coverage of the BSS

When looking at the distribution of the BSS stations throughout the cities, it can be noted that not the entire city is served by the system. BSS generally serve only a small section of a city's population. As an example, in a socio-spatial analysis of the coverage of the BSS in Glasgow, Clark & Curl (2016) found that only 9% of the city's population lived within a 400m radius of a BSS station. To understand to what extent the BSS serves the resident population of the cities investigated in this research, population data (per census tract, neighbourhood or locality) were used to calculate the percentage of the city's population living in a 300m and 400m buffer around the BSS stations, as metrics of a walkable distance to BSS stations.

In Limassol, 13% of the city's population lives within a 400m radius, and 8% in a 300m radius of the BSS stations (see Figure 6.9). In Las Palmas de Gran Canaria 33% of the city's population lives within a 400m radius of a BSS station, and 28% live within a 300m radius of a BSS station (see Figure 6.10). In Malta, the calculations were based on the main urban area of the Maltese Islands, where the majority of BSS stations are found; the Northern and Southern Harbour districts that are located on either side of the capital Valletta. Of the population living in these districts, 29% live within a 400m radius of a BSS station, and 22% within a 300m radius (see Figure 6.11).

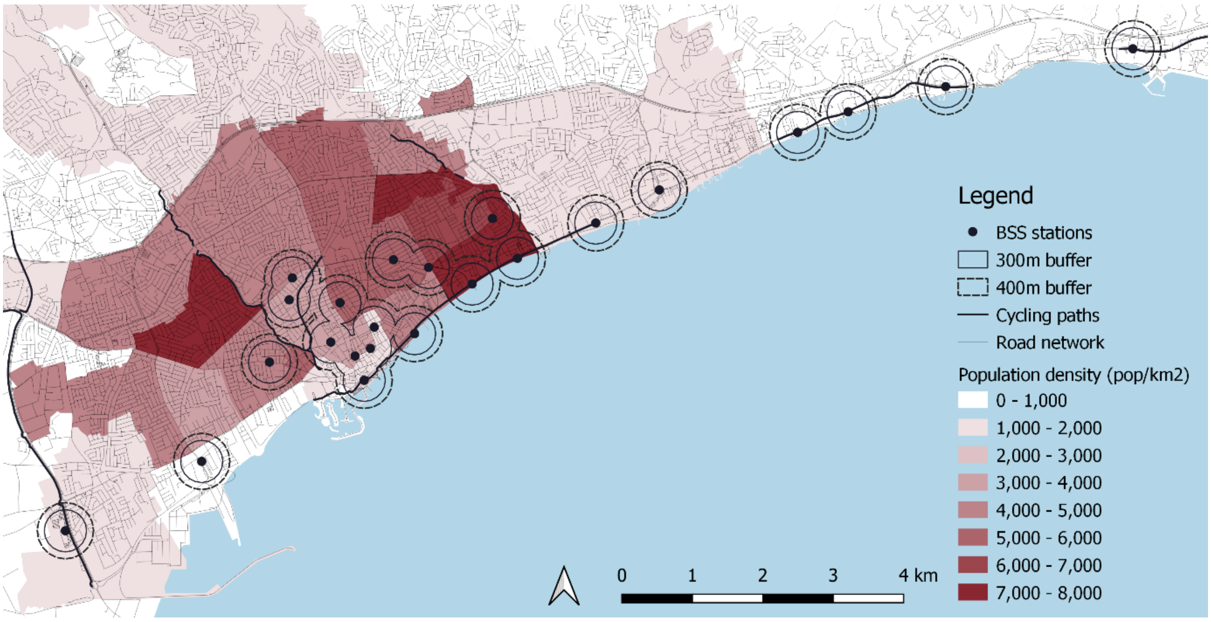


Figure 6.9: Population density and spatial coverage of the BSS in Limassol

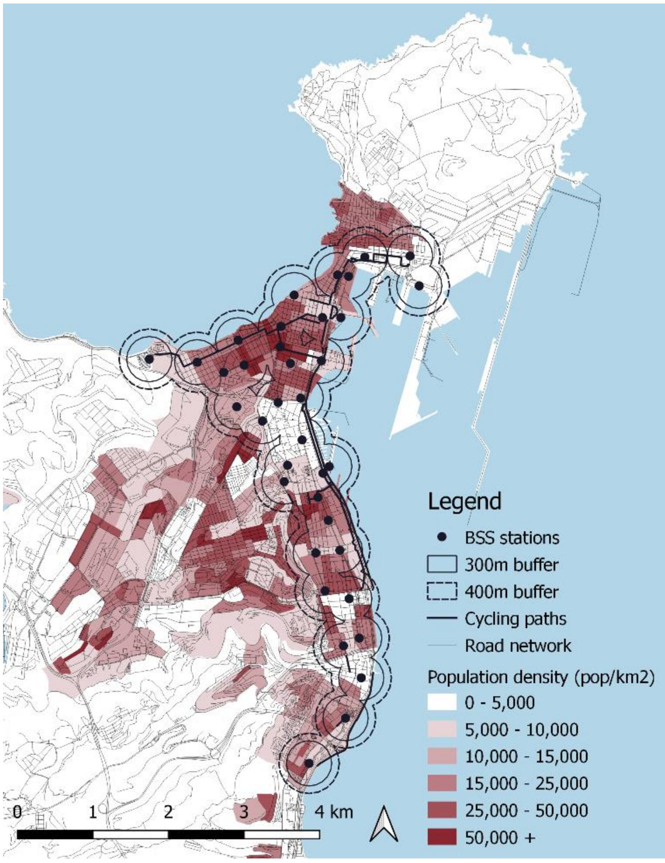


Figure 6.10: Population density and spatial coverage of the BSS in Las Palmas de Gran Canaria

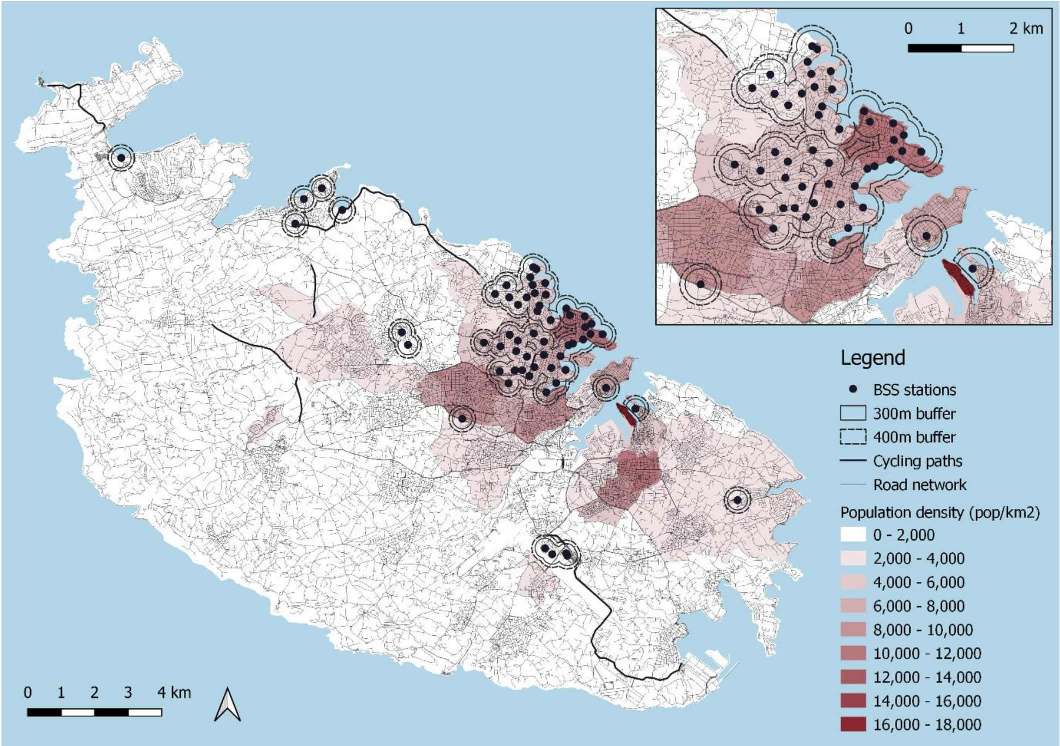


Figure 6.11: Population density and spatial coverage of the BSS in Malta

Compared to the abovementioned BSS coverage in Glasgow, where 9% of population live within a 400m buffer, in Las Palmas de Gran Canaria and the Northern and Southern Harbour districts of Malta, the BSS reaches a much larger portion of the population of their respective cities. However, there are still areas that are not well covered. In Las Palmas de Gran Canaria, there are parts of the city with high population density, notably in the upper part of the city, as well as on the peninsula to the north of the city centre around Santa Catalina station, that are currently not served by the BSS. In Malta, the BSS stations are mainly found in the Northern Harbour district, to the north of the capital city Valletta, whereas the other main urban area, the Southern Harbour district is much less covered, with only a few stand-alone stations. In Limassol, the BSS network is quite linear and spaced out along the city's long coastline. This, coupled with Limassol's overall lower population density means that the BSS serves only a smaller percentage of the population at their place of residence. This is particularly apparent in the residential neighbourhoods to the north and west of the city centre, which have a higher than average population density, but are not currently covered by the BSS. The fact that a large number of the stations are located along the coast of the cities also means their potential sphere of influence is more limited, as part of the walkable distance towards such stations is in fact not part of the city, but extends into the sea.

In all the three cities, these areas also represent lower-income neighbourhoods, when compared to the neighbourhoods currently served by the BSS. This can be partly by design, as BSS operators determine where to place stations based on the expected uptake and on the location of possible trip attractors such as urban centres, employment hubs and university campuses. However, to offer a true transport alternative to the city's residents, the network connectivity and spatial coverage of the BSS needs to be addressed.

6.4.3 The influence of the road environment on BSS use

In the survey, respondents were asked about which road environment they most frequently cycle in: on a separated bicycle path; on a bicycle lane on the road; on the road in mixed traffic; or on the pavement or promenade. The responses per city are presented in Figure 6.12. A big difference can be observed between the majority of respondents in Limassol and Las Palmas de Gran Canaria, who indicate to cycle most frequently on a bicycle path or lane, versus respondents in Malta who most frequently cycle on the road in mixed traffic, and also to a higher degree on the pavement or promenade. This difference can be explained by the near absence of cycling infrastructure in the urban area where the BSS is present in Malta. What is interesting is the similar profile of responses in Limassol and Las Palmas de Gran Canaria, showing that cycling is taking place mostly on bicycle paths and lanes. Considering the more limited cycling infrastructure in Limassol, this means the BSS use is more concentrated and constricted, as has been observed from the maps presenting the OD flows as well. This confirms the strong positive relationship between dedicated cycling infrastructure and BSS use.

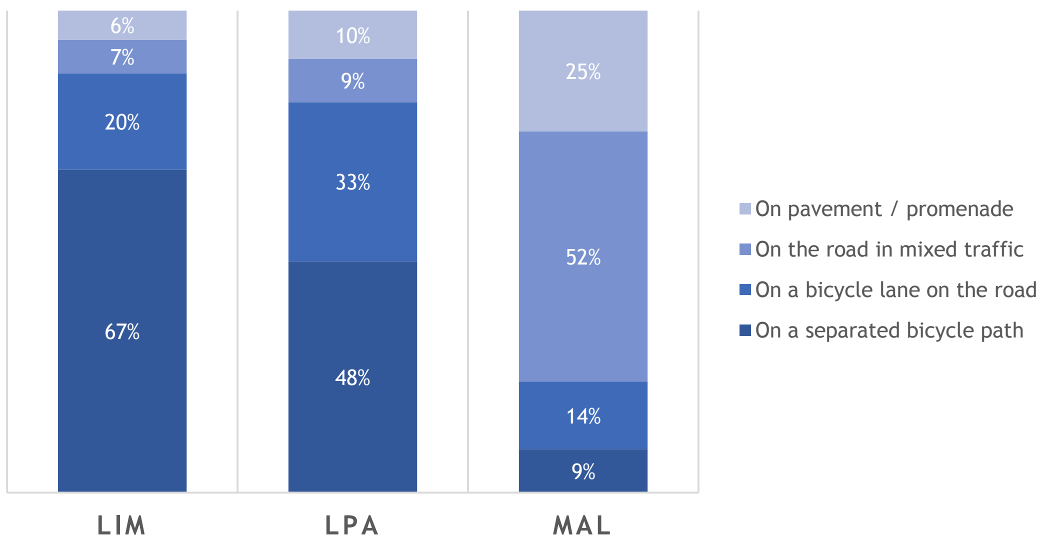


Figure 6.12: Most frequent road environment for BSS use in LIM, LPA and MAL

When respondents were asked about their perception of safety in the different types of road environments, a very similar profile emerged for each city (see Figure 6.13). Respondents overwhelmingly indicate to feel safest on a segregated bicycle path, and least safe on the road in mixed traffic, without cycling infrastructure. This finding corroborates findings from around the world where an association was found between BSS use and cycling infrastructure (Buck & Buehler, 2012; Faghih-Imani et al., 2014; Mateo-Babiano et al., 2016; Rixey, 2013) and specifically in Southern European cities, where the lack of a safe cycling network was identified as the main barrier to more (shared) bicycle use, e.g. in Lisbon, Portugal (Félix et al., 2019), in Larnaca, Cyprus (Nikolaou et al., 2020), in Drama (Nikitas, 2018) and Rethymno (Crete), Greece (Bakogiannis et al., 2019).

6.5 When is the BSS used?

This section looks at the "*when*" of BSS use: the timing of BSS trips in terms of daily usage patterns, including both weekdays and weekends, and the temporal variation of BSS over the period of a year.

6.5.1 Daily BSS usage patterns

Time series of daily usage patterns, based on the aggregated data of the yearly renting times (at origin stations) and returning times (as destination stations), are presented in Figure 6.14. Weekday trips in Limassol exhibit a double peak, between 07:00-09:00, and between 17:00-20:00, which is usually characteristic of commuting patterns. However, as results from the survey show that the system is used more frequently for leisure and exercise, the weekday double peak is more likely to be related to before and after work exercise and leisure behaviour, in addition to commuting trips. In Las Palmas de Gran Canaria, the hourly time series of aggregated weekday and weekend day trips shows that weekdays exhibit a triple peak, in the morning between 07:00-08:00, around 14:00 and between 17:00-19:00. These observations are concurrent with observations in other Southern European cities, where in addition to the morning and evening commuting peaks, a lunch hour or afternoon peak can be observed, e.g. in Lyon, Seville and Barcelona (Borgnat et al., 2011; Castillo-Manzano & Sanchez-Braza, 2013; Faghih-Imani et al., 2017). In Malta, the BSS shows a strong double peak on weekdays, with a strong morning peak between 07:00-09:00 and a more drawn out peak in the late afternoon, from 17:00 onwards, which are primarily associated with commuting behaviour.

The weekend trips in Limassol show a flatter curve, with the bulk of trips between 09:00 and 18:00, related to leisure activities, which is also observed in the weekend use of other BSS (Fishman, 2016; Pfrommer et al., 2014). In Las Palmas de Gran Canaria, the weekend peaks are found primarily between 11:00-13:00 and 16:00-18:00, and are less pronounced than the weekday usage. In Malta, the weekend usage shows a flatter curve, with the highest usage between midday and the late afternoon, associated with leisure use. When looking at the ratio between weekday and weekend trips, in Limassol weekday trips constitute 67% of the total trips, with 33% of the trips taking place on the weekends. In Las Palmas de Gran Canaria, weekend use represents 20% of the total, with 80% of the total trips occurring on weekdays. In Malta, 76% of total trips are on weekdays, versus 24% of trips on the weekend days. These figures are in line with the more frequent use of the BSS in Las Palmas de Gran Canaria and Malta for commuting purposes, which primarily take place on weekdays, and the more frequent use of the BSS for exercise and leisure in Limassol, which are expected in higher frequency on weekend days, in people's leisure time.

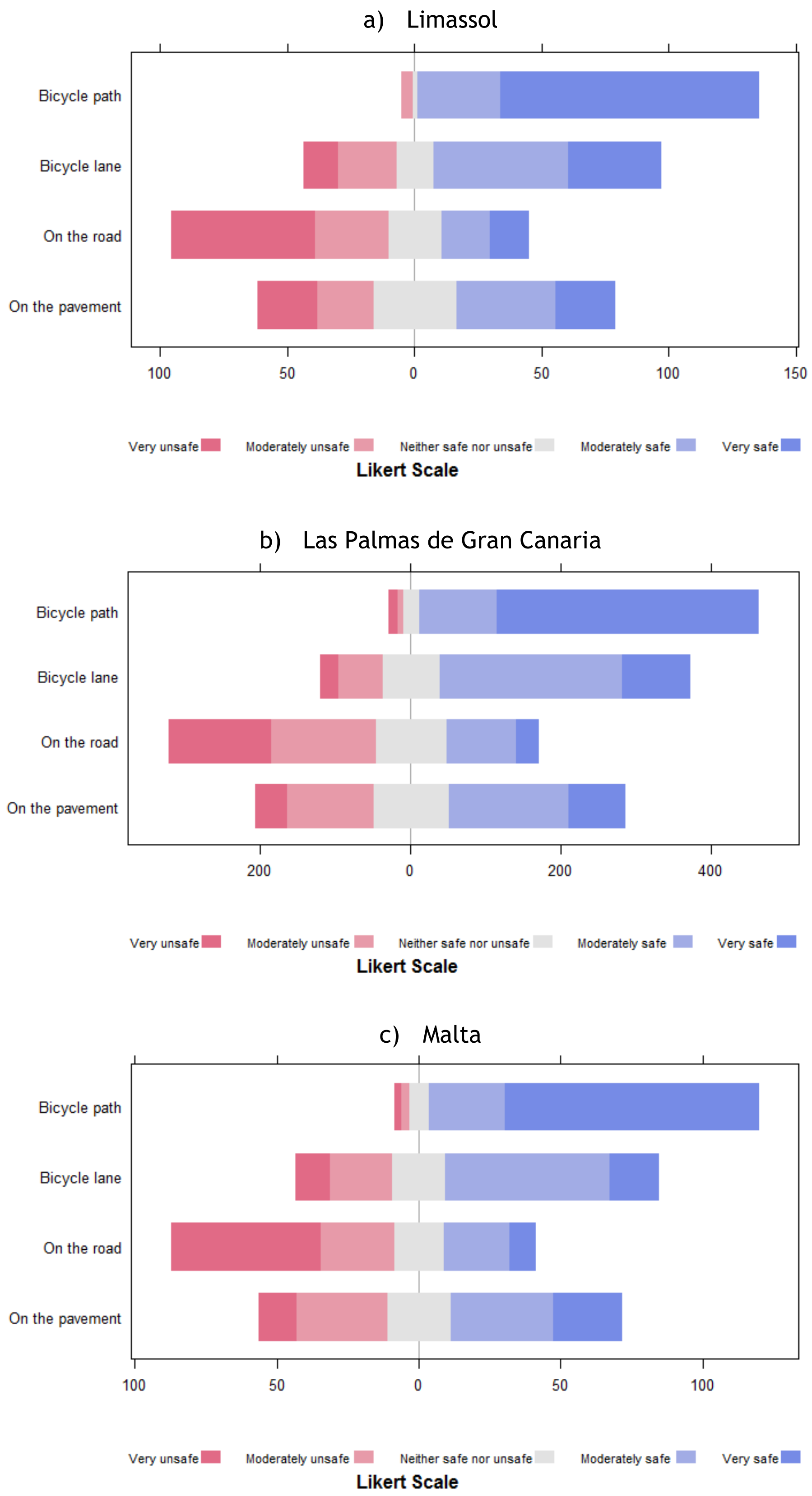


Figure 6.13: Perception of cycling safety in different road environments, in: a) Limassol, b) Las Palmas de Gran Canaria, and c) Malta

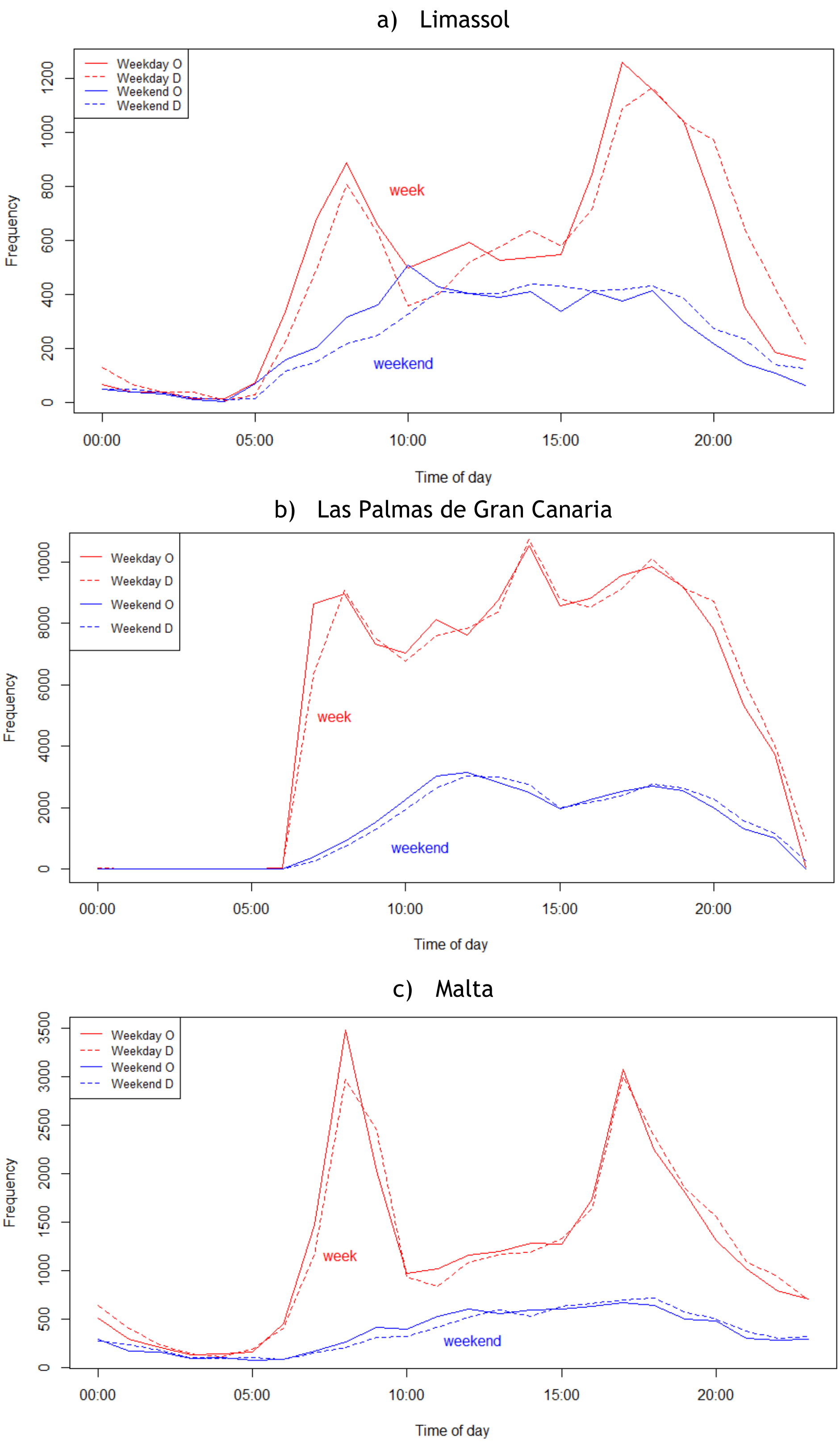


Figure 6.14: Time series of aggregated renting time at Origin (O) and return time at Destination (D) in: a) Limassol, b) Las Palmas de Gran Canaria, and c) Malta (Maas et al., 2020)

The survey also contained a question asking respondents whether they use the BSS mostly on weekdays, on weekend days, or both. The results presented in Table 6.9 show a similar picture as the analysis from the BSS trip data, with highest weekend use in Limassol and highest weekday use in Las Palmas de Gran Canaria. The highest value for 'both on weekdays and weekends' was found in Malta.

Table 6.9: Weekday and weekend BSS use in LIM, LPA and MAL

	LIM	LPA	MAL
Mostly on weekdays	21%	32%	21%
Mostly on weekends	40%	24%	30%
Both on weekdays and weekends	39%	44%	49%

6.5.2 Temporal variation of BSS use

When looking at the temporal variation of the BSS over the course of a year (April 2018 to March 2019) in Figure 6.15, it can be observed that there is an association with the identified seasons, in terms of weather and tourist numbers. In Limassol and Malta, the temporal variation of usage follows the two distinct seasons that can be observed in the two cities. There is a clear contrast between BSS usage in the generally warm and dry extended summer period (April to October), also the main tourist season (with 84% of total tourist arrivals in Limassol; and 73% in Malta), and the winter season with moderate temperatures and the majority of the rainfall (November to March). In Las Palmas de Gran Canaria, where temperatures and rainfall patterns are more stable, the BSS usage shows less extreme fluctuations. Apart from the first month (April 2018), when the BSS was just starting out, the usage is relatively stable and slowly increasing during the predominant tourist season in the Canary Islands, which is the winter season (70% of tourist arrivals between October and April). Looking at the distribution of trips between the seasons, in Limassol, 73% of total trips take place in the high season (April to October), in Las Palmas de Gran Canaria, 61% of total trips take place in the high season (October to April) and in Malta, 74% of total trips take place in the high season (April to October).

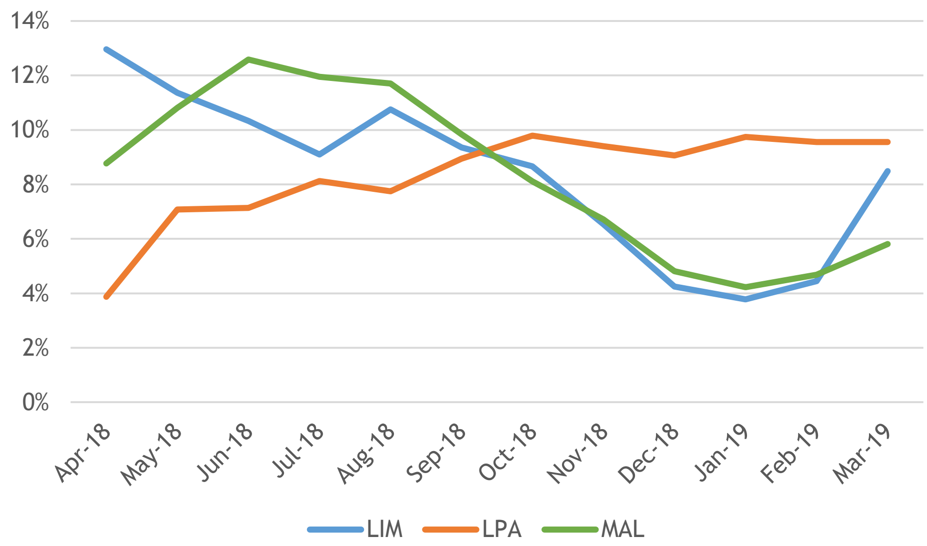


Figure 6.15: Monthly BSS usage as a percentage of total BSS yearly use in LIM, LPA and MAL

6.6 How much BSS use is there?

This section looks at "*how much*" BSS use there is, including the frequency of BSS trips, in terms of the number of trips per bicycle per day overall and per month, and the characteristics of the trip durations.

6.6.1 BSS trip frequency

A number of characteristics related to the trip frequency of the BSS in Limassol, Las Palmas de Gran Canaria and Malta are presented in Table 6.10. The total amount of trips varies quite widely, with Limassol representing the smallest usage and Las Palmas de Gran Canaria the largest. The seasonal fluctuation is evident from the low number of minimum trips/day in Limassol and Malta. The differences in number of unique users is less extreme, with only around a factor 3 difference between Limassol and Las Palmas de Gran Canaria. This highlights how the higher usage in Las Palmas de Gran Canaria is predominantly explained by unique active users making more trips on average, rather than by more unique users using the BSS. This is also evident from the figures for the mean number of trips per user per year. In addition, a small percentage of users make a large percentage of the total BSS trips, in all three cities; the most active 1% of users make respectively 23% (Limassol), 23% (Las Palmas de Gran Canaria) and 28% (Malta) of all the trips. The flipside of this is that many BSS users are not regular users, but rather use the BSS as a one-off trial or experience, or complementary to their primary mode of transport (Barbour et al., 2019; Fishman, 2016). Of the total unique users, 23% (Limassol), 39% (Las Palmas de Gran Canaria) and 31% (Malta) only used the BSS once in the year under study.

Table 6.10: Trip frequency characteristics in LIM, LPA and MAL

	LIM	LPA	MAL
Total trips/year	17,532	162,871	37,306
Minimum trips/day	3	166	5
Maximum trips/day	130	726	203
Mean trips/day	48	456	102
Unique users / year	3,070	9,006	4,082
Unique one-time users	718	3,472	1,268
Mean trips / user / year	5.7	18.1	9.1

The number of trips per day per bicycle (TDB) is one of the main metrics used to assess BSS usage and performance (Fishman, 2016; Médard de Chardon et al., 2017). Yearly and monthly TDB values are presented for the three cities in Table 6.11. Mean TDB is calculated by dividing the total trips per year by the amount of bicycles in the city and the days in the year. The maximum TDB is calculated by dividing the maximum trips per day recorded by the amount of bicycles. The monthly TDB is calculated by dividing the total trips per month by the amount of bicycles and the days in that month. While a TDB of at least 1.0 (representing 1 trip per day per bicycle) has been mentioned as an important psychological minimum of TDB (Médard de Chardon et al., 2017), lower BSS usage rates have been observed in many BSS, even where schemes have quite a lot of subscribed members (Nikitas, 2019; Wang et al., 2018).

Table 6.11: Yearly and monthly TDB in LIM, LPA and MAL

Yearly TDB	LIM	LPA	MAL
Total trips/year	17,532	162,871	37,306
Total # bicycles	170	375	400
Mean TDB	0.28	1.22	0.26
Maximum TDB	0.76	1.94	0.51
Monthly TDB	**LIM**	**LPA**	**MAL**
Apr-18	0.45	0.56	0.27
May-18	0.38	0.99	0.33
Jun-18	0.36	1.03	0.39
Jul-18	0.30	1.14	0.36
Aug-18	0.36	1.09	0.35
Sep-18	0.32	1.30	0.31
Oct-18	0.29	1.37	0.24
Nov-18	0.22	1.36	0.21
Dec-18	0.14	1.27	0.14
Jan-19	0.13	1.36	0.13
Feb-19	0.16	1.48	0.16
Mar-19	0.28	1.34	0.17

In the survey, respondents were asked about their frequency of the use of the BSS. Figure 6.16 shows how the frequency of BSS use in Las Palmas de Gran Canaria is the highest, with 14% of respondents using the BSS on a 'daily' basis, 29% 'often' (a few days a week) and 19% 'sometimes' (at least once every 2 weeks). In Limassol that is 7% 'daily', 14% 'often' and 17% 'sometimes', and in Malta 12% 'daily', 20% 'often' and 13% 'sometimes'.

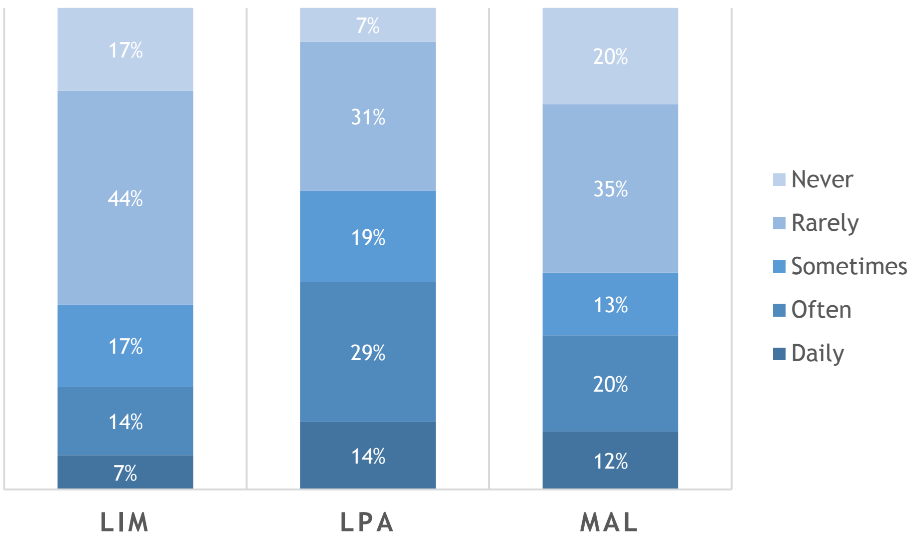


Figure 6.16: Frequency of BSS use in LIM, LPA and MAL

There was also a question in the survey that asked respondents whether they cycle more often since using the BSS. The results are presented in Figure 6.17 and show that in Limassol and Las Palmas de Gran Canaria a larger share of the respondents indicated that they cycle more, when compared to Malta. However, in all three cities, the majority of respondents indicated that they cycle more frequently since using the BSS.

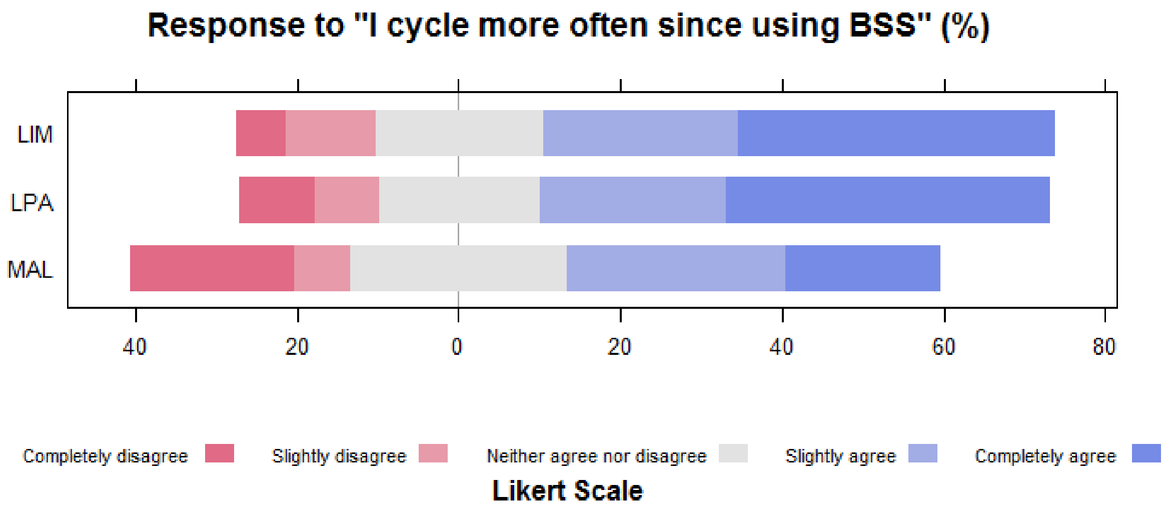


Figure 6.17: Respondents who cycle more since using the BSS in LIM, LPA and MAL

6.6.2 BSS trip duration

Based on the full datasets of BSS trips between 2 and 500 minutes, the median, mean and standard deviation (SD) of the trip duration in minutes is presented in Table 6.12 for each city. When comparing the three cities, Las Palmas de Gran Canaria and Malta have shorter median trip durations of 13 and 14 minutes respectively. The average (mean) trip duration in Las Palmas de Gran Canaria is ~20 minutes, whereas in Malta it is ~30 minutes. The values for Las Palmas de Gran Canaria are in line with average trip duration observed in other commuter-dominated BSS, e.g. in Melbourne, Brisbane, Washington DC, Minnesota and London, which show an average trip duration between 16 and 22 minutes (Fishman, 2016). The higher median trip duration of 39 minutes and average trip duration of ~60 minutes in Limassol can be at least partially explained by the different pricing structure in Limassol, with a fixed pay-as-you-go rate for the first 1 hour of use, and 120 free minutes of use for subscription users, as opposed to the more common 30-minute flat fee interval (FFI) for casual users, and free rental time for subscribed users (Bordagaray et al., 2016). The higher standard deviation in Limassol and Malta indicate there is greater variability in the trip durations of the trips observed in these cities, when compared to Las Palmas de Gran Canaria.

Table 6.12: BSS trip duration in LIM, LPA and MAL

Trip duration	LIM	LPA	MAL
Median	39.00	13.00	14.00
Mean	60.66	19.49	30.10
Standard deviation	66.97	29.08	51.11

Histograms representing the frequency distributions of the trip duration (up to 60 minutes) in the three cities are presented in Figure 6.18. All three histograms show a right-skewed frequency distribution, indicating the majority of trips constitute short trips. This is typical for BSS, as they encourage short journeys by using incremental price increases (Pfrommer et al., 2014). Frequency distributions from all three cities peak around the 10-minute mark. However, the shape of the curve is noticeably different in the case of Limassol, which does not flatten out as quickly as in the other two cities, with a higher share of longer trips, explained by the different flat fee interval and by the more frequent use of the BSS for leisure or exercise purposes, which are associated with longer trip durations.

The results from the survey question "How long does your most frequent BSS trip take?" further supported these findings, with the longest trip duration indicated by respondents in Limassol, and the shortest trip duration by respondents in Las Palmas de Gran Canaria, thus showing consistency between the self-reported (perceived) trip duration obtained from the survey results, and the actual trip duration obtained from the observed BSS trip data. The Dunn test, used to capture significant differences between values across the three cities, showed a significant difference (at *p*-value <0.01) for the responses to this question between Limassol and the other two cities; the mean response was 3.5 for Limassol (between categories (3) '*20-30 minutes*' and (4) '*30-60 minutes*'), whereas the mean value was 2.5 for Las Palmas de Gran Canaria and 2.7 for Malta (between categories (2) '*10-20 minutes*' and (3) '*20-30 minutes*').

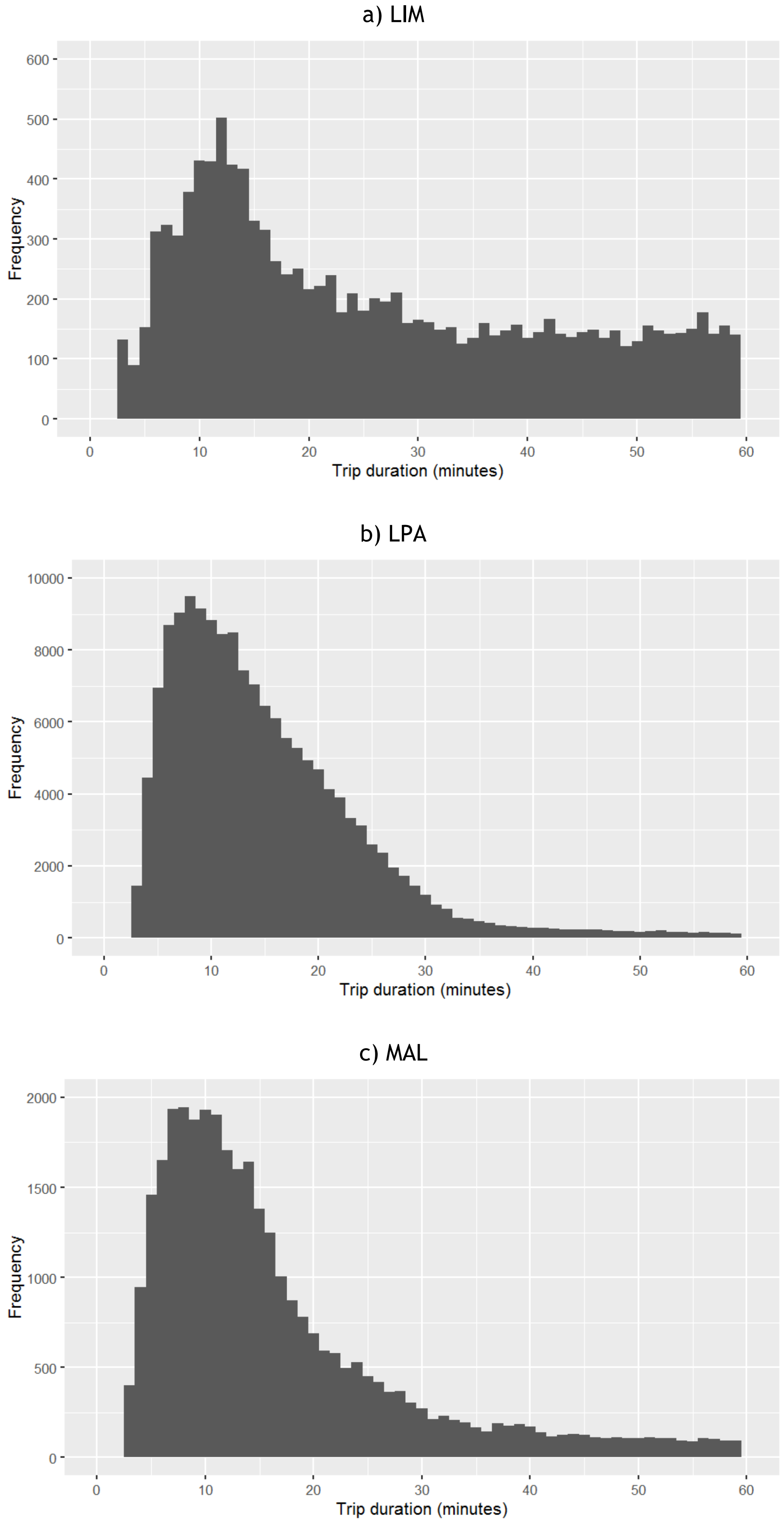


Figure 6.18: Histogram of frequency of trip duration (up to 60 minutes) in: a) LIM, b) LPA, and c) MAL

6.7 Comparative analysis of BSS use

Who uses the BSS was captured through the user survey, showing differences in the gender of respondents, with more female respondents in Limassol, and more males in Las Palmas de Gran Canaria and Malta, and a higher mean age in Las Palmas de Gran Canaria when compared to Limassol and Malta. The majority of BSS users were permanent residents of the cities, but with a higher share of foreign residents in Limassol and Malta. In all three cities, the majority of respondents were in full-time employment, had generally high levels of education and average income levels. The majority of respondents indicated having a driving license, but ownership of cars was more dispersed, with figures highest in Limassol and lowest in Malta. In terms of BSS use, in Las Palmas de Gran Canaria 62% of respondents used the BSS at least once every 2 weeks (‘daily’, ‘often’ or ‘sometimes’), versus 38% of respondents in Limassol and 45% in Malta. When asked about a modal shift because of BSS use, the main shift was from walking, and thereafter from public transport and private car use.

The most frequent trip purpose for daily BSS use was ‘for commuting’ in Las Palmas de Gran Canaria and Malta and ‘for exercise’ in Limassol. The high share of round trips in Limassol confirmed a system dominated by leisure use, whereas the BSS in Las Palmas de Gran Canaria, and in Malta to a lesser extent, were dominated by use for transport: for commuting, shopping or errands. When asked about what motivated respondents to use the BSS, the top three motivating factors are consistent among the three cities: health, being environmentally friendly and fun. In Las Palmas de Gran Canaria ‘convenience’ and in Malta ‘convenience’ and ‘time-saving’ were also important motivating factors for the BSS users, consistent with commuter-type goals. Satisfaction with the BSS was high overall in the three cities. In terms of encouraging factors, ‘more cycle lanes or paths’ received the strongest positive response in Limassol and Malta as a factor that would encourage more cycling and BSS use. The need for ‘greater cycling safety awareness’ scored the highest in Las Palmas de Gran Canaria, and also highly in Limassol and Malta. The main discouraging factor in all three cities was ‘concerned for safety in traffic’. The results of the encouraging and discouraging factors highlighted the importance of dedicated infrastructure and improved road safety for cycling and BSS use.

BSS use in Limassol was found to be extremely concentrated around a handful of stations along the bicycle path lining the coastal promenade. The BSS in Las Palmas de Gran Canaria showed more diffuse use, with popularly used stations concentrated around the northern city centre and the southern city centre, both around the primary bus stations. In Malta, BSS use was concentrated between a limited number of stations, primarily those in the Northern Harbour area along the promenade. The positive association with cycling infrastructure, areas with a high land use mix and points-of-interest (POI) and the location of recreational areas, especially near the sea, with BSS use, was evident from the results. In terms of population coverage, considering a 400m buffer around the BSS stations, the BSS in Las Palmas de Gran Canaria reached 33% of the population, in Malta 29% and in Limassol 13%. When asked about their perception of safety in different road environments, respondents overwhelmingly indicated that they feel safest on a segregated bicycle path, and least safe on the road in mixed traffic, without cycling infrastructure.

In terms of the daily usage of the BSS, Limassol and Malta showed weekday morning and evening peaks, related to commuting behaviour, but also leisure use before and after work hours. The usage profile in Las Palmas de Gran Canaria showed an additional peak around midday, consistent with lunch time trips, also observed in other Southern European cities. Weekend use was characterised by a flatter curve representing usage throughout the day, from mid-morning to late afternoon, consistent with weekend leisure use. Weekend use was highest in Limassol, whereas weekday use was highest in Las Palmas de Gran Canaria. In terms of the temporal variation of BSS use over the year, BSS use in Las Palmas de Gran Canaria was more evenly spread, with less obvious seasonality, whereas in Limassol and Malta there was a clear domination of BSS use in the high season, with almost three-quarters of trips.

A small percentage of users made a large percentage of the total BSS trips, in all three cities: the most active 1% of users make respectively 23% (Limassol), 23% (Las Palmas de Gran Canaria) and 28% (Malta) of all the trips. On the other hand, many BSS users were not regular users, with around a third of unique users only making one trip in the year under study. The average trips per day per bicycle is 0.28 in Limassol, 1.22 in Las Palmas de Gran Canaria and 0.26 in Malta, relatively low BSS usage rates. The BSS in Las Palmas de Gran Canaria and Malta had shorter median trip durations, indicative of commuting use, whereas the longer median and mean trip durations in Limassol indicated more use for leisure and exercise. The longer trip duration in Limassol is partly due to the different pricing structures, but also because of the different nature of the use of the BSS.

6.8 Conclusion

In this concluding section, the results of the descriptive statistics using the results of the BSS user survey and the BSS trip data, presented in this chapter, are summarised. This chapter focused on the introduction and operation of the BSS, and the use of the BSS, in terms of the *"who", "why", "where", "when"* and *"how much"* of BSS use.

This chapter started by introducing the history and operation of the three BSS analysed in this study: *Nextbike Cyprus* in Limassol, which was introduced in 2012, *Sítycleta* in Las Palmas de Gran Canaria, which started operation in 2018 and *Nextbike Malta* in Malta, which was launched in 2016. In terms of demographic and socio-economic differences, more female BSS users responded to the survey in Limassol, and more males in Las Palmas de Gran Canaria and Malta, and they had a higher mean age in Las Palmas de Gran Canaria when compared to Limassol and Malta. The most frequent trip purpose for daily BSS use was 'for commuting' in Las Palmas de Gran Canaria and Malta and 'for exercise' in Limassol. The top three motivating factors were consistent among the three cities: for reasons of 'health', the 'environment' and 'fun'. The main discouraging factor in all three cities was 'concerned for safety in traffic'. BSS use in Limassol was extremely concentrated on a handful of stations along the bicycle path lining the coastal promenade. In Las Palmas de Gran Canaria, the system was used more diffusely, spread across the city, with clusters of use around the two main city centres. In Malta, use was concentrated around the harbour area north of Valletta. In terms of population coverage, considering a 400m buffer around the BSS stations, the BSS in Las Palmas de Gran Canaria reached 33% of the population, in Malta 29%, but in Limassol only 13%. The trip data from the BSS in Limassol and Malta showed weekday morning and evening peaks, related to commuting behaviour, but also leisure use before and after work hours, whereas the data from Las Palmas de Gran Canaria showed an additional peak around midday, consistent with lunch time trips. In all three cities, a small percentage of users made a large percentage of the total BSS trips. Median trip durations in

Las Palmas de Gran Canaria and Malta were shorter than in Limassol, indicative of commuting use versus more use for leisure and exercise.

In the next chapter, *Chapter 7,* the relationships between individual and social environment factors and BSS use is investigated. *Chapter 8* then delves deeper into the associations between physical environment factors and BSS use. The results presented in this chapter will be further discussed in relation to findings from the literature in *Chapter 9.*

7. The influence of individual and social environment factors on BSS use

This chapter addresses the fourth research question (RQ4) of this study: *What is the influence of individual and social environment factors on BSS use?* This chapter will describe how user characteristics, their attitudes, habits and perceptions, encouraging and discouraging factors, social norms and perceived environment factors influence their BSS use, through analysis of the BSS user survey responses from the three case study cities. A comparative analysis of the influence of individual and social environment factors is also included, addressing research question six (RQ6): *How do BSS use and influencing factors in the case study cities compare?* As outlined in *Chapter 3,* BSS use is influenced by multiple levels of factors: from individual factors to social and physical environment factors. The way in which individual factors and social environment factors, on which this chapter focuses, influence BSS use, is highlighted in the theoretical framework guiding this research in Figure 7.1.

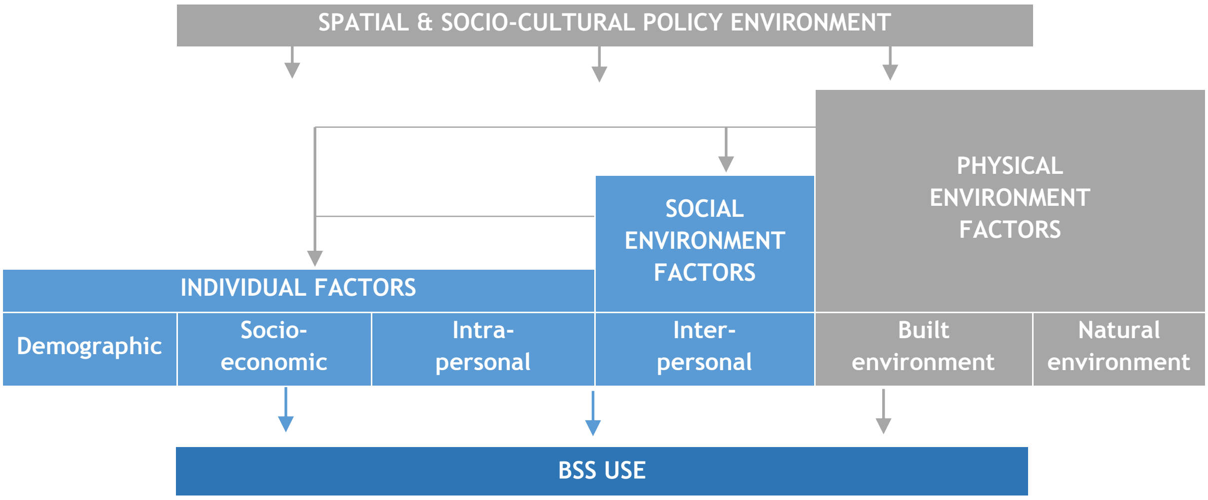


Figure 7.1: Position of individual factors and social environment factors in the theoretical framework

In section 7.1 of this chapter, the relationship between the dependent variable and independent variables is assessed through Chi-Square and Kruskal-Wallis tests, and through bivariate correlation analysis for the relationships between variables measured on Likert scales. In section 7.2, binary logistic regression models are fitted on the datasets. First, the identified independent variables with a significant association with the dependent variable are assessed for multicollinearity and balancing the datasets for use in the models. Then, training and testing datasets are used to confirm model accuracy, using Goodness-of-Fit tests to confirm model fit. The outputs of the binary logistic regression models are compared with neural networks, a machine-learning based modeling technique, to compare model output and aid in the interpretation, as it shows relative variable importance. In section 7.3, the results from the bivariate correlation analysis and the binary logistic regression models are linked with each other to interpret the results per city. Section 7.4 presents a comparative analysis based on the results from the three cities, looking at similarities and differences in the influence of individual and social environment factors on BSS use. In section 7.5, the datasets of the three cities are aggregated, in order to understand differences in the demographic and socio-economic characteristics of frequent vs. infrequent BSS users, and differences in the influence of attitudes and perceptions of frequent vs. infrequent BSS users. By determining significant differences between frequent and infrequent BSS users across the survey data from the three cities, more generic conclusions can be drawn up for what encourages and discourages BSS use and cycling in these and similar 'starter' cycling cities. In the final section, 7.6, the results from this chapter are summarised and the next chapter is introduced.

7.1 Associations between dependent and independent variables

7.1.1 Preparation of the datasets

In this section, bivariate correlation analysis is used to find out which independent variables showed a significant association with the dependent variable 'Use_bikeshare', using Chi-Square tests (for nominal/ordinal variables) and a Kruskal-Wallis test (for the continuous variable 'age'). The dependent variable 'Use_bikeshare' was re-coded from an ordinal five-point Likert scale to a binary variable 'Use_bikeshare_bin' with two classes: frequent and infrequent users. To determine which independent variables show a significant association with the binary dependent variable 'Use_bikeshare_bin', Chi-square tests were performed to analyse the relationship between the dependent variable and nominal and ordinal variables, and the Kruskal-Wallis test to analyse the relationship between age (discrete variable) and the dependent variable. The significant associations that were found between the dependent variable and the independent variables are presented for the three case study cities; in Table 7.1 for the Limassol dataset, in Table 7.2 for the Las Palmas de Gran Canaria dataset, and in Table 7.3 for the Malta dataset. For pairs of variables that showed a significant association in the Chi-Square or Kruskal-Wallis test (*p*-value <.05) the relationship was further explored. For variables on a binary or nominal scale that showed a significant relationship with the dependent variable, the relationship was visually assessed through box plots and cross tables.

The following associations were found between the dependent variable and independent variables measured on a binary or nominal scale. For Limassol, the Chi-Square test results show significant associations between 'Use_bikeshare' and 'Own_motor' (more frequent BSS use associated with a higher percentage of respondents owning a motorcycle), and 'Multimod_walk' (more frequent BSS use associated with respondents who indicate using multimodal transport, combining BSS use with walking). For Las Palmas de Gran Canaria, the Chi-Square test results show significant associations between 'Use_bikeshare' and 'Residency' (most frequent BSS use associated with temporary residents, then with permanent residents and visitors for work/education, and least frequent BSS use with visiting tourists), 'Own_car' (more frequent BSS use associated with a higher percentage of respondents that do not own a car), 'Skill' (more frequent BSS use associated with respondents who self-report higher cycling skill), 'Environment' (more frequent BSS use associated with respondents who mostly cycle on bicycle paths), 'Multimod_walk' (more frequent BSS use associated with respondents who indicate using multimodal transport, combining BSS use with walking) and 'Electric' (more frequent BSS use associated with respondents who indicate preferring a standard bicycle over an electric bicycle). For Malta, the Chi-Square test results show significant associations between 'Use_bikeshare' and 'Native' (more frequent BSS use associated with non-native respondents), 'Household' (more frequent BSS use associated with respondents living in a one-person household, versus households with two, or three or more members), 'Residency' (more frequent BSS use associated with temporary residents and visitors, less frequent BSS use associated with permanent residents), and 'Own_car' (more frequent BSS use associated with a higher percentage of respondents that do not own a car).

Variables measured on an ordinal scale with at least a five- or six-point Likert scale can be considered quantitative variables, and therefore their association can be assessed through a Spearman's correlation test, to determine the strength and direction of the association. The results from the Spearman's test are discussed in the next subsection on correlation analysis.

Table 7.1: Limassol - Significant associations between dependent and independent variables

Limassol dataset (*n*=140)		
Dependent variable	**Definition (scale)**	
Use_bikeshare_bin	Frequency of use of BSS (binary)	
Independent variables	**Definition (scale)**	***p*-value**
Income	Gross annual income (ordinal)	.015
Own_motor	Private motorcycle ownership (binary)	.018
Use_bicycle	Frequency of use of private bicycle (ordinal)	.001
Use_motor	Frequency of use of motorcycle (ordinal)	.000
Use_PT	Frequency of use of public transport (ordinal)	.000
Use_cardriver	Frequency of use of private car (as a driver) (ordinal)	.049
Use_taxi	Frequency of use of taxi (ordinal)	.001
Dist_home	Walking distance from residence to nearest station (ordinal)	.028
Dist_dest	Walking distance to frequent destination from nearest station (ordinal)	.028
Multimod_walk	Multimodal transport combination, BSS with walking (binary)	.033
Mot_money	Money-saving as a motivating factor (ordinal)	.049
Mot_conv	Convenience as a motivating factor (ordinal)	.027
Sat_regist	Satisfaction with sign-up / registration process (ordinal)	.048
Sat_price	Satisfaction with the pricing of the BSS (ordinal)	.009
Safe_road	Perceived safety on the road (without cycling infrastructure) (ordinal)	.004
Friends	Perception of support of cycling behaviour by friends and family (ordinal)	.001
Cycle_accept	Perception of cycling as an accepted form of transport in city (ordinal)	.006

Table 7.2: Las Palmas de Gran Canaria - Significant associations between dependent and independent variables

Las Palmas de Gran Canaria dataset (*n*=491)		
Dependent variable	**Definition (scale)**	
Use_bikeshare_bin	Frequency of use of BSS (binary)	
Independent variables	**Definition (scale)**	***p*-value**
Residency	Resident or visitor of city of BSS (nominal)	.004
Own_car	Private car ownership (binary)	.010
Use_walking	Frequency of walking (more than 5 minutes) (ordinal)	.005
Use_motor	Frequency of use of motorcycle (ordinal)	.010
Use_PT	Frequency of use of public transport (ordinal)	.025
Use_cardriver	Frequency of use of private car (as a driver) (ordinal)	.000
Use_taxi	Frequency of use of taxi (ordinal)	.001
Skill	Cycling skill level (ordinal)	.002
Dist_home	Walking distance from residence to nearest station (ordinal)	.005
Dist_dest	Walking distance to frequent destination from nearest station (ordinal)	.000
Environment	Road environment in which users most frequently cycle (nominal)	.000
Multimod_walk	Multimodal transport combination, BSS with walking (binary)	.000
Mot_money	Money-saving as a motivating factor (ordinal)	.000
Mot_conv	Convenience as a motivating factor (ordinal)	.000
Mot_time	Time-saving as a motivating factor (ordinal)	.000
Mot_health	Health benefits as a motivating factor (ordinal)	.013
Mot_env	Environmentally friendly as a motivating factor (ordinal)	.019
Sat_regist	Satisfaction with sign-up / registration process (ordinal)	.000
Sat_price	Satisfaction with the pricing of the BSS (ordinal)	.000
Sat_loc	Satisfaction with locations of the stations (ordinal)	.015
Sat_avail	Satisfaction with availability of bicycles (ordinal)	.006
Sat_rent	Satisfaction with renting/returning bicycles (ordinal)	.014
Sat_comf	Satisfaction with comfort of the bicycles (ordinal)	.006
Sat_brand	Satisfaction with the branding of the BSS (ordinal)	.011
Electric	Preference for standard or electric bicycle (nominal)	.023
Safe_path	Perceived safety on a separated bicycle path (ordinal)	.002
Safe_lane	Perceived safety on a bicycle lane on the road (ordinal)	.000
Safe_road	Perceived safety on the road (without cycling infrastructure) (ordinal)	.006
Safe_pave	Perceived safety on the pavement / promenade (pedestrian space) (ordinal)	.042
Like_cycling	Attitude towards liking cycling as a mode of transport (ordinal)	.019
Conv_cycling	Attitude towards the convenience of cycling as a mode of transport (ordinal)	.000
Need_car	Attitude towards the need for using a car for daily tasks (ordinal)	.000
Cycle_rain	Attitude towards cycling when it is rainy and windy (ordinal)	.032
Appear	Attitude towards worrying about appearance after cycling (ordinal)	.029
Friends	Perception of support of cycling behaviour by friends and family (ordinal)	.000
Road_users	Perception of respect of other road users towards cyclists (ordinal)	.020
Enc_paths	'More cycling paths' as an encouraging factor (ordinal)	.009
Enc_speed	'Roads with lower vehicle speeds' as an encouraging factor (ordinal)	.017
Enc_aware	'Greater cycling safety awareness' as an encouraging factor (ordinal)	.034
Enc_carprice	'Making driving more expensive/difficult' as an encouraging factor (ordinal)	.008
Disc_carconv	'Driving a car is more convenient' as a discouraging factor (ordinal)	.001
Disc_PTconv	'Public transport is more convenient' as a discouraging factor (ordinal)	.012
Disc_safe	'Concerned for safety in traffic' as a discouraging factor (ordinal)	.042
Disc_cost	'Too costly' as a discouraging factor (ordinal)	.002

Table 7.3: Malta - Significant associations between dependent and independent variables

Malta dataset (*n*=128)		
Dependent variable	**Definition (scale)**	
Use_bikeshare_bin	Frequency of use of BSS (binary)	
Independent variables	**Definition (scale)**	***p*-value**
Native	Native or non-native to country of BSS (binary)	.000
Household	Household size (nominal)	.044
Residency	Resident or visitor of city of BSS (nominal)	.038
Own_car	Private car ownership (binary)	.032
Use_motor	Frequency of use of motorcycle (ordinal)	.028
Use_PT	Frequency of use of public transport (ordinal)	.007
Use_taxi	Frequency of use of taxi (ordinal)	.003
Dist_home	Walking distance from residence to nearest station (ordinal)	.002
Dist_dest	Walking distance to frequent destination from nearest station (ordinal)	.010
Mot_money	Money-saving as a motivating factor (ordinal)	.001
Mot_conv	Convenience as a motivating factor (ordinal)	.044
Mot_time	Time-saving as a motivating factor (ordinal)	.000
Sat_regist	Satisfaction with sign-up / registration process (ordinal)	.000
Sat_loc	Satisfaction with locations of the stations (ordinal)	.021
Sat_avail	Satisfaction with availability of bicycles (ordinal)	.019
Sat_rent	Satisfaction with renting/returning bicycles (ordinal)	.044
Sat_comf	Satisfaction with comfort of the bicycles (ordinal)	.043
Safe_road	Perceived safety on the road (without cycling infrastructure) (ordinal)	.005
Road_users	Perception of respect of other road users towards cyclists (ordinal)	.007
Cycle_accept	Perception of cycling as an accepted form of transport in city (ordinal)	.000
Enc_carprice	'Making driving more expensive/difficult' as an encouraging factor (ordinal)	.018
Disc_PTconv	'Public transport is more convenient' as a discouraging factor (ordinal)	.035

7.1.2 Correlation analysis

Where a significant association between the dependent variable and independent variable was confirmed through the Chi-Square test, Spearman's correlation test was used to determine the strength and direction of the relationship. The correlation coefficients are presented in Table 7.4. All variables that showed an association in the Chi-Square test were included in the Spearman's correlation test. However, some variables that showed a significance in the Chi-Square test did not show a significant correlation in the Spearman's test:

- Limassol dataset: 'Income', 'Sat_regist' and 'Sat_price';
- Las Palmas de Gran Canaria dataset: 'Use_motor', 'Mot_health', 'Sat_loc', 'Safe_pave', 'Enc_aware', 'Disc_PTconv' and 'Disc_safe'; and
- Malta dataset: 'Enc_carprice'.

Table 7.4: Relationships between dependent variable and ordinal independent variables

Dependent variable	Definition	Spearman's correlation coefficients [b]		
Use_bikeshare_bin	Frequency of use of BSS (binary)			
Independent variables	Definition [a]	LIM *(n=140)*	LPA *(n=491)*	MAL *(n=128)*
Use_walking	Frequency of walking (>5 minutes)	-	0.133***	-
Use_bicycle	Frequency of use of private bicycle	0.249***	-	-
Use_motor	Frequency of use of motorcycle/scooter	0.447***	-	0.267***
Use_PT	Frequency of use of public transport	0.212**	0.132***	0.294***
Use_cardriver	Frequency of use of car as a driver	-0.176**	-0.172***	-
Use_taxi	Frequency of use of taxi	0.292***	0.137***	0.274***
Dist_home	Walking distance from residence to nearest BSS station	-0.210**	-0.134***	-0.333***
Dist_dest	Walking distance to frequent destination from nearest BSS station	-0.279***	-0.231***	-0.265***
Mot_money	Money-saving as a motivating factor	0.171**	0.260***	0.336***
Mot_conv	Convenience as a motivating factor	0.180**	0.258***	0.229***
Mot_env	Environmentally friendly as a motivating factor	-	0.127***	-
Mot_time	Time-saving as a motivating factor	-	0.321***	0.424***
Sat_regist	Satisfaction with sign-up / registration process	-	0.191***	0.201**
Sat_price	Satisfaction with the pricing of the BSS	-	0.392***	-
Sat_loc	Satisfaction with locations of the stations	-	-	0.278***
Sat_avail	Satisfaction with availability of bicycles	-	0.165***	0.245***
Sat_rent	Satisfaction with renting/returning bicycles	-	0.148***	0.227**
Sat_comf	Satisfaction with comfort of the bicycles	-	0.142***	0.221**
Sat_brand	Satisfaction with BSS brand / marketing	-	0.150***	-
Safe_path	Perceived safety on separated bicycle paths	-	0.149***	-
Safe_lane	Perceived safety on bicycles lanes on road	-	0.201***	-
Safe_road	Perceived safety on the road (in mixed traffic)	0.255***	0.136***	0.221**
Like_cycling	Attitude towards liking cycling	-	0.135***	-
Conv_cycling	Attitude towards the convenience of cycling	-	0.211***	-
Need_car	Attitude towards needing a car for daily tasks	-	-0.216***	-
Cycle_rain	Attitude towards cycling when it is rainy/windy		-0.104**	
Appear	Attitude towards worrying about appearance after cycling	-	0.104**	
Friends	Perception of support of cycling behaviour by friends and family	0.353***	0.213***	-
Road_users	Perception of respect of other road users towards cyclists	-	0.146***	0.217**
Cycle_accept	Perception of cycling being an accepted form of transport in city	0.263***	-	0.331***
Enc_paths	'More cycling paths' as an encouraging factor	-	0.130***	-
Enc_speed	'Roads with lower vehicle speeds' as an encouraging factor	-	0.110**	-
Enc_carprice	'Making driving more expensive/difficult' as an encouraging factor	-	0.149***	-
Disc_carconv	'Driving a car is more convenient' as a discouraging factor	-	-0.010**	-
Disc_PTconv	'Using public transport is more convenient' as a discouraging factor	-	-	0.215**
Disc_cost	'Too costly' as a discouraging factor	-	-0.179 *	-

[a]: all variables are on an ordinal scale; [b]: - not significant; significant at ** <0.05; *** <0.01 level

While the relationship between 'Use_bikeshare' and the use of alternative modes of transport is positive (e.g. 'Use_walking', in Las Palmas de Gran Canaria, 'Use_bicycle', in Limassol and Las Palmas de Gran Canaria, 'Use_motor', in Limassol and Malta, and 'Use_PT' and 'Use_taxi', in all three cities), the relationship with car use ('Use_cardriver' in Limassol and Las Palmas de Gran Canaria) is negative; more private car use is associated with less BSS use. The greater the distance between a respondent's residence ('Dist_home', in all three cities) or frequent destination ('Dist_dest', in all three cities), the lower the use of the BSS.

Money and convenience as motivating factors ('Mot_money' and 'Mot_conv') are positively associated with higher BSS use in all three cities, as are time-saving ('Mot_time', in Las Palmas de Gran Canaria and Malta) and environmental friendliness ('Mot_env', in Las Palmas de Gran Canaria). Satisfaction with the service also shows a positive relationship with BSS use in Las Palmas de Gran Canaria and Malta; with the registration process ('Sat_regist'), the availability of bicycles ('Sat_avail'), renting and returning bicycles ('Sat_rent'), comfort of the bicycles ('Sat_comf',), with the price ('Sat_price') and the brand ('Sat_brand'), in Las Palmas de Gran Canaria, and with the locations of the stations ('Sat_loc') in Malta. These associations did not show significant results for Limassol, indicating that the satisfaction with the BSS is not significantly impacting frequent versus infrequent BSS use there.

The relationship between BSS use and road safety perceptions is evident; a higher perceived safety on bicycle paths and lanes ('Safe_path' and 'Safe_lane', in Las Palmas de Gran Canaria) is associated with higher BSS use. Higher perceived safety on the road without cycling infrastructure ('Safe_road', in all three cities) is also positively associated with BSS use. This can be understood as higher BSS use by respondents who are less daunted by the road environment and cycling in mixed traffic, as from the descriptive statistics in section 6.4.3 in *Chapter 6*, it is clear that respondents perceive cycling on the road as the least safe option.

Agreement with the statement that cycling is convenient ('Conv_cycling', in Las Palmas de Gran Canaria) is positively correlated with BSS use, while agreement with the statement that a car is needed to perform daily tasks ('Need_car', in Las Palmas de Gran Canaria) is negatively correlated with BSS use. Agreement with not liking to cycle when it is rainy and windy ('Cycle_rain', in Las Palmas de Gran Canaria) is negatively correlated with BSS use, indicating that frequent BSS users are less hampered by this than infrequent users. Agreement with worrying about their appearance after cycling ('Appear', in Las Palmas de Gran Canaria) is positively correlated with BSS use, indicating that this sentiment is relevant for frequent BSS users, even if it doesn't seem to present a serious barrier to their BSS use. A positive social norm is associated with BSS use, as evidenced by the positive relationship between BSS use and the perception of support of cycling behaviour by friends and family ('Friends', in Limassol and Las Palmas de Gran Canaria), the perception of respect of other road users towards cyclists ('Road_users', in Las Palmas de Gran Canaria and Malta) and the perception of cycling being an accepted form of transport in the city ('Cycle_accept' in Limassol and Malta).

Frequent BSS use is positively associated with agreement with the statement that more cycle lanes/paths would encourage more cycling ('Enc_paths', in Las Palmas de Gran Canaria) and with the statement that roads with lower vehicle speeds would encourage more cycling ('Enc_speed', in Las Palmas de Gran Canaria). Agreement with the statement that driving a car is more convenient ('Disc_carconv', in Las Palmas de Gran Canaria) is associated with less frequent BSS use, indicating there is competition with this mode of transport. Agreement with the statement that using public transport is more convenient ('Disc_PTconv', in Malta) is associated with more BSS use, indicating there is complementarity between the use of public transport and BSS. Agreement with the BSS being too costly ('Disc_cost', in Las Palmas de Gran Canaria) is negatively correlated with BSS use, indicating that this is less of an issue for frequent BSS users than for infrequent users.

7.2 Binary logistic regression models

7.2.1 Preparation of model: testing for multicollinearity

In this section, binary logistic regression (BLR) models are fitted on the datasets to analyse the influence of, and interrelation between, a set of independent variables on the dependent variable: the frequency of BSS use. The independent variables that showed association with the dependent variable in the previous section were assessed for multicollinearity, using the corrplot() function from the *corrplot* package in R. In the resulting correlation matrices (presented in *Annex F: Correlation matrices*), variables that exhibit multicollinearity, based on the commonly used value of +/- 0.7 (Dormann et al., 2013), were identified. In cases where multicollinearity between independent variables was present, the independent variable with the strongest association with the dependent variable was retained, while the other independent variable(s) were removed from the dataset. In the Limassol dataset, no multicollinearity was found between the selected independent variables. In the Las Palmas de Gran Canaria dataset, multicollinearity was present between 'Own_car' and 'Use_cardriver', where the latter was retained as it showed a stronger association with the dependent variable, and between 'Mot_health' and 'Mot_env', where again the latter was retained. In the Malta dataset 'Mot_conv' was removed as it was multicollinear with 'Mot_time', and 'Road_users' was removed as it showed multicollinearity with both 'Safe_road' and 'Cycle_accept'.

7.2.2 Balancing datasets

Prior to building the models, the datasets were split into training (80%) and testing (20%) datasets, using the Python function "train_test_split". Since the number of observations in the Malta dataset was quite small it was decided not to split the data into the training and testing sets.

The balance of the dependent variable was then assessed for each dataset. Imbalanced data is defined as one of the classes having many more observations than the other class (Sun et al., 2009). In this analysis, a share of 45-55% for each binary class was considered to constitute a balanced dataset; ±5% from perfectly balanced. In the case of Limassol, analysis of the binary dependent variable showed that the two classes were not balanced (61% infrequent; 39% frequent). In the case of Las Palmas de Gran Canaria, the classes were also not balanced (37% infrequent; 63% frequent). In the case of Malta, the two classes were reasonably balanced (55% infrequent; 45% frequent).

To address the class imbalance in the Limassol and Las Palmas de Gran Canaria training datasets, the Python tool SMOTE-NC (Synthetic Minority Oversampling Technique) was used to create synthetic data for the datasets, which uses existing examples from the minority class to create new synthetic examples for the minority class, in order to come to a balanced training dataset for further use in the analysis.

7.2.3 Determining binary logistic regression models for the datasets

To determine the best model fit on the training datasets, forward stepwise variable selection was used, starting with a null model and adding independent variables one by one, starting from the most significant variable (based on its *p*-value). Further variables were added, ensuring the *p*-value of independent variables in the model showed significance (<0.05), while limiting the size of the standard errors. The Likelihood Ratio Tests determine each variable's contribution to the model and whether including the variable leads to a significantly different outcome than using the null model (without any independent variables). The Likelihood Ratio Tests for the datasets, showing the independent variables that were selected based on their significant contribution to the model, are presented in Table 7.5 for the Limassol dataset, in Table 7.6 for the Las Palmas de Gran Canaria dataset and in Table 7.7 for the Malta dataset. The Likelihood Ratio Tests of the constructed models were calculated using SPSS.

Table 7.5 presents all the independent variables that showed significance (*p*-value <.05) in the model for the Limassol dataset. Some of the other variables that were selected based on the Chi-Square tests - 'Use_motor', 'Dist_dest', 'Sat_regist' and 'Sat_price' - were significant but showed very large standard errors in the table of coefficients and were therefore excluded. The other variables that were selected based on the Chi-Square tests – 'Friends', 'Use_taxi', 'Use_PT', 'Multimod_walk', 'Mot_money' - were not significant and thus were not included in the model. In Table 7.6 the significant independent variables that were included in the Las Palmas de Gran Canaria model are presented. The other variables that showed an association in the Chi-Square tests did not show significance in the model and were therefore excluded: 'Residency', 'Use_walking', 'Use_PT', 'Use_cardriver', 'Environment', 'Dist_home', 'Dist_dest', 'Mot_money', 'Mot_conv', 'Mot_env', 'Sat_regist', 'Sat_rent', 'Sat_avail', 'Sat_comf', 'Sat_brand', 'Electric', 'Safe_path', 'Safe_lane', 'Safe_pave', 'Conv_cycling', 'Friends', 'Like_cycling', 'Cycle_rain', 'Appear', 'Enc_paths', 'Enc_aware', 'Enc_carprice', 'Disc_PTconv' and 'Disc_cost'. Table 7.7 presents the independent variables that showed significance in the model fitted for the Malta dataset. The variables whose *p*-value was greater than .05 and therefore not included in the model were: 'Household', 'Residency', 'Own_car', 'Use_motor', 'Dist_dest', 'Sat_regist', 'Sat_loc', 'Sat_rent', 'Sat_avail', 'Sat_comf', 'Safe_road', 'Cycle_accept' and 'Disc_PTconv'. The parameter estimates for the models presented in the tables above are included in *Annex G: Parameter estimates for BLR models*.

Table 7.5: Likelihood Ratio Tests for Limassol training dataset

Effect	Model Fitting Criteria -2 Log Likelihood of Reduced Model	Likelihood Ratio Tests Chi-Square	df	Sig.
Intercept	78.678[a]	.000	0	.
Use_bicycle	97.822	19.143	4	.001
Dist_home	109.601	30.923	5	.000
Mot_conv	91.444	12.766	4	.012
Safe_road	92.479	13.801	4	.008
Cycle_accept	103.725	25.047	4	.000

Table 7.6: Likelihood Ratio Tests for Las Palmas de Gran Canaria training dataset

Effect	Model Fitting Criteria -2 Log Likelihood of Reduced Model	Likelihood Ratio Tests Chi-Square	df	Sig.
Intercept	354.039[a]	.000	0	.
Use_motor	375.695	21.656	4	.000
Use_taxi	385.465	31.426	4	.000
Skill	376.903	22.865	2	.000
Multimod_walk	365.103	11.064	1	.001
Mot_time	375.442	21.403	4	.000
Sat_price	400.960	46.921	4	.000
Sat_loc	372.961	18.923	4	.001
Safe_road	364.451	10.412	4	.034
Need_car	393.028	38.989	4	.000
Enc_speed	365.767	11.728	4	.019
Disc_carconv	376.903	22.865	4	.000
Disc_safe	369.817	15.779	4	.003

Table 7.7: Likelihood Ratio Tests for Malta dataset

Effect	Model Fitting Criteria -2 Log Likelihood of Reduced Model	Likelihood Ratio Tests Chi-Square	df	Sig.
Intercept	76.682[a]	.000	0	.
Native	86.811	10.129	1	.001
Use_PT	88.361	11.679	4	.020
Use_taxi	89.293	12.611	4	.013
Dist_home	109.719	33.038	5	.000
Mot_money	91.741	15.059	4	.005
Enc_carprice	90.137	13.455	4	.009

The Goodness-of-fit tests for the model fitted for the Limassol training dataset, shown in Table 7.8, shows that the *p*-values for the Pearson coefficient and Deviance are 0.824 and 0.912 respectively. The respective *p*-values for the tests on the Las Palmas de Gran Canaria training dataset in Table 7.9 are 0.442 and 0.998. While for the Malta dataset the Pearson coefficient did not show significance (likely due to the relatively small sample size), the Deviance *p*-value of 0.971 in Table 7.10 confirms the Goodness-of-Fit. As the majority of the *p*-values of the Goodness-of-Fit tests are >.05, this confirms that the models fit the datasets well.

Table 7.8: Goodness-of-Fit tests for Limassol training dataset

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	79.355	92	.824
Deviance	74.284	92	.912

Table 7.9: Goodness-of-Fit tests for Las Palmas de Gran Canaria training dataset

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	439.669	436	.442
Deviance	354.039	436	.998

Table 7.10: Goodness-of-Fit test for Malta dataset

Goodness-of-Fit

	Chi-Square	df	Sig.
Deviance	76.682	102	.971

Confusion matrices are used to show the predictions made for the training dataset based on the fitted model, highlighting where the model correctly or incorrectly classifies observations in the dependent variable categories. The values on the diagonal are correct predictions. The results for the Limassol Binary Logistic Regression (BLR) model on the training dataset are shown in Table 7.11. Overall, 87.3% of the cases are classified correctly. Table 7.12 shows the confusion matrix with the results of the Las Palmas de Gran Canaria BLR model fitted on the training dataset, where 84.5% of classifications are correct. The confusion matrix for the BLR fitted on the Malta dataset is shown in Table 7.13, showing that 88.3% of cases were correctly classified.

Table 7.11: Confusion matrix for Limassol training dataset

Classification

	Predicted		
Observed	0	1	Percent Correct
0	57	10	85.1%
1	7	60	89.6%
Overall Percentage	47.8%	52.2%	**87.3%**

Table 7.12: Confusion matrix for Las Palmas de Gran Canaria training dataset

Classification

	Predicted		
Observed	0	1	Percent Correct
0	214	37	85.3%
1	41	210	83.7%
Overall Percentage	50.8%	49.2%	**84.5%**

Table 7.13: Confusion matrix for Malta dataset

Classification

Observed	Predicted 0	Predicted 1	Percent Correct
0	64	6	91.4%
1	9	49	84.5%
Overall Percentage	57.0%	43.0%	**88.3%**

The constructed models were then fitted on the testing dataset to see how well they perform. The results of the cross-tabulation for the Limassol testing dataset are shown in Table 7.14, whereas the results for Las Palmas de Gran Canaria are presented in Table 7.15. Again, the values on the diagonal are correct predictions. For the Limassol testing dataset, of the total 28 predictions, 19 were correct, resulting in a model accuracy of 67.9%. For the Las Palmas de Gran Canaria testing dataset, 63 of the total 99 predictions were correct; a model accuracy of 63.6%. As the Malta dataset was deemed too small to be split in a training and testing dataset, this step was not performed for this dataset.

Table 7.14: Cross-tabulation of predicted values on Limassol testing dataset

Use_bikeshare * Predicted Value Cross-tabulation

		Predicted Value 0	Predicted Value 1	Percent correct
Use_bikeshare	0	10	5	66.6%
	1	4	9	69.2%
Overall Percentage		50%	50%	**67.9%**

Table 7.15: Cross-tabulation of predicted values on Las Palmas de Gran Canaria testing dataset

Use_bikeshare * Predicted Value Cross-tabulation

Count

		Predicted Value 0	Predicted Value 1	Percent correct
Use_bikeshare	0	19	23	45.2%
	1	13	44	77.2%
Overall percentage		32%	68%	**63.6%**

7.2.4 Comparing model outputs with neural networks

The outputs from the binary regression models were compared with Neural Networks, an alternative classification technique based on machine learning algorithms, to determine the model with the best predictive power and interpretation. The results from the neural network analysis are presented here to compare the classification accuracy with the outputs from the Binary Logistic Regression models. Results are presented for the Limassol and Las Palmas de Gran Canaria datasets. Table 7.16 presents the classification table for Limassol and Table 7.17 for Las Palmas de Gran Canaria.

When comparing the classification results from the neural network analysis with the binary logistic regression outputs, it can be observed that in the case of Limassol, the binary logistic regression model classified more cases correctly than the neural network model for the training dataset (87.3% vs. 75.4%), while achieving the same classification result for the testing dataset (67.9%**)**. For the case of Las Palmas de Gran Canaria, the binary logistic regression model classified more cases correctly than the neural network model for the training dataset (84.5% vs. 75.4%), while for the classification of the cases in the testing dataset, the binary logistic regression model showed less accuracy in the classification than the neural network model (63.6% vs.73.7%).

Table 7.16: Neural network classification table for Limassol training and testing datasets

Classification

		Predicted		
Sample	Observed	0	1	Percent Correct
Training	0	58	9	86.6%
	1	24	43	64.2%
	Overall Percent	61.2%	38.8%	**75.4%**
Testing	0	13	6	68.4%
	1	3	6	66.7%
	Overall Percent	57.1%	42.9%	**67.9%**

Dependent Variable: Use_bikeshare_bin

Table 7.17: Neural network classification table for Las Palmas de GC training and testing datasets

Classification

		Predicted		
Sample	Observed	0	1	Percent Correct
Training	0	212	39	84.5%
	1	52	199	79.3%
	Overall Percent	52.6%	47.4%	**81.9%**
Testing	0	26	16	61.9%
	1	10	47	82.5%
	Overall Percent	36.4%	63.6%	**73.7%**

Dependent Variable: Use_bikeshare_bin

The results from the neural networks show that in general, the binary logistic regression model has superior or similar predictive power. It is also a simpler model to interpret and requires less computational power. However, one aspect where the neural networks models adds value to the outputs from the binary logistic regression model is in the identification of the independent variable importance. In addition to testing the predictive capability of neural networks in comparison with binary logistic regression, neural networks were employed to enable the identification of the independent variable importance. Figure 7.2

and Figure 7.3 present the independent variable importance for the Limassol and Las Palmas de Gran Canaria datasets respectively, showing their normalised relative importance; the importance values divided by the largest importance value, expressed as a percentage. This enables the identification of the variables with the strongest influence on the outcome of the dependent variable; 'Cycle_accept' in the case of Limassol, and 'Need_car' in the case of Las Palmas de Gran Canaria.

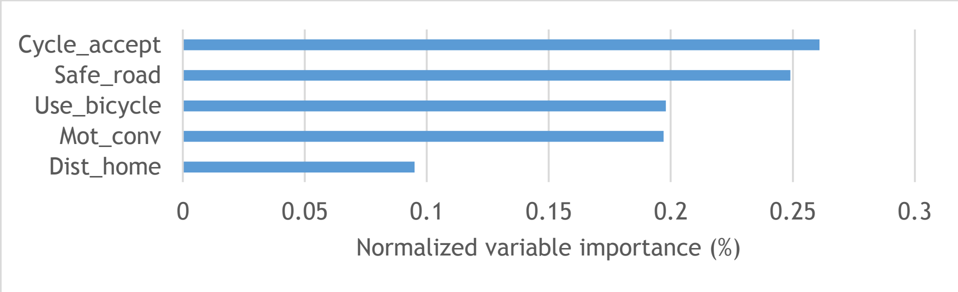


Figure 7.2: Independent variable importance for the Limassol dataset

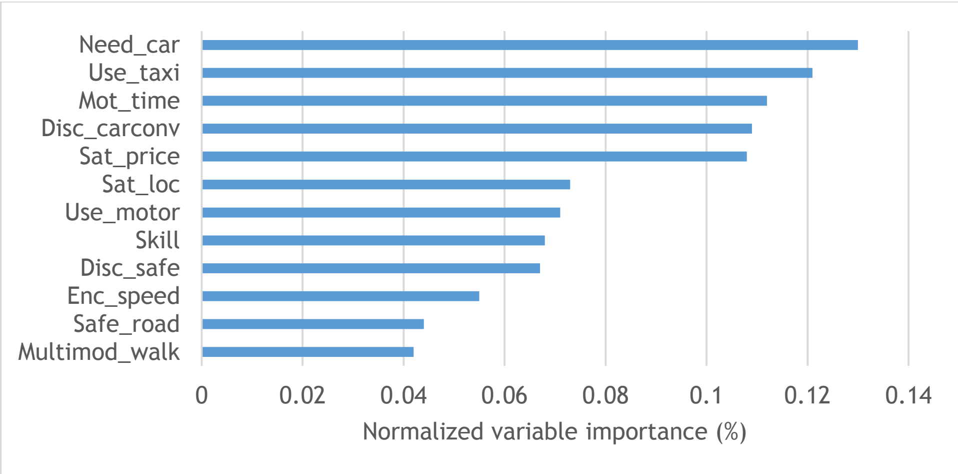


Figure 7.3: Independent variable importance for the Las Palmas de Gran Canaria dataset

7.3 Interpretation of correlation and regression analysis

In this section, the results from the bivariate correlation analysis and the binary logistic regression model are linked to each other and interpreted. The bivariate correlations show the significant associations between individual independent variables and the dependent variable and allow for an interpretation of the strength and direction of the relationship between that independent variable and the dependent variable. In the binary logistic regression models, the best fitting model, containing a combination of a set of independent variables is used to predict the probability of an outcome (frequent or infrequent BSS use). The results of the binary logistic regression models and the interpretation of the variables included in the model are discussed for each case study city.

In Limassol, the following independent variables were included in the binary logistic regression model: 'Use_bicycle', 'Dist_home', 'Mot_conv', 'Safe_road', and 'Cycle_accept'. All of the above independent variables, except for 'Dist_home', show positive associations with frequent BSS use, in the following order of importance: (1) respondents who believe cycling is an accepted mode of transport in Limassol ('Cycle_accept'); (2) who feel more safe cycling on the road in mixed traffic ('Safe_road'); (3) who use a bicycle more frequently ('Use_bicycle') and (4) who are more motivated by convenience ('Mot_conv') are more likely to be frequent BSS users. The distance between the respondent's residence and the nearest BSS station ('Dist_home') (5), shows a negative association, indicating that the further away the respondents live from a BSS station, the less likely it is that they are frequent BSS users.

In Las Palmas de Gran Canaria, the following independent variables were included in the binary logistic regression model: 'Use_motor', 'Use_taxi', 'Skill', 'Multimod_walk', 'Mot_time', 'Sat_price', 'Sat_loc', 'Safe_road', 'Need_car', 'Enc_speed', 'Disc_carconv', and 'Disc_safe'. The strongest effect of the independent variable on the likelihood that respondents are frequent BSS users is (1) feeling the need to use a car for daily tasks, which has a negative association with the frequency of BSS use. The following variables, in order of importance, have a positive association: (2) The frequency of the use of taxis as a mode of transport ('Use_taxi') and (3) being motivated by time-saving ('Mot_time') show a positive association. Finding the private car more convenient ('Disc_carconv') displayed a negative association (4). Higher satisfaction with the price of the BSS ('Sat_price') (5) showed a positive association with more frequent BSS use, as did (6) satisfaction with the locations of BSS stations ('Sat_loc'), (7) the frequency of use of a motorcycle/scooter ('Use_motor'), (8) higher cycling skill ('Skill'), (9) being encouraged by reduced vehicular speeds ('Enc_speed'), (10) feeling more safe cycling on the road in mixed traffic ('Safe_road') and (11) more frequent multimodal BSS use, in combination with walking ('Multimod_walk').

In Malta, the following independent variables were included in the binary logistic regression model: 'Native', 'Use_PT', 'Use_taxi', 'Dist_home', 'Mot_money', 'Enc_carprice'. No information is available on the variable importance, as it was decided not to run a neural network on the Malta dataset due to its smaller size. All of the above independent variables, except for 'Dist_home', show positive associations with frequent BSS use: respondents who are non-native ('Native'), who more frequently use public transport ('Use_PT') and taxis ('Use_taxi'), who are more motivated by convenience ('Mot_money'), and who are encouraged by making driving more expensive or difficult ('Enc_carprice') are more likely to be frequent BSS users. There is a negative association between the distance between the respondent's residence and the nearest BSS station ('Dist_home'), showing that the further away the respondents live from a BSS station, the less likely it is that they are frequent BSS users.

7.4 Comparative analysis of individual and social environment factors on BSS use

This section contains a comparative analysis of the survey results from the three cities, looking at similarities and differences in the influence of individual and social environment factors on BSS use. Values are compared across cities to determine if they are significantly different from each other or not, using Chi-square tests for the comparison of nominal variables and Kruskal-Wallis tests for the comparison of ordinal variables. The first subsection, 7.4.1 analyses the differences in nominal variables, whereas the second subsection, 7.4.2, addresses the ordinal variables included in the surveys.

7.4.1 Analysis of differences in nominal variables

The majority of the demographic and socio-economic variables included as explanatory factors were measured on a binary or nominal scale, as well as a number of questions related to the respondents' mobility practices and travel habits. To assess whether there are significant differences in the individual characteristics and travel habits of BSS users between the cities, Chi-Square tests were performed. Table 7.18 shows the significant differences between the responses by BSS users from the different cities.

Table 7.18: Chi-Square Test results for significantly different responses in nominal variables

Dependent variable	Definition (scale)	
City	City name [LIM/LPA/MAL] (nominal)	
Independent variables	**Definition (scale)**	***p*-value**
Gender	Gender (binary)	.011
Native	Native or non-native to country of BSS (binary)	.000
Education	Highest completed education (nominal)	.001
Household	Household size (nominal)	.014
Residency	Resident or visitor of city of BSS (nominal)	.003
License	Car driving license (binary)	.003
Own_car	Private car ownership (binary)	.000
Helmet	Habit of wearing a helmet (nominal)	.001
Membership	Type of BSS membership (nominal)	.000
Days	Predominant week or weekend use (nominal)	.001
Trip_before	Previous mode of transport for trip (nominal)	.000
Environment	Most frequent road environment used for cycling (nominal)	.000
Multimod_walk	Multimodal transport: BSS with walking (binary)	.002
Multimod_PT	Multimodal transport: BSS with public transport (binary)	.000
Multimod_car	Multimodal transport: BSS with car (binary)	.000
Electric	Preference for standard/electric bike (nominal)	.000

In terms of gender ('Gender'), there was a significant difference between Limassol, where the majority of the respondents was female, compared to Las Palmas de Gran Canaria and Malta, where males were the dominant category. Whereas in Limassol and Las Palmas de Gran Canaria the majority of respondents were native to the country ('Native', i.e. originally from the country in which the BSS is located), in Malta non-native users represented the majority; indicating higher use by expats, temporary residents and visitors. The results of the Chi-Square test showed significant differences for the variable education ('Education'), with a higher percentage of respondents from Limassol with a postgraduate degree, and a higher percentage of respondents from Malta with secondary school as the highest level of education (to a certain extent explained by respondents of a younger age). While there was not much difference in the percentage of 1-person households between the respondents from the three cities, Limassol and Las Palmas de Gran Canaria had a higher percentage of respondents from a 2-person household, whereas respondents from Malta were more often from a 3+-person household. In terms of residency, a higher percentage of respondents in Las Palmas de Gran Canaria were permanent residents (84%), when compared to Limassol (75%) and Malta (74%).

When looking at access to travel options, respondents in Limassol and Las Palmas de Gran Canaria were more likely to have a driving license ('License') and own a car ('Own_car') than the respondents from Malta. There were no significant differences between ownership of motorcycles ('Own_motor') and private bicycles ('Own_bike'), or in level of cycling skill ('Skill'), between the respondents from the different cities. Regarding helmet use ('Helmet'), respondents from Limassol and Las Palmas de Gran Canaria indicate less frequent helmet use than respondents in Malta. In terms of membership ('Membership'), the majority of respondents from Las Palmas de Gran Canaria are subscribed members, whereas the respondents from Limassol and Malta are predominantly casual users who pay-as-you-go. There was a significant difference in the days of the week BSS users most frequently cycle ('Days'; weekdays or weekend, or both), where in Limassol there is more BSS use by respondents on weekend days, in Las Palmas de Gran Canaria on weekdays, and respondents from Malta most frequently answer 'both'. In terms of differences in modal shift ('Trip_before'); the mode that was used before for the most frequent BSS trip, the main differences can be found in the shift from public transport, with a higher percentage of respondents from Las Palmas de Gran Canaria and Malta indicating a shift from this mode, and in Limassol more respondents shifting from walking and private car use. When looking at the road environment ('Environment') in which the BSS users most frequently cycle, there is a clear difference between Limassol and Las Palmas de Gran Canaria, where the majority of respondents indicated that they use cycling paths, versus Malta, where the majority said that they cycle on the road (in mixed traffic), and to a lesser extent on the pavement/promenade (pedestrian space). The stark difference can be explained by the fact that there is little to no cycling infrastructure found in Malta in the conurbation where the BSS is predominantly operational.

In terms of multimodal use, using BSS in combination with other transport modes, multimodal use with walking ('Multimod_walk') is most common in Las Palmas de Gran Canaria, then in Malta, and lastly in Limassol. Multimodal use in combination with public transport ('Multimod_PT') is more common in Las Palmas de Gran Canaria and Malta and less so in Limassol. Combining BSS use with private car use ('Multimod_car') shows the opposite, with more frequent use in Limassol, and less in Las Palmas de Gran Canaria and Malta. In terms of preference for standard and electric bicycle use ('Electric'), respondents in Limassol indicate more preference for standard bicycle use, whereas in Las Palmas de Gran Canaria and particularly in Malta there is more support for electric bicycles. The other binary and nominal variables were also tested, but did not show a significant difference between the three cities: 'Occupation', 'Own_motor', 'Own_bike', and 'Skill'.

7.4.2 Analysis of differences in ordinal variables

To understand how the results from the three case study cities compare across the factors measured on an ordinal scale, Kruskal-Wallis tests were performed to assess whether a significant difference between the means of ranks of ordinal independent variables in the different cities was present. In positive cases, this was further explored through the post-hoc Dunn's Test, for pairwise multiple comparisons of the means. Table 7.19 presents the means per city and the significance for each pairwise comparison between the three cities.

Age, the only continuous socio-demographic variable, shows significant differences between Limassol and Malta on the one hand, with a lower mean age (around the age of 30), versus Las Palmas de Gran Canaria, where the mean age is higher. 'Income', an ordinal socio-economic variable, did not show any significant differences between the cities. Significant differences are observed in the frequency of use of different transport modes. In terms of BSS use ('Use_bikeshare'), there is a significant difference between the use in

Las Palmas de Gran Canaria on the one side, and Limassol and Malta on the other, with respondents in the former indicating more frequent use. The use of walking as a mode of transport (‘Use_walking’) is higher in Las Palmas de Gran Canaria and Malta than in Limassol, as is the use of public transport (‘Use_PT’). The use of private bicycles (‘Use_bicycle’) is higher among respondents from Malta than those from Las Palmas de Gran Canaria. In Limassol there is the highest use of private cars (both as a driver and a passenger: ‘Use_cardriver’ and ‘Use_carpass’) among respondents from the three cities. ‘Use_taxi’ did not show a significant difference between the cities. Distances from respondents’ residence (‘Dist_home’) and most frequent destination (‘Dist_dest’) are the smallest in Las Palmas de Gran Canaria and the largest in Limassol, reflecting the higher urban density in Las Palmas de Gran Canaria as well as distribution of the BSS stations.

Table 7.19: Dunn’s Test results for significantly different responses in ordinal variables

Variable	LIM mean	LPA mean	*p*-value	LIM mean	MAL mean	*p*-value	LPA mean	MAL mean	*p*-value
Age	30.8	38.9	***	30.8	29.0	-	38.9	29.0	***
Use_bikeshare	2.5	3.1	***	2.5	2.7	-	3.1	2.7	***
Use_walking	4.2	4.6	***	4.2	4.5	**	4.6	4.5	-
Use_bicycle	2.2	2.1	-	2.2	2.5	-	2.1	2.5	**
Use_PT	2.3	3.2	***	2.3	3.3	***	3.2	3.3	-
Use_cardriver	4.0	3.3	***	4.0	3.0	***	3.3	3.0	*
Use_carpass	3.4	2.6	***	3.4	3.0	**	2.6	3.0	***
Dist_home	4.0	2.8	***	4.0	3.4	***	2.8	3.4	***
Dist_dest	3.7	2.9	***	3.7	3.4	**	2.9	3.4	**
Mot_money	2.8	3.2	***	2.8	3.2	**	3.2	3.2	-
Mot_conv	3.3	4.2	***	3.3	4.1	***	4.2	4.1	-
Mot_time	3.1	3.8	***	3.1	4.0	***	3.8	4.0	-
Mot_env	4.0	4.5	***	4.0	4.3	**	4.5	4.3	-
Sat_price	3.7	3.3	**	3.7	3.4	-	3.3	3.4	-
Sat_loc	3.9	3.9	-	3.9	3.4	**	3.9	3.4	***
Sat_comf	3.6	3.8	-	3.6	3.4	-	3.8	3.4	***
Conv_cycling	3.9	4.4	***	3.9	4.4	***	4.4	4.4	-
Need_car	4.1	2.9	***	4.1	3.0	***	2.9	3.0	-
Cycle_more	3.8	3.8	-	3.8	3.2	***	3.8	3.2	***
Cycle_rain	4.3	4.0	***	4.3	3.8	***	4.0	3.8	-
Cycle_sun	3.4	3.8	**	3.4	3.4	-	3.8	3.4	**
Friends	3.9	4.0	-	3.9	3.5	**	4.0	3.5	***
Busy_road	4.1	4.0	-	4.1	4.3	**	4.0	4.3	***
Road_users	2.9	2.7	-	2.9	2.5	**	2.7	2.5	-
Cycle_accept	3.6	3.4	-	3.6	2.5	***	3.4	2.5	***
Enc_paths	4.8	4.4	***	4.8	4.9	-	4.4	4.9	***
Enc_speed	4.1	3.9	-	4.1	4.2	-	3.9	4.2	**
Enc_people	4.1	4.0	-	4.1	4.4	**	4.0	4.4	***
Enc_friends	4.2	3.9	***	4.2	4.1	-	3.9	4.1	-
Enc_carprice	3.3	3.2	-	3.3	4.0	***	3.2	4.0	***
Disc_carconv	4.2	2.6	***	4.2	3.5	***	2.6	3.5	***
Disc_PTconv	3.0	3.3	**	3.0	2.9	-	3.3	2.9	**
Disc_safe	4.1	3.8	**	4.1	4.4	**	3.8	4.4	***
Disc_cost	3.1	3.0	-	3.1	3.5	**	3.0	3.5	***
Disc_people	3.0	2.8	-	3.0	3.4	**	2.8	3.4	***
Disc_friends	3.1	2.7	***	3.1	3.2	-	2.7	3.2	***
Disc_home	3.6	3.3	**	3.6	3.7	-	3.3	3.7	**
Disc_PT	3.5	3.5	-	3.5	3.8	**	3.5	3.8	**

Note: - not significant; significant at ** <0.05; *** <0.01 level

In terms of motivational factors, differences can be observed between Las Palmas de Gran Canaria and Malta on the one side and Limassol on the other, showing that respondents from the former two cities are more motivated by ‘commuter’ goals like money-saving ('Mot_money'), convenience ('Mot_conv') and time-saving ('Mot_time'). Environmental friendliness as a motivating factor ('Mot_env') also shows significant differences, with a higher mean value in Las Palmas de Gran Canaria and Malta when compared to Limassol. The other motivational factors, 'Mot_health' and 'Mot_fun' did not show significant differences between the cities.

Satisfaction with the price ('Sat_price') is higher in Limassol than in Las Palmas de Gran Canaria and Malta. Although the membership is the most expensive in Limassol, the flat fee interval is higher (1 hour for members, versus 30 minutes in Las Palmas de Gran Canaria and Malta), therefore making the price more acceptable to users. Satisfaction with the locations ('Sat_loc') is higher in Limassol and Las Palmas de Gran Canaria when compared to responses from Malta. Satisfaction with the comfort of the bicycles ('Sat_comf') is highest in Las Palmas de Gran Canaria; likely since the BSS is the newest and bicycles are still relatively new and in good condition. The other aspects of satisfaction ('Sat_regist', 'Sat_avail', 'Sat_rent' and 'Sat_brand') did not show any significant differences between the cities.

Differences in attitudes towards cycling were measured through the level of agreement with attitudinal statements. There is no significant difference between the responses from the three cities in terms of liking cycling ('Like_cycling'). Cycling is seen less as a convenient mode of transport ('Conv_cycling') in Limassol than in Las Palmas de Gran Canaria and Malta, and there is a stronger perception in Limassol that a car is a necessity to perform daily tasks ('Need_car'). Respondents in Limassol and Las Palmas de Gran Canaria more strongly agree with cycling more frequently since using the BSS ('Cycle_more') than respondents in Malta. Respondents in Limassol more strongly agree with not liking to cycle when it is rainy and windy ('Cycle_rain') than respondents in Las Palmas de Gran Canaria and Malta. Respondents in Las Palmas de Gran Canaria are most in agreement with liking to cycle when it is hot and sunny ('Cycle_sun'); more than respondents from Limassol and Malta. This can be explained by more extreme summer temperatures with high humidity in the latter two. The support of friends and family in cycling behaviour ('Friends') is stronger for respondents in Limassol and Las Palmas de Gran Canaria than in Malta. In Malta, compared to Limassol and Las Palmas de Gran Canaria, there is the strongest negative effect of busy roads ('Busy_roads'), the least feeling of respect from other road users ('Road_users') and the least feeling of cycling being an accepted form of transport ('Cycle_accept'). These perceptions are probably amplified by the fact that there is little to no cycling infrastructure in the urban core in Malta, where the highest density of BSS stations is located.

More cycle lanes and paths as an encouraging factor ('Enc_paths') receives a stronger positive response in Limassol and Malta than in Las Palmas de Gran Canaria, which underlines the positive effect of the investment in a connected cycling network in Las Palmas de Gran Canaria. Lowering road speeds ('Enc_speed') and making driving a car more difficult or expensive ('Enc_carprice') receive stronger responses in Malta than in Limassol and Las Palmas de Gran Canaria, indicating that respondents in Malta see a need for reducing the freedom of the private car to promote road safety. Respondents in Malta also more strongly agree that seeing more people cycling ('Enc_people') would support their cycling behaviour. Respondents in Limassol and Malta show more agreement with being encouraged by friends or family who cycle ('Enc_friends'). These results indicate that Las Palmas de Gran Canaria may be a step ahead in creating positive subjective and descriptive social norms around cycling, when compared to Limassol and Malta. The other included encouraging factors

(‘Enc_aware’, ‘Enc_route’, ‘Enc_home’, ‘Enc_work’, ‘Enc_PT’) did not show any significant differences between the responses from the three cities.

The car is considered to be a more convenient form of transport than the use of the BSS (‘Disc_carconv’) in Limassol, and to a lesser extent in Malta, when compared to Las Palmas de Gran Canaria. Conversely, in Las Palmas de Gran Canaria, public transport is considered to be a more convenient mode of transport than BSS (‘Disc_PTconv), when compared to Limassol and Malta. In Malta, respondents are most discouraged by a lack of road safety (‘Disc_safe’). The cost of the BSS is also more of a discouraging factor for respondents in Malta than in the other two cities; a logical result as these have a longer flat fee interval (Limassol) or more affordable memberships (Las Palmas de Gran Canaria). The lack of seeing other cyclists (‘Disc_people’) or not having friends or family who cycle (‘Disc_friends’) is more strongly felt by respondents in Limassol, and especially in Malta, when compared to respondents from Las Palmas de Gran Canaria. Not having BSS stations close enough to home (‘Disc_home’) is a discouraging factor for BSS users in Limassol and Malta, more than in Las Palmas de Gran Canaria. Finally, the lack of integration of public transport with the BSS (‘Disc_PT’) is most strongly felt by respondents from Malta. The other included discouraging factors (‘Disc_cost’ and ‘Disc_work’) did not show any significant differences between the responses from the three cities.

The above factors primarily highlight where the responses to the BSS user survey differ between the three case study cities. Other factors included in the survey did not show significant differences between the cities. Notably, the Kruskal-Wallis test showed that there were no significant differences between responses from the different cities in terms of respondents’ perception of safety on different types of infrastructure. Respondents in all three cities feel most safe on separated bicycle paths (‘Safe_path’), and least safe cycling on the road without cycling infrastructure (‘Safe_road’). This shows how the important role of cycling infrastructure and road safety on the decision to cycle is universal; not dependent on the specific city context.

7.5 Aggregated analysis of frequent vs. infrequent BSS users

In this section, the survey responses from the three case study cities are aggregated to draw generic conclusions as to which factors are encouraging or discouraging BSS use in these cities, and potentially in other ‘starter’ cycling cities with a similar context. The first subsection, 7.5.1, looks at differences in the demographic and socio-economic characteristics of frequent vs. infrequent BSS users, whereas the second subsection, 7.5.2, investigates differences in the association of habits, attitudes and perceptions on frequent vs. infrequent BSS use.

The number of respondents for each case study city vary quite widely, from 491 respondents in Las Palmas de Gran Canaria, to 140 respondents in Limassol and 128 respondents in Malta. Therefore, two weighting adjustments were applied to the datasets in the analysis, to ensure the results are robust and representative of the aggregated datasets, and not dominated by the results from one city. The first weighting criterion (‘Weight1’) was based on the proportion of the active BSS users in the city as a percentage of the total of the three case study cities. The second weighting criterion (‘Weight2’) was based on equal representation of the three case study cities; a contribution of a third each to the total. The determination and application of the weights was explained in full in section 4.3.3 in *Chapter 4*.

All the below mentioned associations showed significant results (at a *p*-value of <0.05) in the Chi-Square tests between variables in the unweighted dataset, as well as in the two weighted datasets, unless noted otherwise. The dependent variable is the binary variable 'Use_bikeshare_bin', with two categories: frequent and infrequent BSS users.

7.5.1 Socio-demographic characteristics of frequent vs. infrequent BSS users

Firstly, the associations between demographic and socio-economic characteristics of frequent and infrequent BSS users were compared. Factors that were included are demographic factors such as the gender, age, household size, residency status and nationality of respondents, as well as socio-economic factors such as level of education, occupation, income, access to different transport modes, and the distance from the respondents' residence and most frequent destination to the nearest BSS station.

The following significant associations were found between the binary dependent variable 'Use_bikeshare_bin' and the demographic and socio-economic characteristics of respondents:

- Frequent BSS use is associated with respondents living in a 1-person household ('Household'), whereas infrequent BSS use is more associated with respondents living in a larger (3+ persons) household.
- Frequent BSS use is most associated with temporary residents (<1 year), then with visitors for work/education, permanent residents, and lastly with visitors for tourism ('Residency'). This result was obtained from the analysis on the unweighted dataset. However, when applying the Chi-Square tests on the two weighted datasets, this variable no longer showed significance, indicating the results of the aggregated dataset were in this case dominated by the results from Las Palmas de Gran Canaria.
- Frequent BSS use is associated with respondents who do not own a car ('Own_car').
- Frequent BSS use is associated both with a shorter distance from the respondents' residence to the nearest BSS station, as well as their most frequent destination ('Dist_home' and 'Dist_dest'), as can be seen in Figure 7.4.

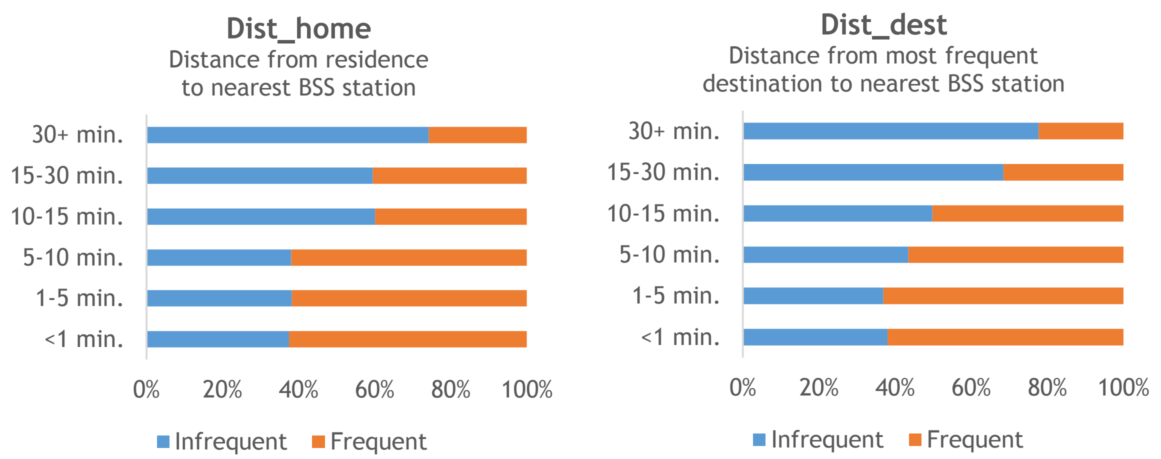


Figure 7.4: Association of distance with frequent/infrequent BSS use

Other variables included in the tests on both the unweighted and the two weighted datasets did not show significant differences in their association with frequent or infrequent BSS use: 'Gender', 'Age', 'Native', 'Education', 'Occupation', 'Income', 'License', 'Own_motor' and 'Own_bike'.

7.5.2 Habits, attitudes and perceptions of frequent vs. infrequent BSS users

In a second step, the significant associations between respondents' habits, attitudes and perceptions and their frequent or infrequent BSS use were analysed. Factors include the respondents' travel behaviour, e.g. the frequency of using different transport modes, the transport mode they used for the trip before using the BSS, the road environment they commonly cycle in and multimodal transport use. Furthermore, the analysis looks at motivating factors and the level of satisfaction with different aspects of the BSS, as well as the perception of road safety and potential motivators and barriers. Lastly, the analysis investigates differences in the agreement with encouraging and discouraging factors for BSS use.

The following significant associations were found between the binary dependent variable 'Use_bikeshare_bin' and the habits, attitudes and perceptions of respondents:

- Frequent BSS use is associated with frequent use of other 'alternative' transport modes (other than the private car) by respondents: on foot, by private bicycle, by motorcycle/scooter, by public transport or by taxi ('Use_walking', 'Use_bicycle', 'Use_motor', 'Use_PT', 'Use_taxi'). Infrequent BSS use is associated with frequent use of the private car ('Use_cardriver'). The only transport mode that did not show a significant association with BSS use was the use of the car as a passenger ('Use_carpass').
- Frequent BSS use is associated with a greater modal shift ('Trip_before') from cycling (private bicycle), motorcycle/scooter and public transport, whereas infrequent BSS use is associated with a greater modal shift from private car use (both as driver and passenger), as well as with a higher share of new trips, as can be seen in Figure 7.5.

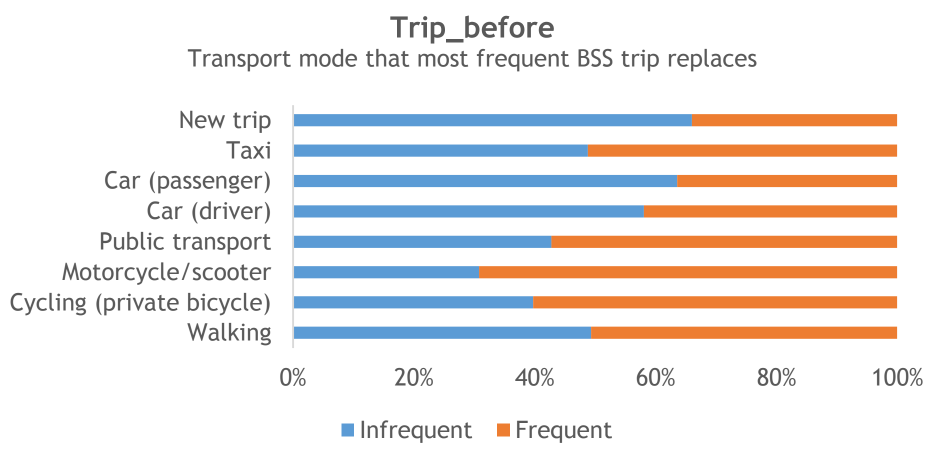


Figure 7.5: Distribution of modal shift between frequent/infrequent BSS users

- Frequent BSS use is associated with the use of bicycle paths or bicycle lanes as the most frequently used road environment for cycling (‘Environment’). Infrequent BSS use is associated with more cycling on the road (in mixed traffic) and on the pavement/promenade.
- Frequent BSS use is associated with more frequent multimodal use of BSS in combination with walking (more than 5 minutes) (‘Multimod_Walk’). Infrequent BSS use is associated with respondents who indicate not to use BSS as part of a multimodal trip (‘Multimod_No’) and with those who more frequently use BSS in combination with a private car (‘Multimod_Car’).
- Frequent BSS use is associated with more agreement with money-saving (‘Mot_money’), convenience (‘Mot_conv’), and time-saving (‘Mot_time’) as motivating factors. There is a weaker association with health as a motivating factor (‘Mot_health’; no significant association in the ‘Weight2’ dataset) and being environmentally friendly as a motivating factor (‘Mot_env’; no significant association in either of the weighted datasets).
- Frequent BSS use is associated with a higher satisfaction with the BSS, in terms of the registration process (‘Sat_regist’), the price (‘Sat_price’), the location of stations (‘Sat_loc’), the availability of bicycles (‘Sat_avail’), renting and returning a bicycle (‘Sat_rent’), and the comfort of the bicycles (‘Sat_comf’). The satisfaction with the branding and marketing of the BSS (‘Sat_brand’) showed a less strong association (no significant association in the ‘Weight2’ dataset).
- Frequent BSS use is associated with respondents who show a preference for using a standard bicycle over an electric bicycle (‘Electric’, no significant association in the ‘Weight2’ dataset). As currently the BSS primarily offer standard bicycles, this is logical, but it shows there is latent potential to encourage more BSS use by infrequent users by adding electric bicycles to the fleet, as they indicate a preference for electric bicycles.
- Frequent BSS use shows an association with the following statements. Frequent BSS use is associated with a stronger agreement with liking cycling (‘Like_cycling’) in the unweighted dataset, but not in either of the weighted datasets. Frequent BSS use is associated with more agreement with finding cycling convenient (‘Conv_cycling’), with liking to cycle when it is hot and sunny (‘Cycle_sun’), but also with not minding to cycle when it is rainy or windy (‘Cycle_rain’). Furthermore, frequent BSS use shows an association with feeling supported by friends and family in their cycling behaviour (‘Friends’), with feeling respected by other road users (‘Road_users’) and with thinking that cycling is perceived as an accepted form of transport in the city (‘Cycle_accept’). Frequent BSS use is associated with less agreement with needing a car for daily tasks (‘Need_car’). Frequent BSS use is associated with respondents who indicate to worry more about their appearance after cycling (‘Appear’; no significant association in the ‘Weight2’ dataset). While this does not seem to deter them from using the BSS, it can be explained by respondents who frequently use the BSS for commuting purposes, as the appearance afterwards (i.e. at work, school, or another destination) would be more important, when compared to using BSS for fun or exercise.
- Frequent BSS use is associated with a higher level of cycling skill (‘Skill’).

- Frequent BSS use is associated with a higher perceived safety on cycling lanes ('Safe_lane') and cycling on the road, in mixed traffic ('Safe_road'), and conversely, there is significantly less perceived safety of these road environments by infrequent users.
- Frequent BSS use is associated with the following encouraging factors. Frequent BSS use is associated with respondents who indicate they are more encouraged by making driving a car more difficult/expensive ('Enc_carprice'; no significant association in the 'Weight2' dataset). Infrequent BSS users are more likely to disagree with this, as they are more frequent car users themselves. Frequent BSS use is associated with respondents who indicate to be encouraged by more cycling paths ('Enc_paths'; no significant associated in the unweighted and 'Weight1' datasets, only for 'Weight2' dataset).
- Frequent BSS use is associated with the following discouraging factors. Frequent BSS use is associated with less agreement with the statement that using a car is more convenient ('Disc_carconv). Frequent BSS use is associated with less agreement with being discouraged by the cost ('Disc_cost'; no significant association in the 'Weight2' dataset), and less agreement with being concerned over safety ('Disc_safe'; no significant association in the 'Weight2' dataset).

Other variables included in the tests on both the unweighted and the two weighted datasets did not show a significant association with frequent or infrequent BSS use: 'Use_carpass', 'Helmet', 'Multimod_PT', 'Mot_fun', 'Uphill', 'Busy_road', 'Safe_path', 'Safe_pave', 'Enc_aware', 'Enc_friends', 'Enc_home', 'Enc_people', 'Enc_PT', 'Enc_route', 'Enc_speed', 'Enc_work', 'Disc_PTconv', 'Disc_friends', 'Disc_home', 'Disc_people', 'Disc_PT', 'Disc_work'. While many of these factors were scored highly as being important to respondents overall (e.g. see the results presented in *Chapter 6*), the fact that they did not show a significant association with the dependent variable means that their value does not vary significantly between frequent and infrequent BSS users.

7.6 Conclusion

In this concluding section, the results found through the analyses described in this chapter are summarised. This chapter focused on the influence of individual and social environment factors; how user characteristics, their habits, attitudes and perceptions, encouraging and discouraging factors, social norms and perceived environment factors influence their BSS use.

The results from the correlation analysis and binary regression models developed separately for each case study city, showed that some factors have a significant association with BSS use in each city, e.g. the use of public transport and taxis as alternative modes of transport, the importance of distance to the respondents' residence and most frequent destination, motivating factors such as money-saving and convenience, and the perceived safety while cycling on the road. Other factors were more specific to the city context. In Limassol, the importance of cycling habits and the social norm, in terms of support from friends and family and feeling that cycling is an accepted mode of transport, showed strong significant associations. In Las Palmas de Gran Canaria, satisfaction with the BSS, especially in terms of its affordability, showed importance, as well as the convenience that the BSS provides as a mode of transport, also when compared to the use of the private car for daily tasks. In Malta, whether respondents were native to the country or not showed a strong association with BSS use, with more frequent BSS use by non-native respondents. Time-saving as a motivating factor also showed a strong association in this city, as well as the perception of cycling being accepted as a form of transport and the perception of respect from other road users. A binary regression model was fitted on the dataset of each city, to understand the interplay between the independent variables and create an understanding of what predicts BSS use in the specific city context.

The comparative analysis of the survey results from the three case study cities shed light on differences and similarities in survey responses between BSS users in the different cities. Results from the comparative analysis were split into a comparison of the nominal variables, analysed through Chi-square tests, and a comparison of the ordinal variables, analysed through Kruskal-Wallis tests. Some notable differences in the comparative analysis of nominal variables were the higher percentage of non-native users (i.e. foreign residents) in Malta, the lower multimodal use of BSS in combination with public transport in Limassol, and the majority of respondents in Las Palmas de Gran Canaria being subscribed members, versus a majority of pay-as-you-go users in Limassol and Malta. The comparative analysis of ordinal variables showed noteworthy differences in the mean age, with a significantly higher mean in Las Palmas de Gran Canaria, the highest satisfaction with the price in Limassol (which has a higher flat fee interval), and the strongest negative perception of the influence of busy roads and other road users in Malta, where there is little to no cycling infrastructure in the urban core. Respondents in all three cities feel most safe on separated bicycle paths and least safe cycling on the road without cycling infrastructure, underlining the universal importance of safe cycling infrastructure on the decision to cycle.

Following the separate analysis per case study city, and the comparative analysis of the findings from the three case study cities, the datasets of the three cities were then aggregated to be able to analyse the association of individual and social environment factors with frequent versus infrequent BSS use in the more general context of Southern European island cities, and cities with similar characteristics. The majority of demographic and socio-economic characteristics, such as gender, age, education, occupation and income, did not show significant differences between frequent and infrequent BSS users. Socio-economic factors that did show an association were household size, residency status and car ownership. Temporary residents and visitors for work/education were more frequent BSS users, when compared to permanent residents and tourists. Distance to respondents' residence and most frequent destination again came out as important factors, with more frequent BSS use where distances to the nearest BSS station are shorter. In terms of travel habits and mobility practices, frequent BSS use is positively associated with frequent use of other 'alternative' transport modes (other than the private car). Frequent BSS use is mainly associated with 'commuter-type' motivating factors, such as money-saving, convenience and time-saving. Satisfaction with the BSS (the use and price of the system, the comfort of the bicycles and locations of the stations) also shows strong associations with frequent BSS use, as did higher perceived safety of cycling, with most frequent BSS users using dedicated cycling infrastructure (bicycle paths or lanes). Weather factors, including hot and sunny conditions, as well as rainy and windy weather, both showed a positive association with more frequent BSS use, suggesting that weather conditions are not negatively affecting BSS use of frequent users. A positive social norm, in terms of support from friends and family, respect from other road users, and feeling that cycling is an accepted form of transport, showed positive associations with BSS use, confirming the importance of such factors in building a cycling culture.

In the following chapter, *Chapter 8,* the relation of physical environmental factors, including both built and natural environment factors, with BSS use in the cities, is explored through an analysis of the observed BSS trip data and secondary datasets. The results presented in this chapter will be discussed in relation to findings from the literature in *Chapter 9*.

8. The influence of physical environment factors on BSS use

This chapter addresses the fifth research question (RQ5) of this study: *What is the influence of physical environment factors on BSS use?* This chapter will clarify how physical environment factors, including both spatial and temporal variables, influence BSS use, by using trip data from the BSS in the three case study cities, as well as secondary datasets capturing the spatial and temporal variables included as independent variables. A comparative analysis of the influence of physical environment factors is also included, addressing research question six (RQ6): *How do BSS use and influencing factors in the case study cities compare?* How the influence of physical environment factors is positioned in the theoretical framework guiding this research is highlighted in Figure 8.1.

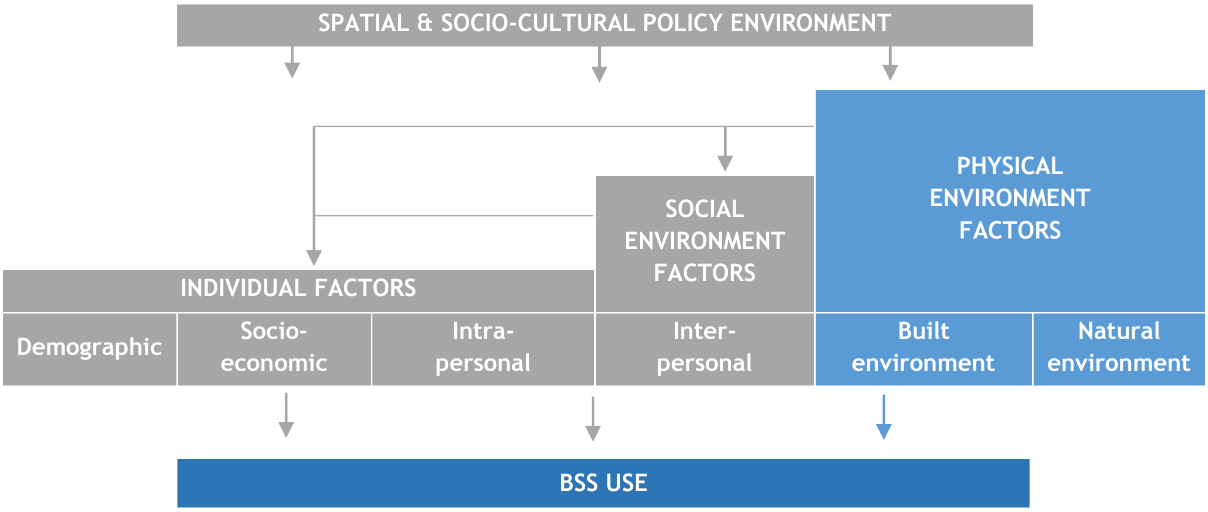


Figure 8.1: Position of physical environment factors in the theoretical framework

In section 8.1, the relationship between the dependent variables and the spatial variables, including both built and natural environmental factors, is investigated, through bivariate correlation analysis. Section 8.2 starts with the construction of simple OLS models to estimate the effects of the independent spatial variables on yearly BSS use. Section 8.3 analyses the influence of both spatial and temporal factors on BSS use, utilising linear mixed models to analyse the combined effect of the influence of spatial and temporal variables on BSS use, on a monthly basis. In section 8.4, the results from the three case study cities are discussed in a comparative analysis, to understand differences and similarities in the influence of spatial and temporal factors on their BSS use. Section 8.5 presents an analysis of the influence of the construction of new cycling infrastructure on BSS use in Las Palmas de Gran Canaria, by comparing the before and after use of BSS stations through linear mixed models, using a second year of trip data. The final section, 8.6, summarises the results from this chapter and introduces the next chapter.

8.1 BSS use at station level

8.1.1 Use of BSS stations as origins and destinations

The use of BSS stations as origins and destinations, COUNTO and COUNTD, aggregated over a year, in the three case study cities are shown in Figure 8.2: (a) for Limassol, (b) for Las Palmas de Gran Canaria and (c) for Malta. Maps showing the use of stations as origins and destinations on a monthly basis are presented in *Annex H: Monthly BSS station use as origins and destinations*. In Limassol, BSS use is concentrated along the promenade, between a string of stations stretching from the Old Port near the city centre and Limassol Marina towards the eastern part of the city. In Las Palmas de Gran Canaria, BSS use is more evenly spread, although two clusters, around the two main city centres, is evident, with lower BSS use at stations on the periphery of the system. In Malta, BSS use is concentrated in the Northern Harbour area, north of Valletta, especially at the stations located along the coastline, with very limited use of the isolated stations elsewhere on the island. The BSS use at station level in Malta shows the strongest visible difference between stations' use as an origin and a destination; there are more stations with dominant use as an origin located further inland, at a higher elevation, and more stations used as a destination located in the low-lying parts of the urban area, near the coastline.

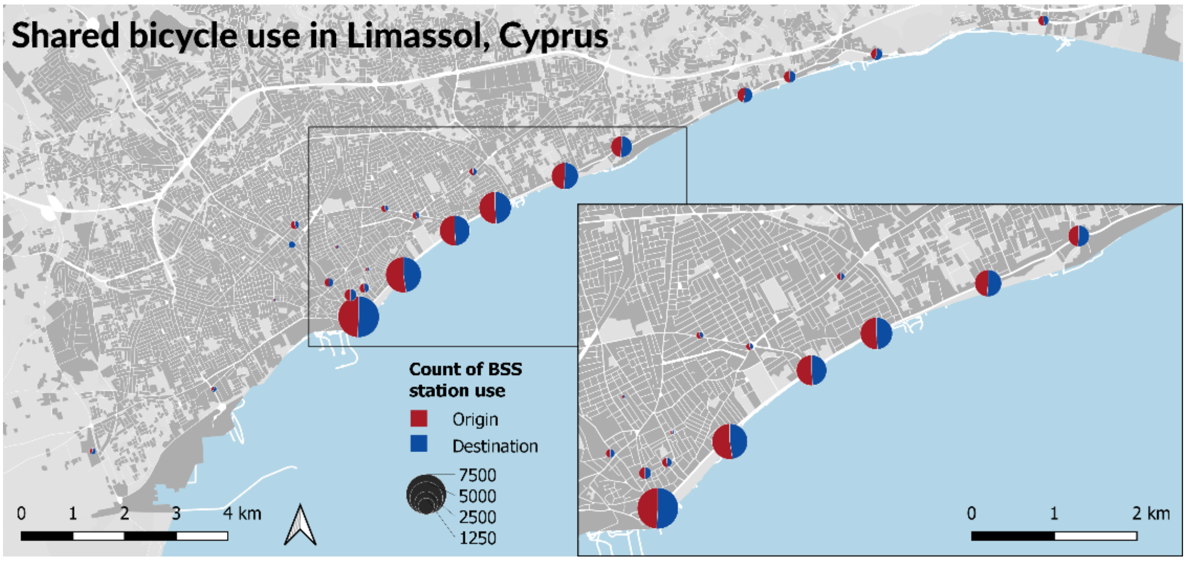


Figure 8.2a: BSS station use as origins and destinations in Limassol (Maas et al., 2021a)

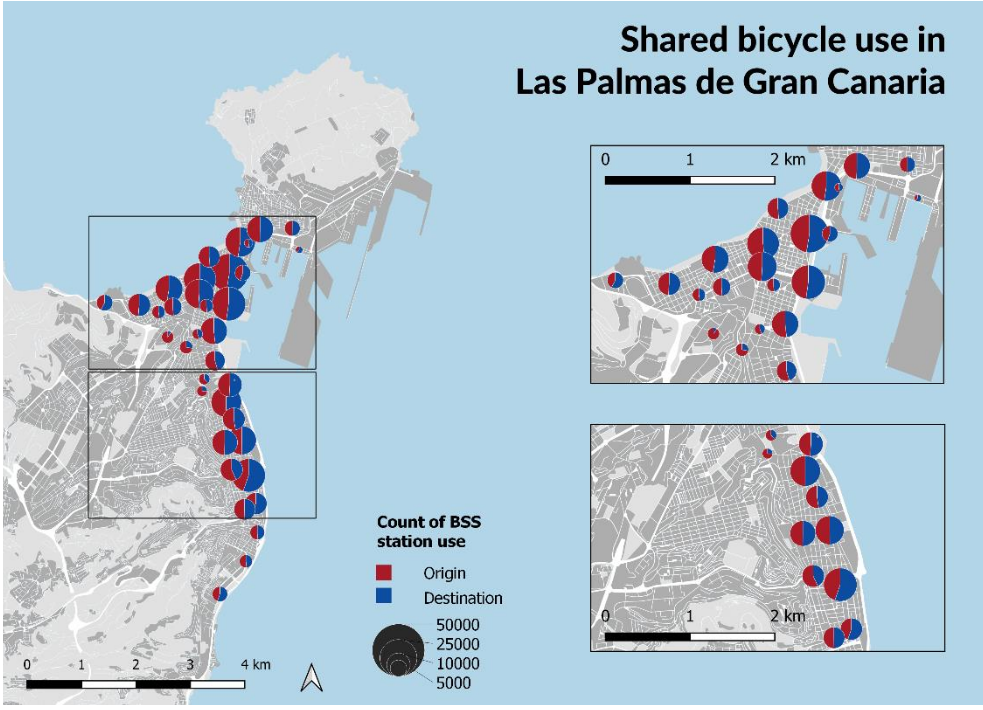


Figure 8.2b: BSS station use as origins and destinations in Las Palmas de Gran Canaria (Maas et al., 2021a)

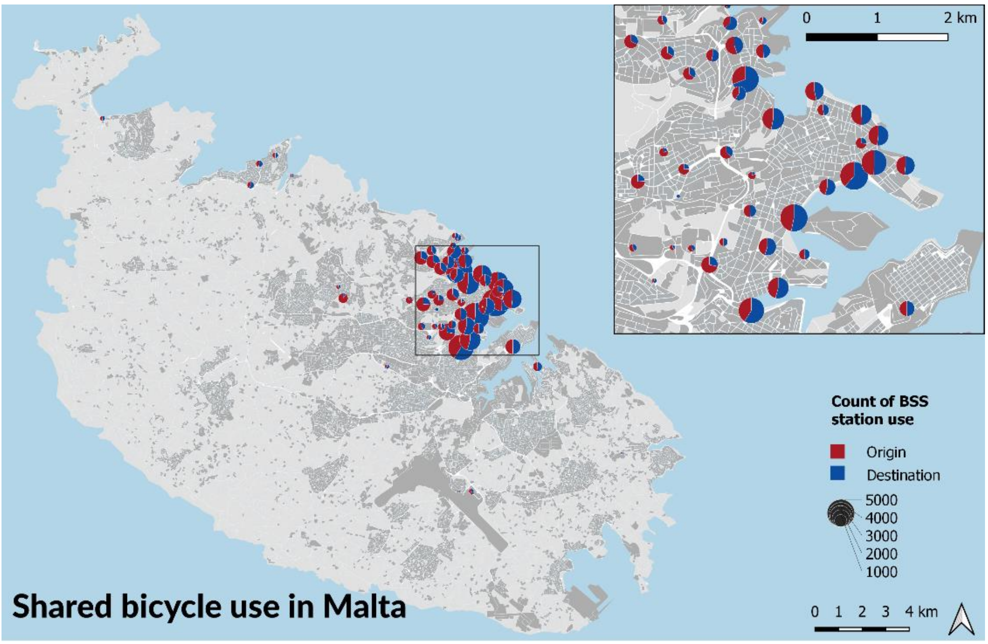


Figure 8.2c: BSS station use as origins and destinations in Malta (Maas et al., 2021a)

8.1.2 Associations between dependent and independent variables

To get an initial understanding of the influence of the spatial independent variables (including land use, network and socio-economic variables) and temporal variables (weather and tourism variables) on the dependent variables 'COUNTO' and 'COUNTD' (the use of BSS stations as origins and destinations respectively), bivariate correlation analysis was employed. To incorporate both spatial and temporal factors in the analysis, observations were included on a monthly basis for each station location. In Limassol there are a total of 276 observations (23 stations x 12 months). In the other two cities the total observations do not amount exactly to the product of the number of stations and months, as a small number of stations (4 stations in Las Palmas de Gran Canaria and 2 stations in Malta) were added over the course of the year, and observations for these stations were thus only included from the month of their installation. Spatial factors remain stationary over time, whereas temporal factors remain stationary across all station locations, as they were collected at the city level. Table 8.1 presents the results of the bivariate correlation analysis. The correlation analysis, using the Pearson correlation coefficient *r*, showed that a number of the independent variables were significantly correlated with BSS use at the 5% or 1% level. Most variables showed the expected relationship, based on results from BSS use in other cities as identified in the literature review, but some variables showed opposite effects for the different case study cities (e.g. PERC_EDU3, the percentage of population with a tertiary education, and TOT_RAIN, the total rainfall).

Table 8.1: Bivariate correlation results: Pearson correlation coefficient (r) and p-value

	LIM (*n* observations = 276)				LPA (*n* observations = 422)				MAL (*n* observations = 715)			
Variables	COUNTO		COUNTD		COUNTO		COUNTD		COUNTO		COUNTD	
LU_RES	-.040	-	-.055	-	.123	**	.034	-	.426	***	.355	***
LU_COM	-.058	-	-.043	-	-.198	***	-.117	**	-.232	***	-.188	***
LU_PARK	.513	***	.508	***	-.008	-	.016	-	-.009	-	.002	-
LU_TOUR	-.044	-	-.054	-	.393	***	.388	***	.179	***	.195	***
LU_CAFE	.315	***	.315	***	.507	***	.496	***	.228	***	.294	***
LU_SHOP	-.216	***	-.239	***	.270	***	.322	***	.340	***	.368	***
LU_UNI	-.163	***	-.172	***	.067	-	.065	-	-.154	***	-.145	***
LU_BEACH	.605	***	.608	***	.324	***	.394	***	.305	***	.433	***
LU_BUS	-.196	***	-.203	***	.173	***	.273	***	.082	**	.123	***
LU_LEN_CYC	.469	***	.480	***	.524	***	.523	***	-.184	***	-.144	***
LU_DISTSEA	-.492	***	-.483	***	-.168	***	-.281	***	-.329	***	-.392	***
LU_DISTBUS	-.089	-	-.081	-	-.345	***	-.389	***	-.156	***	-.143	***
LU_DISTUNI	-.136	**	-.127	**	-.035	-	.007	-	-.294	***	-.220	***
LU_NODES	-.116	-	-.112	-	.195	***	.205	***	.312	***	.183	***
ELEV	-.512	***	-.509	***	-.296	***	-.409	***	-.281	***	-.417	***
POP_DENS	.165	***	.130	**	.246	***	.208	***	.446	***	.419	***
PERC_EDU3	-.165	***	-.154	**	.129	***	.106	**	.218	***	.171	***
GEND_RATIO	.072	-	.093	-	-.275	***	-.286	***	.006	-	.058	-
AGING_POP	-.157	***	-.165	***	.111	**	.215	***	.194	***	.178	***
FORGN_POP	.547	***	.547	***	.366	***	.375	***	.340	***	.365	***
DIST_MEAN	-.297	***	-.279	***	-.145	***	-.055	-	-.301	***	-.220	***
COUNT_STAT	-.096	-	-.100	-	.214	***	.139	***	.228	***	.233	***
COUNT_STA2	.153	**	.131	**	.225	***	.139	***	.288	***	.269	***
TOT_TOUR	.167	***	.170	***	.086	-	.077	-	.292	***	.228	***
AVG_MAXC	.158	***	.161	***	.003	-	.003	-	.293	***	.229	***
TOT_RAIN	-.193	***	-.197	***	.126	***	.113	**	-.268	***	-.210	***

Notes: - = correlation not significant; correlation significant at *p*-value: ** <0.05; *** <0.01.

The bivariate correlation analysis (Table 8.1) shows that there are a number of variables that have a relationship of the same direction and similar strength across the three cities. The number of cafes and restaurants (LU_CAFE) within a 300m buffer around a BSS station show a positive and significant correlation in all three cities. The presence of the beach or promenade (LU_BEACH) within a 300m buffer around a BSS station is strongly positively and significantly correlated in all three cities. The distance to the coastline (LU_DISTSEA) also shows a strong relationship, where the negative association indicates that the further away from the coastline, the less BSS use there is. Elevation (ELEV) has a strong negative association with BSS use, both for origin and destination stations, in all three cities. A stronger negative association is found with the station use as a destination than as an origin in Las Palmas de Gran Canaria and Malta, where elevation differences are greater than in Limassol. Higher population density (POP_DENS) and a higher percentage of foreign population (FORGN_POP) both show a positive relationship with BSS use in the three cities. The network variables showed similar results for the three cities: a negative relationship with distance (DIST_MEAN); the further away from the centre of the BSS, the less use, particularly for station use as an origin, and a positive relationship with the count of other BSS stations within a 1,200m buffer around the station (COUNT_STA2).

Other variables showed mixed results for the cities. The number of shops (LU_SHOP) in the station buffers shows a positive relation with the use of a BSS station as an origin and destination in Las Palmas de Gran Canaria and Malta. In Limassol however, the association is negative, both for origin and destination use of a station. Cycling infrastructure (LU_LEN_CYCLE) shows a positive effect in the two cities with cycling paths in the city centre and near the BSS stations; in Limassol and Las Palmas de Gran Canaria. In Malta however, there is a negative correlation observed. This can be explained by the near total absence of cycling paths in Malta's urban area where the BSS is present, with the only cycling infrastructure located outside of the urban area, where BSS usage is low compared to the centre of the conurbation. The percentage of population with a tertiary education (PERC_EDU3) and the percentage of population over 65 years (AGING_POP) show a positive relationship in Las Palmas de Gran Canaria and Malta, but a negative association in Limassol. BSS use in Limassol and Malta has a negative relationship with total rainfall (TOT_RAIN), highlighting higher use in the extended summer season. In Las Palmas de Gran Canaria the association with total rainfall was positive. As there is very limited rainfall in Las Palmas de Gran Canaria, this result shows how in this case it does not act as a deterrent, where instead the months with relatively higher rainfall represent months in the year with higher volumes of cycling, because of more cycling for commuting purposes (non-holiday months) and higher visitor numbers.

Certain correlations only showed significance in one or two of the case study cities. A higher percentage of residential land use (LU_RES) showed a positive association in Malta for station use as origin and destination, and in Las Palmas de Gran Canaria only for origin use. A higher percentage of industrial/commercial land use (LU_COM) in the buffer around the stations shows a negative association with BSS use in Las Palmas de Gran Canaria and Malta. The percentage of park land use (LU_PARK) shows a positive association in Limassol. The number of hotels (LU_TOUR) in the buffer show a positive and significant relationship in Las Palmas de Gran Canaria and Malta. Distance to the nearest bus station (LU_DISTBUS) showed a negative relationship with both origin and destination station use in Las Palmas de Gran Canaria and Malta, indicating that the nearer to a bus station, the higher the BSS use. This effect is not observed in Limassol, which can be explained by the much lower modal share of public transport use, compared to Las Palmas de Gran Canaria and Malta. The presence of the university within a 300m buffer around a station (LU_UNI) showed a significant negative association in both Limassol and Malta, indicating that BSS use in the vicinity of the university campuses is low in these cities. This is in contrast to what has been found in many other cities, where the university community represents a key BSS user group (Castillo-Manzano & Sanchez-Braza, 2013). In Las Palmas de Gran Canaria, no significant relationship is present, as the main university campus is located outside of the city. Surprisingly, the distance from the university (LU_DISTUNI) also shows a negative association with BSS use in Limassol and Malta, indicating that further away from the university, BSS use is lower. This can be explained by the fact that the university campus in both cities is located in or near the city centre, and the distance variable is reflective of the association with the city centre rather than with the university campus. The count of nodes in the road network (LU_NODES), as an expression of the density of the land use, shows a positive association in Las Palmas de Gran Canaria and Malta, but not in Limassol. This further underlines how the predominant use in the former two cities is cycling for transport, in areas with a higher urban density, whereas BSS use in Limassol is characterised by leisure use, for exercise and for fun, predominantly along the coastline. The quotient of male and female residents at the station locations (GEND_RATIO) showed a significant negative relationship with BSS use in Las Palmas de Gran Canaria, indicating that areas with a higher percentage of male population have lower BSS use. No significant association was found in Limassol or Malta. In terms of temporal variables, the results for Limassol and Malta are similar, but for Las Palmas de Gran Canaria, with a different tourism pattern and less seasonal weather variation, the outcome is different. A positive relationship was found with the total number of tourists (TOT_TOUR) and average maximum temperature (AVG_MAXC) for Limassol and Malta, but not for Las Palmas de Gran Canaria.

In preparation for the model-based approaches presented in sections 8.2 and 8.3, correlation matrices were created for the spatial and temporal variables, to examine the collinearity between independent variables so as to avoid including two or more multicollinear variables in the different variations of the models, before settling on the best model fit. A threshold of ±0.7 was assumed to indicate multicollinearity (Dormann et al., 2013).

8.2 Modeling the influence of spatial factors on BSS use

To get an understanding of the relationship between the spatial variables and the dependent variables, traditional Ordinary Least Squares (OLS) regression models were the starting point. Before adding further complexity in terms of the temporal variation in BSS use and the influence of temporal variables (which will be explored in the next section 8.3), the first step was to create an OLS model for each city's BSS station use as an origin (COUNTO) and a destination (COUNTD), based on aggregated yearly use.

8.2.1 Preparations for estimating the OLS models

Correlation matrices were created to examine the collinearity between the spatial variables, to avoid including two or more multicollinear variables in the different variations of the regression model. Multicollinearity was found between certain variables that both showed a significant association with BSS use (e.g. LU_TOUR and LU_CAFE in Las Palmas de

Gran Canaria, and LU_DISTSEA and FORGN_POP in Limassol). In some cases, multicollinear variables take each other's place in the COUNTO versus COUNTD models (e.g. LU_DISTSEA and LU_BEACH in Malta).

BSS station use is typically right-skewed instead of normally distributed, with a small number of stations seeing a lot of use, and many stations with little use. To address that, different authors that have used regression models suggest to transform the dependent variable to better fit under a normal curve, when assessing the influence of land use and socio-demographic characteristics on BSS use. Wang et al. (2016) used a log transformation on the dependent variable 'station activity' (sum of count trip origin and destination), whereas Rixey (2013) transformed the 'average monthly rentals'. However, when comparing model fit of the models using the untransformed dependent variables (COUNTO; COUNTD) with a log transformation and the square root of the dependent variable, it turned out that model fit was best for the models using untransformed variables, and interpretation of the results was also more intuitive. In fact, when constructing an OLS model the dependent and independent variables do not need to be normally distributed, as long as the residuals show a normal distribution (Frost, 2019).

In order to confirm the assumptions for an OLS model were met, the regression diagnostics of the fitted models were analysed (Frost, 2019). The results show normality of the residuals, linearity in the coefficients and error term, and examination of the residuals confirmed homoscedasticity. Correlation plots including all independent variables were created to be able to identify and address cases of multicollinearity. Where multicollinearity was present, only the variable with the strongest association with the dependent variable was retained in the model, to ensure the absence of collinearity in the data and avoid overfitting the models on the dataset. Independence of errors was confirmed by plotting the residuals against the independent variables. Some outliers were present, but their limited number was acceptable. Various regression models were built and tested, based on different combinations of the variables that showed the strongest influence and significance in the bivariate regression, using a Backward Stepwise Regression Analysis (BSRA) based on the Akaike Information Criterion (AIC) to omit non-statistically significant variables. The aim was to balance the maximum predictive power of the model (as measured by Adjusted R^2) with a parsimonious design, while ensuring variables followed the expected direction of influence, were not multicollinear with other variables, and were all statistically significant at the 0.05 level (or supported the model to maintain significance of other variables) (Maas, Attard & Caruana, 2020; Maas et al., 2021b).

8.2.2 OLS model results

Various OLS regression models were developed and tested, for both COUNTO and COUNTD, based on different combinations of the variables that showed the strongest influence and significance in the bivariate correlation analysis. Some variables that were identified as significantly correlated with BSS use in the correlation analysis are not present in the OLS model. This is primarily due to the multicollinearity between variables. The final OLS regression models, including the coefficient estimates, standard errors and p-values are presented in Table 8.2, Table 8.3 and Table 8.4. The standardised coefficients have been included too, to be able to compare the relative impact of the independent variables on the dependent variable.

The regression models for Limassol (Table 8.2) show a very high fit, due to the high concentration of the BSS use between a selected number of stations, along the bicycle path by the promenade. Unsurprisingly therefore, the presence of the beach or promenade (LU_BEACH) shows the strongest positive impact on BSS use. The length of cycling infrastructure (LU_LEN_CYC) within the station buffer also has a positive relation with BSS use. A higher percentage of residential (LU_RES), commercial/industrial (LU_COM) and park (LU_PARK) land use, as well as a higher number of cafes and restaurants within the station buffer, show a positive influence on BSS use, as does the count of BSS stations within a 1,200m buffer around the station (COUNT_STA2). There is a negative association with the number of hotels and hostels within a 300m buffer around BSS stations (LU_TOUR), which suggests that the system is not dominated by tourist use, but rather by local residents' use. BSS use shows a negative association with neighbourhoods where a higher share of the population has a tertiary degree (PERC_EDU3). This results contrasts with findings from other studies which found a positive association (e.g. Rixey, 2013; Shaheen et al., 2012). A potential explanation is that higher education level tend to be associated with higher income levels, which is in turn associated with higher car ownership and use. Alternative transport modes in Limassol (and Cyprus in general) are still often perceived as being "only for people who cannot afford a car" (PTV, 2019). The distance from the centre of the BSS shows a negative association with BSS use in the COUNTD model, indicating that the destination of trips is associated with closer proximity to the centre of the BSS.

Table 8.2: OLS model results for BSS in Limassol (n stations = 23; n trips = 17,532)

	COUNTO model				COUNTD model			
Variable	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*
(Intercept)	-2,023	542		0.003***	-1,398	596.2		0.037**
LU_RES	2,659	670	0.468	0.002***	2,073	643.5	0.372	0.007***
LU_COM	3,111	777	0.419	0.002***	2,896	681.6	0.398	0.001***
LU_PARK	4,495	1,259	0.226	0.003***	3,553	1,114	0.183	0.008***
LU_TOUR	-138.8	46.9	-0.222	0.011**	-131.2	39.9	-0.214	0.006***
LU_CAFE	29.54	7.27	0.227	0.001***	27.19	6.2	0.214	0.001***
LU_BEACH	1,917	187	0.876	0.000***	1,808	161	0.843	0.000***
LU_LEN_CYC	1.13	0.30	0.276	0.002***	1.26	0.25	0.315	0.000***
PERC_EDU3	-3,324	977	-0.204	0.005***	-2,990	815	-0.187	0.003***
DIST_MEAN	-	-	-	-	-0.07	0.03	-0.157	0.084*
COUNT_STA2	79.76	28.33	0.214	0.015**	52.81	24.71	0.145	0.053*
Adjusted R^2	**0.939**				**0.957**			
***p*-value**	**0.000*** **				**0.000*** **			

Notes: - = variable not included in this model; significant at: * 0.10; ** 0.05; *** 0.01 level

In the OLS models for Las Palmas de Gran Canaria (Table 8.3), variables with a positive influence on BSS are the length of cycling infrastructure (LU_LEN_CYC) and the presence of tourist accommodations (LU_TOUR) in a 300m buffer around the station. Distance to the coastline (LU_DISTSEA) was only included in the COUNTO model and was significant only at the 0.1 level, but indicates that for stations as an origin, further distance from the coastline is associated with more use. In terms of socio-economic variables, only the gender quotient (GEND_RATIO) showed a significant association with the dependent variable, with a negative association between station locations in areas with a larger male population and BSS use, potentially contrary to results found in BSS use in many other cities where use is dominated by men (Fishman, 2016). However, since BSS use at a station location is not necessarily dominated by people living in close vicinity to the station, this association may be capturing another relation between characteristics of such stations and higher BSS use. The distance to the nearest bus station (LU_DISTBUS) was included to support the models, as without it, other variables were not found to be significant, as well as because of its expected relevance in explaining variation in station use, due to the combination of shared bicycle and public transport use.

Table 8.3: OLS model results for BSS in Las Palmas de Gran Canaria (n stations = 37; n = 162,871)

	COUNTO model				COUNTD model			
Variable	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*
(Intercept)	27,870	7,368		0.001***	34,540	8,162		0.000***
LU_TOUR	371.4	105.3	0.443	0.001***	369.2	119.5	0.393	0.004***
LU_DISTBUS	-0.94	0.60	-0.192	0.127	-1.05	0.66	-0.192	0.124
LU_DISTSEA	3.96	2.07	0.260	0.065*	-	-	-	-
LU_LEN_CYC	3.91	0.89	0.569	0.000***	3.48	0.89	0.451	0.000***
GEND_RATIO	-29,110	8,148	-0.430	0.001***	-34,750	9,210	-0.458	0.001***
Adjusted R^2	0.559				0.542			
***p*-value**	**0.000*****				**0.000*****			

Notes: - = variable not included in this model; significant at: * 0.10; ** 0.05; *** 0.01 level

The regression models for Malta (Table 8.4) show the positive association with the presence of the beach or promenade (LU_BEACH), bus stations (LU_BUS) and clothing shops (LU_SHOP) within a 300m buffer around a BSS station. The percentage of foreign population (FORGN_POP) at the station locations also shows a positive relationship with BSS use. The presence of university buildings (LU_UNI) has a negative association with BSS use, indicating challenges with promoting uptake among the university community. While the distance to university (LU_DISTUNI) shows a significant negative correlation, indicating the closer to university, the higher the use, this is most likely confounded by its multicollinearity with the distance to the centre of the BSS (DIST_MEAN). A higher percentage of commercial/industrial land use (LU_COM) has a negative relation with BSS use. LU_COM has a high negative correlation with LU_RES (r = -0.655), indicating that use is more influenced by residential land use (as also seen in the bivariate correlations between COUNTO/D and LU_RES in Table 8.1).

Table 8.4: OLS model results for BSS in Malta (n stations = 60; n = 37,306)

	COUNTO model				COUNTD model			
Variable	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*	*Coefficient estimate*	*Standard error*	*Standardised coefficient*	*p-value*
(Intercept)	555	171		0.002***	846	248		0.001***
LU_COM	-857.2	380.8	-0.230	0.029**	-1,050	499.3	-0.211	0.040**
LU_SHOP	62.1	34.9	0.190	0.081*	98.3	46.1	0.226	0.038**
LU_UNI	-57.1	28.6	-0.226	0.051*	-	-	-	-
LU_BEACH	259.9	141.5	0.216	0.072*	496.6	238.1	0.309	0.042**
LU_BUS	271.1	160.1	0.181	0.096*	408.1	208.8	0.203	0.056*
LU_DISTUNI	-0.09	0.03	-0.388	0.000***	-	-	-	-
ELEV	-	-	-	-	-5.97	3.92	-0.220	0.134
FORGN_POP	2,091	1,049	0.225	0.052*	-	-	-	-
DIST_MEAN	-	-	-	-	-0.09	0.03	-0.284	0.006***
Adjusted R^2	0.437				0.436			
***p*-value**	**0.000*****				**0.000*****			

Notes: - = variable not included in this model; significant at: * 0.10; ** 0.05; *** 0.01 level

8.3 Modeling the influence of spatio-temporal factors on BSS use

Building on the analysis in the OLS models, the influence of both spatial and temporal factors was examined in linear mixed models (LMM). Linear mixed models were employed to allow for multiple observations per station, as the inclusion of temporal factors in the analysis meant that monthly observations of temporal factors related to weather and tourism were included in the dataset, in addition to the stationary spatial factors.

8.3.1 Preparations for estimating the linear mixed models

Before estimating the linear mixed models, the temporal variables were first assessed for multicollinearity. In the Limassol dataset there was a strong correlation between TOT_RAIN and both TOT_TOUR and AVG_MAXC, from which only the first variable was retained, as it showed the strongest relationship with the dependent variables. In Las Palmas de Gran Canaria, there was a relatively strong correlation between TOT_TOUR and TOT_RAIN (just below the threshold of 0.7), but the former did not show significance in the models when included, and is thus not present in the final models. In the Malta dataset, a strong correlation was present between the total visiting tourists (TOT_TOUR) and the average maximum temperature (AVG_MAXC), where the latter was retained in the models.

Several iterations of the linear mixed models for COUNTO and COUNTD, including only the stations numbers (STATION_NU) as a random effect, or both station number and month (MONTH) as random effects, were tested in random intercept models, based on different combinations of the variables that showed the strongest influence and significance in the bivariate correlation analysis. Effort was made to balance maximum predictive power of the model with a parsimonious design, while ensuring variables follow the expected direction of influence and were statistically significant at least at or below the 0.05 level. Better model fit was obtained with only including the stations as a random effect. The selected random intercept models were compared to a null model to confirm the significance of the model as a whole ($p < 0.05$) and a smaller AIC (Akaike Information Criterion) value to confirm the best model fit. The final linear mixed models, including the standardised coefficient estimates, standard errors and p-values are presented in Table 8.5 for Limassol, Table 8.6 for Las Palmas de Gran Canaria and Table 8.7 for Malta. The variance and standard deviation of the random effects are reasonable values, and the standard errors of the fixed effects are all relatively small, smaller than the coefficient estimates, which indicate a good model fit.

8.3.2 Linear mixed models results

The linear mixed models for Limassol (Table 8.5) show a strong positive impact of the presence of the beach or promenade in the 300m buffer around stations (LU_BEACH) and the length of cycling infrastructure (LU_LEN_CYC) with BSS use, as in the OLS models. The count of hotels and hostels within a 300m buffer around stations (LU_TOUR) shows a negative relation, again as in the OLS models. The distance from the centre of the BSS (DIST_MEAN) shows a negative association with BSS use, indicating that most trips take place at the stations closer to the centre of the BSS. Total rainfall (TOT_RAIN), the temporal variable that showed the strongest association with BSS use, shows a negative relationship, with more BSS use in months with less rainfall. In the COUNTD model, the variable of the count of shops within a 300m buffer around the stations (LU_SHOP) is negatively associated with use of the stations as a destination, confirming that BSS use is not positively associated with shopping or running errands, but is used for leisure purposes, away from areas with a higher concentration of shops. The density of the road network (LU_NODES) shows a positive association in the COUNTD model, indicating that trips end more frequently in areas with higher urban density.

Table 8.5: Linear mixed models for COUNTO and COUNTD in Limassol (n observations = 276) (Maas et al., 2021a)

	COUNTO model			COUNTD model		
Random effects	***Variance***	***Standard deviation***		***Variance***	***Standard deviation***	
STATION_NU	0.193	0.439		0.130	0.361	
Residual	0.142	0.376		0.145	0.380	
Fixed effects	***Coefficient estimate***	***Standard error***	***p-value***	***Coefficient estimate***	***Standard error***	***p-value***
Intercept	0.000	0.094	1.000	0.000	0.078	1.000
LU_TOUR	-0.274	0.114	0.028	-0.328	0.097	0.004
LU_SHOP	-	-	-	-0.211	0.100	0.051
LU_BEACH	0.669	0.135	0.000	0.721	0.126	0.000
LU_LEN_CYC	0.267	0.128	0.053	0.285	0.108	0.018
LU_NODES	-	-	-	0.271	0.101	0.016
DIST_MEAN	-0.440	0.107	0.001	-0.418	0.096	0.000
TOT_RAIN	-0.193	0.023	0.000	-0.197	0.023	0.000
	Model *p*-value compared to null model		0.000	Model *p*-value compared to null model		0.000

Notes: Coefficient estimates are standardised; -: variable not included in this model.

The linear mixed models for Las Palmas de Gran Canaria (Table 8.6) show a strong positive association with the length of cycling paths within a 300m buffer around the stations (LU_LEN_CYC), in line with the OLS models. The gender quotient (GEND_RATIO) showed a strong negative association in both the COUNTO and COUNTD models, as in the OLS models. The temporal variables included, the average maximum temperature (AVG_MAXC) and total rainfall (TOT_RAIN) both show a positive relationship with BSS use. The presence of tourist accommodation within the stations' buffers (LU_TOUR) shows a positive association in the COUNTO model. As LU_TOUR was highly correlated with LU_CAFE, the count of cafes/restaurants (r = 0.768), this variable is indicative of areas with leisure and entertainment facilities associated with the use of stations as an origin, especially in the area around *Las Canteras* and *Santa Catalina*, which draws both local residents and tourists to enjoy the beach and city life (Maas, Attard & Caruana, 2020). The distance from the nearest bus station (LU_DISTBUS) shows a negative association in the COUNTD model, where a longer distance to the bus station is associated with less use of BSS stations, highlighting the positive relationship between BSS use at a station as a destination and public transport use, in accordance with findings from other cities with a positive association between BSS and public transport use (Murphy & Usher, 2015).

The linear mixed models for Malta (Table 8.7) show a positive association with the presence of shops in the 300m buffer around stations (LU_SHOP) and a negative relationship with the distance from the centre of the BSS (DIST_MEAN), highlighting the higher use of the BSS in the central urban area, close to facilities for shopping and services, as was also observed in the OLS models. In terms of temporal variables there is a positive relationship between BSS use and a higher average maximum temperature (AVG_MAXC) and a negative association with total rainfall (TOT_RAIN), with lower BSS use in the winter months with lower temperatures and more rainfall, and higher BSS use in the extended summer season.

Table 8.6: Linear mixed models for COUNTO and COUNTD in Las Palmas de Gran Canaria (n observations = 422) (Maas et al., 2021a)

	COUNTO model			COUNTD model		
Random effects	*Variance*	*Standard deviation*		*Variance*	*Standard deviation*	
STATION_NU	0.387	0.622		0.498	0.706	
Residual	0.114	0.338		0.097	0.311	
Fixed effects	*Coefficient estimate*	*Standard error*	*p-value*	*Coefficient estimate*	*Standard error*	*p-value*
Intercept	-0.049	0.104	0.643	-0.052	0.117	0.658
LU_TOUR	0.457	0.112	0.000	-	-	-
LU_LEN_CYC	0.435	0.105	0.000	0.482	0.117	0.000
LU_DISTBUS	-	-	-	-0.303	0.119	0.015
GEND_RATIO	-0.487	0.110	0.000	-0.332	0.120	0.009
AVG_MAXC	0.144	0.021	0.000	0.128	0.020	0.000
TOT_RAIN	0.244	0.021	0.000	0.217	0.020	0.000
	Model *p*-value compared to null model		0.000	Model *p*-value compared to null model		0.000

Notes: Coefficient estimates are standardised; -: variable not included in this model.

Table 8.7: Linear mixed models for COUNTO and COUNTD in Malta (n observations = 715) (Maas et al., 2021a)

	COUNTO model			COUNTD model		
Random effects	*Variance*	*Standard deviation*		*Variance*	*Standard deviation*	
STATION_NU	0.446	0.668		0.485	0.696	
Residual	0.213	0.461		0.176	0.419	
Fixed effects	*Coefficient estimate*	*Standard error*	*p-value*	*Coefficient estimate*	*Standard error*	*p-value*
Intercept	0.000	0.088	0.995	0.000	0.091	0.993
LU_COM	-0.194	0.088	0.033	-	-	-
LU_SHOP	0.280	0.090	0.003	0.255	0.095	0.010
LU_DISTSEA	-0.201	0.090	0.003	-	-	-
LU_BEACH	-	-	-	0.380	0.095	0.000
DIST_MEAN	-0.254	0.090	0.006	-0.245	0.092	0.010
AVG_MAXC	0.206	0.023	0.000	0.161	0.021	0.000
TOT_RAIN	-0.126	0.023	0.000	-0.098	0.021	0.000
	Model *p*-value compared to null model		0.000	Model *p*-value compared to null model		0.000

Notes: Coefficient estimates are standardised; -: variable not included in this model.

A higher percentage of industrial/commercial land use (LU_COM) shows a negative association with use of BSS stations as an origin, as in the OLS model. LU_COM has a high negative correlation with LU_RES (*r* = -0.654), indicating that use is more influenced by residential land use (as also seen in the bivariate correlations between COUNTO/D and LU_RES in Table 8.1). The effect of the proximity to the coastline or beach/promenade is present in both models, but captured through two different variables: in the COUNTO model there is a negative association with the distance to the coastline (LU_DISTSEA), with lower

BSS use further away from the coastline, whereas in the COUNTD model this is included as a positive association with the presence of the beach/promenade within the 300m buffer around the stations.

8.4 Comparative analysis of the influence of physical environment factors on BSS use

To assess which independent variables significantly influence BSS use (COUNTO & COUNTD), Table 8.8 compares the significant associations between dependent and independent variables in the bivariate correlation analysis in section 8.1, the OLS models in section 8.2 and the linear mixed models in section 8.3, as well as the direction of that relationship (positive or negative, indicated respectively with a positive sign and green colour, or with a negative sign and red colour). In terms of the stations' use as origins and destinations, the spatial pattern of BSS use in Malta showed the strongest visible difference between station use as origin and destination, with more stations with dominant use as an origin located further inland, at a higher elevation, and more stations used as a destination located in the low-lying parts of the urban area, near the coastline.

Looking at the land use variables, LU_RES, the percentage of residential land use, generally shows a positive effect, although it did not show significance in the majority of the models. LU_COM, the percentage of commercial/industrial land use shows a negative relation with BSS use in Malta, but no significant effect in Las Palmas de Gran Canaria, whereas in Limassol it actually shows the opposite effect in the OLS model. LU_PARK, the percentage of park land use in the station buffer, has a positive association with BSS use in Limassol, but shows no significant relation with BSS use in the other two cities, confirming that BSS use in Limassol is more associated with leisure use, and more with cycling for transport in Las Palmas de Gran Canaria and Malta. LU_TOUR, the count of hotels, shows a negative association in Limassol, but a positive one in Las Palmas de Gran Canaria. The negative association in Limassol can be explained by a predominance of BSS use by local residents, not tourists, as well as the fact that many of the hotels and the main tourist area are located at the eastern end of the city, away from the city centre and the main cycling path along the promenade. LU_CAFE, the count of cafes/restaurants, shows a positive relationship with BSS use in all cities, but predominantly in the bivariate correlation analysis, not in the models. LU_SHOP, the count of clothing shops as a proxy for shopping, services and commercial centres, has a positive relation with BSS use in Malta for station use both as an origin and a destination, where there is more cycling for transport, but a negative association for stations as a destination in Limassol, with more cycling for leisure.

The association with the count of university buildings, LU_UNI, is negative in Limassol and Malta, indicating uptake at the university campuses is low, despite them being included in the BSS network. LU_BEACH, the presence of coastline in the 300m buffer, shows a positive association with BSS use, especially in Limassol and Malta, where the variable is significant in both the OLS and LMM models. LU_LEN_CYC, the length of cycling paths in the buffer, has a positive relation with BSS use in Limassol and Las Palmas de Gran Canaria. This relationship is not present in the Malta models as there is almost no cycling infrastructure in the urban area. The distance from the nearest bus station (LU_DISTBUS) shows a negative association in Las Palmas de Gran Canaria, in particular for use of BSS stations as a destination, highlighting the positive relationship between BSS and public transport use. This relationship is also weakly visible in Malta (through the negative association with

LU_DISTBUS and positive relationship with LU_BUS), but is absent in Limassol, where public transport modal share is very low. While the relationship with elevation (ELEV) is negative in all three cities in the bivariate correlation analysis, the effect is not significant in any of the models, apart from the COUNTD OLS model in Malta.

Table 8.8: Comparison of associations between dependent and independent variables in: bivariate correlation analysis (BCA), Ordinary Least Squares models (OLS) and linear mixed models (LMM)

	LIM COUNTO & COUNTD			**LPA** COUNTO & COUNTD			**MAL** COUNTO & COUNTD		
Variables	BCA	OLS	LMM	BCA	OLS	LMM	BCA	OLS	LMM
LU_RES	--	+	--	+[a]	--	--	+	--	--
LU_COM	--	+	--	—	--	--	—	—	—[a]
LU_PARK	+	+	--	--	--	--	--	--	--
LU_TOUR	--	—	—	+	+	+[a]	+	--	--
LU_CAFE	+	+	--	+	--	--	+	--	--
LU_SHOP	—	--	—[b]	+	--	--	+	+	+
LU_UNI	—	--	--	--	--	--	—	—[a]	--
LU_BEACH	+	+	+	+	--	--	+	+	+[b]
LU_BUS	—	--	--	+	--	--	+	+	--
LU_LEN_CYC	+	+	+	+	+	+	—	--	--
LU_DISTSEA	—	--	--	—	+[a]	--	—	--	—[a]
LU_DISTBUS	--	--	--	—	—	—[b]	—	--	--
LU_DISTUNI	—	--	--	--	--	--	—	—[a]	--
LU_NODES	--	--	+[b]	+	--	--	+	--	--
ELEV	—	--	--	—	--	--	—	—[b]	--
POP_DENS	+	--	--	+	--	--	+	--	--
PERC_EDU3	—	—	--	+	--	--	+	--	--
GEND_RATIO	--	--	--	—	—	—	--	--	--
AGING_POP	—	--	--	+	--	--	+	--	--
FORGN_POP	+	--	--	+	--	--	+	+[a]	--
DIST_MEAN	—	—[a]	—	—[a]	--	--	—	—[b]	—
COUNT_STAT	--	--	--	+	--	--	+	--	--
COUNT_STA2	+	+	--	+	--	--	+	--	--
TOT_TOUR	+	n/a	--	--	n/a	--	+	n/a	--
AVG_MAXC	+	n/a	--	--	n/a	+	+	n/a	+
TOT_RAIN	—	n/a	—	+	n/a	+	—	n/a	—

Notes: -: negative association; +: positive association; --: no significant result; n/a: not applicable, as not included in OLS model; [a] significant for COUNTO only; [b] significant for COUNTD only

In terms of socio-economic variables, POP_DENS has a positive relationship with BSS use in the bivariate correlation analysis in all three cities, as does a higher percentage of foreign population (FORGN_POP). The effects of a more highly educated (PERC_EDU3) and older (AGING_POP) population are mixed; from the bivariate correlation analysis the relationships are negative in Limassol, but positive in Las Palmas de Gran Canaria and Malta. The gender quotient (GEND_RATIO) showed a significant negative relationship with BSS use in Las Palmas de Gran Canaria, with less BSS use in locations with a higher percentage of male population, whereas no significant effect was observed in the other two cities.

Looking at the network variables, the distance from the centre of the BSS (DIST_MEAN) has a negative association with BSS use, whereas the number of stations within a 1,200 m buffer around a BSS station (COUNT_STA2) has a positive relationship with BSS use, in all three cities. The temporal variables show a similar picture for Limassol and Malta, with a negative association with rainfall (TOT_RAIN) and a positive association with AVG_MAXC, the average maximum temperature and the total number of visiting tourists (TOT_TOUR). While the relationship with temperature is positive in Las Palmas de Gran Canaria, as in the other two cities, surprisingly, so is the association with rainfall.

8.5 Investigating the influence of new cycling infrastructure in Las Palmas de Gran Canaria

It is evident from the literature how important connected cycling infrastructure is for the promotion of cycling as a mode of transport. Making use of planned investment in the extension to the cycling network, this section details the results of a before and after study of the impact of new cycling infrastructure on the use of BSS stations in Las Palmas de Gran Canaria. The difference in BSS use at station level, after the addition of nearly 10km of new cycling lanes and paths in the summer of 2019 is studied, by comparing the aggregated BSS station use from six months before the implementation of the new infrastructure, with the aggregated use from six months after, while controlling for the overall observed increase in BSS use. Linear mixed models were used to assess the difference between stations that were impacted by the change, and those that were not. Stations were classified as belonging to either the ‘treatment’ group (stations with new cycling infrastructure within a set buffer around the station) or ‘control’ group (stations without new cycling infrastructure in the buffer). The dependent variable is the overall station use (COUNTOD): the aggregated usage of the station as an origin (COUNTO) and a destination (COUNTD). The independent variables are the factor TIME, a dummy variable indicating the ‘before’ period (six months during the baseline year 0) and the ‘after’ period (year 1) and the factor GROUP, a dummy variable indicating whether the station in question was impacted by the new cycling infrastructure or not, separating stations in a ‘treatment’ and a ‘control’ group. The analysis aids in understanding and quantifying the effect of the extension of cycling infrastructure on the use of a dock-based BSS. Figure 8.3 shows the extent and location of the new cycling infrastructure (lanes and paths), and the BSS stations with a 50m buffer around them. Figure 8.4 includes photos with a number of examples of new cycling lanes and paths installed in the summer of 2019.

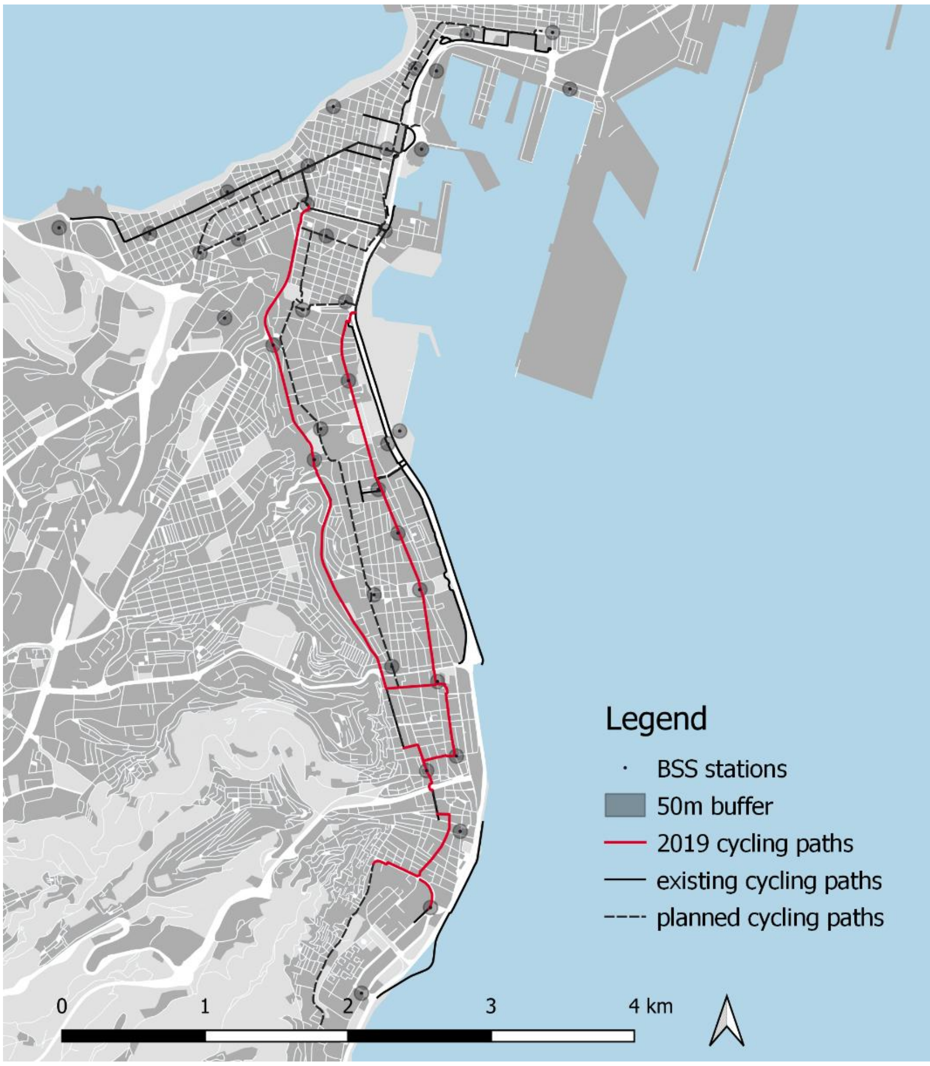


Figure 8.3: Map of new cycling lanes and paths (summer 2019) in Las Palmas de Gran Canaria

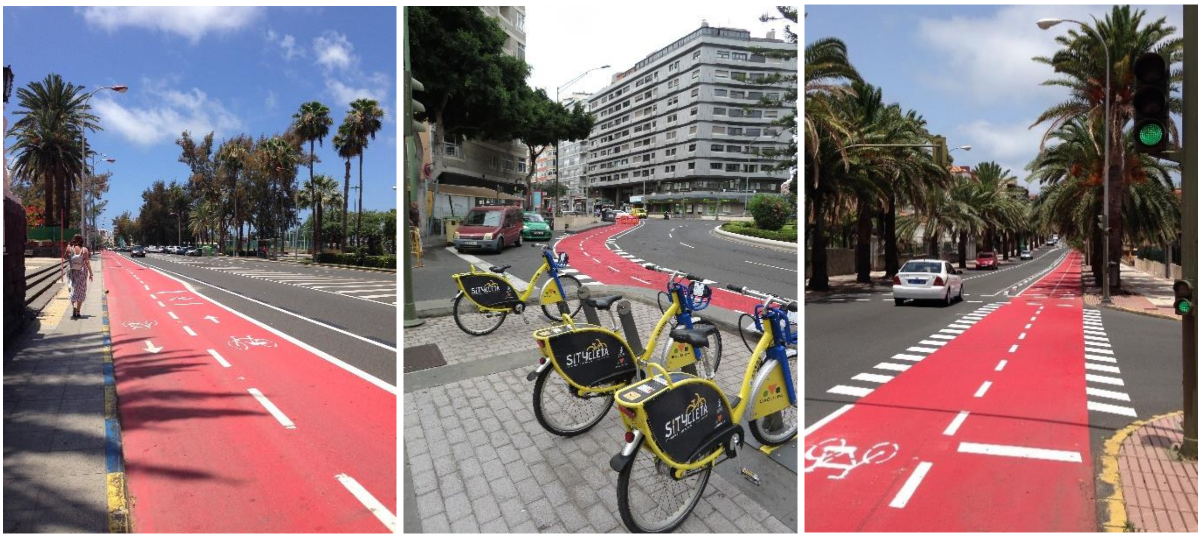


Figure 8.4: Examples of new cycling lanes and paths in Las Palmas de Gran Canaria (summer 2019)

Different sizes of buffers around the station were used to model the impact of the new cycling infrastructure on BSS use, to analyse which measure of distance best captures the effect of the new cycling infrastructure on the BSS use at station level. Buffers of 25m, 50m, 100m, 200m, and 300m were created around the point locations of the stations. Figure 8.5 shows three examples of stations with buffers around them, and explains in which cases stations were considered to form part of the 'treatment' group (new cycling infrastructure) or the 'control' group (no new cycling infrastructure).

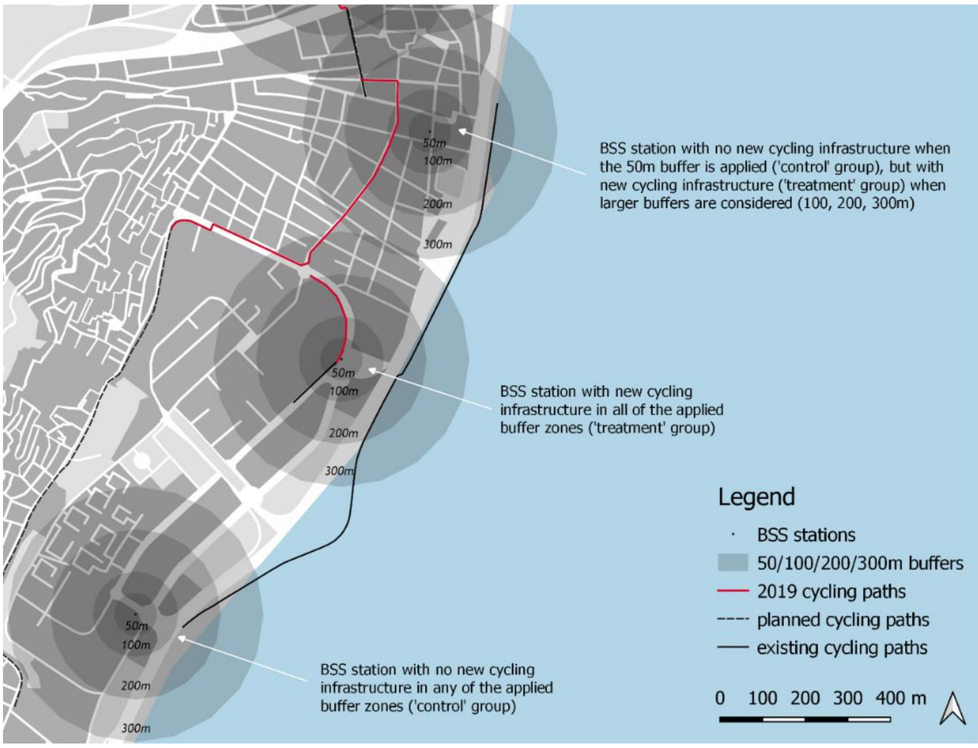


Figure 8.5: Comparison of different buffers around BSS stations in Las Palmas de Gran Canaria

Table 8.9 presents the results from the different linear mixed models based on the different sizes of buffers. The stations (STATION_NU) were included as random effects, to account for the repeated measures per station: the aggregated use of the station from six months before, and six months after. The fixed effects included in the analysis are: TIME, the difference between the six-month period 'before' (baseline, year 0) and the six-month period 'after' (year 1) for the reference group (the 'control' group); and an interaction effect TIME:GROUP, which measured the effect of the group of stations that received the 'treatment' versus the 'control' group of stations. Figure 8.6 shows station BSS use for stations in the 'control' and 'treatment' groups, in the 'before' and 'after' situation (year 0 vs year 1).

From the results in Table 8.9 it is evident that the effect is best captured in the models estimated using the 50m and 25m buffers. In this case, they are identical, capturing the same stations that were impacted by the new infrastructure. These results show that the effect of new cycling infrastructure on BSS station use is positive, and that it is strongest when they are implemented in the near vicinity of the station. Looking at the results from the model using the 50m buffer around the BSS stations (highlighted in light blue in Table 8.1), the coefficient for the fixed effect TIME for the 'control' group was 989.44, meaning the average increase of total trips for 'control' stations between the six-month baseline period (year 0) and the six-month period following the implementation of new cycling infrastructure (year 1) was nearly 1,000 trips. The effect of the treatment (the implementation of new cycling infrastructure within the buffer around the BSS station) was captured through the interaction effect of TIME:GROUP, which measured the effect of treatment (new cycling infrastructure within a station's buffer) in addition to the fixed effect TIME for the 'control' group. The overall effect was 1,955.35, meaning the average increase of total trips for stations with treatment was nearly 2,000 trips, double the value of the stations without treatment, when comparing year 1 (after) with the baseline year 0 data (before).

Table 8.9: Linear mixed model results analysing the before-after effect of new cycling infrastructure in Las Palmas de Gran Canaria (n=74)

	300m buffer	200m buffer	100m buffer	50m buffer	25m buffer
Random effects	***Variance (standard deviation)***				
STATION_NU	14,204,151 (3,769)	14,032,773 (3,746)	13,906,290 (3,729)	13,766,981 (3,710)	13,766,981 (3,710)
Residual	1,289,857 (1,136)	1,314,575 (1,147)	1,238,246 (1,113)	1,023,293 (1,012)	1,023,293 (1,012)
Fixed effects	***Coefficient estimate (standard error)***				
Intercept	4,973.78*** (647.11)	4,973.78*** (644.04)	4,973.78*** (639.77)	4,973.78*** (632.25)	4,973.78*** (632.25)
TIME	987.17** (409.54)	1,167.48*** (350.54)	1,091.30*** (325.59)	989.44*** (279.12)	989.44*** (279.12)
TIME:GROUP	981.48* (526.50)	932.59* (526.42)	1,267.14** (522.43)	1,955.35*** (505.58)	1,955.35*** (505.58)

Notes: significant at: * 0.10; ** 0.05; *** 0.01 level; reference categories: TIME: baseline, year 0; GROUP: control.

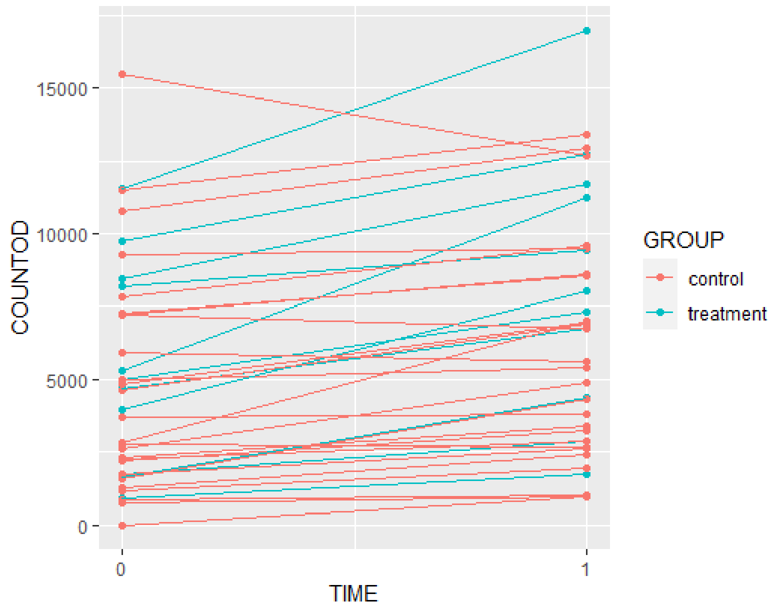


Figure 8.6: Comparison of station BSS use between year 0 (TIME 0: 'before') and 1 (TIME 1: 'after') for the 'control' and 'treatment' groups

8.6 Conclusion

In this concluding section, the results found through the analyses described in this chapter are summarised. This chapter focused on the influence of spatial and temporal factors on BSS use, looking at station use both as an origin and a destination. Independent variables included land use, socio-economic and network factors (spatial) and weather and tourism factors (temporal). Associations were first investigated through bivariate correlation analysis. Thereafter, the influence of spatial factors was assessed in OLS models based on the aggregated BSS use of a year of trip data. Finally, the combined influence of spatial and temporal factors was analysed, by looking at BSS use on a monthly basis in linear mixed models.

The analyses were based on two dependent variables: COUNTO and COUNTD; the station's use as an origin and destination. BSS station use in Malta showed the strongest visible difference between origins and destinations, with stations with higher use as an origin located at higher elevations than stations more frequently used as destinations. In all three cities, the origin and destination models shared the majority of independent variables, which are discussed below. There were however also some differences between the variables included in the origin and destination models, highlighting specific factors acting as draws for station use as an origin or as a destination. In Limassol, the presence of shops (clothing) showed a negative association in the destination model, whereas a denser road network showed a positive association. This shows that although trips may end in an urban environment with greater density, the purpose of the BSS trip is not associated with shopping or running errands, but rather with leisure purposes, as also gathered from the descriptive statistics of the BSS use in Limassol. In Las Palmas de Gran Canaria, a positive association was present in the model between station use as an origin and the presence of tourist accommodation in the vicinity. As the BSS is mostly used for transport purposes, and thus not dominated by tourists, this result can be explained by the fact that the tourist accommodations are located in an area with many leisure and entertainment venues, which was also evident from the multicollinearity between the number of tourist accommodations, and the count of cafes and restaurants in the buffer around BSS stations.

From the combined results of the bivariate correlation analysis, the spatial OLS models and the spatio-temporal LMMs, a handful of spatial factors showed consistent positive associations with BSS use in the case study cities, based on their presence within a 300m buffer around the BSS stations: LU_RES, the percentage of residential land use; LU_CAFE, the count of cafes and restaurants; LU_BEACH, the presence of the coastline; LU_NODES, the number of road intersections, as a measure of urban density; FORGN_POP, the percentage of foreign population, and COUNT_STA2, the number of BSS stations within a 1,200m buffer around the station, as a measure of network connectivity. DIST_MEAN, the distance from the centre of the BSS, as a measure of centrality, showed a negative relationship with BSS use in all three cities, as did elevation (ELEV). In terms of temporal factors, only temperature (AVG_MAXC) showed a consistent association across all three case cities, with higher temperatures associated with an increase in BSS use.

Other factors only showed an association in one or two of the case study cities, or had opposite associations (positive vs negative) in the different cities. These differences can be explained by the different spatial structures and temporal conditions in the cities, different types of BSS usage, i.e. more for transport or more for leisure, and the level of integration with other modes of transport, e.g. the relationship with public transport use captured through the influence of the presence or distance to a bus station. As the university campus in Las Palmas de Gran Canaria is located on the outskirts of the city and outside the area covered by the BSS, there is no relationship between the two variables. In Malta, the few cycling paths that exist in the country are primarily located outside of the urban area, resulting in a negative relationship between the length of cycling infrastructure (LU_LEN_CYC) in a buffer around the BSS stations. This is in contrast to the results from Las Palmas de Gran Canaria and Limassol, where there is a strong positive relationship, as expected and based on findings from the literature. LU_PARK, the percentage of park land use, only showed a positive association in Limassol, where the BSS use is dominated by leisure use, but no significant associations in the other two cities. LU_BUS, the presence of a bus station, was positively associated with BSS use in Las Palmas de Gran Canaria and Malta, but was negative in Limassol, where the modal share of public transport use is lower and there is less utilitarian BSS use, which is more associated with multimodal transport use. Socio-economic factors in terms of higher education (PERC_EDU3) and age (AGING_POP) showed a positive association with BSS use in Las Palmas de Gran Canaria and Malta, but a negative association in Limassol. In terms of temporal variation, whereas higher rainfall was negatively associated with BSS use in Limassol and Malta, this relationship was positive in Las Palmas de Gran Canaria, where total rainfall is lower and more distributed.

The creation of new cycling infrastructure in Las Palmas de Gran Canaria during the period of this research, offered the opportunity to study the effect of the new cycling lanes and paths on BSS use, while being able to control for the overall observed increase in BSS use. A linear mixed model was used to assess the influence of the new cycling infrastructure on BSS use, by comparing a dataset from before and after. The results showed that BSS use on its own increased over time, by an average of almost 1,000 trips when comparing the after with the before dataset, while the average increase of total trips for stations which were affected by the new cycling infrastructure (within 50 m of the station location) was nearly 2,000, double the increase in BSS use at stations that were not impacted by the change.

The next chapter, *Chapter 9,* presents the discussion, in which the results from *Chapters 5* to *8* are discussed in relation to findings from the literature. Following the discussion, this dissertation is concluded in the final chapter, *Chapter 10.*

9. Discussion

This chapter addresses the seventh research question (RQ7) of this study: *Which lessons can be learned from the promotion of cycling and BSS use in the case study cities?* This final research question aims to wrap up the findings from this research in light of the overall research aim: *To analyse the role of BSS in promoting cycling as a mode of transport in Southern European island cities*. Throughout the research, this was analysed from different perspectives, presented in four dedicated results chapters:

- from the geographical and socio-cultural context and relevant land use and transport policy and legislation, in *Chapter 5: Case studies context*;
- from the observed use of the BSS, in terms of who uses it, where, why, when and how much, in *Chapter 6: BSS use in the case studies*;
- from the analysis of the BSS user survey to understand the influence of user characteristics, attitudes, habits and perceptions, encouraging and discouraging factors, social norms and perceived environment factors on BSS use, in *Chapter 7: The influence of individual and social environment factors*; and
- from the analysis of the BSS trip data to understand the influence of natural and built environment factors, such as urban form, infrastructure, weather and elevation, on BSS use, in *Chapter 8: The influence of physical environment factors*.

The discussion of findings is presented in section 9.1, focusing on the results of the analysis presented in the four results chapters. Section 9.2 puts forward policy implications of the findings and contains a number of policy recommendations for the promotion of cycling and BSS use in the case study cities, as well as for other cities with similar characteristics. The strengths and limitations of this research are discussed in Section 9.3. The final section, 9.4, summarises this chapter and links to the conclusion of this dissertation in *Chapter 10*.

9.1 Discussion of findings

In this first section, the results from the four previous chapters with the main findings of this study, are discussed in relation to findings from the literature. This section is organised according to the factors that were identified through the literature review in *Chapter 2* and summarised in the theoretical framework in *Chapter 3*. Figure 3.4 presented a socio-ecological model of cycling behaviour and BSS use, including factors at multiple levels that can influence the travel behaviour being studied; BSS use. The results are discussed here according to the factors in that framework: individual factors including demographic, socio-economic and intra-personal factors; inter-personal factors, such as social norms and modelled behaviour, emerging from the social environment; and physical environment factors including both built and natural environment factors. Table 3.1 presented an overview of the findings from the literature on the influence of the different factors on cycling and BSS use, including the positive or negative expected direction of the effect of each factor.

9.1.1 Demographic factors

This section discusses the findings related to demographic factors: gender, age and nationality. The gender balance of respondents to the BSS user survey showed disparate results for the three case study cities, with a female majority in Limassol and a male majority in Las Palmas de Gran Canaria and Malta. In line with most BSS research, especially in cities without a strong cycling culture, an initial predominance of male users is expected (Murphy & Usher, 2015; Faghih-Imani & Eluru, 2015). This is usually explained as a result of women being more risk-averse than men (Pucher & Buehler, 2008), underlining the importance of improving road safety for all cyclists, through lowering vehicular speeds and reducing traffic volumes or creating dedicated cycling infrastructure. The majority of BSS use in Limassol takes place between the stations along the promenade connected by a segregated cycling path, which represents a safer cycling environment, appealing to cyclists of all genders.

The majority of BSS users in Limassol and Malta fell within the 18 to 34 years' age bracket, in line with findings from the literature (Fishman et al., 2015; Murphy & Usher, 2015). The age distribution in Las Palmas de Gran Canaria however, showed a more evenly distributed picture, with the main age groups of BSS users being the 25-34, 35-44 and 45-54 age brackets, and remarkably less users in the younger age categories.

While the survey did not include questions surrounding ethnicity or race, as some research on BSS in the US has explicitly done (Hyland et al., 2018; Wang et al., 2016), the survey did include questions around the respondents' nationality and residency status. As the case study cities attract foreigners as temporary or more permanent residents (e.g. from employment in the harbour and tourism industries, service industry, as well as expats), their BSS use was of particular interest in this study. In the aggregated analysis of the BSS user survey data, temporary residents were significantly associated with more frequent BSS use, when compared to permanent residents and visitors. In Limassol and Malta, around half of the respondents to the survey are foreign residents. In Malta, there was a significant positive association between BSS use and non-native respondents. These results were also confirmed by the spatial analysis of the BSS use in the three case study cities, where in all cities there was a significant positive association between a higher percentage of foreign residents and BSS use at stations in those neighbourhoods or census tracts. Foreigners, as visitors or residents in the city, may be more accustomed to using a bicycle or BSS in their own country and can therefore represent an accessible target group that can play a role in inspiring cycling as a mode of transport for local residents (Bakogiannis et al., 2019).

9.1.2 Socio-economic factors

This section discusses the findings related to socio-economic factors: education, income, occupation, household structure, and vehicle ownership and access. In terms of education level and employment status, the BSS users in all three cities are generally highly educated and in employment, in line with user characteristics of other BSS (Fishman, 2016; Médard de Chardon et al., 2017). Income levels are not as high as found in some other BSS (Fishman et al., 2015; Murphy & Usher, 2015), with most survey respondents indicating an income in the low to average range (from <€10.000 to €30.000/year), which can be at least partially explained by the relatively young average age of users, including students. While students do make up some of the user base of the BSS in the three case study cities (from 10% in Las

Palmas de Gran Canaria to 34% in Malta), results from the spatial analysis of the trip data show a negative association with BSS use in the vicinity of the university campus in Limassol and Malta, even though it is located within the catchment area of the BSS. This result contrasts with many other cities, where the university community and campus is often a hotspot for cycling and students and staff make up a key user group of the BSS use (Castillo-Manzano & Sanchez-Braza, 2013; Molina-García et al., 2013). In Las Palmas de Gran Canaria, there was no significant relationship, as the main university campus is located outside the city. Results from the analysis of the aggregated survey results from the three case study cities showed that frequent BSS use is most strongly associated with respondents living in a 1-person household, and increasingly less with larger (3+ person) households, in line with insights from the literature, which found that people living as singles or couples are most likely to cycle (Heinen et al., 2010) or use a BSS (Hyland et al., 2018).

A large majority of the respondents to the survey has a driving license, and ownership of a car ranges from half of the respondents (in Malta) to three-quarters of the respondents (in Limassol). Results from the survey analysis showed a positive association between BSS use and not owning a car in Las Palmas de Gran Canaria and Malta, whereas in Limassol there was no significant association. In the aggregated analysis, with the survey results from all three cities, frequent use of a private car as a driver is significantly associated with more infrequent BSS use. Results from the literature showed mixed associations, e.g. a positive relationship with lower car ownership in Melbourne (Jain et al., 2018), but a negative relationship in Minneapolis (Maurer, 2011), which suggests that the relationship may depend on other factors, such as mobility culture, land use mix and density. Around half of the respondents in each of the case study cities has access to a private bicycle, meaning that for the other 50%, the BSS has contributed to providing access to a bicycle, where previously respondents may not have had such access. Providing easier access to a bicycle is associated with increased cycling (Pucher et al., 2010) and BSS in particular can enable cycling for people who may not have the ability to purchase or maintain a private bicycle, or to safely store it (Faghih-Imani & Eluru, 2016b; Murphy & Usher, 2015).

9.1.3 Intra-personal factors

This section discusses the findings related to intra-personal factors: attitudes, habits, perceived barriers and facilitators, and perceived behavioural control, or self-efficacy. Respondents to the survey in all three cities have a strong positive attitude towards ‘liking cycling’, as intuitively expected and found in the literature (Heinen et al., 2010). The top three motivating factors for BSS users in the three case study cities were ‘health’, ‘being environmentally friendly’ and ‘fun’, confirming the positive association between BSS use and a positive attitude towards environment and sustainability (Shaheen et al., 2011; Yin et al., 2018) and health reasons as a motivating factor (Félix et al., 2019; Fishman et al., 2015). ‘Convenience’ and ‘saving money’ emerged as the two factors most strongly correlated with BSS use in all three cities, in line with findings from other BSS research, particularly in relation to commuting cycling (Fishman, 2016). Other facilitators for cycling identified in the course of the study are access to bicycles and parking facilities, which are in principle delivered by dock-based BSS, but can be dependent on use and availability of bicycles and docking stations. The overall satisfaction with the BSS in all three case study cities was high, including the availability of bicycles and docks. Satisfaction with the operation of the BSS, a user-centric design, and a high level of service to users have been identified as important contributors to BSS usage and scheme longevity (Morton, 2018; Nikitas, 2019).

The strongest barriers identified are related to busy roads and a lack of respect from other road users. This was particularly evident in Malta, with the least available dedicated cycling infrastructure or traffic calmed streets. Several studies looking at cities in Southern Europe found the lack of safe cycling infrastructure to be the main barrier to more cycling uptake, e.g. in Lisbon, Portugal (Félix et al., 2019), in Larnaca, Cyprus (Nikolaou et al., 2020), and in Drama (Nikitas, 2018) and Rethymno (Crete), Greece (Bakogiannis et al., 2019). Respondents in all three case study cities in this study indicated that they feel most safe on separated bicycle paths and least safe while cycling on the road without cycling infrastructure, underlining the universal importance of safe cycling infrastructure on the decision to cycle.

Long distances to BSS stations from home or frequent destinations can also be a barrier to BSS use (Félix et al., 2019; Iwińska et al., 2018). A shorter distance to the respondents' residence and most frequent destination showed a significant positive association with BSS use in all three cities in the survey. This finding is particularly relevant in Limassol, which has a less dense urban form and where only a quarter of the respondents to the survey live within a 5-minute walk from the nearest station, in contrast to 60% of respondents in Las Palmas de Gran Canaria. Mandatory helmet use has also been identified as a strong barrier to BSS use in the literature (Fishman et al., 2015). However, helmet use is not mandatory in any of the case study cities. The majority of respondents in Limassol and Las Palmas de Gran Canaria indicate that they 'never' wear a bicycle helmet while using the BSS, whereas in Malta over half of the respondents 'sometimes' or 'always' wear a helmet. This difference between Limassol and Las Palmas de Gran Canaria on the one hand and Malta on the other can be explained by better provision of cycling infrastructure near the BSS in the former two cities, whereas cycling infrastructure in the urban area in Malta is lacking. This suggests more BSS use in mixed traffic, and therefore a likely higher (perceived) risk of accidents by BSS users. As a consequence, this affects the decision by a larger percentage of users to opt for a helmet for personal safety.

Around half of the respondents in all three cities consider themselves to be experienced cyclists, with only a small percentage indicating they are inexperienced (around 10%). However, not knowing how to cycle can be an issue for potential users. This is evident in Malta, where around a third of respondents to a nation-wide shared mobility survey indicated 'not knowing how to cycle' to be one of the main reasons not to consider using the BSS (Maas & Attard, 2020). To address inadequate cycling skill, efforts can be made in cycling education (Pucher & Buehler, 2010), e.g. as offered by Nextbike Malta through their *Bikeability* training, as well as in investment in the cycling network, which can make cycling safe and attractive to people of all ages and abilities (Reynolds et al., 2009). In terms of affordability, the response in the survey was generally positive, with the strongest positive response in Limassol, where the pay-as-you-go fee is higher than the other two cities, but covering a longer period of time (2 hours instead of 30 minutes), thus representing better value for money for its users. A larger share of respondents are subscribed members in Las Palmas de Gran Canaria, versus a majority of pay-as-you-go users in Limassol and Malta. This can potentially be explained by the more economical membership offers in Las Palmas de Gran Canaria (partially subsidised by the municipality through income from paid parking), and how this encourages people to become a subscribed member rather than a casual user. Memberships are also more associated with BSS use for commuting purposes as this is a recurring and frequent activity. Indeed, higher commuting frequency was indicated by respondents to the survey in Las Palmas de Gran Canaria, whereas casual users more often use the BSS for leisure or for exercise, which could be more sporadic (Fishman, 2016; O'Brien et al., 2014).

9.1.4 Inter-personal factors

This section discusses the findings related to inter-personal factors: the social norms around cycling, and mobility in general, in terms of social subjective norms (the general attitude to cycling) and social descriptive norms (seeing behaviour modelled by others). These are discussed within the wider socio-cultural context surrounding transport and mobility, including issues related to car dependence, types of cycling behaviour and multimodal transport use.

All three case study cities so far have a low cycling modal share, a high rate of motorisation and a high car modal share, the latter especially in Limassol and Malta. In cities with a low cycling modal share, the dominant habits and customs tend to deter cycling (Pucher, Dill, & Handy, 2010), e.g. as a result of the lack of adequate infrastructure (Félix et al., 2019), the inability to imagine oneself as a cyclist (Gatersleben & Appleton, 2007), or the perception of cycling as something from the past, as something for poor people, or only as a sport or leisure activity (Aldred & Jungnickel, 2014). In the aggregated analysis of the survey responses from the three case study cities, a positive social norm, in terms of support from friends and family, respect from other road users, and feeling that cycling is an accepted form of transport, showed positive associations with BSS use, confirming the importance of such factors in building a cycling culture. 'Support from family and friends', and the feeling that 'cycling is an accepted form of transport' was scored higher by respondents from Limassol and Las Palmas de Gran Canaria than by those from Malta, where the social norm around cycling seems less supportive of cycling. The normality of cycling, both in terms of it being an accepted form of transport by an individual, as well as by wider society, is an important driver for cycling behaviour (Goodman, Green, & Woodcock, 2014). BSS can encourage different societal groups to start cycling, through social contagion (Schoner et al., 2016). Analysis of BSS use in Seville and Dublin showed that the majority of respondents to a survey about their BSS use indicated that they had not been cycling before starting using the BSS (Castillo-Manzano et al., 2015; Murphy & Usher, 2015). However, as put forward by Ricci (2015) in her review of BSS research, for BSS to contribute to an increase in cycling modal share, complementary pro-cycling measures and wider support to sustainable mobility are needed. This is also advocated in the application of socio-ecological models to bring about behaviour change; in addition to the creation of safe and attractive places (e.g. safe cycling infrastructure) and the physical provision of the required tools (e.g. access to a bicycle and parking), there is a need for educational and motivational programs to encourage the behaviour, as well as for mass media campaigns and community organisation to change social norms and culture (Sallis et al., 2006).

It is evident in all three case study cities, to different degrees, that there is a dominant car culture and a strong social norm around private car use, fuelled by powerful industry and commercial interests behind the car-oriented transport system (car importers, fuel importers, fuel stations, building and infrastructure contractors) and their political influence. Perpetuating and further promoting car dependence has led to several transport issues in cities, effects such as congestion, land uptake for parking, pollution and road safety concerns, which have been recognised for decades already (Thomson, 1977). Allowing continued growth of private vehicular traffic goes completely contrary to the environmental and social goals that cities are required to pursue in their efforts to mitigate climate change and to create healthier and more liveable urban environments. Such commitments are laid down in the Paris Agreement and the European climate and energy framework, and the national governments of the case study cities have an obligation to meet the targets in these agreements and have transposed these into national law. The European Green Deal document highlights that to achieve climate neutrality in 2050, “a 90% reduction in transport emissions is needed by 2050”, which can only be achieved through the promotion of “more affordable, accessible, healthier and cleaner alternatives” to mobility (European Commission, 2019). However, research has shown that focusing on the promotion of alternative modes alone does not bring about significant modal shift, and that only an approach that also includes measures to deter car use simultaneously can effectively change mobility behaviour (Piatkowski, Marshall, & Krizek, 2019).

In terms of BSS use in combination with other modes of transport, the majority of those who do use BSS as part of multimodal transport do so in combination with walking, in all three case study cities. Apart from walking, there is more multimodal use with public transport in Las Palmas de Gran Canaria and Malta, and more with private car use in Limassol. When looking at the modal shift for the most frequent BSS trip, the dominant category across the three case study cities is a shift from walking, in line with findings from other cities (Fishman et al., 2014; Murphy & Usher, 2015). Compared to walking, BSS use provides increased speed and thus contributes to reduced travel time and increased convenience (Ricci, 2015). Modal shift from private car use was around 20% in the three case study cities, in line with findings from Brisbane, Melbourne and Minnesota (Fishman et al., 2014). In the case of modal shift from private car use, BSS use contributes to emission reductions and reduced air pollution, as well as an increase in physical activity (Médard de Chardon et al., 2017). Modal shift from public transport was highest in Las Palmas de Gran Canaria and lowest in Limassol. These results show that in Las Palmas de Gran Canaria and Malta, where respondents to the survey reported higher public transport use than in Limassol, there is also more competition between public transport and BSS use. Evidence of a substitution effect from public transport to BSS use was also found by Shaheen et al. (2012), but the reported higher multimodal use of BSS with public transport by respondents in Las Palmas de Gran Canaria and Malta also supports the complementarity of the two modes of transport, and the role of BSS as a feeder service to public transport (Murphy & Usher, 2015). Compared to public transport, the BSS can provide more flexibility and freedom, and its use contributes to an increase in physical activity.

The shorter median trip durations in Las Palmas de Gran Canaria and Malta, as well as the morning and evening peaks in the usage patterns, indicate that the predominant use of the BSS is for transport. The high share of round trips, the longer median trip duration and higher use throughout the day on both weekdays and weekends in Limassol indicate a system dominated by leisure use. This is partly due to the different pricing structures, but also to the different nature of the use of the BSS. Results from the survey confirmed that respondents from Las Palmas de Gran Canaria and Malta indicated their most frequent trip purpose was ‘for commuting’, whereas in Limassol that was ‘for exercise’. Leisure use can also be a predecessor for cycling for transport (Kroesen & Handy, 2014; Muñoz et al., 2013), as people feel comfortable riding a bicycle and cycling is normalised.

9.1.5 Built environment factors

This section discusses the findings related to the built environment, including factors related to urban form (such as population density, land use mix and distance) as well as in terms of infrastructure (such as road design, public transport infrastructure and the provision of cycling infrastructure).

From the analysis of the urban form of the three case study cities, a sharp difference in population density emerged, with lower density in Limassol, which is more sprawling in nature, and higher densities in Malta and Las Palmas de Gran Canaria. This is also reflected in the percentage of the population that lives within a walkable distance from a BSS station. An example from the literature shows that in Glasgow only 9% of the population lives within a 400m radius around a BSS station (Clark & Curl, 2016), whereas 33% of the population in Las Palmas de Gran Canaria and 29% of the population of the conurbation around Valletta in Malta live within a 400m radius of a BSS station. In Limassol, the figure is less than in the other two cities included in this study, with 13% of the city's population living within a walkable distance from a BSS station. Lower density settlements with greater distances between origins and destinations, have resulted in higher reliance on private vehicle mobility to access services (Hanson, 2004). In terms of land use density and the location of specific Points-of-Interest (POI), the results showed significant positive associations with higher population density, with the presence of the beach or promenade, and with the number of cafes and restaurants, in all three case study cities. This was also found in Barcelona and Seville, Spain (Faghih-Imani et al., 2017), and Rethymno (Crete), Greece (Bakogiannis et al., 2019), which found higher BSS use in areas with a high land use mix, with many POI, including places of historic interest, recreational and commercial activities. High urban density and mixed land uses have been found to be essential factors for walkable and bikeable cities (Heinen et al., 2010; van Wee & Handy, 2016). This is also the premise of the '15-minute city', which was adopted at policy level in Paris in 2020 as a planning concept in order to give neighbourhoods an economic boost, while enhancing social cohesion and promoting active travel options to access daily needs (Moreno et al., 2021). Another alternative to car-centric planning is proposed by the 'Superblock' concept originating in Barcelona, which removes through-traffic from the interior roads of city blocks, creating opportunities for the reallocation of road space to create more public open and green spaces and make streets safe and pleasant spaces for walking and cycling (Mueller et al., 2020).

The presence of a bus station within a 300m buffer around BSS stations was positively associated with BSS use in Las Palmas de Gran Canaria and Malta, but negatively in Limassol, where the modal share of public transport use is lower and there is less utilitarian BSS use, which is more associated with multimodal transport use. The results from the spatial analysis confirm there is at least some degree of complementarity between public transport use and BSS use in the former two cities. These findings support the insights obtained from the surveys with the BSS users, where reported public transport use and a multimodal combination of BSS and public transport use was evident in Las Palmas de Gran Canaria and Malta, but not in Limassol. The recent investments in the reorganisation and upgrading of the bus system in Cyprus for inter- and intra-city public transport aims to increase the modal share of public transport use. The complementarity between public transport and BSS use can be strengthened in all case study cities. The use of public transport, to cover larger distances, and cycling, to complete the journeys, is a powerful combination, and can provide a real alternative to private car use (Olafsson et al., 2016).

As seen from the results of the survey with BSS users, and as found in other studies from around the world (e.g. Félix et al., 2019; Fishman et al., 2014), the lack of safety for cyclists, on the road and at junctions, is the major barrier for cycling. These results are echoed by results of the spatial analysis in Las Palmas de Gran Canaria and Limassol, where there is a strong positive relationship between BSS use and the length of cycling infrastructure in a 300m buffer around the BSS stations. The before-and-after analysis of the impact of new cycling infrastructure in Las Palmas de Gran Canaria confirms these findings, with increased BSS use at stations in the near vicinity of new cycling paths and lanes. The above results confirm the positive association between BSS use and nearby bicycle lanes and paths found in the literature, e.g. from results in Washington DC (Buck & Buehler, 2012) and Brisbane (Mateo-Babiano et al., 2016). In Malta, the relationship between cycling infrastructure and BSS use was negative, but this can be explained by the near total absence of cycling paths in the urban area where the BSS is present, with the only cycling infrastructure located outside of the urban area, where BSS usage is low compared to the centre of the conurbation.

Network factors, such as the distance to the centre of the BSS, as a measure of how central or peripheral a BSS station is, and the number of other BSS stations within a radius around a station, show that in general, BSS use is higher closer to the centre of the BSS and at BSS stations that are better connected to other stations (more stations in close vicinity, and therefore more available connections). These findings echo the conclusions of Rixey (2013) who found that network effects have a strong influence on BSS use and recommends the installation of additional stations to ensure there is a continuous connection with the broader network. This recommendation is particularly relevant to Limassol, with lower density and a more spread out BSS, and Malta, with a number of isolated stations and station clusters.

9.1.6 Natural environment factors

This section discusses the findings related to the natural environment, including elements of the topography and weather factors. From the literature, challenges for the promotion of cycling and shared bicycle use are identified in terms of weather factors, such as high summer temperatures and rainy winter days, and as a result of elevation differences. Rain, wind, darkness, and any type of extreme temperatures, whether cold or hot, can make cycling unpleasant and in general results in people cycling less (Fraser & Lock, 2011; Heinen et al., 2010). The presence of elevation differences and steep inclines in general has a negative impact on the level of cycling (Fraser & Lock, 2011; Heinen et al., 2010).

In the survey, respondents agreed with the statement that ‘cycling uphill is difficult’. However, the variable did not show any significant associations with the frequency of BSS use in the city-specific regression models, nor in the aggregated analysis assessing frequent vs. infrequent BSS use. This shows that this barrier remains there for all respondents; there is no observed influence of a different attitude towards elevation between respondents using the BSS more or less frequently. The spatial analysis confirmed the negative association between BSS use and elevation in the bivariate correlation analysis in each city’s analysis, with lower use at stations at a higher elevation. These findings are in line with analysis of BSS use in e.g. Lyon (Tran et al., 2015) and Barcelona (Faghih-Imani et al., 2017), which also showed a negative association with BSS stations at higher elevations. However, elevation did not play a significant role in the spatial and spatio-temporal models in any of the three case study cities, indicating that other spatial and temporal factors more strongly affect the use.

In terms of respondents' attitudes to weather, overall, respondents agree not to like cycling in rainy and windy weather, with the strongest negative response in Limassol. Survey respondents' attitudes to hot and sunny weather is positive in all three case study cities, with a slightly stronger positive response in Las Palmas de Gran Canaria. This can be explained by the less extreme temperature variations compared to Limassol and Malta, where high summer temperatures and humidity can make it uncomfortable to cycle. Findings from the literature show that in general, higher temperatures are associated with more BSS use. Extreme temperatures (i.e. above 30˚C) however, can result in a decrease in BSS use (Corcoran et al., 2014; Gebhart & Noland, 2014). That this was not captured in the spatio-temporal models for Limassol and Malta is likely due to the monthly-based analysis, which does not manage to capture diurnal variation. When assessing the association between frequent BSS use and respondents' attitude to weather factors aggregated across the three case study cities, weather factors, including hot and sunny conditions on the one hand, and rainy and windy weather on the other, both showed a positive association with more frequent BSS use, suggesting that weather conditions are not negatively affecting BSS use of frequent users. They may however, discourage more infrequent BSS users, as well as potential future users. The spatial analysis also showed a positive association between BSS use and higher temperatures in all three cities, but a negative association with higher rainfall in Limassol and Malta, versus a positive association in Las Palmas de Gran Canaria. While in Las Palmas de Gran Canaria BSS use is more evenly spread over the year and seasonality is less obvious, in Limassol and Malta there is a clear domination of BSS use in the high season, with almost three-quarters of trips and a positive association with increased tourist arrivals in the bivariate correlation analysis of the spatio-temporal datasets. This is however, not necessarily due to increased use by tourists, as the presence of hotels does not show a clear influence on the top OD flows stations in the spatio-temporal analysis, but rather by the high season signifying the months characterised by better weather conditions, with less rain, higher temperatures and more daylight, which are more attractive for outdoor leisure and exercise, for residents and tourists alike.

9.2 Policy implications and recommendations

In this second section of the discussion, the policy implications of the findings from this study are discussed and policy recommendations are proposed, based on the findings and best practices found in the literature.

9.2.1 Adopting an integrated approach to sustainable urban mobility planning

In order to promote active transport and public transport as the preferred modes of transport in cities, transport planning needs to move away from the a priori prioritisation of private car mobility in planning (Zipori & Cohen, 2015). The European Union has adopted the concept of Sustainable Urban Mobility Planning (SUMP) as the paradigm to guide future mobility policies (European Commission, 2016), shifting the focus of transport planning from traffic to people; from traffic flow control and speed improvement as its primary objectives, to ensuring accessibility, sustainability and quality of life. While all three case study cities have created, or are in the process of creating, a Sustainable Urban Mobility Plan and supporting policies, which on paper contain aims and targets to promote active modes of transport, the quality and extent of their implementation varies. It is essential that such high-level policy aims and targets are accompanied by shorter term action plans that guide planning and decision-making, using evidence-based standards and guidelines for infrastructure and road designs (e.g. as presented in *Annex A – Cycling infrastructure and traffic calming designs*), as well as supporting legal frameworks that protect vulnerable road users and improve road safety for all, such as the concept of presumed liability, adopted in the majority of European countries (Pucher & Buehler, 2008). The Avoid-Shift-Improve approach provides a useful framework to prioritise actions to promote sustainable mobility. To enable sustainable urban mobility planning, there is a need for new approaches to transport planning and modeling, as the traditional four-step models cannot adequately incorporate active modes, micro-mobility and shared mobility.

To encourage modal shift to active travel, public transport and shared mobility schemes such as bike- and car-sharing, an integrated approach to sustainable urban mobility planning is needed. As advocated in the application of socio-ecological models to promote physical activity, interlinked interventions on multiple levels are needed, including the creation of safe, convenient and attractive places for physical activity, the implementation of educational and motivational programs, and the use of media and community organisation to change social norms and culture (Sallis et al., 2006). Investment in alternative modes of transport on its own does not bring about significant modal shift; effective change in mobility behaviour only occurs when there is a combination of 'carrots' and 'sticks' (Nikitas, 2018; Piatkowski et al., 2019). The combination of efforts to increase the safety, convenience, and feasibility of walking, cycling, and public transport, with policies to reduce and restrict car use has been shown to have the greatest positive impact on increasing liveability and sustainable mobility in cities and achieving modal shift towards active transport (Buehler et al., 2017; Oldenziel et al., 2016; Piatkowski et al., 2019).

9.2.2 Enabling the synergy between new cycling infrastructure and BSS

The importance of dedicated cycling infrastructure is evident from both the OLS model of the trip data, as well as from the responses to the user survey. The creation of an integrated cycling network, comprising segregated cycling paths along high-speed or high-volume roads, as well as traffic-calmed streets, connecting residential, employment and entertainment areas, could further promote cycling and BSS use in the three case study cities. In the historic urban fabric with narrow streets in the three cities, which are often one-way, there are opportunities for applying filtered permeability solutions (interventions allowing pedestrians and cyclists to pass, but not motorised vehicles) or contraflows for cyclists, allowing for more direct routes in the cycling network. The growth in cycling modal share in Seville (Marqués et al., 2015), another Southern European city that has promoted cycling in recent years through the creation of a connected network of separated bicycle infrastructure and the introduction of a BSS, highlights the potential for the case study cities studied in this research. Evidence on the cumulative impact of extension of the cycling infrastructure network and introduction of BSS, as observed in the analysis of the effect of the new cycling infrastructure in Las Palmas de Gran Canaria, was also shown by an analysis of cyclist volumes and types in Lisbon. The results there showed that the expansion of the segregated cycling network in the city centre led to a 3.5-fold growth from one year to the next, and showed an added 2.5-fold growth the following year, after the introduction of the

BSS (Félix et al., 2020). In Rethymno (Crete), users of a newly introduced dockless BSS commented that the investment would have been more meaningful if it had been accompanied by the creation of appropriate infrastructure, including cycling paths, traffic calming and bicycle parking facilities (Bakogiannis et al., 2019).

The creation of dedicated cycling infrastructure on arterial roads, reduction of speed limits on residential and rural roads, and awareness raising among all road users are proven strategies to improve road safety for cyclists and promote cycling (Handy et al., 2014; Heinen et al., 2010). Oldenziel and de la Bruhèze (2011) stress the importance of embedding the building of cycling infrastructure in a broader effort to promote bicycle culture and politics, as without that, efforts are "likely to lead to technological rather than user-driven designs and solutions". The municipality of Las Palmas de Gran Canaria's extension of the integrated bicycle network, with implementation of the first new sections in 2019, showed promising initial results, with good uptake of the BSS in the first year of operations, which increased further following the investment in connecting the cycling network in the city. Further efforts can be made in the next step to connect this network with the areas currently not served by the BSS, including on the peninsula and the upper city, as well as to connect to the university campus outside of the city, as an important trip attractor and potential target group. The creation of dedicated cycling paths between residential, employment and entertainment areas could further promote cycling and BSS use, especially in the case of Malta, where almost no cycling infrastructure is provided in the urban area. A start could be made by connecting the most intensely used areas for cycling, such as along the promenade in the Northern Harbour area, while connecting to residential, entertainment, and employment and education centres, though a combination of segregated cycling paths and traffic calmed streets, where necessary allowing contra-flows. In Limassol, there is opportunity to connect the fragmented sections of cycling infrastructure along the promenade together, as well as the bicycle path along the linear park *Garyllis*, and the creation of traffic calmed streets on secondary roads and in residential neighbourhoods, to start creating an integrated cycling network, connecting different locations within the city with safe cycling infrastructure.

9.2.3 Collaborating with local authorities

As certain aspects of the operation of the BSS lie within the remit of public authorities, such as permits and guidelines for the use of public space and conditions for running the scheme, they are unlikely to be successful without the backing of the local transport authority (Beroud & Anaya, 2012). The benefits of close collaboration with municipal organisations has been identified as a good practice in BSS operation by several authors (Beroud & Anaya, 2012; Nikitas, 2019; Ricci, 2015). In smaller cities, BSS can go beyond providing a last-mile solution, and provide a flexible and affordable alternative mode of transport to complement and extend the existing public transport offer available in the city (Nikitas, 2019). BSS can be suitable as a mobility solution and fill a market niche for short journeys in small or medium-sized cities, where BSS can provide a relatively inexpensive and agile alternative to larger, more expensive investments in mass-transit solutions (Castillo-Manzano et al., 2015). In collaboration with local authorities, solutions can be found to fund and support the operation of the BSS and ensure it is affordable to everyone, for example through subsidised memberships funded through income from parking fees or congestion charging.

The case study from Las Palmas de Gran Canaria presents an example of how collaboration between the public-private operator responsible for the BSS and parking management, together with the municipal authority responsible for transport planning, has led to good uptake of the BSS in the first year of operation. The location of the BSS stations was decided hand in hand with the existing and planned new cycling infrastructure, to maximise the synergy between the provision of bicycles and a safe cycling network. The fees for BSS memberships in Las Palmas de Gran Canaria, managed by a public-private operator are noticeably lower than those in Limassol and Malta, managed by private operators, which was enabled by funnelling part of the operators' income from parking management to subsidise the BSS memberships. Such an integrated approach reduces car use on the one hand, by reducing the availability of parking spaces and pricing them, while on the other hand improving accessibility and mobility by making alternative modes of transport, BSS use in this case, more affordable (Clements, 2020). Using the pricing of the BSS to make this mode of transport more attractive when it is most needed, during peak-hour congestions, has also been suggested as a potential avenue to explore (Jurdak, 2013). BSS use could be incentivised by providing longer flat-fee intervals or cost-free durations; dynamically linking the price structure to traffic conditions. Around one-fifth of all BSS trips in the case study cities replaced private car trips according to the survey results, in line with findings from other cities with a relatively large car modal share (Fishman et al., 2014; Fishman et al., 2015). The avoided external costs associated with substituting private car use for shared bicycle use can be communicated in terms of economic benefits for the city as a whole, in terms of environmental improvements and benefits to public health; arguments that could be used to gain financial support from the city administration for the operation of the BSS (Nikitas, 2019).

9.2.4 Integrating BSS use with public transport

Enabling and promoting the complementary relationship between (shared) bicycle use and public transport can promote multimodal travel as an efficient alternative to private vehicle use. Using public transport for longer distances and (shared) bicycles to cover the first or last mile can provide an avenue for growth for cycling modal share and bicycle sharing use (Handy et al., 2014; Heinen & Bohte, 2014; Olafsson et al., 2016). Results from a survey with BSS users in Dublin showed that 40% of trips are made in conjunction with another mode of transport, of which over 90% constituted public transport (Murphy and Usher, 2015).

The positive relationship between BSS use and public transport in Las Palmas de Gran Canaria and Malta is evident from the higher use of BSS stations in close proximity to bus stations, as well as a ferry landing site in the latter. In contrast, in Limassol, public transport modal share is low and analysis of BSS use showed no positive relation with public transport hubs. However, the recent upgrading and reorganization of the (inter)city bus system provides opportunities for better integration between the bus service and BSS.

Further integration in terms of real-time information provision and integrated payment options could promote more multimodal use (Handy et al., 2014; Heinen & Bohte, 2014). Survey results from the three case study cities show that younger respondents in particular are more likely to use public transport on a daily basis as a mode of transport, including in combination with the BSS. The benefits of the combination between public transport and bicycle, and the alternative it provides to private car use, could be further promoted through special offers or combination subscriptions for younger users.

9.2.5 Promoting BSS use with different user groups

Social norms play a big role in the perception of normality of cycling and a person's decision to cycle. Schoner et al. (2016) suggest the creation of "take your friend on a bike ride" types of marketing schemes to promote BSS use. There is also potential in workplace schemes, promoting shared bicycle use for commuting and for work and business purposes, through collaborations between the BSS operator and local companies, businesses and (public) authorities. Promoting bicycle use for their staff can benefit them, in terms of reduced health costs and sick leave days and reduced need for parking (Handy et al., 2014). In return, employers should then consider providing lockers, showers and changing facilities, as these have been shown to be important for employees considering utilitarian cycling to work (Heinen et al., 2010). Research has shown that there is a stronger influence of behaviour on attitude than vice versa (Kroesen & Chorus, 2018), indicating that exposure and experience are important to create a habit. Encouraging more people to try out cycling, by promoting the BSS through encouragement of friends, family or the workplace, can be a good way to enable that. To promote cycling for children and youths, who can benefit from more active and independent modes of transport and the potential creation of lifelong active transport habits, there is a clear need for a safer road environment, through infrastructure, education for all road users, enforcement of illegal and irresponsible driving behaviour, and targeted interventions, such as 'safe routes to school'.

As Limassol and Malta both have mild winters, there is opportunity to further promote cycling and BSS use, for transport and for leisure, in the low season months. Special offers could target local residents and the university community, where use is still low, as well as weekends and public holidays, since daylight before and after work hours is limited. In Las Palmas de Gran Canaria, expanding the system with electric bicycles could play a role in encouraging uptake among the student population, as the university campus is located relatively far from the city centre, as well as for residents of neighbourhoods located at higher altitudes, as there are steep inclines between the 'lower' and 'upper' city. Ensuring that the system is expanded to also serve lower income neighbourhoods, and creating a dedicated outreach campaign, potentially including discounted memberships could encourage people on lower incomes to use BSS as an affordable mode of transport (Rixey, 2013). Flexible memberships, allowing people to change their subscription depending on their current needs, can also play a role in ensuring the BSS remains an affordable and attractive mobility solution for users (Ricci, 2015). Offering a more inclusive range of types of bicycles, including cargo-bikes, tricycles or bicycles fitted with a child-seat could enable more different types of users to try out cycling (Nikitas, 2019).

Contrary to what may have been expected for BSS in tourist destinations such as the three case study cities, the majority of users are local residents, as emerged both from the survey responses and the insights from the interviews. The effect of tourist accommodation within a 300m buffer around the BSS stations showed mixed results in the spatial models (negative in Limassol, positive in Las Palmas de Gran Canaria and no significant effect in Malta), indicating that these results have more to do with the location of these tourist accommodations than with their nature. In Las Palmas de Gran Canaria, where the majority of BSS users are local residents, it is not the tourist accommodations themselves that have a positive effect on BSS use, but rather their location in an area with many leisure and entertainment opportunities, as there was also a strong multicollinearity between the count of tourist accommodations and the number of cafes and restaurants within the station buffers. In fact, in none of the case study cities do tourists make up a large part of the user base. Considering the large numbers of annual visitors in these tourist destinations, there is scope for promoting the system as a mode of transport to tourists during their stay, for example through direct promotion at and in collaboration with hotels and hostels, and through the provision of a dedicated subscription option for tourists (e.g. a multi-day or week pass). While foreign visitors or residents can bring with them a more bicycle-friendly mobility culture (Bakogiannis et al., 2019), there can also be challenges, due to potential divergent expectations of the road environment and behaviour towards cyclists. To this end, education on road safety for all, including to tourists, is important when promoting cycling and BSS use.

9.2.6 Improving network coverage and connectivity

The 'network effect' of BSS is a contested topic, with some authors arguing an increase in BSS stations will lead to an exponential increase in trips, while a dedicated analysis of different systems showed that high or low BSS use (measured as trips per day per bicycle; TDB) showed no consistent correlation with higher network connectivity, indicating that other factors are at play (Médard de Chardon et al., 2017). For sure, the design and distribution of BSS stations, their capacity, and a continuous connection between stations are factors influencing overall BSS use (Rixey, 2013). In the spatial analysis, the variables included to capture the influence of the network on BSS use showed the expected results in all three case study cities: lower BSS use further away from the centre of the BSS, and higher BSS use at better connected stations, i.e. with more stations in their vicinity. Faghih-Imani et al. (2014) recommend to increase density of stations by creating more, small-sized, stations, particularly in areas with many Points-of-Interest, so as to create better connectivity between stations and provide more connections between potential origins and destinations. There is a clear potential in all cities to extend the BSS into residential neighbourhoods to better serve all of the city's population, not just those users who have trip origins or destinations in the city centre or near the seaside. Communities that are not currently served by the BSS, can be reached by extending the BSS into these areas, as was done with the extension of the BSS in London (Goodman & Cheshire, 2014), as well as through a dedicated outreach programme, including discounted memberships, which could encourage people on lower incomes to use BSS as an affordable mode of transport (Rixey, 2013).

9.2.7 Addressing weather and elevation challenges

To overcome weather and elevation challenges, several strategies can be pursued. The provision of electric bicycles, although more expensive for the operators, can play a role in encouraging uptake among new target groups and for trips to destinations located at higher altitudes, during summer heat or for longer distances. The results from the BSS user survey showed that in Las Palmas de Gran Canaria and particularly in Malta, there was a higher preference for electric bicycles, and the aggregated analysis also showed stronger support by infrequent BSS users, indicating they could be encouraged by the provision of electric bicycles. Active collaboration with local or national authorities to get financial support, through subventions, grants or subsidies, can assist in making electric bicycle sharing more affordable, to enable cycling as a realistic alternative to other modes of transport by overcoming the barriers associated with high temperatures and elevation differences. In Malta, there are already grants and tax rebates for the purchase of electric bicycles for individuals or for companies (up to 20 bicycles), but these could be extended further to include a bigger fleet of bicycles, and could also be used to subsidise electric BSS membership for users.

When considering and designing cycling infrastructure and routes, elevation should be taken into account, by planning routes on more gradual slopes and avoiding having to traverse large elevation differences where possible, through the use of bridges, elevators or a special bicycle lift (e.g., the *Trampe* bicycle lift in Trondheim, Norway). Short and direct cycling routes are key, to avoid additional expense of energy and time, and were found to be the most important variable to determine route choice for cyclists in Dublin (Caulfield et al., 2012). Providing ancillary facilities such as showers and lockers at key destinations can aid in mitigating the effect of exertion or high temperatures as a barrier to cycling (Heinen et al., 2010). The use of green infrastructure to provide shading near active transport infrastructure can create a cooler, more attractive environment for cycling (Kim & Miller, 2019; Norton et al., 2015).

9.2.8 Learning from mistakes made previously or elsewhere

Last, but not least, it is important to learn from mistakes made previously or elsewhere. The wave of globally operating dockless BSS, such as *Ofo* and *Mobike*, that rapidly popped up around the world in the last few years, showed how a one-size-fits-all, profit-centred approach to BSS in most cases did not have a successful outcome. Many of their BSS were riddled with issues of theft and abuse, and low usage rates and public acceptance. Instead, more successful BSS are characterised by a strong relationship with the city, its inhabitants and its administration, and a user-centred approach (Nikitas, 2019). This also emerged from the survey results, which showed a strong relationship between BSS use and satisfaction with the system, in terms of its price and user-friendliness, the comfort of the bicycles and the locations of the stations. The experience from Las Palmas de Gran Canaria shows that a city's BSS can be reinvented; following two previous shared bicycle systems with only limited use and success, the introduction of *Sítycleta* – a modern, third-generation BSS - managed to surpass the expectations with a good uptake in the first year of operations, and further increase in use in the following year. With adequate planning and integration with investment in cycling infrastructure and promotional campaigns, the operators managed to install a new, more successful system.

9.3 Strengths and limitations of the research

The third section of the discussion highlights the key strengths and limitations of the research, discussing the approaches used to strengthen or mitigate them, and their implications on the results.

9.3.1 Strengths of the research

Using a combination of different data collection and analysis methods allows for the validation and triangulation of results that adds to the breadth and depth of a research (Johnson et al., 2007). Analysis of the trip data alone does not capture differences in travel behaviour by individual users and the barriers they may experience, both for frequent users and for non-frequent or potential users, while survey results fail to capture objective environmental effects and can be influenced by different types of bias. Furthermore, an understanding of the wider spatial and social context is essential to understand dominant mobility patterns and social norms towards different modes of transport. Combining and cross-validating the results from the interviews with mobility experts and practitioners in each case study city, the survey results with BSS users and the spatio-temporal analysis based on the BSS trip data offers the ability to validate and triangulate results, making more convincing and accurate case study conclusions adding to the breadth and depth of a research (Johnson et al., 2007; Yin, 2014). Taking a wider perspective on the case studies also assists in identifying potential rival explanations for the phenomenon under study, e.g. another intervention or by broader social trends (Yin, 2014).

Accessing BSS trip data is perceived as “notoriously difficult” (Bakogiannis et al., 2019), due to the sensitive personal data, economic value and potential competitive market. Contact and collaboration with the operators, and support provided by project partners in the H2020 CIVITAS DESTINATIONS project, enabled the provision of access to comparable year-long datasets of BSS usage in the three case study cities. Analysis of this data allowed for the assessment of the influence of different spatio-temporal factors across and between cities, specifically in the context of ‘starter’ cycling cities, which are still at the beginning of the promotion of cycling as a mode of transport. Together with findings from BSS research in other Southern European cities, e.g. in Lisbon (Félix et al., 2020) and Rethymno (Bakogiannis et al., 2019), the results of this research can contribute to identify the specific barriers and motivators in this specific spatial and cultural context and contribute to the promotion of cycling in these, and similar, cities.

9.3.2 Limitations of the research

Self-reported data obtained through voluntary-based survey responses is subject to a number of possible biases, such as social desirability bias, sampling bias and participation bias. The support from the operator in sharing the survey and offering a free gift in exchange for participation could lead respondents to give socially desirable answers. To minimise social desirability bias, the survey was kept anonymous. In Las Palmas de Gran Canaria, sampling bias was observed, as a majority of the survey respondents was male, whereas user statistics of the BSS shows a more balanced gender distribution. In Limassol and Malta, there was difficulty to reach the target number of participants in the survey, which can likely be explained by the smaller number of active users and the relative small size of the target population (‘BSS users’). In an effort to address sampling and participation bias and increase the response rate, the survey was shared through different channels and locations (i.e. on social media, through email newsletter, in-person, through freebie left on the bicycles), to try and reach different types of users: casual and subscribed users, frequent and occasional users. However, a certain level of bias is still expected in any self-report survey study (Bachand-Marleau et al., 2012; Bryman, 2016). The methodology employed in this research only captures the views of individuals that are already BSS users, either as registered or casual users. Extending the survey to non-users could unearth a broader perspective on the barriers and motivators for BSS use. In their study comparing the views of users and non-users of BSS in two Australian cities, Fishman et al. (2015) found differences between the two groups, for example in the perceived safety of cycling, which was higher for those who cycle (using the BSS) than for those who do not.

The results of the binary logistic regression models show that socioeconomic characteristics (gender, age, education, income) did not significantly affect BSS frequency of use. This can be explained by the fact that the influence of these factors are collinear with individual's responses to questions about their attitudes and perceptions, which did show significance in the models. However, using explanatory variables that reflect attitudes and perceptions of respondents limits the usability of such a model for future predictions. To address this, hybrid choice modeling techniques could have been used, where attitudes and perceptions are included as latent variables, explained by socioeconomic characteristics, and then are utilized as explanatory variables in the regression or choice models (Kamargianni et al., 2014). The inclusion of the household situation of respondents showed significance in some of the models. However, living in a larger household can mean that a respondent lives in a family unit (as a parent or child), or in a shared household with roommates. Asking respondents for further clarification on their specific living situation could have enabled a more detailed analysis.

A further limitation of this study is the quality and comparability of the spatial and temporal data from secondary sources included in the models. Effort was made to obtain data at the finest-grain level possible, as well as data that was collected in recent years. Some data were only available at a coarser spatial scale, e.g., at the neighbourhood or locality level, rather than the census tract level. This spatial level may be less suitable to adequately capture spatial characteristics that contribute to variations in frequency of station use, e.g. as observed in the counterintuitive result of the impact of the gender quotient on the dependent variables (negative influence of higher M/F quotient) in Las Palmas de Gran Canaria. Furthermore, while a 300m buffer was selected as the most suitable measure of a walkable distance from/to nearby origins and destinations, based on findings from the literature, when analysing the effect of new cycling infrastructure in Las Palmas de Gran Canaria, the effect was observed most strongly in a 50m buffer. Different buffer sizes should be tried to verify which distance to the station best captures the impacts of different spatial variables. Data limitations also apply to the temporal variables obtained from secondary data sources. Although an effort was made to obtain data at the finest-grain level possible, as recent as possible and comparable between the three cities, averaging values over a monthly period means some detail was lost. With respect to the temporal variables, the potential negative effect of summer temperatures above 30˚C, as found by Corcoran et al. (2014) and Gebhart & Noland (2014) could not be captured in the monthly spatio-temporal models, even though the summer temperature in Limassol and Malta can reach a daily average high of 35˚C - 40˚C. Only the positive effect of warmer temperatures was captured in the models, indicating in general that there is more BSS use in warmer months than in colder months.

Whereas the cities chosen as case studies in this research share a number of characteristics, they of course still have their unique idiosyncrasies. It is evident from the results that even cities that share similarities are different, with different urban fabric, social norms and usage patterns. While lessons can be learned from the BSS usage in the different cities, the results from this research highlight the importance of the local context, including the (potential) users and target groups, and how every city requires tailor-made solutions and different treatments.

9.4 Conclusion

This chapter focused on the discussion of the findings from the three case study cities included in this research, based on a mix of data collection and analysis techniques, in view of the findings from body of knowledge on this topic presented in the literature. The discussion of findings in the first section highlighted the similarities and differences between the findings from the case study cities, in light of those from other cities, to better understand the influence of individual factors, social environment factors and physical environment factors on BSS use and cycling. In the second section, the policy implications and specific recommendations for these, and similar, cities were presented. The third section discussed the strengths and limitations of this research, and the strategies that were employed to strengthen or overcome them.

This chapter showed the relevance of this research, particularly in the context of Southern European cities that are just starting to promote cycling, and what role BSS can and do play in that cycling transition. The final chapter, *Chapter 10*, concludes this research by summarizing the followed approach and key findings and discussing avenues for further work.

10. Conclusion

This final chapter concludes and summarises the findings from this research. In section 10.1, the key findings are summarised according to the research questions guiding this research. Section 10.2 highlights the contributions of this research to the body of knowledge. The final section, 10.3, discusses potential avenues for future work, building on the findings of this research.

10.1 Summary of findings

The aim of this research was *to analyse the role of BSS in promoting cycling as a mode of transport in Southern European island cities*. The research focused specifically on three cities to study the introduction and use of the BSS there: Limassol in Cyprus, Las Palmas de Gran Canaria in the Canary Islands, Spain, and the main conurbation on Malta. The research aim was further broken down into research objectives (RO 1-5) and specific research questions (RQ 1-7).

Research Objective 1 (RO1): ***To understand the main characteristics of BSS and their role within sustainable urban mobility***

This research objective was addressed through the literature review, in *Chapter 2*. The main urban transport problems, experienced in cities around the world, were discussed, including traffic congestion, issues with public transport capacity, environmental impacts and accidents and road safety concerns, particularly for vulnerable road users. Guiding principles for sustainable mobility planning, including the Avoid-Shift-Improve approach, and the promotion of Sustainable Urban Mobility Plans at a European level, were introduced. As a low-cost, low-polluting and active mode of transport, cycling is an integral part of sustainable urban mobility planning. The introduction of bicycle sharing systems – shared bicycle fleets allowing short-term public use - has enabled cycling for a wider group of citizens, by lowering barriers for urban cycling, by providing access to bicycles, with the advantage of renting over owning, by normalising the image of cycling, by increasing the number and diversity of visible cycling role models and by providing safety in numbers.

An overview of the different types of operational models of BSS was provided, and findings from the literature about different BSS around the world, and who uses them, why, where, how much and when, were discussed. BSS have the potential to contribute to reductions in air pollution, traffic congestion and carbon emissions in cities as a result of decreased car use, but to what extent depends on how frequently they replace private vehicle trips. BSS generally provide positive health benefits to users, based on an increase on physical activity, at least when the trip is a shift from motorised vehicles (private and public transport), which generally constitutes the majority of trips. The implementation of a BSS in a city has the potential to increase bicycle use as well as private bicycle ownership, especially when the introduction of the BSS occurs in conjunction with the creation, extension and improvement of bicycle infrastructure as well as the promotion of other sustainable mobility policies.

Research Objective 2 (RO2): ***To identify the factors influencing travel behaviour for cycling and BSS use***

This research objective was addressed through the theoretical framework developed, in *Chapter 3.* Travel behaviour theory builds upon economic utility theory and the theories of planned and repeated behaviour. In an effort to capture the multiple levels of factors that influence travel behaviour, socio-ecological models include factors at the individual, the social environment and the physical environment level. Individual level factors include demographic and socio-economic factors, as well as intra-personal factors: a person's attitudes, habits, perceptions and self-efficacy. The social environment level refers to inter-personal factors, including social subjective and objective norms. The physical environment level includes built and natural environment factors, such as land use, urban form and infrastructure on the one hand, and topographic and climatic factors on the other. These multiple levels of factors are influenced by the spatial and socio-cultural context of a city and the urban and transport planning policies and legislation in place. A framework for a socio-ecological model of cycling behaviour and BSS use was developed, based on factors identified in the theory, and supported by findings from the literature. The expected effect of the individual, social environment and physical environment factors on cycling, and BSS use in particular, was summarised, including the main findings from the literature and their expected effect in terms of their direction and strength.

Research Objective 3 (RO3): ***To understand the spatial and social context of cycling and BSS use in Southern European island cities***

This research objective was addressed through two specific research questions, in *Chapter 5*. The first research question addressed the spatial and socio-cultural context in the case study cities, whereas the second research question looked at the policies and entities influencing cycling and BSS use.

RQ1: *What are the spatial & socio-cultural characteristics in relation to cycling and BSS use?*

Chapter 5 delved deeper into the context of the case study cities, describing their spatial and socio-cultural characteristics, including their geographic form, location and position in the country, and factors related land use and transport planning, as well as existing mobility practices and social norms around cycling. While the case study cities share certain similarities in urban form, in terms of their historic centres with narrow streets, the port-city relations in their metropolitan area, and tourism pressure on their mobility system, there are also differences between them, for example in terms of their population density. Limassol and Malta have similar weather patterns, with warm and dry summers and mild, wet winters. Las Palmas de Gran Canaria however has more stable weather conditions, with less temperature fluctuations and lower rainfall, and thus lower expected impact of extreme hot weather, or heavy rainfall. All three case studies cities have a relatively high rate of motorization and high car modal share, particularly in Limassol, where over 90% of trips are made with a private car. The lack of safety for cyclists, on the road and on junctions, is the major barrier for cycling. In Malta, there is hardly any cycling infrastructure in the urban area of the island, whereas Limassol and Las Palmas de Gran Canaria have fragmented sections of cycling paths, and the latter started investing in further extension and connection of the network. The need for a change in mentality to cycling was evident in all three cities: cycling is often still seen as something from the past, as something for poor people, or only as a sport or leisure activity.

RQ2: *Which policies and entities exist that influence cycling and BSS use?*

Relevant land use, transport and mobility laws and policies were presented in the policy and legislative framework, and entities and stakeholders active in the governance and promotion of cycling and BSS use were introduced, to understand the context in which the operation of the BSS and the promotion of cycling take place. While policy targets related to the promotion of safe, sustainable and active modes of transport are present in all three case study cities, they are not always prioritised or actually implemented. Decisions to invest in different forms of mobility, particularly concerning the re-allocation of road space are politically sensitive. For a city to seriously promote cycling as a mode of transport, putting in place a holistic plan for a cycling network, including implementation and monitoring frameworks, and standards and guidelines for cycling infrastructure is a necessity.

Research Objective 4 (RO4): ***To analyse BSS use and assess the factors influencing travel behaviour of BSS users in the case study cities***

This research objective was addressed through three specific research questions, in three consecutive chapters. Research question three addressed the use of the BSS in the case study cities, looking at who uses the BSS, and why, where, when and how much, presented through descriptive statistics of the BSS user survey and the trip data in *Chapter 6*. The fourth research question looked at the influence of individual and social environment factors on BSS use, based on correlation and regression analysis of the BSS user survey discussed in *Chapter 7*. The fifth research question looked at the influence of physical environment factors, using spatial regression models and linear mixed models to analyse spatio-temporal effects, the results of which were presented in *Chapter 8*.

RQ3: *How is the BSS used, when, where, by whom and for what purposes?*

Chapter 6 started with an introduction on the history and operation of the three BSS analysed in this study: *Nextbike Cyprus* in Limassol, which was introduced in 2012, *Sítycleta* in Las Palmas de Gran Canaria, which started operation in 2018 and *Nextbike Malta* in Malta, which kicked off in 2016. In line with findings from the literature, the average age of BSS users in Limassol and Malta was around 30 years, although in Las Palmas de Gran Canaria, the average age lay almost 10 years higher, at 39. Despite being tourist cities, the majority of users of the BSS are permanent residents, but in Limassol and Malta around half of the users are not native to the country (i.e. foreign residents). BSS users in all three cities are generally highly educated and in employment, in line with user characteristics of other BSS. Results from the survey showed that the BSS in Las Palmas de Gran Canaria and Malta is most frequently used for commuting, whereas in Limassol the dominant use is for exercise. This is supported by the median of the trip duration, which shows a shorter duration in the former two cities than in the latter. This can partly be explained by the longer flat fee interval in Limassol; 120 minutes' free daily use for subscribed users, as opposed to the more common 30-minute FFI. The top three motivating factors for BSS users are consistent among the three cities: for health, fun, and environmentally friendly reasons. The main discouraging factor in all three cities is the concern for their safety in traffic. The spatial pattern of BSS use differed between the city, with use in Limassol concentrated on a handful of stations along the bicycle path lining the coastal promenade, more diffuse use focused on the two main city centres in Las Palmas de Gran Canaria, and in Malta a concentration of use between the BSS stations in the harbour area north of Valletta, one of the main residential, employment and entertainment centres on the island. In all cities, there are areas that have only very limited connection to the BSS, e.g. the western side of Limassol, the 'upper city' located at a higher plateau in Las Palmas de Gran Canaria, and the southern harbour area in Malta. To determine to what extent the BSS serves the city's population, a 400m buffer around the BSS stations was used, showing that the BSS reaches 33% of the population in Las Palmas de Gran Canaria, 29% in Malta, but only 13% in Limassol, due to its lower population density and smaller number of stations.

RQ4: *What is the influence of individual and social environment factors on BSS use?*

In *Chapter 7*, the BSS user survey results were analysed through correlation and regression analysis, first for the case study cities separately, and then aggregated, to find out which factors have the strongest impact on BSS use in the more general context of Southern European island cities, and cities with similar characteristics. The aggregated dataset was split into frequent users, who use the BSS at least once every two weeks, and infrequent users, who use the BSS less often than that. The majority of demographic and socio-economic characteristics did not show a significant difference between frequent and infrequent BSS users. The only socio-economic characteristics that did show a significant association with more frequent BSS use were: a smaller household size; temporary residency status (<1 year); and lower car ownership. The BSS appears to be most attractive to temporary residents, as these are looking for affordable and reliable transport to move around the city, and are perhaps less likely to make the investment in private transport, as shown by their lower car ownership. A shorter distance to respondents' residence and most frequent destination was also positively associated with more frequent BSS use. Frequent BSS use was positively associated with frequent use of other 'alternative' transport modes (other than the private car). Stronger agreement with motivating factors such as money-saving, convenience and time-saving, were associated with more frequent BSS use.

Satisfaction with the BSS (the use and price of the system, the comfort of the bicycles and locations of the stations) also shows strong associations with frequent BSS use, as did higher perceived safety of cycling, with most frequent BSS users using dedicated cycling infrastructure (bicycle paths or lanes). Frequent BSS use was positively associated with both types of weather conditions included in the survey (hot and sunny; rainy and windy), indicating that frequent BSS users are less perturbed by weather conditions than infrequent users. A positive social norm, in terms of support from friends and family, respect from other road users, and feeling that cycling is an accepted form of transport, showed positive associations with frequent BSS use, confirming the importance of such factors in building a cycling culture.

RQ5: *What is the influence of physical environment factors on BSS use?*

Chapter 8 analysed the BSS trip data in conjunction with spatial and temporal secondary datasets, to understand the influence of physical environment factors on BSS use, for station use as an origin or destination. The use of BSS stations as origins and destinations was assessed through: a) bivariate correlation analysis of BSS use and all the independent variables, b) a spatial OLS model based on yearly use, looking at the influence of land use, socio-economic and network factors, and c) a spatio-temporal linear mixed model (LMM) based on monthly use, also incorporating temporal variables related to weather and tourist numbers.

In all three cities, the origin and destination models shared the majority of independent variables; there was thus not a great difference in the factors explaining the BSS use for stations as origin or as destination. The few differences between the variables included in the origin and destination models, highlight city-specific factors acting as draws for station use as an origin or as a destination. Based on the results of the bivariate correlation analysis, the spatial OLS models and the spatio-temporal LMMs, a number of spatial factors showed consistent associations with BSS use in the case study cities, based on their presence within a 300 m buffer around the BSS stations. Higher BSS use at the stations was associated with the following spatial factors:

- A higher percentage of residential land use;
- A larger number of cafes and restaurants;
- The presence of the coastline;
- A higher number of road intersections, as a measure of urban density;
- A higher percentage of foreign population;
- A larger number of BSS stations within a 1,200m buffer around the station, as a measure of network connectivity;
- A shorter distance from the centre of the BSS, as a measure of centrality;
- Lower elevation;

In terms of temporal factors, only a higher temperature (monthly average maximum) showed a positive consistent association with BSS use across all three case cities. The total number of tourists showed a strong correlation with the weather variables, particularly in Limassol and Malta.

Other spatial and temporal factors showed different associations in the case study cities, due to their particular spatial structures or temporal conditions, and different dominant use of the BSS. A higher percentage of park land use showed a positive association in Limassol, where BSS use is dominated by leisure use. A positive association was found with public transport hubs in Las Palmas de Gran Canaria and Malta, where public transport modal share is higher than in Limassol. Nearby cycling infrastructure showed a positive association with BSS use in Limassol and Las Palmas de Gran Canaria, but not in Malta, as there is little to no cycling infrastructure in the conurbation, where most BSS stations are located. Investment in new cycling infrastructure in Las Palmas de Gran Canaria offered the opportunity to study the effect on BSS use by analysing six-months datasets of BSS station use from ‘before’ and ‘after’ the intervention, while controlling for an overall change in BSS use. Results from a linear mixed model comparing the before and after situation showed that overall BSS use increased over time, by an average of almost 1,000 trips per station, while stations which were located within 50m of the new cycling infrastructure saw an increase of 2,000 trips, double the amount of the stations not impacted by the change.

Research Objective 5 (RO5): ***To compare BSS use in the case study cities in order to make recommendations for promoting cycling***

This research objective was addressed through two specific research questions, aimed at integrating the findings from the three case study cities. Research question six focused on a comparative analysis of the findings from the case study cities, to elicit the main similarities and differences. Research question seven discussed the research findings in light of the existing literature and presented the lessons that can be learned from these case studies, in order to make recommendations for these, and similar, cities.

RQ6: *How do BSS use and influencing factors in the case study cities compare?*

All of the results chapters, *Chapters 5* to *8*, contained a section to compare the findings from the case study cities, to highlight similarities and differences between the cities. This research used multiple-case studies, to be able to look at BSS use and cycling promotion in three cities with a similar context, to elicit generative causal mechanisms that can be used to analyse and guide other cities with similar contexts. At the same time, even though the case study cities have a similar context in some respects, they have their own characteristics and idiosyncrasies. The comparative analysis therefore also allowed for a deeper understanding and appreciation of the influence of different social and spatial contexts, and their structures and institutions, and how these can result in different outcomes.

There were a number of similarities that emerged from the findings described in the four results chapters. The starting point for the comparison of the three case study cities was their similar geographical and cultural context. In all three cities, the majority of BSS users that took part in the survey are in full-time employment, have generally high levels of education and average income levels, and are permanent residents. Modal shift as a result of BSS use was found to be primarily from walking, and thereafter from public transport and private car use. A small percentage of users make a large percentage of the total BSS trips; in all three cities, the most active 1% of users make around a quarter of total trips, whereas around a third of unique users only made one trip in the year-long period covered by the datasets.

Motivating factors and barriers are consistent among the three case study cities, with health, environment and fun being strong motivators, and the lack of road safety for cyclists identified as the main barrier by the BSS users taking part in the survey. Respondents in all three cities feel most safe on separated bicycle paths and least safe cycling on the road without cycling infrastructure. Satisfaction with the operation of the BSS was high in all three case study cities. Spatial and temporal factors that showed a consistent influence on BSS use in the three case study cities were a higher percentage of residential land use, a larger number of cafes and restaurants, the presence of the coastline within a 300 m buffer around the station, a higher number of road intersections, a higher percentage of foreign population, a larger number of BSS stations within a 1,200 m buffer around the station, a shorter distance from the centre of the BSS, lower elevation at the station location, and higher average monthly temperatures.

Differences also became apparent from the analysis of the three case study cities. There was a difference in population density, with Limassol in particular having lower density development and a more sprawled urban form, which has repercussions on the distances to nearby services and a stronger reliance on private motorised transport, particularly in light of the very limited public transport use. From the analysis of mobility policies and guidelines, it emerged that while all cities have policy documents containing sustainable mobility goals and targets, there is a difference in the level of implementation. Only in Las Palmas de Gran Canaria is there evidence of real commitment to promoting sustainable mobility, through investment in a substantial extension and connection of their cycling infrastructure, supported by other sustainable mobility policies (e.g. BRT, parking management) and promotional campaigns.

In contrast with most European countries, Cyprus and Malta have not adopted the system of 'presumed liability' to protect vulnerable road users and improve road safety for all. In terms of BSS use, there was a difference between Las Palmas de Gran Canaria and Malta on the one hand, where the main use was for commuting, with shorter median trip durations and more diffuse use throughout the city centre(s), and Limassol on the other, where the BSS was used more for exercise, with longer trip durations and use concentrated at the cycling path along the coastal promenade. In Limassol and particularly in Malta, there was a high share of foreign residents using the BSS. BSS users that took part in the survey were notably older in Las Palmas de Gran Canaria, than in Limassol and Malta, where the average age was more in line with findings from the literature. Differences in the relationship with spatial and temporal factors were found in the influence of tourist accommodations and shops in the vicinity of BSS stations, with a negative association in Limassol, but a positive association in the other two cities. There was a negative association with the location of the university campus in Limassol and Malta, in contrast to findings from the literature. BSS stations in neighbourhoods with a population with a higher education level and higher average age showed a positive association with BSS use in Las Palmas de Gran Canaria and Malta, but a negative association in Limassol. The presence of a bus station was positively associated with BSS use in Las Palmas de Gran Canaria and Malta, but was negative in Limassol, where the modal share of public transport use is lower and there is less utilitarian BSS use. The effects of seasonality were more obvious in Limassol and Malta, with almost three-quarters of trips taking place in the high season. BSS use in Las Palmas de Gran Canaria was more evenly spread, in line with their more year-round tourist season and limited rainfall, which did not have the negative association with BSS use that it showed in Limassol and Malta.

RQ7: *Which lessons can be learned from the promotion of cycling and BSS use in the case study cities?*

Chapter 9 discussed the outcomes of this research and put forward a number of policy recommendations for the promotion of cycling and BSS use in the case study cities. The results of this research can be used to better understand to what extent the BSS serves the city's population, what motivates current users, how to attract other user groups, and ultimately, how to promote (shared) bicycle use in a city with a low cycling modal share. The following policy recommendations, based on the research findings and best practices found in the literature, were suggested for the case study cities, and cities with similar characteristics:

1. Adopt an integrated approach to sustainable urban mobility planning, by combining a combination of 'carrot' and 'stick' policy interventions and ensuring that high-level policy aims and targets are accompanied by shorter term action plans and evidence-based standards and guidelines;

2. Enable the synergy between new cycling infrastructure and BSS, by promoting dedicated cycling infrastructure on arterial roads, the creation of traffic calmed city centres, the reduction of speed limits on residential and rural roads, and awareness raising among all road users, to improve road safety for cyclists and promote cycling.
3. Collaborate with local authorities, by focusing on the health, environmental and economic benefits of BSS for a city's residents and its administration.
4. Integrate BSS use with public transport, by easing the physical interchange between modes, and by providing real-time information and integrated payment options through smartcards or apps, to promote easier multimodal use and enable the combination of BSS and public transport to cover longer distances.
5. Promote BSS use with different user groups, by creating dedicated outreach, promotions and collaborations, to reach target groups such as youths and students, tourists, and employees of local companies, and by offering a wider variety of bicycle types to be more inclusive, e.g. for families and those with reduced mobility.
6. Improve network coverage and connectivity, by increasing the density of (small-sized) stations, to improve accessibility to Points-of-Interest and to create better coverage in residential neighbourhoods, in order to link more origins and destinations.
7. Address weather and elevation challenges, by providing electric bicycles, special infrastructure to scale height differences (e.g. elevators, lifts) and ancillary facilities (e.g. lockers, showers, sheltered parking) and by planning cycling routes to be as direct as possible, incorporating green infrastructure to provide shade and cooling and avoiding steep slopes.
8. Learn from mistakes made previously or elsewhere, by adopting a user-centred approach, creating a strong relationship with the city, its residents and visitors, and aligning the investment in the BSS with interlinked strategies to promote cycling, including interventions to improve road safety and limit car use, and promotional campaigns to encourage sustainable mobility.

10.2 Contributions to knowledge

The previous section summarised the key findings of this research. In this section, the main contributions to the body of knowledge around BSS use and the promotion of cycling are highlighted.

This research used a multiple case-study of three 'starter' cycling cities in Southern Europe, with a low cycling modal share and limited cycling infrastructure, to understand the use of the BSS and the factors influencing BSS use, in order to better understand the barriers and motivators for promoting cycling as a mode of transport. While case study findings cannot be used to extrapolate the findings directly to other contexts, the insights they provide - especially in a multiple-case study such as in this research – can be used to expand and generalise theories about the phenomenon under study. Based on a socio-ecological model to explain travel behaviour, a combination of different quantitative datasets from the three case study cities were analysed to understand BSS use, allowing for the validation and triangulation of the results. Specific attention to the spatial and social contexts of the cities, enabled a deeper understanding of the influence of specific structures, institutions and policy decisions. The results contain findings that were true for all the case study cities on the one hand (e.g. the positive effects of nearby cafes and restaurants on BSS use), as well as findings more specific to the local context on the other (e.g. the relationship between BSS and public transport). Furthermore, while a number of findings support the wider literature, and highlight effects that seemingly work in the same way in different geographical and cultural locations (e.g. road safety concerns as the major barrier to more cycling), there were also findings specific to these case studies that contrasted with findings from other cities (e.g. the association with the university campus). The results of this research have contributed to the identification of the barriers and motivators in this specific spatial and cultural context, which led to the formulation of recommendations for the promotion of BSS use and cycling in these, and similar cities.

Of particular interest to the context provided by the three case study cities was the use of the BSS by tourists. While it may be expected that tourist use of the BSS would be high in such holiday destinations, in fact the BSS user survey results showed that in all three cities, the majority of BSS use is by residents. The inclusion of the location of tourist accommodations in the spatial models of BSS use did not provide consistent results with BSS use across the three case study cities, with the results indicating other factors at play: a negative association in Limassol due to the distance between the majority of hotels and the centre of the city and the BSS, versus a positive association in Las Palmas de Gran Canaria due to the central location of hotels, next to a popular promenade and beach and in close proximity to one of the city's centres, with a high number of cafes, restaurants and shops.

This research also attempted to capture the influence of tourist numbers on BSS use by including it as a temporal factor in linear mixed models. While the bivariate correlation analysis between BSS use and tourist numbers did show a positive association in Limassol and Malta, the variable was not included in the final linear mixed models, as it was highly collinear with the included weather variables, with the latter showing a stronger influence on BSS use. These results highlight how the high season months characterised by better weather conditions, with less rain, higher temperatures and more daylight, are more attractive for active mobility, for transport and for leisure, for residents and tourists alike. The case study cities are not only tourist destinations, but are also home to a relatively large share of foreign residents. The spatial analysis showed higher BSS use in neighbourhoods with a higher share of foreign population. In Limassol and Malta, around half of the respondents to the survey are foreign residents, and the survey results of the latter showed a significant positive association between BSS use and non-native respondents. Across all three case study cities, compared to permanent residents and visitors, there was significantly more frequent BSS use by temporary residents, who may be attracted by the flexible and low-cost transport solution for their temporary stay.

In cities with a low cycling modal share, investing in cycling infrastructure, by creating segregated paths, on-road lanes, or traffic calmed streets, is not an easy political decision, as it entails the reallocation of road space and revision of traffic management rules. The story of what comes first, bicycle infrastructure or the cyclists, is an ongoing debate. This research investigated the influence of cycling infrastructure on BSS use through the BSS user survey, as well as through spatial analysis. The survey results paint a very clear picture: across the three case study cities, road safety concerns are the major barrier to cycling as a mode of transport, and BSS users indicate to feel safest on separated bicycle paths and least safe while cycling on the road without cycling infrastructure. In Limassol and Las Palmas de Gran Canaria, where there are fragmented sections of cycling infrastructure in the parts of the city where the BSS is operational, the spatial analysis confirmed a strong positive relationship between BSS station use and nearby cycling infrastructure. The before-and-after analysis of the impact of new cycling infrastructure in Las Palmas de Gran Canaria further confirmed these findings, with increased BSS use at stations in the near vicinity of new cycling paths and lanes. This analysis showed how BSS trip data can be used to analyse the impact of new cycling infrastructure, while controlling for the overall increase in BSS use due to other factors (e.g. because of normalization of cycling, increased campaigns to promote sustainable mobility, financial incentives).

10.3 Future work

The previous two sections concluded this research by looking back on the previous chapters to summarise the key findings of this research and highlight the main contributions to the literature. This final section provides an opportunity to look forward.

At an operational level, further work can focus on a more fine-grained analysis of the influence of temporal variables on BSS use, based on weekly or daily time-series data, or zooming in on specific days with particularly low or high temperatures. In future work on this topic, other multi-variate regression techniques could be explored, as well as multi-level or nested mixed models. More detailed spatial and temporal analysis of BSS trip data can be used to formulate policy recommendations to optimise system use and guide future extension of a system to better serve city residents and visitors. Understanding which factors influence demand, based on a typology of different cities, can be used to estimate demand, to determine the optimal system size and to design and plan the network and station locations of BSS in cities with similar characteristics. The wealth of data now available through trip-based datasets (obtained from data from transport smartcards, GPS tracks, station-based shared mobility services, and personal movement trackers and smartphones) enables the creation of context-specific, demand-based models that can be part of the solution to adequately model and plan for alternative modes of transport, instead of relying on traditional four-step transport models.

To obtain more accurate behavioural models, instead of a binary logistic regression model, future work in the modeling of individual choice and behaviour could utilise an ordered probit model, with as a dependent variable the frequency of BSS use, as well as the use of hybrid choice modeling techniques to better capture the latent variables and social interaction effects leading to models with a higher explanatory power of individuals' travel behaviour. Future work could also extend analysis to other user groups, either by focusing more specifically on the views of specific user groups such as tourists or students, or by including the views of non-users, to understand if there are differences in the barriers or motivators for cycling and BSS use between different groups. An additional avenue for future research is the differences in attitudes and perceptions between regular bicycle users and electric bicycle users, especially in light of the growth of the latter in recent years.

At a strategic level, there is opportunity for further investigation of the effectiveness of strategies to overcome the barriers to cycling, identified in this research and in the wider literature. The before-and-after analysis of new cycling infrastructure showed how BSS trip data was used to measure the effect of this investment in the vicinity of BSS stations, while controlling for the overall change in BSS use. A similar station-based approach – or even better, using GPS tracks from smartbikes - could be used to test the effectiveness of other interventions in the built environment, such as traffic calming schemes, filtered permeability solutions, the creation of new contraflows or vertical connections. The insights provided by this research about the use of BSS in 'starter' cycling cities in Southern Europe can be used in a comparative analysis with results from other similar case studies, to contribute to a better understanding of the pathways that can successfully lead to the promotion of cycling as a mode of transport.

To conclude, the transport bias of the past decades has led cities down a path in which public space has been sacrificed for parking, people's health is compromised by air pollution, inactivity and traffic accidents, children can no longer walk or cycle to school unsupervised due to road safety concerns, while the need for moving from A to B is fuelling the global climate crisis. The policy shift towards the promotion of sustainable urban mobility provides an opportunity to correct these mistakes and create safer, healthier and more liveable cities. Cycling is an affordable, efficient, and healthy mode of transport, and together with other active transport and clean public transport, can provide a real alternative to private car use. Future work on overcoming the barriers and leveraging the motivators for the promotion of cycling can contribute to making sustainable urban mobility a reality.

References

Abduljabbar, R. L., Liyanage, S., & Dia, H. (2021). The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transportation Research Part D: Transport and Environment, 92*, 102734.

Achilleos, M. (2019, May 8). *Nicosia: Energy Transition from Global to Local Level* [Conference presentation]. Cyprus Energy Agency. Nicosia City-Zen Roadshow, Nicosia, Cyprus.

Ackroyd, S. (2009). Research Designs for Realist Research. In: D. Buchanan, & A. Bryman (Eds.), *Handbook of Organizational Research Methods*. Sage.

AEMET (2019). *Valores climatológicos normales. Gran Canaria Aeropuerto*. Madrid, Spain: Agencia Estatal de Meteorología. http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/valoresclimatologicos?l=C649I&k=undefined

Ahillen, M., Mateo-Babiano, D., & Corcoran, J. (2015). Dynamics of Bike Sharing in Washington, DC and Brisbane, Australia: Implications for policy and planning. *International Journal of Sustainable Transportation, 10*(5), 441-454.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.

Aldred, R., & Jungnickel, K. (2014). Why culture matters for transport policy: the case of cycling in the UK. *Journal of Transport Geography, 34*, 78-87.

Alfonzo, M. A. (2005). To walk or not to walk? The hierarchy of walking needs. *Environment and Behavior, 37*(6), 808-836.

Ang, G., & Marchal, V. (2013). Mobilising private investment in sustainable transport: The case of land-based passenger transport infrastructure. *OECD Environment Working Group Papers*. OECD Publishing.

Attard, M., & Ison, S. (2015). The effects of road user charges in the context of weak parking policies: The case of Malta. *Case Studies on Transport Policy, 3*(1), 37-43.

Attard, M., Von Brockdorff, P., & Bezzina, F. (2015). *The External Costs of Passenger and Commercial Vehicles Use in Malta*. Msida, Malta: Institute for Climate Change and Sustainable Development, University of Malta.

Ayuntamiento de Las Palmas de Gran Canaria (2015). *Movilidad en Transformación*. Las Palmas de Gran Canaria, Canary Islands, Spain: https://civitas.eu/projects/destinations/documents/movilidad

Ayuntamiento de Las Palmas de Gran Canaria (2018). *Observatorio Socio-económico Urbano: El municipio en cifras. Informes: Núcleos*. Las Palmas de Gran Canaria, Canary Islands, Spain: Ayuntamiento de Las Palmas de Gran Canaria. https://www.laspalmasgc.es/es/la-ciudad/observatorio-socioeconomico-urbano/

Ayuntamiento de Las Palmas de Gran Canaria (2019). *Actualidad socioeconómica Las Palmas de Gran Canaria*. Las Palmas de Gran Canaria, Canary Islands, Spain: https://www.laspalmasgc.es/es/la-ciudad/observatorio-socioeconomico-urbano/

Bachand-Marleau, J., Lee, B. H., & El-Geneidy, A. M. (2012). Better understanding of factors influencing likelihood of using shared bicycle systems and frequency of use. *Transportation Research Record, 2314*(1), 66-71.

Bae, C. C. (2004). Transportation and the Environment. In: S. Hanson, & G. Giuliano (Eds.), *The Geography of Urban Transportation* (Third edition). Guilford Press.

Bajada, T., & Titheridge, H. (2016). To contract or to operate publicly? Observations from the bus service reform transition process in Malta. *Research in Transportation Economics, 59*, 281-291.

Bakogiannis, E., Siti, M., Tsigdinos, S., Vassi, A., & Nikitas, A. (2019). Monitoring the first dockless bike sharing system in Greece: Understanding user perceptions, usage patterns and adoption barriers. *Research in Transportation Business & Management, 33*, 100432.

Bakogiannis, E., Vassi, A., Christodoulopoulou, G., & Siti, M. (2018). Bike Sharing Systems as a Tool to Increase Sustainable Coastal And Maritime Tourism. The Case of Piraeus. *Regional Science Inquiry, 10*(3), 57-70.

Banister, D., Marshall, S., & Blackledge, D. (2007). Land Use and Transport: The Context. In: S. Marshall, & D. Banister (Eds.), *Land Use and Transport: European Research towards Integrated Policies*. Emerald Group Publishing Limited.

Banister, D. (2008). *The sustainable mobility paradigm. Transport policy, 15*(2), 73-80.

Banister, D. (2011). Cities, mobility and climate change. *Journal of Transport Geography, 19*(6), 1538-1546.

Barbour, N., Zhang, Y., & Mannering, F. (2019). A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. *Journal of Transport & Health, 12*, 253-262.

Basch, C. H., Ethan, D., Rajan, S., Samayoa-Kozlowsky, S., & Basch, C. E. (2014). Helmet use among users of the Citi Bike bicycle-sharing program: a pilot study in New York City. *Journal of Community Health, 39*(3), 503-507.

Bauman, A. E., & Rissel, C. (2009). Cycling and Health: an opportunity for positive change? *Medical Journal of Australia, 190*(7), 347.

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine, 23*(2), 5-14.

Bauman, A., E., Crane, M., Drayton, B. A., & Titze, S. (2017). The unrealised potential of bike share schemes to influence population physical activity levels – A narrative review. *Preventive Medicine, 103*, S7-S14.

Bélanger-Gravel, A., Gauvin, L., Fuller, D., & Drouin, L. (2015). Implementing a public bicycle share program: impact on perceptions and support for public policies for active transportation. *Journal of Physical Activity and Health, 12*(4), 477-482.

Bélanger-Gravel, A., Gauvin, L., Fuller, D., & Drouin, L. (2014). Association of implementation of a public bicycle share program with intention and self-efficacy: The moderating role of socioeconomic status. *Journal of Health Psychology, 21*(6), 944-953.

Beroud, B., & Anaya, E. (2012). Private Interventions in a Public Service: An Analysis of Public Bicycle Schemes. In: J. Parkin (Ed.), *Cycling and Sustainability* (pp. 269-301). Emerald Group Publishing Limited.

Bertolini, L. (2012). Integrating Mobility and Urban Development Agendas: A Manifesto. *disP - the Planning Review, 48*(1), 16-26.

Biehl, A., Ermagun, A., & Stathopoulos, A. (2018). Community mobility MAUP-ing: A socio-spatial investigation of bikeshare demand in Chicago. *Journal of Transport Geography, 66*, 80-90.

Bikeplus (2017). *Public Bike Share Users Survey Results 2017*. UK: Bikeplus.

Bizakis, A. (2018, May 14-15). *Findings from the Limassol SUMP study* [Conference presentation]. The 5Th European Conference on Sustainable Urban Mobility Plans Nicosia, Cyprus.

Böcker, L., Anderson, E., Uteng, T. P., & Throndsen, T. (2020). Bike sharing use in conjunction to public transport: Exploring spatiotemporal, age and gender dimensions in Oslo, Norway. *Transportation Research Part A: Policy and Practice, 138*, 389-401.

Bohte, W., Maat, K., & van Wee, B. (2009). Measuring attitudes in research on residential self-selection and travel behaviour: a review of theories and empirical research. *Transport Reviews, 29*(3), 325-357.

Boissevain, J., & Bear, L. (1965). *Saints and Fireworks: Religion and Politics in Rural Malta*. Berg Publishers.

Bollars, C., Breda, J., Kiaer, T., Kouzeh, M., Mcgale, L., de Morais, I. L., Roux, P., Whiting, S., & Wijnhoven, T. (2013). *Country profiles on nutrition, physical activity and obesity in the 28 European Union Member States of the WHO European Region*. Copenhagen, Denmark: WHO Regional Office for Europe.

Bordagaray, M., dell'Olio, L., Fonzone, A., & Ibeas, Á. (2016). Capturing the conditions that introduce systematic variation in bike-sharing travel behavior using data mining techniques. *Transportation Research Part C: Emerging Technologies,* (71), 231-248.
Borgnat, P., Abry, P., Flandrin, P., Robardet, C., Rouquier, J., & Fleury, E. (2011). Shared bicycles in a city: A signal processing and data analysis perspective. *Advances in Complex Systems, 14*(03), 415-438.
Bouf, D., & Hensher, D. A. (2007). The dark side of making transit irresistible: The example of France. *Transport Policy, 14*(6), 523-532.
Bradshaw, C. (2004). *The Green Transportation Hierarchy: A Guide for Personal & Public Decision-Making*. Prepared for Ottawalk and the Transportation Working Committee of the Ottawa-Carleton Round-table on the Environment. Ottawa, Canada. Greenprint.
Brundtland, G. H. (1987). *Our Common Future. Report of the World Commission on Environment and Development*. United Nations.
Bryman, A. (2016). *Social Research Methods* (5th ed.). Oxford University Press.
Bryman, A., & Cramer, D. (1994). *Quantitative Data Analysis for Social Scientists* (Revised edition ed.). Routledge.
Buck, D., & Buehler, R. (2012). Bike Lanes and Other Determinants of Capital Bikeshare Trips [Conference presentation]. The Transportation Research Board Annual Meeting 2012, Washington, DC.
Buck, D., Buehler, R., Happ, P., Rawls, B., Chung, P., & Borecki, N. (2013). Are Bikeshare Users Different from Regular Cyclists? *Transportation Research Record: Journal of the Transportation Research Board, 2387*, 112-119.
Buehler, R., & Hamre, A. (2014). *Economic benefits of Capital Bikeshare: a focus on users and businesses*. (No. VT-2013-06). Mid-Atlantic Universities Transportation Center.
Buehler, R., Pucher, J., Gerike, R., & Götschi, T. (2017). Reducing car dependence in the heart of Europe: lessons from Germany, Austria, and Switzerland. *Transport Reviews, 37*(1), 4-28.
Buijs, W., Martijnse, R., Gorris, T., & Ellul, A. (2017). *SUMP Baseline Report*. (Deliverable 2.1), CIVITAS DESTINATIONS project.
Burt, J. E., & Barber, G. M. (1996). *Elementary Statistics for Geographers* (2nd edition ed.). The Guilford Press.
Carmona, M., Heath, T., Tiesdell, S., & Oc, T. (2010). *Public Places, Urban Spaces: The Dimensions of Urban Design*. Routledge.
Carnall, D. (2000). Cycling and health promotion. A safer, slower urban road environment is the key. *BMJ (Clinical Research Ed.), 320*(7239), 888.
Cass, N., & Faulconbridge, J. (2016). Commuting practices: New insights into modal shift from theories of social practice. *Transport Policy, 45*, 1-14.
Castillo-Manzano, J. I., & Sanchez-Braza, A. (2013). Managing a smart bicycle system when demand outstrips supply: the case of the university community in Seville. *Transportation, 40*(2), 459-477.
Castillo-Manzano, J. I., Castro-Nuño, M., & López-Valpuesta, L. (2015). Analyzing the transition from a public bicycle system to bicycle ownership: A complex relationship. *Transportation Research Part D: Transport and Environment, 38*, 15-26.
Caulfield, B., Brick, E., & McCarthy, O. T. (2012). Determining bicycle infrastructure preferences–A case study of Dublin. *Transportation Research Part D: Transport and Environment, 17*(5), 413-417.
Caulfield, B., O'Mahony, M., Brazil, W., & Weldon, P. (2017). Examining usage patterns of a bike-sharing scheme in a medium sized city. *Transportation Research Part A: Policy and Practice, 100*, 152-161.
Cavallaro, F., Galati, O. I., & Nocera, S. (2017). Policy Strategies for the Mitigation of GHG Emissions caused by the Mass-Tourism Mobility in Coastal Areas. *Transportation Research Procedia, 27*, 317-324.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199-219.

Christensen, J., Chatterjee, K., Marsh, S., Sherwin, H., & Jain, J. (2012). *Evaluation of the Cycling City and Towns Programme: Qualitative research with residents*. UK: Department for Transport.

Chrysostomou, A. (2018, September 25). Laws regulating use of bicycles to be in force end of October. *Cyprus Mail*. https://cyprus-mail.com/2018/09/25/laws-regulating-use-of-bicycles-to-be-in-force-end-of-october

Clark, B., Chatterjee, K., & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice, 89*, 89-105.

Clark, J., & Curl, A. (2016). Bicycle and car share schemes as inclusive modes of travel? A socio-spatial analysis in Glasgow, UK. *Social Inclusion, 4*(3), 83-99.

Clements, R. (2020). Parking: An opportunity to deliver sustainable transport. *Handbook of Sustainable Transport* (). Edward Elgar Publishing.

CONEBI (2016). *European bicycle market*. Brussels: Confederation of the European Bicycle Industry.

Copenhagenize Design Co (2013). Copenhagenize Bicycle Planning Guide. In: Colville-Andersen M. (Ed.), *Copenhagenize Bicycle Planning Guide*. Copenhagenize.com.

Corcoran, J., Li, T., Rohde, D., Charles-Edwards, E., & Mateo-Babiano, D. (2014). Spatio-temporal patterns of a Public Bicycle Sharing Program: the effect of weather and calendar events. *Journal of Transport Geography, 41*, 292-305.

CROW (2016). Design Manual for Bicycle Traffic. In: De Groot R. (Ed.), *Design Manual for Bicycle Traffic*. CROW Fietsberaad.

Cushing, M., Hooshmand, J., Pomares, B., & Hotz, G. (2016). Vision Zero in the United States versus Sweden: infrastructure improvement for cycling safety. *American Journal of Public Health, 106*(12), 2178-2180.

CyStat (2012). *Population Census 2011*. Nicosia, Cyprus: Ministry of Finance, Statistical Service, Republic of Cyprus. https://www.mof.gov.cy/mof/cystat/statistics.nsf/populationcondition_22main_en

CyStat (2018). *Transport Statistics 2016* (Series II, Report No.32). Nicosia, Cyprus: Statistical Service, Republic of Cyprus.

CyStat (2019a). *Population and Social Conditions: Population*. Nicosia, Cyprus: Statistical Service, Republic of Cyprus. http://www.cystat.gov.cy/mof/cystat/statistics.nsf/populationcondition_21main_en/populationcondition_21main_en?OpenForm&sub=1&sel=2

CyStat (2019b). *Statistical services: Tourism*. Nicosia, Cyprus: Ministry of Finance, Statistical Service, Republic of Cyprus. https://www.mof.gov.cy/mof/cystat/statistics.nsf/services_71main_en/services_71main_en?OpenForm&sub=1&sel=2

Daley, M., & Rissel, C. (2011). Perspectives and images of cycling as a barrier or facilitator of cycling. *Transport Policy, 18*(1), 211-216.

de Hartog, J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environmental Health Perspectives, 118*(8), 1109-1116.

De Nazelle, A., Fruin, S., Westerdahl, D., Martinez, D., Ripoll, A., Kubesch, N., & Nieuwenhuijsen, M. (2012). A travel mode comparison of commuters' exposures to air pollutants in Barcelona. *Atmospheric Environment, 59*, 151-159.

Deidda, M. (2016). Insularity and economic development: a survey. *International Review of Economics, 63*(2), 107-128.

Deka, D. (2004). Social and Environmental Justice Issues in Urban Transportation. In: S. Hanson, & G. Giuliano (Eds.), *The Geography of Urban Transportation* (Third edition ed.). Guilford Press.

DeMaio, P. (2009). Bike-sharing: History, impacts, models of provision, and future. *Journal of Public Transportation, 12*(4), 41-56.

Demetriou, D. (2018, May 16). *The mobility situation in Cyprus and the SUMP of Limassol* [Conference presentation]. Public Works Department, Ministry of Transport, Communication & Works, Government of Cyprus. CIVITAS Prosperity Project Meeting, Limassol, Cyprus.

Demetriou, D. (2019, March 28-29). *The Sustainable Urban Mobility Plan (SUMP) for Limassol* [Conference presentation]. Public Works Department, Ministry of Transport, Communication & Works, Government of Cyprus. The 6Th Cyprus Sustainable Mobility and Intelligent Transport Conference, Nicosia, Cyprus.

DG MOVE (2013). *Attitudes of Europeans towards Urban Mobility* (Special Eurobarometer 406). Brussels, Belgium: European Commission.

Di Ciommo, F., Comendador, J., López-Lambas, M. E., Cherchi, E., & de Dios Ortúzar, J. (2014). Exploring the role of social capital influence variables on travel behaviour. *Transportation Research Part A: Policy and Practice, 68*, 46-55.

Dill, J., & McNeil, N. (2013). Four types of cyclists? Examination of typology for better understanding of bicycling behavior and potential. *Transportation Research Record: Journal of the Transportation Research Board,* (2387), 129-138.

Dill, J., & Rose, G. (2012). Electric bikes and transportation policy: Insights from early adopters. *Transportation Research Record: Journal of the Transportation Research Board,* (2314), 1-6.

Dimitriou, L., & Savvides, A. (2019, March 28-29). *Mobility Analysis and Morphologies: The case of Cypriot Major Cities* [Conference Presentation]. University of Cyprus. The 6Th Cyprus Sustainable Mobility and Intelligent Transport Conference, Nicosia, Cyprus.

Dobson, R., Dunbar, F., Smith, C. J., Reibstein, D., & Lovelock, C. (1978). Structural models for the analysis of traveler attitude-behavior relationships. *Transportation, 7*(4), 351-363.

Doorley, R., Pakrashi, V., & Ghosh, B. (2015). Quantifying the Health Impacts of Active Travel: Assessment of Methodologies. *Transport Reviews, 35*(5), 559-582.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J. R. G., Gruber, B., Lafourcade, B., & Leitao, P. J. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography, 36*(1), 27-46.

Dotter, F. (2016). *Mobility-as-a-Service: A new transport model* (No. 18). CIVITAS Insight.

Easton, G. (2010). Critical realism in case study research. *Industrial Marketing Management, 39*(1), 118-128.

EDEI, & EPYPSA (2012). *Asistencia Técnica para la Elaboración de una Estrategia de Movilidad Sostenible en el Municipio de Las Palmas de Gran Canaria. Plan de Movilidad Urbana Sostenible (PMUS) de Las Palmas de Gran Canaria*. Las Palmas de Gran Canaria, Canary Islands, Spain.

EEA (2016). *Air quality in Europe — 2016 report* (No 28/2016). Luxembourg: European Environment Agency; Publications Office of the European Union.

EEA (2017a). *Greenhouse Gas Emissions from Transport*. Copenhagen: European Environment Agency. https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10

EEA (2017b). *Road traffic remains biggest source of noise pollution in Europe*. Copenhagen: European Environment Agency. https://www.eea.europa.eu/highlights/road-traffic-remains-biggest-source

EEA (2018a). *Electric vehicles from life cycle and circular economy perspectives. TERM 2018: Transport and Environment Reporting Mechanism (TERM) report* (No 13/2018). Copenhagen: European Environment Agency.

EEA (2018b). *Urban Atlas 2012* (Copernicus Land Monitoring Service ed.). Copenhagen: European Environment Agency.

Efthymiou, D., Antoniou, C., & Waddell, P. (2013). Factors affecting the adoption of vehicle sharing systems by young drivers. *Transport Policy, 29*, 64-73.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.

El Diario (2017, February 26). Canarias, entre las regiones con más tráfico de España. *El Diario, Canarias Ahora*. https://www.eldiario.es/canariasahora/sociedad/canarias-regiones-trafico-espana-carreteras-traf_1_3557333.html

Elvik, R. (2009). The non-linearity of risk and the promotion of environmentally sustainable transport. *Accident Analysis & Prevention, 41*(4), 849-855.

EPOMM (2018). *TEMS - The EPOMM Modal Split Tool. European Platform on Mobility Management*. http://www.epomm.eu/tems/index.phtml

Estudio Manuel Calvo (2016). *Plan Director de la Bicicleta de Las Palmas de Gran Canaria*. Las Palmas de Gran Canaria: Ayuntamiento de Las Palmas de Gran Canaria.

European Commission (2013). *Together towards competitive and resource-efficient urban mobility* (SWD (2013) 529). Brussels, Belgium: European Commission.

European Commission (2014). *2030 climate & energy framework*. Brussels, Belgium: European Commission. https://ec.europa.eu/clima/policies/strategies/2030_en

European Commission (2016). *A European Strategy for Low-Emission Mobility* (SWD (2016) 244). Brussels, Belgium: European Commission.

European Commission (2019). *The European Green Deal* (COM(2019) 640 final). Brussels, Belgium: European Commission.

European Commission (2020a). *EU climate action and the European Green Deal*. Brussels, Belgium: European Commission. https://ec.europa.eu/clima/policies/eu-climate-action_en

European Commission (2020b). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law)* (COM(2020) 80 final). Brussels, Belgium: European Commission.

European Road Safety Observatory (2017). *Annual Accident Report 2017*. Brussels, Belgium: ERSO.

Eurostat (2021). *Passenger cars per 1,000 inhabitants*. Brussels, Belgium: Eurostat. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqs_carhab&lang=en

Ewing, R. (2001). Impacts of traffic calming. *Transportation Quarterly, 55*(1), 33-46.

Ewing, R., Brown, S., & Hoyt, A. (2005). Traffic Calming Practice Revisited. *Institute of Transportation Engineers. ITE Journal, 75*(11), 22-28.

Faghih-Imani, A., & Eluru, N. (2015). Analysing bicycle-sharing system user destination choice preferences: Chicago's Divvy system. *Journal of Transport Geography, 44*, 53-64.

Faghih-Imani, A., & Eluru, N. (2016a). Determining the role of bicycle sharing system infrastructure installation decision on usage: Case study of Montreal BIXI system. *Transportation Research Part A: Policy and Practice, 94*, 685-698.

Faghih-Imani, A., & Eluru, N. (2016b). Incorporating the impact of spatio-temporal interactions on bicycle sharing system demand: A case study of New York CitiBike system. *Journal of Transport Geography, 54*, 218-227.

Faghih-Imani, A., Eluru, N., El-Geneidy, A. M., Rabbat, M., & Haq, U. (2014). How land-use and urban form impact bicycle flows: Evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography, 41*, 306-314.

Faghih-Imani, A., Hampshire, R., Marla, L., & Eluru, N. (2017). An empirical analysis of bike sharing usage and rebalancing: Evidence from Barcelona and Seville. *Transportation Research Part A: Policy and Practice, 97*, 177-191.

Farrugia, M., & Maas, S. (2020). *Cycling Roundabouts in Malta: Cycling safety issues at local roundabouts and solutions to improve safety*. Malta: Bicycle Advocacy Group (BAG) Malta; Institute for Climate Change and Sustainable Development.

Félix, R., Cambra, P., & Moura, F. (2020). Build it and give 'em bikes, and they will come: The effects of cycling infrastructure and bike-sharing system in Lisbon. *Case Studies on Transport Policy, 8*(2), 672-682.

Félix, R., Moura, F., & Clifton, K. J. (2019). Maturing urban cycling: Comparing barriers and motivators to bicycle of cyclists and non-cyclists in Lisbon, Portugal. *Journal of Transport & Health, 15*, 100628.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Addison-Wesley.

Fishman, E. (2014). *Bikeshare: Barriers, Facilitators and Impacts on Car Use*. [Doctoral dissertation]. Queensland University of Technology, Centre for Accident Research and Road Safety Queensland (CARRS-Q).

Fishman, E. (2016). Bikeshare: A review of recent literature. *Transport Reviews, 36*(1), 92-113.

Fishman, E., & Schepers, P. (2016). Global bike share: what the data tells us about road safety. *Journal of Safety Research, 56*, 41-45.

Fishman, E., Washington, S., & Haworth, N. (2012). Barriers and facilitators to public bicycle scheme use: A qualitative approach. *Transportation Research Part F: Traffic Psychology and Behaviour, 15*(6), 686-698.

Fishman, E., Washington, S., & Haworth, N. (2013). Bike share: a synthesis of the literature. *Transport Reviews, 33*(2), 148-165.

Fishman, E., Washington, S., & Haworth, N. (2014). Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport and Environment, 31*, 13-20.

Fishman, E., Washington, S., & Haworth, N. (2015). Bikeshare's impact on active travel: Evidence from the United States, Great Britain, and Australia. *Journal of Transport & Health, 2*(2), 135-142.

Fishman, E., Washington, S., Haworth, N., & Mazzei, A. (2014). Barriers to bikesharing: an analysis from Melbourne and Brisbane. *Journal of Transport Geography, 41*, 325-337.

Fishman, E., Washington, S., Haworth, N., & Watson, A. (2015). Factors influencing bike share membership: an analysis of Melbourne and Brisbane. *Transportation Research Part A: Policy and Practice, 71*, 17-30.

Fraser, S. D., & Lock, K. (2011). Cycling for transport and public health: a systematic review of the effect of the environment on cycling. *European Journal of Public Health, 21*(6), 738-743.

Froehlich, J., Neumann, J., & Oliver, N. (2009). Sensing and predicting the pulse of the city through shared bicycling. *IJCAI, 9,* 1420-1426.

Frost, J. (2019). *Regression Analysis. An Intuitive Guide for Using and Interpreting Linear Models* (E-book, 1st edition ed.)

Fuller, D., Gauvin, L., Kestens, Y., Daniel, M., Fournier, M., Morency, P., & Drouin, L. (2011). Use of a new public bicycle share program in Montreal, Canada. *American Journal of Preventive Medicine, 41*(1), 80-83.

Fuller, D., Gauvin, L., Kestens, Y., Morency, P., & Drouin, L. (2013a). The potential modal shift and health benefits of implementing a public bicycle share program in Montreal, Canada. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 66.

Fuller, D., Gauvin, L., Kestens, Y., Daniel, M., Fournier, M., Morency, P., & Drouin, L. (2013b). Impact evaluation of a public bicycle share program on cycling: a case example of BIXI in Montreal, Quebec. *American Journal of Public Health, 103*(3), e85-e92.

Gaffron, P., Schubert, U., Skala, F., & Wagner, T. (2007). Planning Urban Structures for Sustainable Transport. In S. Marshall, & D. Banister (Eds.), *Land Use and Transport: European Research Towards Integrated Policies* (pp. 71-103). Emerald Group Publishing Limited.

Galatoulas, N., Genikomsakis, K. N., & Ioakimidis, C. S. (2020). Spatio-Temporal Trends of E-Bike Sharing System Deployment: A Review in Europe, North America and Asia. *Sustainability, 12*(11), 4611.

Galdies, C. (2011). *The Climate of Malta: statistics, trends and analysis 1951-2010*. Valletta, Malta: National Statistics Office.

Gámez-Pérez, K. M., Arroyo-López, P., & Cherry, C. R. (2017). Defining a Primary Market for Bikesharing Programs: A Study of Habits and Usage Intentions in León, Mexico. *Transportation Research Record: Journal of the Transportation Research Board, 2634*, 50-56.

Gatersleben, B., & Appleton, K. M. (2007). Contemplating cycling to work: Attitudes and perceptions in different stages of change. *Transportation Research Part A, 41*(4), 302-312.

Gauthier, A., Hughes, C., Kost, C., Li, S., Linke, C., Lotshaw, S., Mason, J., Pardo, C., Rasore, C., Schroeder, B., & Treviño, X. (2013). *The Bike-share Planning Guide*. ITDP Institute for Planning & Development Policy.

Gavin, K., Bennett, A., Auchincloss, A. H., & Katenta, A. (2016). A brief study exploring social equity within bicycle share programs. *Transportation Letters, 8*(3), 177-180.

Gebel, K., Bauman, A. E., Sugiyama, T., & Owen, N. (2011). Mismatch between perceived and objectively assessed neighborhood walkability attributes: prospective relationships with walking and weight gain. *Health & Place, 17*(2), 519-524.

Gebhart, K., & Noland, R. B. (2014). The impact of weather conditions on bikeshare trips in Washington, DC. *Transportation, 41*(6), 1205-1225.

Geerlings, H., Shiftan, Y., & Stead, D. (2012). The complex challenge of transitions towards sustainable mobility - An introduction. In: H. Geerlings, Y. Shiftan & D. Stead (Eds.), *Transition towards Sustainable Mobility: The Role of Instruments, Individuals and Institutions*. Ashgate.

Geller, R. (2006). *Four Types of Cyclists*. Portland, USA: Portland Office of Transportation. https://www.portlandoregon.gov/transportation/article/264746

Giffinger, R., Fertner, C., Kramar, H., & Meijers, E. (2007). *City-ranking of European medium-sized cities*. Centre of Regional Science, Vienna University of Technology.

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., Foster, S., Lowe, M., Sallis, J. F., Stevenson, M., & Owen, N. (2016). *City planning and population health: a global challenge*.

Godward, M. (2018). *Personal Exposure to Air Quality Whilst Commuting to Campus: Comparing Particle Number Concentration Exposure When Walking, Cycling and in Car and Bus Cabins* [Master's Thesis]. Institute for Transport Studies, The University of Leeds.

Golub, A., & Martens, K. (2014). Using principles of justice to assess the modal equity of regional transportation plans. *Journal of Transport Geography, 41*, 10-20.

Golub, A., Hoffmann, M. L., Lugo, A. E., & Sandoval, G. F. (Eds.) (2016). *Bicycle justice and urban transformation: Biking for all?* Routledge.

Goodman, A., & Cheshire, J. (2014). Inequalities in the London bicycle sharing system revisited: impacts of extending the scheme to poorer areas but then doubling prices. *Journal of Transport Geography, 41*, 272-279.

Goodman, A., Green, J., & Woodcock, J. (2014). The role of bicycle sharing systems in normalising the image of cycling: An observational study of London cyclists. *Journal of Transport & Health, 1*(1), 5-8.

Goodman, A., Panter, J., Sharp, S. J., & Ogilvie, D. (2013). Effectiveness and equity impacts of town-wide cycling initiatives in England: a longitudinal, controlled natural experimental study. *Social Science & Medicine, 97*, 228-237.

Gössling, S., Schröder, M., Späth, P., & Freytag, T. (2016). Urban Space Distribution and Sustainable Transport. *Transport Reviews, 36*(5), 659-679. 10.1080/01441647.2016.1147101

Guo, D., Chen, J., MacEachren, A. M., & Liao, K. (2006). A visualization system for space-time and multivariate patterns (vis-stamp). *IEEE Transactions on Visualization and Computer Graphics, 12*(6), 1461-1474.

Hadjioannou, B. (2019, November 20). Limassol's cycle lane bungle: Report finds 'omissions and errors'. *In-Cyprus*. https://in-cyprus.com/limassols-cycle-lane-bungle-report-finds-omissions-and-errors/

Hägerstrand, T. (1970). What about people in regional science? *Papers of the Regional Science Association, 24*(1) 6-21.

Hamiduddin, I. (2015). Social sustainability, residential design and demographic balance: neighbourhood planning strategies in Freiburg, Germany. *Town Planning Review, 86*(1), 29-53.

Hampshire, R. C., & Marla, L. (2012). *An Analysis of Bike Sharing Usage: Explaining trip generation and attraction from observed demand* [Conference presentation]. The Transportation Research Board 91st Annual Meeting, Washington, DC.

Handy, S. (2005). Critical assessment of the literature on the relationships among transportation, land use, and physical activity. Transportation Research Board and the Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land use. *Resource Paper for TRB Special Report, 282*(1), 1-81.

Handy, S., & Niemeier, D. (1997). Measuring Accessibility: An Exploration of Issues and Alternatives. *Environment and Planning A, 29*(7), 1175-1194.

Handy, S., van Wee, B., & Kroesen, M. (2014). Promoting cycling for transport: research needs and challenges. *Transport Reviews, 34*(1), 4-24.

Handy, S., Xing, Y., & Buehler, T. (2010). Factors associated with bicycle ownership and use: a study of six small US cities. *Transportation, 37*(6), 967-985.

Hanson, S. (2004). The Context of Urban Travel. Concepts and Recent Trends. In: S. Hanson, & G. Giuliano (Eds.), *The Geography of Urban Transportation* (Third edition ed., pp. 3-29). Guilford Press.

Hantrais, L., & Mangen, S. P. (1996). *Cross-National Research Methods in the Social Sciences*. Pinter.

Hart, C. (1998). *Doing a Literature Review: Releasing the Social Science Research Imagination*. Sage Publications Ltd.

Haubold, H. (2016). *Shopping by Bike: Best friend of your city centre*. Brussels, Belgium: European Cyclists' Federation (ECF).

Heinen, E., & Bohte, W. (2014). Multimodal commuting to work by public transport and bicycle: Attitudes toward mode choice. *Transportation Research Record, 2468*(1), 111-122.

Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: an overview of the literature. *Transport Reviews, 30*(1), 59-96.

Hendriksen, I. J., Simons, M., Garre, F. G., & Hildebrandt, V. H. (2010). The association between commuter cycling and sickness absence. *Preventive Medicine, 51*(2), 132-135.

Herlihy, D. V. (2004). *Bicycle: The History*. Yale University Press.

Hupkes, G. (1982). The law of constant travel time and trip-rates. *Futures, 14*(1), 38-46.

Hyland, M., Hong, Z., de Farias Pinto, Helen Karla Ramalho, & Chen, Y. (2018). Hybrid cluster-regression approach to model bikeshare station usage. *Transportation Research Part A: Policy and Practice, 115*, 71-89.

Ibraeva, A., de Almeida Correia, G. H., Silva, C., & Antunes, A. P. (2020). Transit-oriented development: A review of research achievements and challenges. *Transportation Research Part A: Policy and Practice, 132*, 110-130.

IGN (2018). *Modelo Digital del Terreno - MDT05*. Madrid, Spain: Instituto Geográfico Nacional (IGN), Centro de Descargas, Centro de Información Geográfica. https://centrodedescargas.cnig.es/CentroDescargas

INE (2011). *Censos de Población y Viviendas. Indicadores para secciones censales y cartografía digitalizada*. Madrid, Spain: Instituto Nacional de Estadística. https://www.ine.es/censos2011_datos/cen11_datos_resultados_seccen.htm

INE (2016). *Estadística experimental. Atlas de distribución de renta de los hogares: 36.1 Indicadores de renta media / 36.9 Indicadores demográficos*. Madrid, Spain: Instituto Nacional de Estadística. https://www.ine.es/experimental/atlas/exp_atlas_tab.htm

INE (2019). *Demografía y población. Padrón. Población por municipios. Cifras oficiales de población de los municipios españoles*. Madrid, Spain: Instituto Nacional de Estadística. https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736177011&menu=resultados&idp=1254734710990

Institute for Sensible Transport (2018). *Transport Strategy Refresh. Transport, Greenhouse Gas Emissions and Air Quality*. Melbourne, Australia: City of Melbourne.

Iseki, H., & Tingstrom, M. (2014). A new approach for bikeshed analysis with consideration of topography, street connectivity, and energy consumption. *Computers, Environment and Urban Systems, 48*, 166-177.

ISTAC (2020). *Sector servicios: Demanda turística*. Las Palmas de Gran Canaria, Canary Islands, Spain: Instituto Canario de Estadística.
Iwińska, K., Blicharska, M., Pierotti, L., Tainio, M., & de Nazelle, A. (2018). Cycling in Warsaw, Poland – Perceived enablers and barriers according to cyclists and non-cyclists. *Transportation Research Part A: Policy and Practice, 113*, 291-301.
Jacobsen, P. L. (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention, 9*(3), 205-209.
Jain, T., Wang, X., Rose, G., & Johnson, M. (2018). Does the role of a bicycle share system in a city change over time? A longitudinal analysis of casual users and long-term subscribers. *Journal of Transport Geography, 71*, 45-57.
Jäppinen, S., Toivonen, T., & Salonen, M. (2013). Modelling the potential effect of shared bicycles on public transport travel times in Greater Helsinki: An open data approach. *Applied Geography, 43*, 13-24.
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research, 1*(2), 112-133.
Johnston, R. A. (2004). The Urban Transportation Planning Process. In: S. Hanson, & G. Giuliano (Eds.), *The Geography of Urban Transportation* (Third edition ed.). Guilford Press.
Jonuschat, H., Stephan, K., & Schelewsky, M. (2015). Understanding multimodal and intermodal mobility. In: M. Attard, & Y. Shiftan (Eds.), *Sustainable Urban Transport* (pp. 149-176). Emerald Group Publishing Limited.
Jurdak, R. (2013). The impact of cost and network topology on urban mobility: A study of public bicycle usage in 2 US cities. *PloS One, 8*(11), e79396.
Kaltenbrunner, A., Meza, R., Grivolla, J., Codina, J., & Banchs, R. (2010). Urban cycles and mobility patterns: Exploring and predicting trends in a bicycle-based public transport system. *Pervasive and Mobile Computing, 6*(4), 455-466.
Kamargianni, M., Ben-Akiva, M., & Polydoropoulou, A. (2014). Incorporating social interaction into hybrid choice models. *Transportation, 41* (6), 1263-1285.
Kaplan, S., Manca, F., Nielsen, T. A. S., & Prato, C. G. (2015). Intentions to use bike-sharing for holiday cycling: An application of the Theory of Planned Behavior. *Tourism Management, 47*, 34-46.
Kenworthy, J., & Laube, F. (1999). Patterns of automobile dependence in cities: an international overview of key physical and economic dimensions with some implications for urban policy. *Transportation Research Part A: Policy and Practice, 33*(7-8), 691-723.
Kenyon, S., & Lyons, G. (2003). The value of integrated multimodal traveller information and its potential contribution to modal change. *Transportation Research Part F: Traffic Psychology and Behaviour, 6*(1), 1-21.
Kim, G., & Miller, P. A. (2019). The impact of green infrastructure on human health and well-being: The example of the Huckleberry Trail and the Heritage Community Park and Natural Area in Blacksburg, Virginia. *Sustainable Cities and Society, 48*, 101562.
Krizek, K., Handy, S., & Forsyth, A. (2009). Explaining Changes in Walking and Bicycling Behavior: Challenges for Transportation Research. *Environment and Planning B: Planning and Design, 36*(4), 725-740.
Kroesen, M., & Handy, S. (2014). The relation between bicycle commuting and non-work cycling: results from a mobility panel. *Transportation, 41*(3), 507-527.
Kroesen, M., & Chorus, C. (2018). The role of general and specific attitudes in predicting travel behavior – A fatal dilemma? *Travel Behaviour and Society, 10*, 33-41.
Kroesen, M., Handy, S., & Chorus, C. (2017). Do attitudes cause behavior or vice versa? An alternative conceptualization of the attitude-behavior relationship in travel behavior modeling. *Transportation Research Part A: Policy and Practice, 101*, 190-202.
Krykewycz, G. R., Puchalsky, C. M., Rocks, J., Bonnette, B., & Jaskiewicz, F. (2010). Defining a Primary Market and Estimating Demand for Major Bicycle-Sharing Program in Philadelphia,

Pennsylvania. *Transportation Research Record: Journal of the Transportation Research Board, 2341*(1), 117-124.
Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: tests in linear mixed effect models. *Journal of Statistical Software, 82*(13), 1-26.
Kythreotou, N., & Mesimeris, T. (2018). *Cyprus National Greenhouse Gas Inventory 2018*. Nicosia, Cyprus: Department of Environment, Ministry of Agriculture, Rural Development and Environment, Government of Cyprus.
La Provincia (2019, 10/05/2019). Memes de la red del carril bici de Las Palmas de Gran Canaria. *La Provincia*. https://www.laprovincia.es/fotos/las-palmas-de-gran-canaria/2019/05/10/memes-red-carril-bici-palmas-8450591.html#foto=15
Lambrinos, M. (2015, May 11-12). *Integrated Urban Mobility Planning in Cyprus* [Conference presentation). Public Works Department, Ministry of Transport, Communication & Works, Government of Cyprus. The 3rd Cyprus Sustainable Mobility and Intelligent Transport Conference, Nicosia, Cyprus.
Lanzendorf, M., & Busch-Geertsema, A. (2014). The cycling boom in large German cities—empirical evidence for successful cycling campaigns. *Transport Policy, 36*, 26-33.
LaPlante, J., & McCann, B. (2008). Complete streets: We can get there from here. *ITE Journal, 78*(5), 24.
Lathia, N., Ahmed, S., & Capra, L. (2012). Measuring the impact of opening the London shared bicycle scheme to casual users. *Transportation Research Part C: Emerging Technologies, 22*, 88-102.
LCA (2020). *Slow Streets: Rethink mobility*. Marsa, Malta: Local Councils Association. https://issuu.com/lcamalta/docs/slow_20streets_20online
Liao, Y. (2016). Association of sociodemographic and perceived environmental factors with public bicycle use among Taiwanese urban adults. *International Journal of Environmental Research and Public Health, 13*(3), 340.
Limassol Municipality (2019). *Integrated Sustainable Urban Development Strategy. Projects co-financed by the EU (2014-2020)*. Limassol, Cyprus: Limassol Municipality. https://www.limassolmunicipal.com.cy/en/anaptiksiaka-erga-2014-2020
Litman, T. (2008). *Sustainable Transportation Indicators: A Recommended Research Program for Developing Sustainable Transportation Indicators and Data*. Washington, DC: Sustainable Transportation Indicators Subcommittee of the Transportation Research Board.
Litman, T. (2015). *Evaluating Complete Streets: The Value of Designing Roads for Diverse Modes, Users and Activities*. Victoria, Canada: Victoria Transport Policy Institute.
Litman, T. (2017). *Introduction to Multimodal Transportation Planning*. Victoria Transport Policy Institute.
Lovelace, R., Goodman, A., Aldred, R., Berkoff, N., Abbas, A., & Woodcock, J. (2017). The Propensity to Cycle Tool: An open source online system for sustainable transport planning. *Journal of Transport and Land Use, 10*(1), 505-528.
Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*, 105-113.
Maas, S., Attard, M., Nikolaou, P., & Dimitriou, L. (2019, November 21-22). *Understanding shared bicycle use in Southern European island cities: first insights from Limassol, Cyprus* [Conference presentation]. SBE Malta 2019 Conference, Malta.
Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2020). Examining spatio-temporal trip patterns of bicycle sharing systems in Southern European island cities. *Research in Transportation Economics*, 100992.
Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2021a). Heat, Hills and the High Season: A Model-Based Comparative Analysis of Spatio-Temporal Factors Affecting Shared Bicycle Use in Three Southern European Islands. *Sustainability*, 13(6), 3274.
Maas, S., Nikolaou, P., Attard, M., & Dimitriou, L. (2021b). Spatial and temporal analysis of shared bicycle use in Limassol, Cyprus. *Journal of Transport Geography*, 93, 103049.

Maas, S., & Attard, M. (2020). Attitudes and perceptions towards shared mobility services: Repeated cross-sectional results from a survey among the Maltese population. *Transportation Research Procedia, 45*, 955-962.

Maas, S., Attard, M., & Bugeja, M. (2021). Sustainable tourism mobility in Malta: encouraging a shift in tourist travel behavior through an innovative smartphone app for trip planning. In: L. Zamparini (Ed.), *Sustainable Transport and Tourism Destinations* (Transport and Sustainability, Vol.13 ed.). Emerald Publishing Limited.

Maas, S., Attard, M., & Caruana, M. A. (2020). Assessing spatial and social dimensions of shared bicycle use in a Southern European island context: The case of Las Palmas de Gran Canaria. *Transportation Research Part A: Policy and Practice, 140*, 81-97.

Marcus, B. H., Banspach, S. W., Lefebvre, R. C., Rossi, J. S., Carleton, R. A., & Abrams, D. B. (1992). Using the Stages of Change Model to Increase the Adoption of Physical Activity among Community Participants. *American Journal of Health Promotion, 6*(6), 424-429.

Marqués, R., Hernández-Herrador, V., & Calvo-Salazar, M. (2014). Sevilla: a successful experience of bicycle promotion in a Mediterranean context. *WIT Transactions on Ecology and the Environment, 191*, 769-781.

Marqués, R., Hernández-Herrador, V., Calvo-Salazar, M., & García-Cebrián, J. (2015). How infrastructure can promote cycling in cities: Lessons from Seville. *Research in Transportation Economics, 53*, 31-44.

Marshall, S., & Banister, D. (2007). Land Use and Transport. In: S. Marshall, & D. Banister (Eds.), *Land Use and Transport: European Research towards Integrated Policies*. Emerald Group Publishing Limited.

Martens, K. (2012). Justice in transport as justice in accessibility: applying Walzer's 'Spheres of Justice'to the transport sector. *Transportation, 39*(6), 1035-1053.

Martin, E. W., Cohen, A., Botha, J. L., & Shaheen, S. A. (2016). *Bikesharing and Bicycle Safety*. Mineta Transportation Institute Publications.

Martin, E. W., & Shaheen, S. A. (2014). Evaluating public transit modal shift dynamics in response to bikesharing: a tale of two US cities. *Journal of Transport Geography, 41*, 315-324.

Mateo-Babiano, I., Bean, R., Corcoran, J., & Pojani, D. (2016). How does our natural and built environment affect the use of bicycle sharing? *Transportation Research Part A: Policy and Practice, 94*, 295-307.

Maurer, L. K. (2011). *Suitability Study for a Bicycle Sharing Program in Sacramento, California* [Master's Thesis]. University of North Carolina at Chapel Hill, Department of City and Regional Planning.

McCormack, G., Giles-Corti, B., Lange, A., Smith, T., Martin, K., & Pikora, T. J. (2004). An update of recent evidence of the relationship between objective and self-report measures of the physical environment and physical activity behaviours. *Journal of Science and Medicine in Sport, 7*(1), 81-92.

McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation. *Journal of Cleaner Production, 50*, 1-11.

Médard de Chardon, C. (2016). *A Geographical Analysis of Bicycle Sharing Systems* (PhD).

Médard de Chardon, C., Caruso, G., & Thomas, I. (2017). Bicycle sharing system 'success' determinants. *Transportation Research Part A: Policy and Practice, 100*, 202-214.

Médard de Chardon, C. (2019). The contradictions of bike-share benefits, purposes and outcomes. *Transportation Research Part A: Policy and Practice, 121*, 401-419.

Melia, S. (2012). Filtered and unfiltered permeability: The European and Anglo-Saxon approaches. *Project, 4*, 6-9.

MEPA (2012). *Malta LiDAR Digital Terrain Model (DTM)*. Floriana, Malta: Public Geoserver, Malta Environment and Planning Authority (Planning Authority). http://geoserver.pa.org.mt/publicgeoserver

Mesimeris, T., & Kythreotou, N. (2019). *Cyprus' Draft Integrated national energy and climate plan for the period 2021-2030*. Nicosia, Cyprus: Department of Environment, Ministry of Agriculture, Rural Development and Environment, Government of Cyprus.
Met Office (2019). *Malta weather*. London, UK: Met Office UK. https://www.metoffice.gov.uk/weather/travel-and-events/holiday-weather/europe/malta
Michael, S. A. (2019, March 28-29). *Sustainable Mobility in Cyprus* [Conference presentation]. Permanent Secretary, Ministry of Transport, Communications and Works, Government of Cyprus. The 6Th Cyprus Sustainable Mobility and Intelligent Transport Conference, Nicosia, Cyprus.
Michaelides, A. (2017, May 16-17). *Sustainable Mobility in Cyprus* [Conference presentation]. Permanent Secretary, Ministry of Transport, Communications and Works, Government of Cyprus. Presentation at the 5Th Sustainable Mobility and Intelligent Transport Systems Conference, Nicosia, Cyprus.
Midgley, P. (2011). Bicycle-sharing schemes: enhancing sustainable mobility in urban areas. *United Nations, Department of Economic and Social Affairs,* 1-12.
Mifsud, D., Attard, M., & Ison, S. (2019). An exploratory study of the psychological determinants of mobility of older people in Malta. *Research in Transportation Business & Management, 30*, 100373.
MOA (2019). *Recent Weather Data*. Nicosia, Cyprus: Ministry of Agriculture, Rural Development and Environment, Department of Meteorology, Republic of Cyprus. http://www.moa.gov.cy/moa/MS/MS.nsf/DMLmeteo_reports_en/DMLmeteo_reports_en?opendocument
MOI (2019). *Cyprus Digital Terrain Model (DTM)*. The INSPIRE GeoPortal of Cyprus: Annex 2. Republic of Cyprus, Ministry of Interior, Department of Lands and Surveys. https://weba.dls.moi.gov.cy/arcgis/rest/services/INSPIRE/EL_Elevation/MapServer
Mokhtarian, P. L., & Chen, C. (2004). TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets. *Transportation Research Part A: Policy and Practice, 38*(9-10), 643-675.
Molina-García, J., Castillo, I., Queralt, A., & Sallis, J. F. (2013). Bicycling to university: evaluation of a bicycle-sharing program in Spain. *Health Promotion International, 30*(2), 350-358.
Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. *Smart Cities, 4*, 93–111.
Morton, C. (2018). Appraising the market for bicycle sharing schemes: Perceived service quality, satisfaction, and behavioural intention in London. *Case Studies on Transport Policy, 6*(1), 102-111.
MRA (2019). *National Greenhouse Gas Emissions Inventory Report for Malta 2019*. Marsa, Malta: Malta Resources Authority, Ministry for Environment, Sustainable Development and Climate Change. https://unfccc.int/documents/194992
MTI (2014). *Road Safety Strategy Malta 2014-2024*. Floriana, Malta: Ministry for Transport and Infrastructure.
Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., de Nazelle, A., Dons, E., Gerike, R., Goetschi, T., Panis, L. I., Kahlmeier, S., & Nieuwenhuijsen, M. (2015). Health impact assessment of active transportation: a systematic review. *Preventive Medicine, 76*, 103-114.
Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Andrés, D., Ballester, J., Bartoll, X., Daher, C., Deluca, A., Echave, C., Milà, C., Márquez, S., Palou, J., Pérez, K., Tonne, C., Stevenson, M., Rueda, S., & Nieuwenhuijsen, M. (2020). Changing the urban design of cities for health: The superblock model. *Environment International, 134*, 105132.
Muñoz, B., Monzon, A., & Lois, D. (2013). Cycling Habits and Other Psychological Variables Affecting Commuting by Bicycle in Madrid, Spain. *Transportation Research Record, 2382*(1), 1-9.
Murphy, E., & Usher, J. (2015). The role of bicycle-sharing in the city: Analysis of the Irish experience. *International Journal of Sustainable Transportation, 9*(2), 116-125.

Mütze, F. (2018). *Safe Cities across Europe: Integrating Road Safety in the SUMP Planning Cycle*. European Transport Safety Council.

Nair, R., Miller-Hooks, E., Hampshire, R. C., & Bušić, A. (2013). Large-scale vehicle sharing systems: analysis of Vélib'. *International Journal of Sustainable Transportation, 7*(1), 85-106.

Newman, P., & Kenworthy, J. (2015). The end of automobile dependence. *The End of Automobile Dependence* (pp. 201-226). Springer.

Nikitas, A. (2019). How to Save Bike-Sharing: An Evidence-Based Survival Toolkit for Policy-Makers and Mobility Providers. *Sustainability, 11*(3206).

Nikitas, A. (2018). Understanding bike-sharing acceptability and expected usage patterns in the context of a small city novel to the concept: A story of 'Greek Drama'. *Transportation Research Part F: Traffic Psychology and Behaviour, 56*, 306-321.

Nikolaou, P., Basbas, S., Politis, I., & Borg, G. (2020). Trip and Personal Characteristics towards the Intention to Cycle in Larnaca, Cyprus: An EFA-SEM Approach. *Sustainability, 12*(4250)

Noland, R. B., Smart, M. J., & Guo, Z. (2016). Bikeshare trip generation in New York city. *Transportation Research Part A: Policy and Practice, 94*, 164-181.

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning, 134*, 127-138.

NSO (2014). *Census of Population and Housing 2011.* Valletta, Malta: National Statistics Office Malta, Methodology and Research Unit.

NSO (2016). *Demographic Review 2014.* Valletta, Malta: National Statistics Office Malta, Unit C3: Population and Tourism Statistics.

NSO (2017). *Transport Statistics 2016.* Valletta, Malta: National Statistics Office.

NSO (2018). *Population Statistics (Revisions): 2012-2016.* Valletta, Malta: National Statistics Office. https://nso.gov.mt/en/News_Releases/View_by_Unit/Unit_C5/Population_and_Migration_Statistics/Pages/Population%20Revisions.aspx

NSO (2019). *Inbound Tourism: 2018 and 2019.* Valletta, Malta: National Statistics Office.

NSO (2020). *Inbound Tourism.* Unit C3: Tourism and Education Statistics. Valletta, Malta: National Statistics Office. https://nso.gov.mt/en/News_Releases/View_by_Unit/Unit_C3/Tourism_Statistics/Pages/Inbound-Tourism.aspx

O'Brien, O., Cheshire, J., & Batty, M. (2014). Mining bicycle sharing data for generating insights into sustainable transport systems. *Journal of Transport Geography, 34*, 262-273.

OBIS (2011). *Optimising Bike Sharing in European Cities - A Handbook*. OBIS Project.

Ogilvie, F., & Goodman, A. (2012). Inequalities in usage of a public bicycle sharing scheme: socio-demographic predictors of uptake and usage of the London (UK) cycle hire scheme. *Preventive Medicine, 55*(1), 40-45.

Oja, P., Titze, S., Bauman, A., E., de Geus, B., Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: a systematic review. *Scandinavian Journal of Medicine & Science in Sports, 21*(4), 496-509.

Olafsson, A. S., Nielsen, T. S., & Carstensen, T. A. (2016). Cycling in multimodal transport behaviours: Exploring modality styles in the Danish population. *Journal of Transport Geography, 52*, 123-130.

Oldenziel, R., & de la Bruhèze, A. (2011). Contested spaces: Bicycle lanes in urban Europe, 1900-1995. *Transfers, 1*(2), 29-49.

Oldenziel, R., Emanuel, M., de la Bruhèze, A., & Veraart, F. (2016). *Cycling Cities: The European Experience: Hundred Years of Policy and Practice*. Foundation for the History of Technology.

Olivier, J., & Creighton, P. (2016). Bicycle injuries and helmet use: a systematic review and meta-analysis. *International Journal of Epidemiology, 2016*, 1-15.

Oosterhuis, H. (2016). Cycling, modernity and national culture. *Social History, 41*(3), 233-248.

OpenStreetMap contributors. (2019). *OpenStreetMap*. OpenStreetMap Foundation (OSMF).

Oxley, M., Brown, T., Nadin, V., Fernández-Maldonado, A. M., Qu, L., & Tummers, L. (2009). *Review of European Planning Systems*. National Housing and Planning Advice Unit.
PA (2006). *North Harbours Local Plan.* Floriana, Malta: Planning Authority.
PA (2015). *Strategic Plan for the Environment and Development (SPED).* Floriana, Malta: Planning Authority.
Pace, R. (2017, June 15). Traffic congestion: government's 'no' to parking meters, limitations on car use. *Malta Today.* https://www.maltatoday.com.mt/news/xtra/78149/watch_ian_borg_government_will_not_consider_parking_meters_limitations_on_cars
Pacione, M. (2009a). Urban Planning and Policy. In: M. Pacione (Ed.), *Urban Geography: A Global Perspective* (Third edition ed.). Routledge.
Pacione, M. (2009b). Urban Transportation. In: M. Pacione (Ed.), *Urban Geography: A Global Perspective* (Third edition ed.). Routledge.
Parkes, S. D., Marsden, G., Shaheen, S. A., & Cohen, A. P. (2013). Understanding the diffusion of public bikesharing systems: evidence from Europe and North America. *Journal of Transport Geography, 31*, 94-103.
Partington, P. (1999). *Traffic Calming: Chokers*. Trafficcalming.net. http://www.trafficcalming.net/chokers.htm
Pfrommer, J., Warrington, J., Schildbach, G., & Morari, M. (2014). Dynamic vehicle redistribution and online price incentives in shared mobility systems. *IEEE Transactions on Intelligent Transportation Systems, 15*(4), 1567-1578.
Piatkowski, D. P., Marshall, W. E., & Krizek, K. J. (2019). Carrots versus Sticks: Assessing Intervention Effectiveness and Implementation Challenges for Active Transport. *Journal of Planning Education and Research, 39*(1), 50-14.
Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., & Donovan, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science & Medicine, 56*(8), 1693-1703.
Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion, 12*(1), 38-48.
PTV. (2019). *Consultancy Services for the Development of a Sustainable Urban Mobility Plan for the Greater Urban Area of the City of Limassol: Final SUMP Report*. Karlsruhe, Germany: PTV.
Pucher, J. (2004). Public Transportation. In: S. Hanson, & G. Giuliano (Eds.), *The Geography of Urban Transportation* (Third edition ed.). Guilford Press.
Pucher, J., & Buehler, R. (2006). Why Canadians cycle more than Americans: a comparative analysis of bicycling trends and policies. *Transport Policy, 13*(3), 265-279.
Pucher, J., & Buehler, R. (2008). Making cycling irresistible: lessons from the Netherlands, Denmark and Germany. *Transport Reviews, 28*(4), 495-528.
Pucher, J., & Buehler, R. (2011). *Analysis of Bicycling Trends and Policies in Large North American cities: Lessons for New York.* University Transportation Research Center Region 2.
Pucher, J., & Buehler, R. (2017). Cycling towards a more sustainable transport future. *Transport Reviews, 37*(6), 689-694.
Pucher, J., & Buehler, R. (2010). Walking and Cycling for Healthy Cities. *Built Environment, 36*(4), 391-414.
Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine, 50*, S106-S125.
Rank, J., Folke, J., & Jespersen, P. H. (2001). Differences in cyclists and car drivers exposure to air pollution from traffic in the city of Copenhagen. *Science of the Total Environment, 279*(1), 131-136.
Reynolds, C. C. O., Harris, M. A., Teschke, K., Cripton, P. A., & Winters, M. (2009). The impact of transportation infrastructure on bicycling injuries and crashes: a review of the literature. *Environmental Health, 8*(47)

Ricci, M. (2015). Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Research in Transportation Business & Management, 15*, 28-38.

Rixey, R. (2013). Station-level forecasting of bikesharing ridership: Station Network Effects in Three US Systems. *Transportation Research Record: Journal of the Transportation Research Board,* (2387), 46-55.

Roads Task Force. (2013). *The vision and direction for London's streets and roads.* London, UK: Transport for London.

Robbins, N. B., & Heiberger, R. M. (2011). Plotting Likert and other rating scales. *Proceedings of the 2011 Joint Statistical Meeting,* 1058-1066.

Robinson, D. L. (2005). Safety in numbers in Australia: more walkers and bicyclists, safer walking and bicycling. *Health Promotion Journal of Australia, 16*(1), 47-51.

Rojas-Rueda, D., de Nazelle, A., Tainio, M., & Nieuwenhuijsen, M. J. (2011). The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *BMJ (Clinical Research Ed.), 343*, d4521.

Romanillos, G., Zaltz Austwick, M., Ettema, D., & De Kruijf, J. (2016). Big Data and Cycling. *Transport Reviews, 36*(1), 114-133.

Ronda, G., Van Assema, P., & Brug, J. (2001). Stages of change, psychological factors and awareness of physical activity levels in the Netherlands. *Health Promotion International, 16*(4), 305-314.

Ronis, D. L., Yates, J. F., & Kirscht, J. P. (1989). Attitudes, decisions, and habits as determinants of repeated behavior. *Attitude Structure and Function,* 213-239.

Ruddin, L. P. (2006). You can generalize stupid! Social scientists, Bent Flyvbjerg, and case study methodology. *Qualitative Inquiry, 12*(4), 797-812.

Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental Correlates of Walking and Cycling: Findings from the Transportation, Urban Design, and Planning Literatures. *Annals of Behavioral Medicine, 25*(2), 80-91.

SAGULPA (2018). *Estadísticas de Uso del Sistema de Bicicleta Pública de Las Palmas De Gran Canaria, Sítycleta. Del 9 de Abril al 22 de Julio de 2018*. Las Palmas de Gran Canaria, Spain: SAGULPA.

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. *The Lancet, 388*(10062), 2936-2947.

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health, 27*, 297-322.

Sarkar, A., Lathia, N., & Mascolo, C. (2015). Comparing cities' cycling patterns using online shared bicycle maps. *Transportation, 42*(4), 541-559.

Savan, B., Cohlmeyer, E., & Ledsham, T. (2017). Integrated strategies to accelerate the adoption of cycling for transportation. *Transportation Research Part F: Traffic Psychology and Behaviour, 46*, 236-249.

Schepers, P., Fishman, E., Beelen, R., Heinen, E., Wijnen, W., & Parkin, J. (2015). The mortality impact of bicycle paths and lanes related to physical activity, air pollution exposure and road safety. *Journal of Transport & Health, 2*(4), 460-473.

Schönauer, R., Stubenschrott, M., Huang, W., Rudloff, C., & Fellendorf, M. (2012). Modeling concepts for mixed traffic: Steps toward a microscopic simulation tool for shared space zones. *Transportation Research Record: Journal of the Transportation Research Board,* (2316), 114-121.

Schoner, J. E., Harrison, R. A., & Wang, X. (2012). *Sharing to grow: Economic activity associated with Nice Ride Bike share stations* [Master's Paper]. The University of Minnesota.

Schoner, J. E., Lindsey, G., & Levinson, D. (2016). Is bikesharing contagious? Modeling its effects on system membership and general population cycling. *Transportation Research Record: Journal of the Transportation Research Board,* (2587), 125-132.

Segui Pons, J. M., Mateu Llado, J., Ruiz Perez, M., & Martinez Reynes, M. R. (2016). Bike-sharing schemes and sustainable urban mobility. An analysis in the city of Palma (Mallorca, Balearic Islands). *Boletin De La Asociacion De Geografos Espanoles,* (71), 227-245.

Shaheen, S. A., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia: past, present, and future. *Transportation Research Record: Journal of the Transportation Research Board,* (2143), 159-167.

Shaheen, S. A., Martin, E. W., Chan, N. D., Cohen, A. P., & Pogodzinsk, M. (2012). *Public Bikesharing in North America: Early Operator and User Understanding* (MTI Report 11-19). Mineta Transportation Institute.

Shaheen, S. A., & Chan, N. (2016). Mobility and the sharing economy: Potential to facilitate the first-and last-mile public transit connections. *Built Environment, 42*(4), 573-588.

Shaheen, S. A., Cohen, A., & Martin, E. W. (2013). Public bikesharing in North America: early operator understanding and emerging trends. *Transportation Research Record: Journal of the Transportation Research Board,* (2387), 83-92.

Shaheen, S. A., & Guzman, S. (2011). *Worldwide bikesharing*. ACCESS Magazine.

Shaheen, S. A., Martin, E. W., Cohen, A. P., Chan, N. D., & Pogodzinski, M. (2014). *Public Bikesharing in North America During a Period of Rapid Expansion: Understanding Business Models, Industry Trends & User Impacts*. Mineta Transportation Institute.

Shaheen, S. A., Zhang, H., Martin, E. W., & Guzman, S. (2011). China's Hangzhou Public Bicycle: Understanding early adoption and behavioral response to bikesharing. *Transportation Research Record,* (2247), 33-41.

Shoup, D. C. (1997). The high cost of free parking. *Journal of Planning Education and Research, 17*(1), 3-20.

Soliz, A. (2021). Gender and cycling: reconsidering the links through a reconstructive approach to Mexican history. *Mobilities*, 1-22.

Southworth, M., & Ben-Joseph, E. (2013). *Streets and the Shaping of Towns and Cities*. Island Press.

Stylianou, K. (2019, March 28-29). *Cycling in Cyprus* [Conference presentation]. Public Works Department, Ministry of Transport, Communication & Works, Government of Cyprus. The 6Th Cyprus Sustainable Mobility and Intelligent Transport Conference, Nicosia, Cyprus.

Sucher, D. (2003). *City comforts: How to build an urban village* (Revised edition ed.). POD Printing.

Sun, Y., Wong, A. K., & Kamel, M. S. (2009). Classification of imbalanced data: A review. *International Journal of Pattern Recognition and Artificial Intelligence, 23*(04), 687-719.

Sundfør, H. B., & Fyhri, A. (2017). A push for public health: the effect of e-bikes on physical activity levels. *BMC Public Health, 17*(1), 809.

Superintendence of Public Health (2012). *A Healthy Weight for Life: A National Strategy for Malta.* Msida, Malta: Superintendence of Public Health, Health Promotion and Disease Prevention Directorate.

Tang, Y., Pan, H., & Shen, Q. (2011). *Bike-sharing systems in Beijing, Shanghai, and Hangzhou and their impact on travel behavior* [Conference presentation]. The 90th Annual Meeting of the Transportation Research Board, Washington, DC.

Thomas, B., & DeRobertis, M. (2013). The safety of urban cycle tracks: A review of the literature. *Accident Analysis & Prevention, 52*, 219-227.

Thomson, J. M. (1977). *Great Cities and Their Traffic*. Gollancz, Peregrine Edition.

Thornley, A. (1991). *Urban planning under Thatcherism: the Challenge of the Market*. Routledge.

TM (2016a). *National Transport Master Plan - 2025.* Floriana, Malta: Integrated Transport Strategy Directorate, Transport Malta.

TM (2016b). *National Transport Strategy - 2050.* Floriana, Malta: Integrated Transport Strategy Directorate, Transport Malta.

TM (2018). *National Cycling Strategy and Action Plan (draft).* Floriana, Malta: Transport Malta.

Tran, T. D., Ovtracht, N., & D'arcier, B. F. (2015). Modeling bike sharing system using built environment factors. *Procedia CIRP, 30*, 293-298.

Transport for London (2014). *London Cycling Design Standards*. London, UK: Transport for London.
Triandis, H. C. (1977). *Interpersonal behavior*. Brooks/Cole Pub. Co.
UN DESA (2018). *World Urbanization Prospects: The 2018 Revision, Key Facts.* United Nations, Department of Economic and Social Affairs, Population Division.
UN Habitat (2013). *Planning and Design for Sustainable Urban Mobility: Global Report on Human Settlements 2013*. Routledge.
van Acker, V., van Wee, B., & Witlox, F. (2010). When transport geography meets social psychology: toward a conceptual model of travel behaviour. *Transport Reviews, 30*(2), 219-240.
van den Noort, P. J. W. (2007). Promoting Cycling for Public Health. In: S. Marshall, & D. Banister (Eds.), *Land Use and Transport: European Research towards Integrated Policies*. Emerald Group Publishing Limited.
van Nes, R. (2002). *Design of multimodal transport networks: A hierarchical approach* [Doctoral dissertation]. Technische Universiteit Delft.
van Wee, B., & Handy, S. (2016). Key Research Themes on Urban Space, Scale, and Sustainable Urban Mobility. *International Journal of Sustainable Transportation, 10*(1), 18-24.
van Wee, B., Rietveld, P., & Meurs, H. (2006). Is average daily travel time expenditure constant? In search of explanations for an increase in average travel time. *Journal of Transport Geography, 14*(2), 109-122.
Vogel, P., Greiser, T., & Mattfeld, D. C. (2011). Understanding bike-sharing systems using data mining: Exploring activity patterns. *Procedia-Social and Behavioral Sciences, 20*, 514-523.
Vogel, M., Hamon, R., Lozenguez, G., Merchez, L., Abry, P., Barnier, J., Borgnat, P., Flandrin, P., Mallon, I., & Robardet, C. (2014). From bicycle sharing system movements to users: a typology of Vélo'v cyclists in Lyon based on large-scale behavioural dataset. *Journal of Transport Geography, 41*, 280-291.
Volker, J., & Handy, S. (2021). Economic impacts on local businesses of investments in bicycle and pedestrian infrastructure: a review of the evidence. *Transport Reviews,* 1-31.
Walker, I. (2007). Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis & Prevention, 39*(2), 417-425.
Walker, I., Garrard, I., & Jowitt, F. (2014). The influence of a bicycle commuter's appearance on drivers' overtaking proximities: an on-road test of bicyclist stereotypes, high-visibility clothing and safety aids in the United Kingdom. *Accident Analysis & Prevention, 64*, 69-77.
Wang, X., Lindsey, G., Schoner, J. E., & Harrison, A. (2016). Modeling bike share station activity: Effects of nearby businesses and jobs on trips to and from stations. *Journal of Urban Planning and Development, 142*(1), 04015001.
Wang, Y., Douglas, M. A., Hazen, B. T., & Dresner, M. (2018). Be green and clearly be seen: How consumer values and attitudes affect adoption of bicycle sharing. *Transportation Research Part F: Traffic Psychology and Behaviour, 58*, 730-742.
Warner, K. E. (2000). The need for, and value of, a multi-level approach to disease prevention: the case of tobacco control. In: B. D. Smedley, & S. L. Syme (Eds.), *Promoting Health: Intervention Strategies from Social and Behavioral Research* (pp. 417-449). National Academy Press.
Wefering, F., Rupprecht, S., Bührmann, S., & Böhler-Baedeker, S. (2014). *Guidelines: Developing and Implementing a Sustainable Urban Mobility Plan.* Brussels, Belgium: ELTIS.
Wheeler, D., Shaw, G., & Barr, S. (2013). *Statistical techniques in geographical analysis*. Routledge.
Willis, D. P., Manaugh, K., & El-Geneidy, A. M. (2014). Cycling Under Influence: Summarizing the Influence of Perceptions, Attitudes, Habits and Social Environments on Cycling for Transportation. *International Journal of Sustainable Transportation, 9* (8), 565-579.
Winter, B. (2013). *Linear models and linear mixed effects models in R with linguistic applications*. Cognitive and Information Sciences, University of California. https://arxiv.org/abs/1308.5499

Wood, J., Dykes, J., & Slingsby, A. (2010). Visualisation of origins, destinations and flows with OD maps. *The Cartographic Journal, 47*(2), 117-129.
Wood, J., Slingsby, A., & Dykes, J. (2011). Visualizing the dynamics of London's bicycle-hire scheme. *Cartographica: The International Journal for Geographic Information and Geovisualization, 46*(4), 239-251.
Woodcock, J., & Aldred, R. (2008). Cars, corporations, and commodities: Consequences for the social determinants of health. *Emerging Themes in Epidemiology, 5*(4), 4.
Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., & Goodman, A. (2014). Health effects of the London bicycle sharing system: health impact modelling study. *BMJ (Clinical Research Ed.), 348*, 11.
Xing, Y., Handy, S., & Mokhtarian, P. (2010). Factors associated with proportions and miles of bicycling for transportation and recreation in six small US cities. *Transportation Research Part D, 15*(2), 73-81.
Yin, J., Qian, L., & Singhapakdi, A. (2018). Sharing sustainability: How values and ethics matter in consumers' adoption of public bicycle-sharing scheme. *Journal of Business Ethics, 149*(2), 313-332.
Yin, R. (2014). *Case Study Research: Design and Methods* (5th ed.). SAGE Publications.
Young, S., & Caisey, V. (2010). Mind shift, mode shift: A lifestyle approach to reducing car ownership and use based on behavioural economics and social marketing. *Perspectives in Public Health, 130*(3), 136-142.
Zaltz Austwick, M., O'Brien, O., Strano, E., & Viana, M. (2013). The structure of spatial networks and communities in bicycle sharing systems. *PloS One, 8*(9), e74685.
Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D. (2019). A review of machine learning and IoT in smart transportation. *Future Internet, 11*(4), 94.
Zhang, Y., Thomas, T., Brussel, M., & Van Maarseveen, M. (2017). Exploring the impact of built environment factors on the use of public bikes at bike stations: case study in Zhongshan, China. *Journal of Transport Geography, 58*, 59-70.
Zhao, J., Deng, W., & Song, Y. (2014). Ridership and effectiveness of bikesharing: The effects of urban features and system characteristics on daily use and turnover rate of public bikes in China. *Transport Policy, 35*, 253-264.
Zipori, E., & Cohen, M. J. (2015). Anticipating post-automobility: design policies for fostering urban mobility transitions. *International Journal of Urban Sustainable Development, 7*(2), 147-165.

Annexes

Annex A – Cycling infrastructure and traffic calming designs

Cycling infrastructure comes in different forms, such as cycling paths, bicycle lanes and mixed traffic streets, which are suitable for different types of streets and traffic speeds. Cycling standards and guidelines from different countries propose increased separation and protection of cyclists on roads with higher speed limits, in order to promote road safety and reduce the risk of conflict (Copenhagenize Design Co., 2013; Transport for London, 2014; CROW, 2016). The risk of fatality for road users involved in a collision with a vehicle increases exponentially with increase in speed. Estimates of the order of magnitude range from an example from the USA showing a 3-fold difference between the 15% risk of serious injury or death for a pedestrian on a road limited to 20MPH (~30km/h) and a 45% risk on a road with a 30MPH (~50km/h) speed limit (LaPlante & McCann, 2008) to a European example showing a 5-fold fatality risk increase for road users when comparing accidents in a 30km/h zone when compared to a road with a 50km/h speed limit, from 2% to 10% (Mütze, 2018). Table A.1 presents general cycling infrastructure guidelines from the Netherlands, Copenhagen (Denmark) and London (UK).

Cycle paths or cycle tracks are separated from the main road by a raised curb, a strip of green infrastructure, a parking lane, or a combination of the above (Thomas & DeRobertis, 2013). Copenhagenize (2013) suggest bicycle paths are always placed on the passenger side of parked cars, to minimise the risk of 'dooring', where cyclists run the risk of getting hit by struck by a car door that is opened by a driver who didn't check for cyclists in the side mirror. A review of 23 studies of cycle tracks proved that cycle tracks reduces the risk of collisions and injuries, and that one-way cycle tracks are preferred over a two-way track on one side of the road (Thomas & DeRobertis, 2013).

Cycle lanes refer to non-segregated, on-carriageway lanes, often painted in a different colour (CROW, 2016; Transport for London, 2014). They can be on either side of the road, two-directional on one side of the road, or in some cases between traffic lanes (Pucher & Buehler, 2011). On one-way roads a contraflow bicycle lane can be created in order to promote short and direct cycling routes. Although cycle lanes can be effective on roads with reduced speeds, they only lessen the chance of fatal rear or sideswipe collisions. Segregated cycle paths are preferred, especially on high-speed roads, as they almost completely eliminate the risk of collision (Cushing et al., 2016).

Cycle paths and lanes have been proven to significantly contribute to cycling safety when compared to cycling on the street, but junctions and intersections remain dangerous points in the network, especially when not properly accommodating bicycle traffic (Cushing et al., 2016). Adapted intersection design can diminish these risks, for example by: a) routing the cycle path closer to the road, or colouring the lane, prior to arrival at the intersection, to improve cycling visibility; b) adding yield markings for cars when approaching the junction; and c) giving cyclists a head start by creating a demarcated waiting space at an intersection along the full width of the road, in front of the cars (CROW, 2016; Cushing et al., 2016).

Mixed traffic in streets is generally accepted in streets with a maximum speed limit of 30km/h and limited amounts of traffic (Copenhagenize Design Co., 2013; CROW, 2016; LaPlante & McCann, 2008). Low-traffic streets, such as side streets running parallel to main roads, residential streets, narrow city streets, or rural roads already exist and can be part of a low-investment solution to provide a less trafficked and continuous route from here to there (Sucher, 2003). Mixed streets generally include some form of traffic calming, and sometimes apply concepts such as ‘complete streets’ (LaPlante & McCann, 2008), ‘shared spaces’ (Schönauer et al., 2012) or ‘bicycle streets’ (CROW, 2016). Complete streets, a concept applied in the US and Canada in response to urban planning focused solely on the car, refer to road design that takes into account and plans for the needs of all road users: not only car drivers, but also cyclists, public transport users and pedestrians of all ages and abilities (LaPlante & McCann, 2008). Typical features to create a Complete Street are pedestrian walkways, crossings and refuge islands on centre median (including provision of ramps to ensure access for all), bicycle lanes and paths, public transport infrastructure and bus lanes, traffic calming measures, and landscaping and street furnishings (Litman, 2015). The shared space concept, which has been applied in the Netherlands, Germany and the UK, involves reducing travel speeds by introducing traffic calming measures and removing legally binding elements such as pedestrian crossings and separation between transport modes, so that use of space has to be negotiated between different road users (pedestrians, cyclists, car drivers), based on the premise that road users will pay more attention to the behaviour of others and therefore minimising potential conflicts (Schönauer et al., 2012). Bicycle streets, most commonly used in the Netherlands, are similar to mixed traffic streets, but prioritise cyclist movements, by subordinating car traffic to bicycle traffic, minimizing parking, and suppressing through-traffic (CROW, 2016). The concept of filtered permeability (Melia, 2012) takes this one step further, by actively prioritising cycling routes in the mobility network through the creation of faster, safer and more convenient routes for cyclists and restricting rights-of-way, speed and connections for private cars.

Traffic calming mechanisms, volume- or speed-controlling measures to block, reduce or slow traffic along a route (Ewing, 2001), include chokers (curb extensions added to a road to narrow it), as well as bulb-outs at junctions, chicanes (off-set chokers on both sides of the road), raised median or median strip, traffic islands (pelican crossings) and speed humps or tables (Ewing et al., 2005; Partington, 1999). Sharrows, painted symbols on the street, are sometimes used to indicate that cyclists can share the road with other vehicles, often in situations where there is no space for separated bicycle infrastructure (Reynolds et al., 2009). In order to ensure adherence to the 30km/h speed limit, a combination of traffic calming mechanisms and strict enforcement is required (Mütze, 2018).

Table A.1: Comparison of classifications of bicycle infrastructure in the Netherlands, Denmark and the UK (Copenhagenize Design Co., 2013; CROW, 2016; Transport for London, 2014)

Cycling infrastructure	**CROW Design Manual for Bicycle Traffic, the Netherlands (2016)**		**Copenhagenize Bicycle Planning Guide (2013)**	**Transport for London Cycling Design Standards (2014)**
	Description	*Traffic speeds & volumes*	*Traffic speeds*	*Street types (RTF classification**)*
Mixed traffic	Suitable for access roads with limited number of cyclists and motorised traffic; speed reducing measures; parking facilities discouraged	Residential roads max. 30 km/h; <2000 bicycles/24h; <5000 PCU*/24h	<30km/h	Integration with other vehicles on local streets, town squares and city places (plazas)
Cycle lanes	Non-segregated painted lanes, on residential streets or distributor roads up to 50km/h or rural roads up to 60km/h, although cycle paths would be preferred with speeds of 50-60 km/h; parking lane next to cycle lane is strongly discouraged	Residential/ Access roads 30-50km/h; >4000 PCU*/24h; Distributor road max. 50km/h; Rural road max. 60km/h	30-50km/h	Dedicated on-carriageway lanes: mandatory or light segregated lanes on connector roads, city boulevards, high streets and high roads (busy high streets: >20.000 PCU*/24h)
Cycle paths / Cycle tracks	Separated cycling infrastructure, ideally one-way on either side of the road	Distributor roads >50km/h	50-70km/h: curb separated >70km/h: fully separated	Full separation: cycle tracks or segregated lanes on arterial roads and high roads
Advisory cycle lanes	Cycle lanes without legal status; nowadays discouraged: either opt for fully fledged cycle lane or a fully mixed profile to avoid confusion and misunderstandings	-	-	Shared on-carriageway lanes: advisory cycle lanes or shared bus/cycle lanes on connector roads, high roads, high streets, city boulevards and city streets

* PCU: Passenger Car Unit
** Roads Task Force Report – Annexes (2013)

Annex B – Interview guides

VERSION 1: targeting representatives/experts of authorities (urban/transport planning)

Introduction:

- Introduction to BSS research as part of CIVITAS DESTINATIONS project on sustainable mobility in Southern European island cities
- What is the role and mission of your organisation?

General questions about planning, transport and mobility:

- How are transport and mobility embedded in the local urban planning process? How does the planning process work? Who are the relevant authorities and how do they relate to each other?
- Who are the main actors working on topics related to transport and mobility?
- What are the main challenges for transport and mobility in your city?
- What are the main policy objectives for transport and mobility on city (and regional/national) level, for now and the future?

Questions about cycling:

- Who are the main actors working on topics related to cycling and active transport in general?
- What type of cyclists can be found in your city (e.g. sports, recreational, commuters)? Is there a difference between local residents, foreign residents, tourists? Who is cycling and who isn't, and for what reasons? Have you observed any changes?
- What is the modal share of cycling in your city?
- What are the main challenges for cyclists in your city?
- Is cycling being promoted in your city? In what way(s)?
- How are cycling and ancillary facilities (infrastructure, lockers, racks, showers) considered in the urban planning and transport planning processes?
- What is the vision of your department/organization for cycling?
- Are you collecting any data on cycling (modal share, routes, accidents, etc.)?
- Are there any available documents / policy papers / maps that have been created locally about cycling?

Questions about bicycle sharing:

- What are your thoughts on the introduction of the bicycle sharing system?
- How successful is the bicycle sharing system? Who are the users?
- What are the positive/negative impacts of the bicycle sharing system?
- What are the impacts of the introduction of the bicycle sharing system on cycling in general?
- In what ways are bicycle sharing users different from other cyclists? Do they have different needs?

Closing questions:

- Any other interesting documents / data / organizations / people?
- Any further comments?

VERSION 2: targeting BSS operators

Introduction:

- Introduction to BSS research as part of CIVITAS DESTINATIONS project on sustainable mobility in Southern European island cities
- What is the role and mission of your organisation?

General questions about planning, transport and mobility:

- What are the main challenges for transport and mobility in your city?
- What are the main policy objectives for transport and mobility on city (and regional/national) level, for now and the future?

Questions about cycling:

- Who are the main actors working on topics related to cycling and active transport in general?
- What type of cyclists can be found in your city (e.g. sports, recreational, commuters)? Is there a difference between local residents, foreign residents, tourists? Who is cycling and who isn't, and for what reasons? Have you observed any changes?
- What are the main challenges for cyclists in your city?
- Is cycling being promoted in your city? In what way(s)?
- How are cycling and ancillary facilities (infrastructure, lockers, racks, showers) considered in the urban planning and transport planning processes?
- What is the vision of your organization for cycling?
- Are there any available documents / policy papers / maps that have been created locally about cycling?

Questions about bicycle sharing:

- When was the BSS introduced? How many stations, bicycles, users (active/inactive), trips?
- Who was the initiator of the BSS? The company or the government (e.g. through tender)?
- What is your business model for the BSS?
- Who are the users of the BSS?
- What is the purpose of the BSS?
- How do you decide on the location for stations?
- How successful is the BSS? How do you measure success?
- What are the positive/negative impacts of the bicycle sharing system?
- Have there been any unexpected results (stations more or less popular than anticipated, type of users utilizing bicycle sharing, etc.)?
- Have you experienced any struggles or conflict in operating the bicycle sharing system?
- What are your plans for the future for the BSS?
- What are the impacts of the introduction of the BSS on cycling in general?
- In what ways are bicycle sharing users different from other cyclists?
- What data are you collecting about the bicycle sharing system and the users?
- What are the main questions you have about the use / users of your bicycle sharing system?
- What methods do you use to stay in touch with your users (customer care service, newsletter, social media)? Would you be willing/interested to share a BSS user survey through your channels?

Closing questions:

- Any other interesting documents / data / organizations / people?
- Any further comments?

VERSION 3: targeting cycling groups/advocates, local NGOs

Introduction:

- Introduction to BSS research as part of CIVITAS DESTINATIONS project on sustainable mobility in Southern European island cities
- What is the role and mission of your organisation?

General questions about planning, transport and mobility:

- How are transport and mobility embedded in the local urban planning process? How does the planning process work? Who are the relevant authorities and how do they relate to each other?
- Who are the main actors working on topics related to transport and mobility?
- What are the main challenges for transport and mobility in your city?
- What are the main policy objectives for transport and mobility on city (and regional/national) level, for now and the future?

Questions about cycling:

- Who are the main actors working on topics related to cycling and active transport in general? Are you being consulted / are your views included in decision-making?
- What type of cyclists can be found in your city (e.g. sports, recreational, commuters)? Is there a difference between local residents, foreign residents, tourists? Who is cycling and who isn't, and for what reasons? Have you observed any changes?
- What is the modal share of cycling in your city?
- What are the main challenges for cyclists in your city?
- Is cycling being promoted in your city? In what way(s)?
- In what way(s) are you trying to advocate for cycling (rights, infrastructure, facilities)?
- Do you see any progress? In what way(s)?
- How are cycling and ancillary facilities (infrastructure, lockers, racks, showers) considered in the urban planning and transport planning processes?
- What is the vision of your department/organization for cycling?
- Are you collecting any data on cycling (modal share, routes, accidents, etc.)?
- Are there any available documents / policy papers / maps that have been created locally about cycling?

Questions about bicycle sharing:

- What are your thoughts on the introduction of the BSS?
- Who are the users of the BSS?
- How successful is the BSS?
- What are the positive/negative impacts of the BSS?
- What are the impacts of the introduction of the BSS on cycling in general?
- In what ways are bicycle sharing users different from other cyclists?

Closing questions:

- Any other interesting documents / data / organizations / people?
- Any further comments?

Annex C – BSS user survey

Dear [Nextbike/Sítycleta] user,

This survey forms part of a PhD research at the University of Malta about the use of Bicycle Sharing Systems [such as Nextbike/Sítycleta] in Southern European island cities.

We would like to ask you, as a user of [Nextbike/Sítycleta] in [Limassol/LPGC/Malta], to participate in this survey. Through the survey we would like to get a better understanding of your use of the system, your mobility and cycling habits, your experience with using [Nextbike/Sítycleta], and which factors encourage or discourage you from cycling and using the shared bicycles.

Filling the survey will take around 10 minutes. You will not be identifiable from the information provided. Only anonymised and aggregated results of the survey will be published.

We are offering a reward for participation in the survey. If you submit your email address at the end of the survey, you will be entered in a prize draw to win a 1-year free membership of [Nextbike/Sítycleta], which can be redeemed at any point during the next year. If you choose to participate in the prize draw, your email address will only be accessible to the researcher in order to draw the prize winner. This information will be deleted after the prize draw and will not be used for any other purpose.

If you have any questions or want to be kept informed about the research outputs, you can contact the researcher on the email address provided below.

Thank you for your participation, and happy cycling!

Suzanne Maas
PhD researcher, University of Malta
suzanne.maas@um.edu.mt

This research is being conducted as part of the EU Horizon 2020 project CIVITAS DESTINATONS: Sustainable Mobility in Tourism Destinations, in six Southern European island cities, including [Limassol, Cyprus / Las Palmas de Gran Canaria, Spain / Valletta, Malta].

For more information, visit http://civitas.eu/destinations

Part 1: Demographic and socio-economic characteristics

1. Gender:
   - ☐ Female
   - ☐ Male
   - ☐ Other

2. Age: ___

3. Nationality: ________________________

4. Highest completed education (*select one*):
   - ☐ Primary school
   - ☐ Secondary school
   - ☐ Undergraduate degree (college, bachelor degree)
   - ☐ Postgraduate degree (Master’s degree, PhD)
   - ☐ None

5. Main occupation (*select one*):
   - ☐ Full-time employment
   - ☐ Part-time employment
   - ☐ Student
   - ☐ Housewife/husband
   - ☐ Pensioner
   - ☐ Unemployed
   - ☐ Other, please specify: _______________

6. Household situation (*select one*):
   - ☐ 1-person household
   - ☐ 2-person household
   - ☐ 3+ household
   - ☐ Other, please specify: _______________

7. Gross annual income (*select one*):
   - ☐ Less than €10.000/year
   - ☐ Between €10.000 and €20.000/year
   - ☐ Between €20.000 and €30.000/year
   - ☐ Between €30.000 and €40.000/year
   - ☐ Between €40.000 and €50.000/year
   - ☐ More than €50.000/year

8. Are you a resident or visitor of [city/district]? *(select one)*
   - ☐ Permanent resident (for a period over 1 year)
   - ☐ Temporary resident (for a period of less than 1 year)
   - ☐ Visitor (for work/education)
   - ☐ Visitor (for leisure/tourism)

9. Do you have a valid car driving licence? YES / NO
10. Do you own a car? YES / NO
11. Do you own a motorcycle / scooter? YES / NO
12. Do you own a bicycle? YES / NO

Part 2: Mobility practices and travel habits

13. On average, how often do you use the following modes of transport? *(select one answer for each mode of transport)*

	Daily	**Often** a few days per week	**Sometimes** about once every 2 weeks	**Rarely** Less than once a month	**Never**
[*nextbike/Sítycleta*]					
Walking (more than 5 minutes)					
Private bicycle					
Motorcycle / scooter					
Public transport (bus/ferry)					
Private car (driver)					
Private car (passenger)					

14. How would you describe your cycling skill level?
   - ☐ Not experienced
   - ☐ Moderately experienced
   - ☐ Experienced

15. Do you usually wear a helmet when cycling?
   - ☐ Yes, always
   - ☐ Sometimes
   - ☐ No, never

16. When did you start using [*nextbike/Sítycleta*]?
   - ☐ Less than 1 month ago
   - ☐ Between 1 and 3 months ago
   - ☐ Between 3 months and 1 year ago
   - ☐ Between 1 and 2 years ago
   - ☐ More than 2 years ago
   - ☐ Not registered

17. What type of membership do you have? *(select one)*

Limassol:

- ☐ Pay-as-you-go (hourly rate, up to €8/day)
- ☐ Yearly membership (€10/month)
- ☐ Nextbike membership in another city/country
- ☐ No membership (renting a bicycle with someone who is a member)

LPGC:

- ☐ Pay-as-you-go (30 minute rate)
- ☐ Weekly membership (€15/week)
- ☐ Monthly membership (€20/month)
- ☐ Annual membership (€40/year)
- ☐ Annual family membership – 2 persons (€72/year)
- ☐ Annual family membership – 3 persons (€102/year)
- ☐ Nextbike membership in another city/country
- ☐ *No membership (renting a bicycle with someone who is a member)*

Malta:

- ☐ Pay-as-you-go (30 minute rate)
- ☐ Weekly membership (€15/week)
- ☐ Monthly membership (€25/month)
- ☐ Quarterly membership (€35/quarter)
- ☐ Annual membership (€80/year)
- ☐ Nextbike membership in another city/country
- ☐ No membership (renting a bicycle with someone who is a member)

18. How long does it take to walk to the nearest [nextbike/Sítycleta] station from your residence (home/hotel)? *(select one)*
    - ☐ Less than 1 minute
    - ☐ 1-5 minutes
    - ☐ 5-10 minutes
    - ☐ 10-15 minutes
    - ☐ 15-30 minutes
    - ☐ More than 30 minutes

19. How long does it take to walk to the nearest Nextbike station from your most frequent destination (work, school, place of leisure)? *(select one)*
    - ☐ Less than 1 minute
    - ☐ 1-5 minutes
    - ☐ 5-10 minutes
    - ☐ 10-15 minutes
    - ☐ 15-30 minutes
    - ☐ More than 30 minutes

20. When was your most recent trip? *(select one)*
    - ☐ Today
    - ☐ This week
    - ☐ Last week
    - ☐ Last month
    - ☐ Last year
    - ☐ More than 1 year ago

21. On average, how often do you use [nextbike/Sítycleta] for these purposes? *(select one answer per trip purpose)*

	Daily	**Often** a few days per week	**Sometimes** About once every 2 weeks	**Rarely** Less than once a month	**Never**
To commute to/from work/school					
For business travel					
For shopping or errands					
To go out for food or drinks					
To visit a touristic site					
For leisure / fun					
For exercise					
To visit friends or family					

22. Do you use [nextbike/Sítycleta] mostly on weekdays, weekends, or both?
    - ☐ mostly weekdays
    - ☐ mostly weekends
    - ☐ both

23. What is your most frequent trip (*insert name of nextbike/Sítycleta station, street name, or name of destination*)? From _________________ to ________________

24. How long does your most frequent trip take?
    - ☐ less than 10 minutes
    - ☐ between 10 and 20 minutes
    - ☐ between 20 and 30 minutes
    - ☐ between 30 and 60 minutes
    - ☐ between 1 and 3 hours
    - ☐ longer than 3 hours

25. Thinking about your most frequent trip, how did you make this trip before using [nextbike/Sítycleta]? *(select one)*
    - ☐ Walking
    - ☐ Cycling (private bicycle)
    - ☐ Motorcycle/scooter
    - ☐ Public transport (bus/ferry)
    - ☐ Car (driver)
    - ☐ Car (passenger)
    - ☐ Taxi
    - ☐ I didn’t make this trip before (new trip)

26. In which environment do you most frequently cycle? *(select one)*
    - ☐ On a separated bicycle path
    - ☐ On a bicycle lane on the road
    - ☐ On the road (no bicycle infrastructure)
    - ☐ On the pavement or promenade (pedestrian space)

27. Do you use [nextbike/Sítycleta] together with other modes of transport to complete your journeys *(select at least one):*
    - ☐ No
    - ☐ Yes, in combination with walking
    - ☐ Yes, in combination with using public transport
    - ☐ Yes, in combination with driving a car
    - ☐ Other, please specify: __________

Part 3: Attitudes & perceptions

28. What motivates you to use [nextbike/Sítycleta]?

	A lot	A little	Neutral	Not really	Not at all
Saving money (spending less on transport)					
Convenience (easy to get around, no worry about parking, possibility to make one-way trips)					
Saving time (trips are faster, more direct)					
Health benefits (physical exercise and mental well-being)					
Environmentally friendly (no air pollution and carbon emissions)					
Fun (enjoyment and exercise)					

29. How satisfied are you with these aspects of [*nextbike/Sítycleta*]? *(select one answer per aspect)*

	Very satisfied	Slightly satisfied	Neither satisfied nor unsatisfied	Slightly unsatisfied	Very unsatisfied
Sign-up process to become a user (registration)					
The price					
The location of stations					
The availability of bicycles					
Renting and returning a bicycle					
The comfort of the bicycles					
The branding and marketing of the BSS					
Opening hours (only for Sítycleta, which is not open 24h)					

30. Would you choose an electric bicycle over a standard bicycle?
- ☐ No, I prefer using the standard bicycle
- ☐ Yes, but only if the price was the same
- ☐ Yes, also if the price would be double the amount of a standard bicycle

31. How safe do you feel cycling in these environments?

	Very safe	Moderately safe	Neither safe nor unsafe	Moderately unsafe	Very unsafe
On a separated bicycle path (away from the road)					
On a bicycle lane on the road (painted on the road)					
On the road (without bicycle lane)					
On the pavement or promenade (where pedestrians are walking)					

32. What is your opinion on the following statements?

	Completely agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Completely disagree
"I like cycling"					
"Cycling is a convenient way to get to work or school"					
"I need a car to perform my daily tasks"					
"I cycle more often since using [*nextbike/Sitycleta*]"					
"I don't like to cycle when it is rainy and windy"					
"I like to cycle when it is hot and sunny"					
"I worry about my appearance after cycling"					
"Cycling uphill is difficult"					
"My friends and family support my cycling behaviour"					
"Busy roads are a barrier to cycling"					
"Other road users respect cyclists"					
"Cycling is an accepted form of transport in [*Limassol/Malta/LPGC*]"					

33. To what extent would these factors encourage you to cycle more? *(Likert scale)*

	Completely agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Completely disagree
More cycle lanes/paths					
Roads with lower vehicle speeds					
Greater cycling safety awareness					
More information about safe and direct routes					
Seeing more people cycling					
Friends or family-members who cycle					
[nextbike/Sítycleta] stations closer to home					
[nextbike/Sítycleta] stations closer to work / school					
Better integration with public transport					
Making driving a car more expensive or difficult					

34. To what extent do these factors discourage you from cycling, or cycling more? *(Likert scale)*

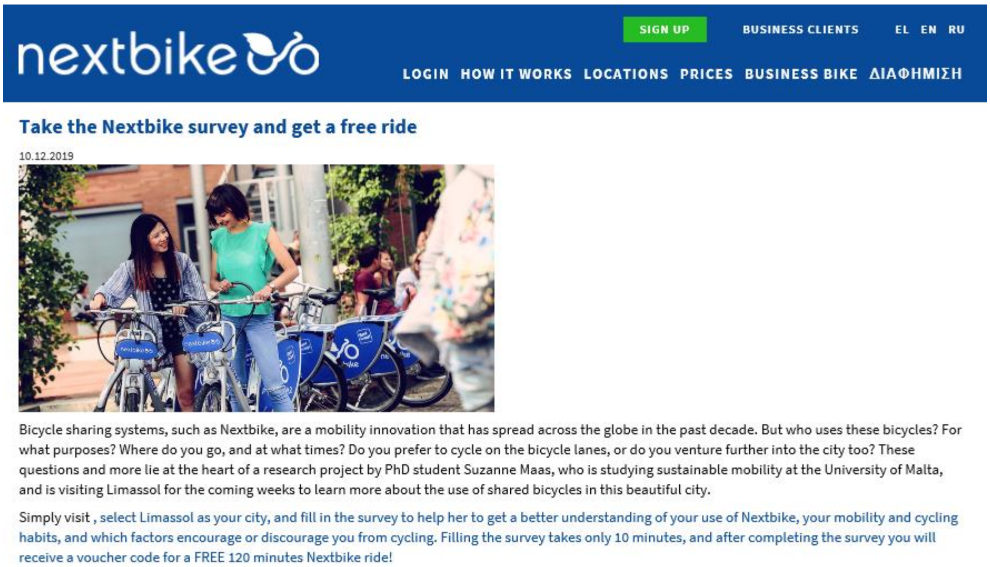
	Completely agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Completely disagree
Driving a car is more convenient					
Public transport is more convenient					
Concerned for my safety in traffic					
Using [nextbike/Sítycleta] is too costly					
Not seeing many other cyclists					
No friends or family-members who cycle					
[nextbike/Sítycleta] stations not close enough to home					
[nextbike/Sítycleta] stations not close enough to work or school					
Lack of integration with public transport					

Thank you for your participation!

Annex D – Survey data collection

Sponsored social media content by Nextbike Cyprus:

News item shared on Nextbike Cyprus website and in app:



Take the Nextbike survey and get a free ride

10.12.2019

Bicycle sharing systems, such as Nextbike, are a mobility innovation that has spread across the globe in the past decade. But who uses these bicycles? For what purposes? Where do you go, and at what times? Do you prefer to cycle on the bicycle lanes, or do you venture further into the city too? These questions and more lie at the heart of a research project by PhD student Suzanne Maas, who is studying sustainable mobility at the University of Malta, and is visiting Limassol for the coming weeks to learn more about the use of shared bicycles in this beautiful city.

Simply visit , select Limassol as your city, and fill in the survey to help her to get a better understanding of your use of Nextbike, your mobility and cycling habits, and which factors encourage or discourage you from cycling. Filling the survey takes only 10 minutes, and after completing the survey you will receive a voucher code for a FREE 120 minutes Nextbike ride!

Newsletter shared by Sítycleta:

Encuesta de usuarios

¿Alguna vez has usado Sítycleta en Las Palmas?

Participa en la encuesta de usuarios: www.survey.bike y llévate un kit de Sitycleta compuesto por camiseta y bidón de agua

Los servicios de préstamo de bicicletas públicas, como Sítycleta, son una innovación de movilidad que se ha extendido por todo el mundo en la última década. ¿Pero quién usa estas bicicletas? ¿Para qué fines? ¿A dónde vas, y en qué horarios? ¿Qué tan importante es la provisión de carriles bici para tí? Estas preguntas y más se encuentran en un proyecto de investigación realizado por doctorandos, que estudia movilidad sostenible en la Universidad de Malta, y visita Las Palmas durante las próximas semanas para obtener más información sobre el uso de bicicletas públicas en esta hermosa ciudad.

Cuéntanos sobre lo que te hace pedalear en la encuesta de usuarios: www.survey.bike (seleccione Las Palmas como su ciudad). Solo te llevará de 5 a 10 minutos y luego obtendrás un kit de Sítycleta GRATIS.

¡Gracias por tu participación, y disfruta pedaleando!

Comienza la encuesta

Posts on social media about the wristband with link to the survey by Sítycleta:

Newsletter shared by Nextbike Malta:

nextbike
original bike sharing

Newsletter - May 2020

Boost your Immunity

The air is cleaner, social distancing is more important and your health and wellbeing is a top priority. Never was it a better time to ride Nextbike

See More

Have you met Suzanne?

Passionate about bicycle sharing, Suzanne is reading for a PhD at the University of Malta and needs help from you Nextbikers!
Take the bike-share survey and in return get a FREE 30-minute voucher for nextbike!

Take the Survey

Social media post shared by Nextbike Malta:

Annex E - Survey numerical codes

Question	Responses	Codes
Gender		
	Male	1
	Female	2
	Other	0
Age		*N/A*
Nationality		
	American	1
	Argentinian/Italian	2
	Austrian	3
	Bolivian	4
	British	5
	Bulgarian	6
	Colombian	7
	Cuban	8
	Dutch	9
	Ecuadorian	10
	Finnish	11
	French	12
	German	13
	Hungarian	14
	Italian	15
	Kazakh	16
	Moroccan	17
	Norwegian	18
	Peruvian	19
	Polish	20
	Portuguese	21
	Russian	22
	Spanish	23
	Spanish/French	24
	Swedish	25
	Swiss	26
	Venezuelan	27
	Australian	28
	Brazilian	29
	Croatian	30
	Cypriot	31
	Cypriot/British	32
	Cypriot/Russian	33
	Danish	34
	Estonian	35
	Greek	36
	Israeli	37
	Lithuanian	38

	Romanian	39
	Serbian	40
	Syrian	41
	Ukrainian	42
	Indian	43
	Irish	44
	Japanese	45
	Maltese	46
	Omani	47
	South African	48
	Belgian	49
	Czech	50
	Other	51
Native (LIM = 31, LPA = 23, MAL = 46)		
	Native	1
	Non-native	0
Highest completed education		
	Primary school	1
	Secondary school	2
	Undergraduate degree	3
	Postgraduate degree	4
	None	0
Main occupation		
	Full-time employment	1
	Part-time employment	2
	Student	3
	Housewife/husband	4
	Pensioner	5
	Unemployed	6
	Self-employed / Freelancer	1
	Other	0
Household size		
	1 person household	1
	2 person household	2
	3+ person household	3
	Other	0
Gross annual income		
	Less than €10.000/year	1
	Between €10.000 and €20.000/year	2
	Between €20.000 and €30.000/year	3
	Between €30.000 and €40.000/year	4
	Between €40.000 and €50.000/year	5
	More than €50.000/year	6
Are you a resident or visitor of [city/district]?		
	Permanent resident (for a period of +1 year)	1
	Temporary resident (for a period less than 1 year)	2
	Visitor (for work/education)	3
	Visitor (for leisure/tourism)	4

Do you have a valid car driving licence?		
	Yes	1
	No	0
Do you own a car?		
	Yes	1
	No	0
Do you own a motorcycle / scooter?		
	Yes	1
	No	0
Do you own a bicycle?		
	Yes	1
	No	0
On average, how often do you use the following modes of transport? BSS / Walking / Private bicycle / Motorcycle / Public transport / Car (driver) / Car (passenger) / Taxi		
	Never	1
	Rarely (less than once a month)	2
	Sometimes (about once every 2 weeks)	3
	Often (a few days per week)	4
	Daily	5
How would you describe your cycling skill level?		
	Not experienced	1
	Moderately experienced	2
	Experienced	3
Do you usually wear a helmet when cycling?		
	No, never	1
	Sometimes	2
	Yes, always	3
When did you start using [nextbike/Sítycleta]?		
	Less than 1 month ago	1
	Between 1 and 3 months ago	2
	Between 3 months and 1 year ago	3
	Between 1 and 2 years ago	4
	More than 2 years ago	5
	Not registered	0
What type of membership do you have?		
	No membership (renting a bicycle with someone who is a member)	0
	Nextbike membership in another city/country	1
	LPA - Pay-as-you-go (30 minute rate)	2
	LPA - Weekly membership (€15/week)	3
	LPA - Monthly membership (€20/month)	4
	LPA - Annual membership (€40/year)	5
	LPA - Annual family membership – 2 persons (€72/year)	6
	LPA - Annual family membership – 3 persons (€102/year)	7
	LIM - Pay-as-you-go (hourly rate, up to €8/day)	8
	LIM - Yearly membership (€10/month)	9
	MAL - Pay-as-you-go (30 minute rate)	10
	MAL - Weekly membership (€15/week)	11

	MAL - Monthly membership (€25/month)	12
	MAL - Quarterly membership (€35/quarter)	13
	MAL - Annual membership (€80/year)	14
Membership (*recoded*)		
	No membership	0
	Membership in another country	1
	Pay-as-you-go	2
	Subscription membership	3
When was your most recent trip?		
	Today	1
	This week	2
	Last week	3
	Last month	4
	Last year	5
	More than 1 year ago	6
How long does it take to walk to the nearest [nextbike/Sítycleta] station from your residence (home/hotel)?		
	Less than 1 minute	1
	between 1 and 5 minutes	2
	between 5 and 10 minutes	3
	between 10 and 15 minutes	4
	between 15 and 30 minutes	5
	More than 30 minutes	6
How long does it take to walk to the nearest Nextbike station from your most frequent destination (work, school, place of leisure)?		
	Less than 1 minute	1
	between 1 and 5 minutes	2
	between 5 and 10 minutes	3
	between 10 and 15 minutes	4
	between 15 and 30 minutes	5
	More than 30 minutes	6
On average, how often do you use [nextbike/Sítycleta] for these purposes?		
	Never	1
	Rarely (less than once a month)	2
	Sometimes (about once every 2 weeks)	3
	Often (a few days per week)	4
	Daily	5
Do you use [nextbike/Sítycleta] mostly on weekdays, weekends, or both?		
	mostly on weekdays	1
	mostly on weekends	2
	both	3
What is your most frequent trip (insert name of nextbike/Sítycleta station, street name, or name of destination)?		*N/A*
How long does your most frequent trip take?		
	less than 10 minutes	1
	between 10 and 20 minutes	2
	between 20 and 30 minutes	3
	between 30 and 60 minutes	4

	between 1 and 3 hours	5
	more than 3 hours	6
Thinking about your most frequent trip, how did you make this trip before using [nextbike/Sítycleta]?		
	Walking	1
	Cycling (private bicycle)	2
	Motorcycle/scooter	3
	Public transport (bus)	4
	Car (driver)	5
	Car (passenger)	6
	Taxi	7
	I didn't make this trip before (new trip)	8
In which environment do you most frequently cycle?		
	On a separated bicycle path	1
	On a bicycle lane on the road	2
	On the road (no bicycle infrastructure)	3
	On the pavement or promenade (pedestrian space)	4
Do you use [nextbike/Sítycleta] together with other modes of transport to complete your journeys (> split into separate columns: Yes, with walking, etc.)		
	No	0
	Yes	1
What motivates you to use [nextbike/Sítycleta]? ***Several statements to score***		
	A lot	5
	A little	4
	Neutral	3
	Not really	2
	Not at all	1
How satisfied are you with these aspects of [nextbike/Sítycleta]? ***Several statements to score***		
	Very satisfied	5
	Slightly satisfied	4
	Neither satisfied nor unsatisfied	3
	Slightly unsatisfied	2
	Very unsatisfied	1
Would you choose an electric bicycle over a standard bicycle?		
	No, I prefer using the standard bicycle	1
	Yes, but only if the price was the same	2
	Yes, also if the price would be double the amount of a standard bicycle	3
How safe do you feel cycling in these environments? ***Several questions to score***		
	Very safe	5
	Moderately safe	4
	Neither safe nor unsafe	3
	Moderately unsafe	2
	Very unsafe	1
What is your opinion on the following statements? ***Several statements to score***		
	Completely agree	5

	Slightly agree	4
	Neither agree nor disagree	3
	Slightly disagree	2
	Completely disagree	1
To what extent would these factors encourage you to cycle more? *Several statements to score*		
	Completely agree	5
	Slightly agree	4
	Neither agree nor disagree	3
	Slightly disagree	2
	Completely disagree	1
To what extent do these factors discourage you from cycling, or cycling more? *Several statements to score*		
	Completely agree	5
	Slightly agree	4
	Neither agree nor disagree	3
	Slightly disagree	2
	Completely disagree	1

Annex F - Correlation matrices

Table F.1: Limassol dataset correlation matrix

	Use_bikeshare_bin	Income	Own_motor	Use_bicycle	Use_motor	Use_PT	Use_cardriver	Use_taxi	Dist_home	Dist_dest	Multimod_walk	Mot_money	Mot_conv	Sat_regist	Sat_price	Safe_road	Cycle_more	Friends	Cycle_accept
Use_bikeshare_bin	1.00	-0.08	0.22	0.29	0.46	0.26	-0.12	0.33	-0.21	-0.28	0.20	0.19	0.19	0.19	0.14	0.27	0.40	0.35	0.26
Income	-0.08	1.00	-0.07	-0.03	-0.25	-0.22	-0.02	-0.06	-0.14	0.06	0.12	-0.15	0.08	0.02	0.04	-0.02	-0.13	0.07	-0.07
Own_motor	0.22	-0.07	1.00	0.27	0.57	0.13	0.06	0.23	-0.02	-0.10	0.05	0.20	0.08	-0.10	0.02	0.10	0.07	-0.10	0.04
Use_bicycle	0.29	-0.03	0.27	1.00	0.60	0.46	-0.17	0.46	-0.08	-0.08	0.17	0.34	0.27	-0.07	0.07	0.39	0.11	0.25	0.32
Use_motor	0.46	-0.25	0.57	0.60	1.00	0.47	0.00	0.60	-0.01	-0.16	0.14	0.37	0.19	0.10	0.16	0.39	0.21	0.10	0.27
Use_PT	0.26	-0.22	0.13	0.46	0.47	1.00	-0.55	0.61	-0.22	-0.11	0.31	0.39	0.24	-0.05	0.00	0.36	0.12	0.08	0.33
Use_cardriver	-0.12	-0.02	0.06	-0.17	0.00	-0.55	1.00	-0.25	0.27	0.17	-0.19	-0.16	-0.09	0.11	0.06	-0.24	-0.01	-0.01	-0.18
Use_taxi	0.33	-0.06	0.23	0.46	0.60	0.61	-0.25	1.00	-0.22	-0.24	0.36	0.35	0.20	-0.07	-0.05	0.48	0.11	0.11	0.28
Dist_home	-0.21	-0.14	-0.02	-0.08	-0.01	-0.22	0.27	-0.22	1.00	0.48	-0.18	-0.12	-0.20	-0.03	-0.02	-0.10	-0.13	-0.11	-0.23
Dist_dest	-0.28	0.06	-0.10	-0.08	-0.16	-0.11	0.17	-0.24	0.48	1.00	-0.18	-0.12	-0.16	-0.08	-0.06	-0.18	-0.23	0.01	-0.12
Multimod_walk	0.20	0.12	0.05	0.17	0.14	0.31	-0.19	0.36	-0.18	-0.18	1.00	0.15	0.21	-0.01	0.05	0.14	0.10	0.03	0.26
Mot_money	0.19	-0.15	0.20	0.34	0.37	0.39	-0.16	0.35	-0.12	-0.12	0.15	1.00	0.67	0.01	0.18	0.33	0.26	0.12	0.44
Mot_conv	0.19	0.08	0.08	0.27	0.19	0.24	-0.09	0.20	-0.20	-0.16	0.21	0.67	1.00	0.15	0.26	0.17	0.20	0.11	0.38
Sat_regist	0.19	0.02	-0.10	-0.07	0.10	-0.05	0.11	-0.07	-0.03	-0.08	-0.01	0.01	0.15	1.00	0.54	-0.03	0.36	0.20	0.04
Sat_price	0.14	0.04	0.02	0.07	0.16	0.00	0.06	-0.05	-0.02	-0.06	0.05	0.18	0.26	0.54	1.00	0.11	0.29	0.17	0.13
Safe_road	0.27	-0.02	0.10	0.39	0.39	0.36	-0.24	0.48	-0.10	-0.18	0.14	0.33	0.17	-0.03	0.11	1.00	0.15	0.24	0.41
Cycle_more	0.40	-0.13	0.07	0.11	0.21	0.12	-0.01	0.11	-0.13	-0.23	0.10	0.26	0.20	0.36	0.29	0.15	1.00	0.44	0.21
Friends	0.35	0.07	-0.10	0.25	0.10	0.08	-0.01	0.11	-0.11	0.01	0.03	0.12	0.11	0.20	0.17	0.24	0.44	1.00	0.32
Cycle_accept	0.26	-0.07	0.04	0.32	0.27	0.33	-0.18	0.28	-0.23	-0.12	0.26	0.44	0.38	0.04	0.13	0.41	0.21	0.32	1.00

Table F.2: Las Palmas de Gran Canaria dataset correlation matrix

	Use_bikeshare_bin	Residency	Own_car	Use_walking	Use_motor	Use_PT	Use_cardriver	Use_taxi	Skill	Dist_home	Dist_dest	Environment	Multimod_walk	Mot_money	Mot_conv	Mot_time	Mot_health	Mot_env	Sat_regist	Sat_price	Sat_loc	Sat_avail	Sat_rent	Sat_comf	Sat_brand	Sat_new	Electric	Safe_path	Safe_lane	Safe_road	Safe_pave	Like_cycling	Conv_cycling	Need_car	Cycle_more	Cycle_rain	Appear	Friends	Road_users	Enc_paths	Enc_speed	Enc_aware	Enc_carprice	Disc_carconv	Disc_PTconv	Disc_safe	Disc_cost
Use_bikeshare_bin	1.00	-0.11	-0.12	0.15	0.04	0.13	-0.15	0.14	0.16	-0.16	-0.25	-0.18	0.18	0.27	0.26	0.32	0.11	0.15	0.21	0.40	0.11	0.16	0.14	0.14	0.16	0.27	-0.12	0.18	0.22	0.13	-0.03	0.14	0.22	-0.22	0.47	-0.08	0.11	0.21	0.14	0.16	0.13	0.12	0.15	-0.09	-0.07	-0.02	-0.18
Residency	-0.11	1.00	-0.02	-0.03	0.08	-0.02	-0.05	-0.06	0.04	0.01	-0.01	0.05	0.00	0.00	0.04	-0.05	0.00	0.02	0.00	-0.02	0.04	0.05	0.06	0.01	0.06	-0.05	0.01	0.05	0.01	0.07	0.05	0.02	0.03	0.04	-0.03	0.00	-0.09	-0.07	-0.02	0.07	0.00	-0.12	-0.04	0.09	0.01	-0.05	0.03
Own_car	-0.12	-0.02	1.00	-0.11	-0.02	-0.32	0.71	-0.10	0.08	0.02	-0.03	0.13	-0.01	-0.13	0.05	-0.09	-0.02	-0.05	-0.06	-0.09	-0.01	-0.07	0.01	-0.01	-0.08	-0.03	0.03	-0.07	0.03	0.07	0.03	0.01	-0.06	0.29	-0.06	0.10	0.12	-0.03	0.00	-0.07	-0.07	0.02	-0.04	0.12	0.06	0.07	0.06
Use_walking	0.15	-0.03	-0.11	1.00	-0.06	0.17	-0.14	0.02	0.05	-0.11	-0.11	-0.03	0.15	0.08	0.09	0.07	0.14	0.15	0.12	0.17	0.11	0.13	0.09	0.10	0.07	0.10	0.02	0.13	0.06	-0.08	-0.08	0.12	0.10	-0.14	0.04	0.00	-0.01	0.06	-0.01	0.13	0.09	0.14	-0.02	-0.06	0.01	0.01	-0.08
Use_motor	0.04	0.08	-0.02	-0.06	1.00	0.01	0.05	0.28	0.04	0.06	0.01	0.00	-0.01	0.02	0.02	0.00	-0.14	-0.18	0.02	0.02	0.03	-0.01	0.03	0.02	0.04	0.01	0.06	-0.03	0.07	0.19	0.13	-0.05	-0.05	0.16	-0.01	0.08	0.12	-0.05	0.17	-0.04	0.05	-0.06	0.07	0.18	0.06	0.01	0.12
Use_PT	0.13	-0.02	-0.32	0.17	0.01	1.00	-0.34	0.20	-0.12	0.01	-0.01	-0.07	0.09	0.14	0.00	0.05	0.12	0.16	0.05	0.04	0.04	0.06	0.08	0.04	0.12	0.01	-0.04	0.08	0.08	0.07	0.02	0.06	0.08	-0.24	0.01	-0.08	-0.04	0.08	0.07	0.14	0.16	0.03	0.13	-0.07	0.23	0.08	0.03
Use_cardriver	-0.15	-0.05	0.71	-0.14	0.05	-0.34	1.00	-0.03	0.02	0.15	0.12	0.17	-0.09	-0.09	-0.01	-0.13	-0.10	-0.12	-0.09	-0.11	-0.03	-0.06	-0.02	-0.03	-0.10	-0.05	0.06	-0.14	-0.03	0.03	0.05	-0.07	-0.18	0.48	-0.09	0.13	0.11	-0.10	0.01	-0.15	-0.13	-0.04	-0.08	0.29	0.08	0.05	0.12
Use_taxi	0.14	-0.06	-0.10	0.02	0.28	0.20	-0.03	1.00	-0.07	-0.13	-0.12	-0.09	-0.03	0.09	0.04	0.06	-0.04	-0.07	0.10	0.10	0.08	0.03	0.08	0.07	0.12	0.12	-0.04	-0.05	0.08	0.13	0.07	-0.05	0.00	0.06	0.11	0.04	0.16	0.07	0.12	-0.06	0.06	-0.02	0.07	0.08	0.06	0.00	0.01
Skill	0.16	0.04	0.08	0.05	0.04	-0.12	0.02	-0.07	1.00	-0.11	-0.11	-0.02	0.04	0.02	0.14	0.19	0.13	0.12	0.03	0.04	0.09	0.05	0.08	0.11	-0.01	0.09	-0.01	0.15	0.18	0.17	0.07	0.31	0.17	-0.04	0.11	-0.13	-0.06	0.12	0.01	0.10	0.06	0.07	0.08	-0.09	-0.03	-0.09	-0.03
Dist_home	-0.16	0.01	0.02	-0.11	0.06	0.01	0.15	-0.13	-0.11	1.00	0.47	0.08	-0.07	-0.08	-0.25	-0.21	-0.14	-0.09	-0.06	-0.17	-0.27	-0.14	-0.09	-0.10	-0.08	-0.18	0.07	-0.15	-0.12	0.01	-0.03	-0.25	-0.21	0.26	-0.15	-0.12	-0.05	-0.09	0.05	-0.17	-0.06	-0.16	-0.04	0.21	0.09	0.03	0.15
Dist_dest	-0.25	-0.01	-0.03	-0.11	0.01	-0.01	0.12	-0.12	-0.11	0.47	1.00	0.17	-0.09	-0.11	-0.35	-0.31	-0.09	-0.13	-0.16	-0.23	-0.31	-0.25	-0.17	-0.15	-0.14	-0.24	0.05	-0.25	-0.19	-0.08	-0.02	-0.18	-0.33	0.27	-0.23	-0.05	-0.05	-0.12	0.01	-0.14	-0.04	-0.18	-0.05	0.19	0.12	0.06	0.17
Environment	-0.18	0.05	0.13	-0.03	0.00	-0.07	0.17	-0.09	-0.02	0.08	0.17	1.00	-0.01	-0.03	-0.16	-0.11	-0.07	-0.08	-0.05	-0.09	-0.12	-0.07	-0.07	-0.03	-0.05	-0.07	0.11	-0.18	-0.11	0.05	0.18	-0.05	-0.08	0.15	-0.16	-0.02	-0.02	-0.09	-0.04	-0.14	-0.07	-0.10	-0.06	0.09	0.09	0.06	0.14
Multimod_walk	0.18	0.00	-0.01	0.15	-0.01	0.09	-0.09	-0.03	0.04	-0.07	-0.09	-0.01	1.00	0.12	0.14	0.19	0.07	0.12	0.05	0.16	0.02	0.10	0.09	0.06	0.13	0.13	0.10	0.14	0.05	-0.03	-0.04	0.05	0.07	-0.14	0.11	-0.02	0.05	0.11	-0.01	0.07	0.07	0.08	0.03	-0.05	0.03	0.05	-0.01

	Use_bikeshare_bin	Residency	Own_car	Use_walking	Use_motor	Use_PT	Use_cardriver	Use_taxi	Skill	Dist_home	Dist_dest	Environment	Multimod_walk	Mot_money	Mot_conv	Mot_time	Mot_health	Mot_env	Sat_regist	Sat_price	Sat_loc	Sat_avail	Sat_rent	Sat_comf	Sat_brand	Sat_new	Electric	Safe_path	Safe_lane	Safe_road	Safe_pave	Like_cycling	Conv_cycling	Need_car	Cycle_more	Cycle_rain	Appear	Friends	Road_users	Enc_paths	Enc_speed	Enc_aware	Enc_carprice	Disc_carconv	Disc_PTconv	Disc_safe	Disc_cost
Mot_money	0.27	0.00	-0.13	0.08	0.02	0.14	-0.09	0.09	0.02	-0.08	-0.11	-0.03	0.12	1.00	0.45	0.48	0.24	0.27	0.23	0.36	0.10	0.17	0.15	0.20	0.24	0.24	0.02	0.23	0.19	0.20	0.10	0.19	0.22	-0.04	0.32	0.02	0.22	0.23	0.13	0.18	0.21	0.20	0.12	0.04	0.06	0.15	-0.10
Mot_conv	0.26	0.04	0.05	0.09	0.02	0.00	-0.01	0.04	0.14	-0.25	-0.35	-0.16	0.14	0.45	1.00	0.66	0.35	0.39	0.35	0.36	0.37	0.35	0.30	0.31	0.31	0.35	-0.10	0.44	0.34	0.17	0.17	0.34	0.41	-0.13	0.38	0.07	0.16	0.29	0.10	0.38	0.32	0.40	0.22	-0.09	-0.07	0.11	-0.17
Mot_time	0.32	-0.05	-0.09	0.07	0.00	0.05	-0.13	0.06	0.19	-0.21	-0.31	-0.11	0.19	0.48	0.66	1.00	0.36	0.41	0.33	0.34	0.28	0.29	0.29	0.32	0.34	0.37	-0.08	0.37	0.31	0.22	0.15	0.35	0.43	-0.16	0.40	-0.04	0.17	0.28	0.09	0.29	0.34	0.33	0.24	-0.13	-0.09	0.09	-0.14
Mot_health	0.11	0.00	-0.02	0.14	-0.14	0.12	-0.10	-0.04	0.13	-0.14	-0.09	-0.07	0.07	0.24	0.35	0.36	1.00	0.73	0.24	0.17	0.26	0.32	0.28	0.32	0.33	0.26	-0.14	0.37	0.26	0.06	0.11	0.44	0.39	-0.11	0.26	-0.02	0.07	0.31	0.03	0.37	0.36	0.45	0.21	-0.12	0.10	0.19	-0.05
Mot_env	0.15	0.02	-0.05	0.15	-0.18	0.16	-0.12	-0.07	0.12	-0.09	-0.13	-0.08	0.12	0.27	0.39	0.41	0.73	1.00	0.24	0.22	0.24	0.31	0.30	0.28	0.32	0.29	-0.10	0.40	0.27	0.07	0.14	0.38	0.40	-0.11	0.27	0.00	0.04	0.31	0.04	0.37	0.37	0.44	0.22	-0.15	0.07	0.20	-0.09
Sat_regist	0.21	0.00	-0.06	0.12	0.02	0.05	-0.09	0.10	0.03	-0.06	-0.16	-0.05	0.05	0.23	0.35	0.33	0.24	0.24	1.00	0.49	0.41	0.44	0.48	0.49	0.54	0.54	-0.06	0.35	0.30	0.18	0.14	0.31	0.30	-0.06	0.32	0.02	0.06	0.27	0.17	0.29	0.23	0.27	0.13	-0.06	0.07	0.07	-0.19
Sat_price	0.40	-0.02	-0.09	0.17	0.02	0.04	-0.11	0.10	0.04	-0.17	-0.23	-0.09	0.16	0.36	0.36	0.34	0.17	0.22	0.49	1.00	0.41	0.42	0.41	0.42	0.44	0.53	-0.10	0.26	0.29	0.20	0.02	0.20	0.29	-0.17	0.43	0.00	0.12	0.27	0.15	0.28	0.22	0.26	0.16	-0.11	0.00	0.03	-0.52
Sat_loc	0.11	0.04	-0.01	0.11	0.03	0.04	-0.03	0.08	0.09	-0.27	-0.31	-0.12	0.02	0.10	0.37	0.28	0.26	0.24	0.41	0.41	1.00	0.67	0.55	0.47	0.43	0.39	-0.17	0.32	0.26	0.16	0.13	0.24	0.32	-0.07	0.22	0.07	0.08	0.24	0.11	0.24	0.19	0.27	0.11	-0.14	-0.01	0.03	-0.17
Sat_avail	0.16	0.05	-0.07	0.13	-0.01	0.06	-0.06	0.03	0.05	-0.14	-0.25	-0.07	0.10	0.17	0.35	0.29	0.32	0.31	0.44	0.42	0.67	1.00	0.59	0.55	0.47	0.45	-0.16	0.36	0.30	0.18	0.15	0.25	0.30	-0.08	0.28	0.06	0.06	0.24	0.12	0.25	0.16	0.25	0.13	-0.11	0.00	0.05	-0.17
Sat_rent	0.14	0.06	0.01	0.09	0.03	0.08	-0.02	0.08	0.08	-0.09	-0.17	-0.07	0.09	0.15	0.30	0.29	0.28	0.30	0.48	0.41	0.55	0.59	1.00	0.53	0.49	0.48	-0.11	0.27	0.26	0.15	0.14	0.25	0.31	-0.01	0.26	0.00	0.06	0.18	0.12	0.21	0.16	0.23	0.10	-0.10	0.02	0.01	-0.22
Sat_comf	0.14	0.01	-0.01	0.10	0.02	0.04	-0.03	0.07	0.11	-0.10	-0.15	-0.03	0.06	0.20	0.31	0.32	0.32	0.28	0.49	0.42	0.47	0.55	0.53	1.00	0.67	0.53	-0.09	0.34	0.31	0.21	0.20	0.33	0.32	-0.01	0.29	-0.02	0.07	0.24	0.14	0.23	0.21	0.24	0.14	-0.04	0.11	0.12	-0.17
Sat_brand	0.16	0.06	-0.08	0.07	0.04	0.12	-0.10	0.12	-0.01	-0.08	-0.14	-0.05	0.13	0.24	0.31	0.34	0.33	0.32	0.54	0.44	0.43	0.47	0.49	0.67	1.00	0.55	-0.10	0.34	0.31	0.26	0.23	0.27	0.30	-0.03	0.29	0.00	0.09	0.35	0.20	0.26	0.28	0.28	0.20	0.00	0.13	0.13	-0.14
Sat_new	0.27	-0.05	-0.03	0.10	0.01	0.01	-0.05	0.12	0.09	-0.18	-0.24	-0.07	0.13	0.24	0.35	0.37	0.26	0.29	0.54	0.53	0.39	0.45	0.48	0.53	0.55	1.00	-0.06	0.34	0.32	0.22	0.08	0.29	0.35	-0.08	0.46	0.03	0.21	0.30	0.16	0.28	0.24	0.29	0.23	-0.08	0.05	0.10	-0.27

	Use_bikeshare_bin	Residency	Own_car	Use_walking	Use_motor	Use_PT	Use_cardriver	Use_taxi	Skill	Dist_home	Dist_dest	Environment	Multimod_walk	Mot_money	Mot_conv	Mot_time	Mot_health	Mot_env	Sat_regist	Sat_price	Sat_loc	Sat_avail	Sat_rent
Electric	-0.12	0.01	0.03	0.02	0.06	-0.04	0.06	-0.04	-0.01	0.07	0.05	0.11	0.10	0.02	-0.10	-0.08	-0.14	-0.10	-0.06	-0.10	-0.17	-0.16	-0.11
Safe_path	0.18	0.05	-0.07	0.13	-0.03	0.08	-0.14	-0.05	0.15	-0.15	-0.25	-0.18	0.14	0.23	0.44	0.37	0.37	0.40	0.35	0.26	0.32	0.36	0.27
Safe_lane	0.22	0.01	0.03	0.06	0.07	0.08	-0.03	0.08	0.18	-0.12	-0.19	-0.11	0.05	0.19	0.34	0.31	0.26	0.27	0.30	0.29	0.26	0.30	0.26
Safe_road	0.13	0.07	0.07	-0.08	0.19	0.07	0.03	0.13	0.17	0.01	-0.08	0.05	-0.03	0.20	0.17	0.22	0.06	0.07	0.18	0.20	0.16	0.18	0.15
Safe_pave	-0.03	0.05	0.03	-0.08	0.13	0.02	0.05	0.07	0.07	-0.03	-0.02	0.18	-0.04	0.10	0.17	0.15	0.11	0.14	0.14	0.02	0.13	0.15	0.14
Like_cycling	0.14	0.02	0.01	0.12	-0.05	0.06	-0.07	-0.05	0.31	-0.25	-0.18	-0.05	0.05	0.19	0.34	0.35	0.44	0.38	0.31	0.20	0.24	0.25	0.25
Conv_cycling	0.22	0.03	-0.06	0.10	-0.05	0.08	-0.18	0.00	0.17	-0.21	-0.33	-0.08	0.07	0.22	0.41	0.43	0.39	0.40	0.30	0.29	0.32	0.30	0.31
Need_car	-0.22	0.04	0.29	-0.14	0.16	-0.24	0.48	0.06	-0.04	0.26	0.27	0.15	-0.14	-0.04	-0.13	-0.16	-0.11	-0.11	-0.06	-0.17	-0.07	-0.08	-0.01
Cycle_more	0.47	-0.03	-0.06	0.04	-0.01	0.01	-0.09	0.11	0.11	-0.15	-0.23	-0.16	0.11	0.32	0.38	0.40	0.26	0.27	0.32	0.43	0.22	0.28	0.26
Cycle_rain	-0.08	0.00	0.10	0.00	0.08	-0.08	0.13	0.04	-0.13	-0.12	-0.05	-0.02	-0.02	0.02	0.07	-0.04	-0.02	0.00	0.02	0.00	0.07	0.06	0.00
Appear	0.11	-0.09	0.12	-0.01	0.12	-0.04	0.11	0.16	-0.06	-0.05	-0.05	-0.02	0.05	0.22	0.16	0.17	0.07	0.04	0.06	0.12	0.08	0.06	0.06
Friends	0.21	-0.07	-0.03	0.06	-0.05	0.08	-0.10	0.07	0.12	-0.09	-0.12	-0.09	0.11	0.23	0.29	0.28	0.31	0.31	0.27	0.27	0.24	0.24	0.18
Road_users	0.14	-0.02	0.00	-0.01	0.17	0.07	0.01	0.12	0.01	0.05	0.01	-0.04	-0.01	0.13	0.10	0.09	0.03	0.04	0.17	0.15	0.11	0.12	0.12

	Sat_comf	Sat_brand	Sat_new	Electric	Safe_path	Safe_lane	Safe_road	Safe_pave	Like_cycling	Conv_cycling	Need_car	Cycle_more	Cycle_rain	Appear	Friends	Road_users	Enc_paths	Enc_speed	Enc_aware	Enc_carprice	Enc_carconv	Disc_PTconv	Disc_safe	Disc_cost
Electric	-0.09	-0.10	-0.06	1.00	-0.03	-0.04	-0.05	0.02	-0.08	-0.08	0.06	-0.11	0.08	0.10	-0.05	-0.01	-0.05	-0.07	-0.04	-0.05	0.13	0.08	0.04	0.08
Safe_path	0.34	0.34	0.34	-0.03	1.00	0.40	0.08	0.21	0.51	0.45	-0.15	0.28	0.12	0.05	0.33	0.06	0.48	0.33	0.37	0.14	-0.07	0.05	0.17	-0.10
Safe_lane	0.31	0.31	0.32	-0.04	0.40	1.00	0.53	0.16	0.28	0.30	-0.06	0.29	0.04	0.04	0.23	0.25	0.28	0.28	0.22	0.15	-0.07	0.03	0.04	-0.11
Safe_road	0.21	0.26	0.22	-0.05	0.08	0.53	1.00	0.42	0.11	0.10	0.13	0.17	-0.06	0.10	0.12	0.41	0.01	0.13	-0.01	0.17	0.12	0.16	-0.06	0.10
Safe_pave	0.20	0.23	0.08	0.02	0.21	0.16	0.42	1.00	0.21	0.16	0.19	0.05	0.05	0.14	0.13	0.16	0.10	0.13	0.14	0.11	0.12	0.14	0.08	0.19
Like_cycling	0.33	0.27	0.29	-0.08	0.51	0.28	0.11	0.21	1.00	0.55	0.01	0.26	0.11	0.08	0.33	0.06	0.42	0.27	0.39	0.17	-0.10	0.08	0.15	-0.07
Conv_cycling	0.32	0.30	0.35	-0.08	0.45	0.30	0.10	0.16	0.55	1.00	-0.11	0.29	0.03	0.08	0.41	0.06	0.47	0.30	0.43	0.24	-0.16	-0.03	0.14	-0.13
Need_car	-0.01	-0.03	-0.08	0.06	-0.15	-0.06	0.13	0.19	0.01	-0.11	1.00	-0.05	0.26	0.17	0.01	0.23	-0.15	-0.07	-0.10	-0.08	0.49	0.20	0.08	0.28
Cycle_more	0.29	0.29	0.46	-0.11	0.28	0.29	0.17	0.05	0.26	0.29	-0.05	1.00	0.05	0.17	0.29	0.20	0.29	0.20	0.23	0.23	-0.06	-0.03	-0.01	-0.23
Cycle_rain	-0.02	0.00	0.03	0.08	0.12	0.04	-0.06	0.05	0.11	0.03	0.26	0.05	1.00	0.24	0.06	0.11	0.07	0.01	0.13	0.05	0.19	0.10	0.14	0.14
Appear	0.07	0.09	0.21	0.10	0.05	0.04	0.10	0.14	0.08	0.08	0.17	0.17	0.24	1.00	0.09	0.15	0.04	0.11	0.15	0.16	0.19	0.17	0.22	0.06
Friends	0.24	0.35	0.30	-0.05	0.33	0.23	0.12	0.13	0.33	0.41	0.01	0.29	0.06	0.09	1.00	0.19	0.28	0.25	0.29	0.15	-0.07	0.03	0.13	-0.05
Road_users	0.14	0.20	0.16	-0.01	0.06	0.25	0.41	0.16	0.06	0.06	0.23	0.20	0.11	0.15	0.19	1.00	0.01	0.06	-0.03	0.11	0.17	0.17	-0.07	0.14

	Use_bikeshare_bin	Residency	Own_car	Use_walking	Use_motor	Use_PT	Use_cardriver	Use_taxi	Skill	Dist_home	Dist_dest	Environment	Multimod_walk	Mot_money	Mot_conv	Mot_time	Mot_health	Mot_env	Sat_regist	Sat_price	Sat_loc	Sat_avail	Sat_rent	Sat_comf	Sat_brand	Sat_new	Electric	Safe_path	Safe_lane	Safe_road	Safe_pave	Like_cycling	Conv_cycling	Need_car	Cycle_more	Cycle_rain	Appear	Friends	Road_users	Enc_paths	Enc_speed	Enc_aware	Enc_carprice	Disc_carconv	Disc_PTconv	Disc_safe	Disc_cost
Enc_paths	0.16	0.07	-0.07	0.13	-0.04	0.14	-0.15	-0.06	0.10	-0.17	-0.14	-0.14	0.07	0.18	0.38	0.29	0.37	0.37	0.29	0.28	0.24	0.25	0.21	0.23	0.26	0.28	-0.05	0.48	0.28	0.01	0.10	0.42	0.47	-0.15	0.29	0.07	0.04	0.28	0.01	1.00	0.51	0.59	0.33	-0.10	0.13	0.25	-0.11
Enc_speed	0.13	0.00	-0.07	0.09	0.05	0.16	-0.13	0.06	0.06	-0.06	-0.04	-0.07	0.07	0.21	0.32	0.34	0.36	0.37	0.23	0.22	0.19	0.16	0.16	0.21	0.28	0.24	-0.07	0.33	0.28	0.13	0.13	0.27	0.30	-0.07	0.20	0.01	0.11	0.25	0.06	0.51	1.00	0.56	0.44	-0.03	0.18	0.20	-0.09
Enc_aware	0.12	-0.12	0.02	0.14	-0.06	0.03	-0.04	-0.02	0.07	-0.16	-0.18	-0.10	0.08	0.20	0.40	0.33	0.45	0.44	0.27	0.26	0.27	0.25	0.23	0.24	0.28	0.29	-0.04	0.37	0.22	-0.01	0.14	0.39	0.43	-0.10	0.23	0.13	0.15	0.29	-0.03	0.59	0.56	1.00	0.28	-0.10	0.09	0.27	-0.14
Enc_carprice	0.15	-0.04	-0.04	-0.02	0.07	0.13	-0.08	0.07	0.08	-0.04	-0.05	-0.06	0.03	0.12	0.22	0.24	0.21	0.22	0.13	0.16	0.11	0.13	0.10	0.14	0.20	0.23	-0.05	0.14	0.15	0.17	0.11	0.17	0.24	-0.08	0.23	0.05	0.16	0.15	0.11	0.33	0.44	0.28	1.00	0.00	0.17	0.20	-0.01
Disc_carconv	-0.09	0.09	0.12	-0.06	0.18	-0.07	0.29	0.08	-0.09	0.21	0.19	0.09	-0.05	0.04	-0.09	-0.13	-0.12	-0.15	-0.06	-0.11	-0.14	-0.11	-0.10	-0.04	0.00	-0.08	0.13	-0.07	-0.07	0.12	0.12	-0.10	-0.16	0.49	-0.06	0.19	0.19	-0.07	0.17	-0.10	-0.03	-0.10	0.00	1.00	0.31	0.24	0.30
Disc_PTconv	-0.07	0.01	0.06	0.01	0.06	0.23	0.08	0.06	-0.03	0.09	0.12	0.09	0.03	0.06	-0.07	-0.09	0.10	0.07	0.07	0.00	-0.01	0.00	0.02	0.11	0.13	0.05	0.08	0.05	0.03	0.16	0.14	0.08	-0.03	0.20	-0.03	0.10	0.17	0.03	0.17	0.13	0.18	0.09	0.17	0.31	1.00	0.36	0.24
Disc_safe	-0.02	-0.05	0.07	0.01	0.01	0.08	0.05	0.00	-0.09	0.03	0.06	0.06	0.05	0.15	0.11	0.09	0.19	0.20	0.07	0.03	0.03	0.05	0.01	0.12	0.13	0.10	0.04	0.17	0.04	-0.06	0.08	0.15	0.14	0.08	-0.01	0.14	0.22	0.13	-0.07	0.25	0.20	0.27	0.20	0.24	0.36	1.00	0.19
Disc_cost	-0.18	0.03	0.06	-0.08	0.12	0.03	0.12	0.01	-0.03	0.15	0.17	0.14	-0.01	-0.10	-0.17	-0.14	-0.05	-0.09	-0.19	-0.52	-0.17	-0.17	-0.22	-0.17	-0.14	-0.27	0.08	-0.10	-0.11	0.10	0.19	-0.07	-0.13	0.28	-0.23	0.14	0.06	-0.05	0.14	-0.11	-0.09	-0.14	-0.01	0.30	0.24	0.19	1.00

Table F.3: Malta dataset correlation matrix

	Use_bikeshare_bin	Native	Household	Residency	Own_car	Use_motor	Use_PT	Use_taxi	Dist_home	Dist_dest	Mot_money	Mot_conv	Mot_time	Sat_regist	Sat_loc	Sat_avail	Sat_rent	Sat_comf	Safe_road	Cycle_more	Road_users	Cycle_accept	Enc_carprice	Disc_PTconv
Use_bikeshare_bin	1.00	-0.40	-0.21	0.22	-0.21	0.23	0.29	0.28	-0.33	-0.28	0.35	0.26	0.39	0.24	0.28	0.26	0.21	0.21	0.32	0.49	0.24	0.34	0.04	0.21
Native	-0.40	1.00	0.48	-0.40	0.19	-0.10	-0.10	-0.07	0.27	0.27	-0.14	-0.11	-0.17	-0.12	-0.16	-0.07	-0.02	0.03	-0.08	-0.22	-0.06	-0.23	0.03	-0.15
Household	-0.21	0.48	1.00	-0.33	0.17	-0.15	-0.05	-0.11	0.14	0.08	-0.12	0.00	0.01	-0.11	-0.15	-0.03	-0.03	0.01	-0.15	-0.19	-0.15	-0.22	0.11	-0.15
Residency	0.22	-0.40	-0.33	1.00	0.02	0.16	0.10	0.09	-0.06	0.01	0.19	0.17	0.15	0.00	0.19	0.02	0.03	0.11	0.37	0.16	0.29	0.42	0.05	0.32
Own_car	-0.21	0.19	0.17	0.02	1.00	-0.02	-0.36	-0.08	0.22	0.12	-0.08	0.08	-0.07	-0.22	-0.19	-0.16	-0.08	-0.08	-0.11	-0.10	-0.11	-0.18	0.06	-0.25
Use_motor	0.23	-0.10	-0.15	0.16	-0.02	1.00	0.12	0.31	0.03	0.11	0.22	0.01	0.10	0.06	0.19	0.00	0.16	0.19	0.46	0.09	0.30	0.37	-0.01	0.29
Use_PT	0.29	-0.10	-0.05	0.10	-0.36	0.12	1.00	0.18	0.05	0.01	0.16	0.00	0.06	0.03	0.04	-0.02	0.06	0.04	0.25	0.19	0.22	0.16	0.05	0.42
Use_taxi	0.28	-0.07	-0.11	0.09	-0.08	0.31	0.18	1.00	-0.15	-0.16	0.22	0.17	0.13	0.21	0.24	0.14	0.02	0.12	0.25	0.19	0.24	0.29	0.04	0.18
Dist_home	-0.33	0.27	0.14	-0.06	0.22	0.03	0.05	-0.15	1.00	0.51	0.12	-0.25	-0.21	-0.31	-0.50	-0.31	-0.15	-0.01	-0.01	-0.25	0.03	-0.05	0.01	-0.01
Dist_dest	-0.28	0.27	0.08	0.01	0.12	0.11	0.01	-0.16	0.51	1.00	0.03	-0.21	-0.22	-0.21	-0.23	-0.26	-0.17	0.02	0.03	-0.23	0.12	0.01	0.05	0.03
Mot_money	0.35	-0.14	-0.12	0.19	-0.08	0.22	0.16	0.22	0.12	0.03	1.00	0.36	0.40	0.10	0.22	0.00	0.09	0.39	0.37	0.28	0.34	0.46	-0.01	0.30
Mot_conv	0.26	-0.11	0.00	0.17	0.08	0.01	0.00	0.17	-0.25	-0.21	0.36	1.00	0.74	0.30	0.38	0.40	0.13	0.25	0.15	0.28	0.14	0.26	0.10	-0.02
Mot_time	0.39	-0.17	0.01	0.15	-0.07	0.10	0.06	0.13	-0.21	-0.22	0.40	0.74	1.00	0.25	0.35	0.40	0.27	0.27	0.21	0.25	0.11	0.25	0.13	-0.04
Sat_regist	0.24	-0.12	-0.11	0.00	-0.22	0.06	0.03	0.21	-0.31	-0.21	0.10	0.30	0.25	1.00	0.23	0.46	0.41	0.16	0.15	0.20	0.12	0.11	-0.07	0.11
Sat_loc	0.28	-0.16	-0.15	0.19	-0.19	0.19	0.04	0.24	-0.50	-0.23	0.22	0.38	0.35	0.23	1.00	0.40	0.19	0.25	0.27	0.36	0.26	0.36	0.13	0.16
Sat_avail	0.26	-0.07	-0.03	0.02	-0.16	0.00	-0.02	0.14	-0.31	-0.26	0.00	0.40	0.40	0.46	0.40	1.00	0.50	0.19	0.16	0.28	0.08	0.08	0.14	-0.07
Sat_rent	0.21	-0.02	-0.03	0.03	-0.08	0.16	0.06	0.02	-0.15	-0.17	0.09	0.13	0.27	0.41	0.19	0.50	1.00	0.35	0.17	0.30	0.13	0.11	-0.01	0.06
Sat_comf	0.21	0.03	0.01	0.11	-0.08	0.19	0.04	0.12	-0.01	0.02	0.39	0.25	0.27	0.16	0.25	0.19	0.35	1.00	0.27	0.23	0.29	0.38	0.16	0.19
Safe_road	0.32	-0.08	-0.15	0.37	-0.11	0.46	0.25	0.25	-0.01	0.03	0.37	0.15	0.21	0.15	0.27	0.16	0.17	0.27	1.00	0.33	0.72	0.65	0.12	0.36
Cycle_more	0.49	-0.22	-0.19	0.16	-0.10	0.09	0.19	0.19	-0.25	-0.23	0.28	0.28	0.25	0.20	0.36	0.28	0.30	0.23	0.33	1.00	0.30	0.31	0.20	0.33
Road_users	0.24	-0.06	-0.15	0.29	-0.11	0.30	0.22	0.24	0.03	0.12	0.34	0.14	0.11	0.12	0.26	0.08	0.13	0.29	0.72	0.30	1.00	0.77	0.24	0.43
Cycle_accept	0.34	-0.23	-0.22	0.42	-0.18	0.37	0.16	0.29	-0.05	0.01	0.46	0.26	0.25	0.11	0.36	0.08	0.11	0.38	0.65	0.31	0.77	1.00	0.03	0.47
Enc_carprice	0.04	0.03	0.11	0.05	0.06	-0.01	0.05	0.04	0.01	0.05	-0.01	0.10	0.13	-0.07	0.13	0.14	-0.01	0.16	0.12	0.20	0.24	0.03	1.00	0.01
Disc_PTconv	0.21	-0.15	-0.15	0.32	-0.25	0.29	0.42	0.18	-0.01	0.03	0.30	-0.02	-0.04	0.11	0.16	-0.07	0.06	0.19	0.36	0.33	0.43	0.47	0.01	1.00

Annex G - Parameter estimates for BLR models

Table G.1: Limassol dataset parameter estimates for fitted BLR model

Use_bikeshare_bin	B	Std. Error	z value	Pr (>|z|)	Signif.[a]
(Intercept)	1.0716	1.6138	0.664	0.50667	
Use_bicycle2	3.6947	1.3622	2.712	0.00668	**
Use_bicycle3	-2.1115	1.1359	-1.859	0.06304	.
Use_bicycle4	-1.9304	1.1462	-1.684	0.09215	.
Use_bicycle5	-1.4128	1.0795	-1.309	0.19062	
Dist_home2	-2.1903	1.3283	-1.649	0.09917	.
Dist_home3	-4.4567	1.6303	-2.734	0.00626	**
Dist_home4	2.5368	1.8673	1.359	0.17430	
Dist_home5	-2.0198	1.6075	-1.256	0.20895	
Dist_home6	-0.1534	1.2747	-0.120	0.90420	
Mot_conv2	1.9162	1.5327	1.250	0.21121	
Mot_conv3	3.4897	1.5780	2.212	0.02700	*
Mot_conv4	-1.3053	1.1853	-1.101	0.27081	
Mot_conv5	0.6277	0.8947	0.702	0.48294	
Safe_road2	-1.5054	0.9039	-1.665	0.09582	.
Safe_road3	1.6217	1.1148	1.455	0.14576	
Safe_road4	-2.0309	1.0724	-1.894	0.05826	.
Safe_road5	-1.2038	1.3058	-0.922	0.35661	
Cycle_accept2	4.5394	1.8309	2.479	0.01316	*
Cycle_accept3	-0.9715	1.1559	-0.840	0.40065	
Cycle_accept4	1.8198	1.3149	1.384	0.16636	
Cycle_accept5	-0.1563	1.2693	-0.123	0.90201	

[a] Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Null deviance: 185.763 on 133 degrees of freedom
Residual deviance: 83.648 on 112 degrees of freedom
AIC: 127.65
Number of Fisher Scoring iterations: 7

Table G.2: Las Palmas de Gran Canaria parameter estimates for fitted BLR model

Use_bikeshare_bin	B	Std. Error	z value	Pr (>|z|)	Signif.[a]
(Intercept)	2.816015	1.403054	2.00706	0.044743	*
Use_motor2	0.240717	0.830232	0.289939	0.771863	
Use_motor3	-1.98008	0.633894	-3.12368	0.001786	**
Use_motor4	0.660991	0.739195	0.894204	0.371213	
Use_motor5	1.881062	0.753989	2.494816	0.012602	*
Use_taxi2	0.993271	0.419441	2.368084	0.017880	*
Use_taxi3	-0.77967	0.517486	-1.50665	0.131902	
Use_taxi4	0.306062	0.659764	0.463897	0.642722	
Use_taxi5	-3.34445	1.292025	-2.58853	0.009639	**
Skill2	-0.43576	0.547326	-0.79616	0.425942	
Skill3	-1.74465	0.553055	-3.15457	0.001607	**
Multimod_walk1	-1.00884	0.308434	-3.27084	0.001072	**
Mot_time2	0.574946	0.649192	0.885633	0.375815	
Mot_time3	0.313807	0.633108	0.495661	0.620134	
Mot_time4	0.177747	0.608066	0.292315	0.770046	
Mot_time5	-1.15644	0.603515	-1.91618	0.055342	.
Sat_price2	-0.8064	0.547011	-1.47419	0.140430	
Sat_price3	-1.43891	0.487357	-2.95248	0.003152	**
Sat_price4	-2.7599	0.533004	-5.178	2.24E-07	***
Sat_price5	-2.89139	0.54749	-5.28118	1.28E-07	***
Sat_loc2	-0.39357	0.914007	-0.4306	0.666762	
Sat_loc3	0.381253	0.906088	0.420768	0.673925	
Sat_loc4	0.137791	0.858035	0.160589	0.872417	
Sat_loc5	1.498443	0.872326	1.717756	0.085841	.
Safe_road2	0.118281	0.391225	0.302334	0.762397	
Safe_road3	0.071546	0.470821	0.151959	0.879219	
Safe_road4	0.937778	0.449025	2.088474	0.036755	*
Safe_road5	-1.49106	0.978433	-1.52392	0.127528	
Need_car2	1.105519	0.502524	2.199934	0.027812	*
Need_car3	-0.08614	0.539664	-0.15962	0.873177	
Need_car4	1.269448	0.499666	2.540592	0.011066	*
Need_car5	2.501768	0.548215	4.563482	5.03E-06	***
Enc_speed2	-2.04461	0.961235	-2.12706	0.033415	*
Enc_speed3	-2.08817	0.779699	-2.67817	0.007403	**
Enc_speed4	-0.99838	0.739594	-1.3499	0.177048	
Enc_speed5	-1.1024	0.732576	-1.50483	0.132367	
Disc_carconv2	-0.32806	0.473824	-0.69238	0.488701	
Disc_carconv3	1.123547	0.465358	2.414369	0.015763	*
Disc_carconv4	0.25353	0.496296	0.510846	0.609459	
Disc_carconv5	-1.53775	0.744621	-2.06515	0.038909	*
Disc_safe2	-1.00836	1.163939	-0.86633	0.386307	
Disc_safe3	-1.74159	1.08535	-1.60463	0.108575	
Disc_safe4	-0.98116	1.059325	-0.92621	0.354338	
Disc_safe5	-0.09846	1.035424	-0.09509	0.924245	

[a] Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Null deviance: 95.92 on 501 degrees of freedom
Residual deviance: 354.04 on 458 degrees of freedom
AIC: 442.04
Number of Fisher Scoring iterations: 6

Table G.3: Malta parameter estimates for fitted BLR model

Use_bikeshare_bin	B	Std. Error	z value	Pr (>|z|)	Signif.[a]
(Intercept)	-0.70762	2.015517	-0.35109	0.725523	
Native1	2.175009	0.748513	2.905772	0.003663	**
Use_PT2	3.12373	1.430324	2.183931	0.028967	*
Use_PT3	1.307799	1.28638	1.016651	0.309320	
Use_PT4	1.111396	1.252278	0.8875	0.374810	
Use_PT5	-0.02031	1.265799	-0.01604	0.987199	
Use_taxi2	-0.39798	0.799896	-0.49754	0.618811	
Use_taxi3	-1.53732	0.945255	-1.62636	0.103874	
Use_taxi4	-3.99326	1.517198	-2.632	0.008488	**
Use_taxi5	0.637205	1.728629	0.368619	0.712412	
Dist_home2	1.632083	1.108492	1.472345	0.140928	
Dist_home3	4.034726	1.618986	2.492132	0.012698	*
Dist_home4	0.554505	1.449782	0.382475	0.702109	
Dist_home5	2.77237	1.29912	2.134037	0.032840	*
Dist_home6	6.906184	1.84761	3.737901	0.000186	***
Mot_money2	-1.06418	1.107851	-0.96058	0.336765	
Mot_money3	-2.6389	1.273407	-2.07232	0.038236	*
Mot_money4	-3.45675	1.116753	-3.09535	0.001966	**
Mot_money5	-3.37581	1.228435	-2.74806	0.005995	**
Enc_carprice2	-2.12218	1.726695	-1.22904	0.219056	
Enc_carprice3	2.075021	1.352721	1.533961	0.125039	
Enc_carprice4	-1.32404	1.158593	-1.1428	0.253120	
Enc_carprice5	-0.59546	1.074077	-0.55439	0.579310	

[a] Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Null deviance: 176.319 on 127 degrees of freedom
Residual deviance: 76.682 on 105 degrees of freedom
AIC: 122.68
Number of Fisher Scoring iterations: 7

Annex H – Monthly BSS station use as origins and destinations

Video with animation of monthly BSS station use in Limassol, Las Palmas de Gran Canaria and Malta: https://youtu.be/_C-kEFphbBU

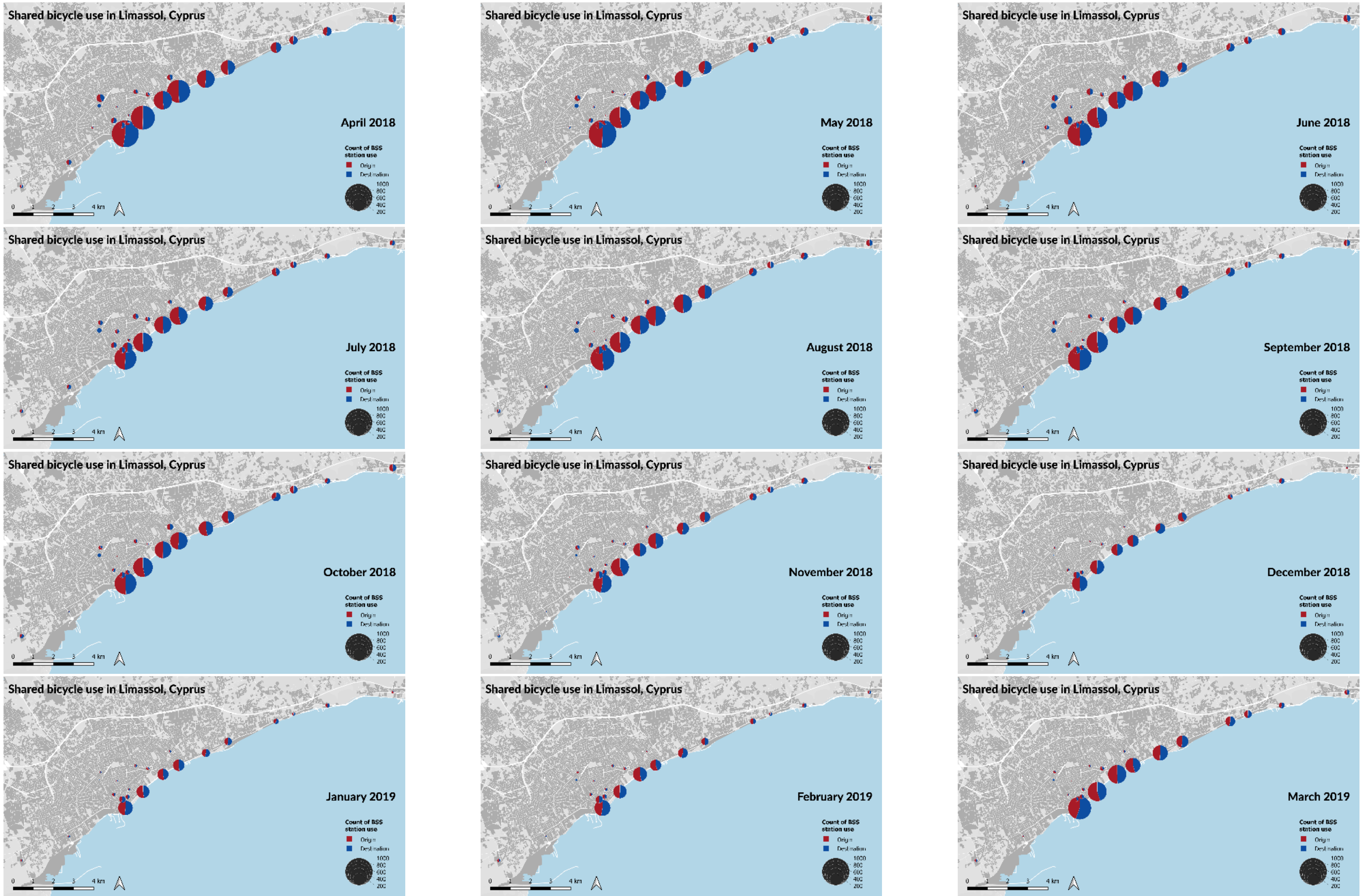


Figure H.1: Monthly BSS station use as origins and destinations in Limassol

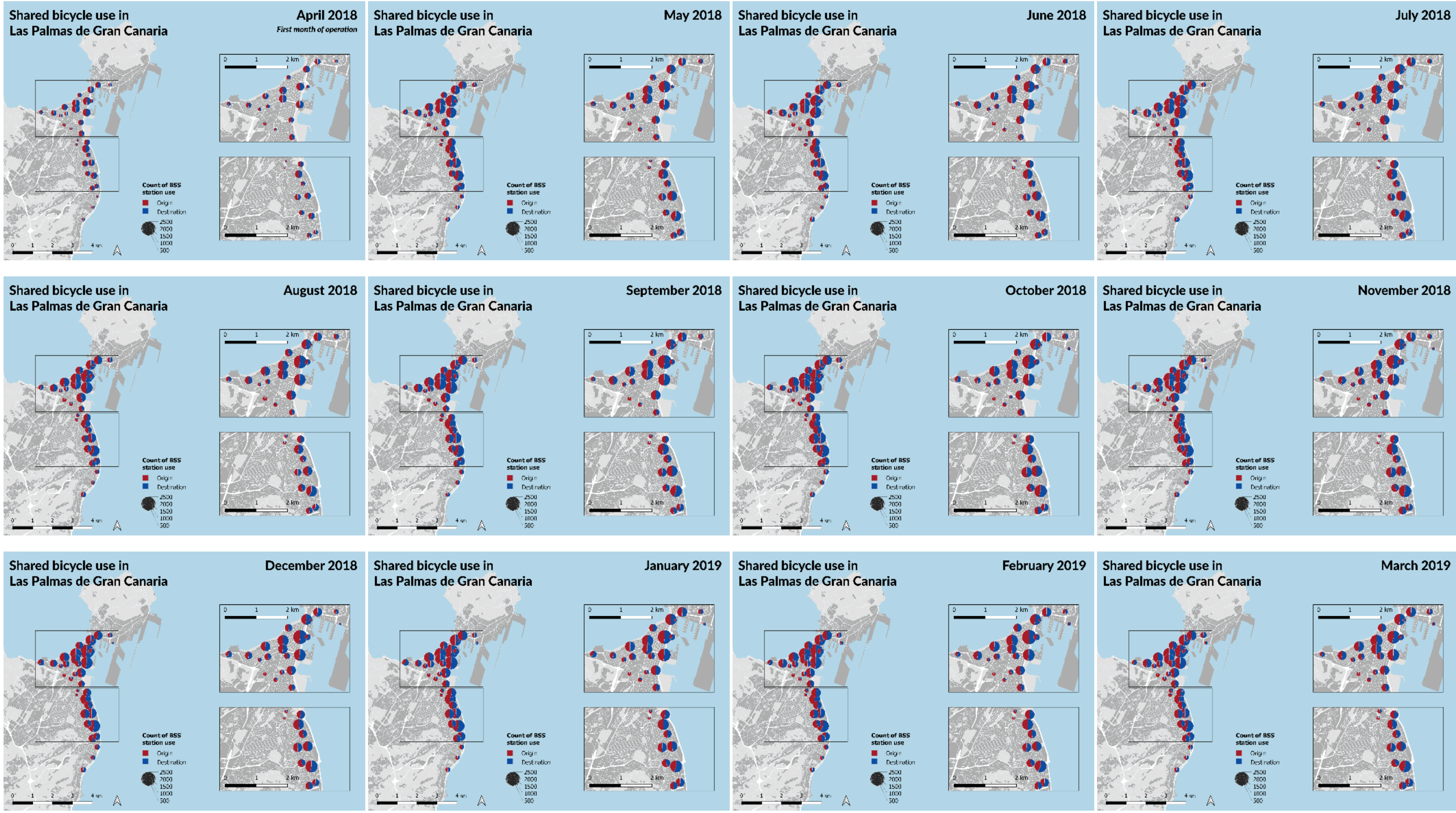


Figure H.2: Monthly BSS station use as origins and destinations in Las Palmas de Gran Canaria

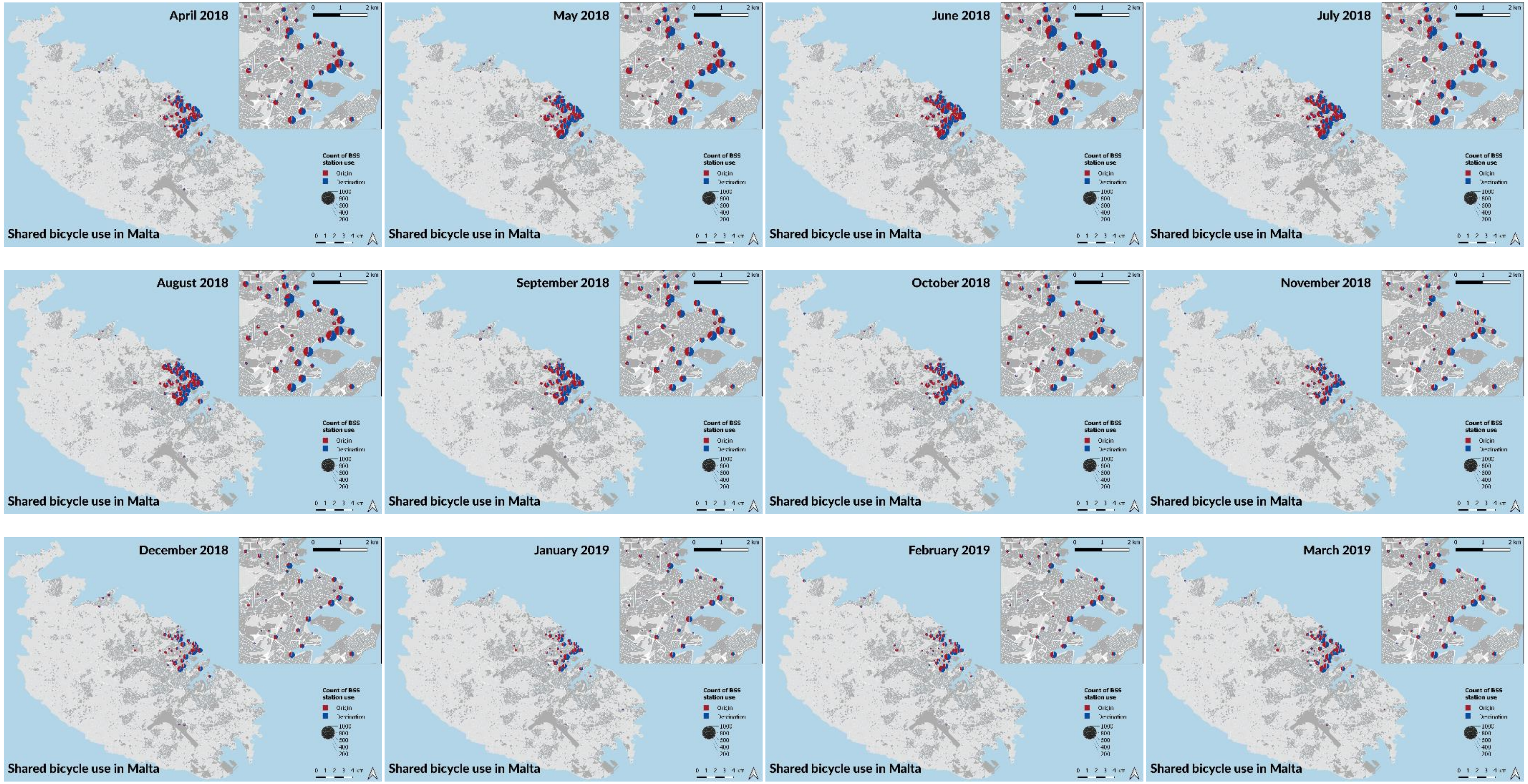


Figure H.3: Monthly BSS station use as origins and destinations in Malta