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Classifying bicycle sharing system use in Southern European island cities: cycling for transport or leisure?

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Abstract

Bicycle sharing systems (BSS) have been implemented in cities worldwide in an attempt to promote cycling. Cycling as a mode of transport has the potential to provide transport alternatives for those marginalized by car-based mobility, to reduce traffic related diseases and injuries, noise and air pollution, and to promote an active lifestyle and improve public health. The three Southern European island cities included in this research, Limassol (Cyprus), Las Palmas de Gran Canaria (Spain) and the Valletta conurbation (Malta), exhibit characteristics considered as barriers to cycling, such as hot summers and high humidity, hilliness and car-oriented culture and infrastructure. Thus far, cycling modal share is low: under 1%. However, bicycle sharing systems and policies promoting cycling have emerged in these cities too. In this research a year of trip data, shared by the BSS operators, is used to analyse the use of the BSS on a system and station level. An analysis of the origin-destination matrices highlights spatial patterns, and the assessment of different types of use captures user behaviour. Particular attention is paid to the influence of tourism on the system use, by analysing the spatial influence of tourist accommodation, points of interests and land use, by classifying BSS trips carried out for leisure or for transport, and by assessing the temporal influence of the tourist season. The comparative analysis between the three cities shows that despite sharing commonalities, the cities exhibit differences in their shared bicycle use.

Keywords: bicycle sharing systems (BSS); cycling; travel behaviour, Southern Europe

1. Introduction

Bicycle sharing systems, or BSS, are shared bicycle fleets allowing short-term public use (Shaheen, Guzman & Zhang, 2010). Since the late 1990s, when only a handful of bicycle sharing systems existed, the number of BSS around

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the world has spread rapidly across the globe, growing to over 1,000 active systems in 2016 (Médard de Chardon et al., 2017). Cities around the world have introduced BSS as part of a wider sustainable transport strategy and cycling promotion. The three Southern European island cities included in this research, Limassol (Cyprus), Las Palmas de Gran Canaria (LPGC) (Canary Islands, Spain) and the Valletta conurbation (Malta), exhibit characteristics considered as barriers to cycling, such as hot summers and high humidity, hilliness and car-oriented culture and infrastructure. Furthermore, cities in Southern Europe, especially those on islands and the coast, need to provide for the seasonal influx of tourists, especially during the summer months, in addition to daily residents' movements for work, education and leisure (Cavallaro et al., 2017). Although cycling modal share is low thus far in the cities (<1%), bicycle sharing systems and policies promoting cycling have emerged in these cities too.

2. Literature review

Twenty-first century bicycle sharing systems are characterised by a system comprised of docking stations and bicycles, which can be unlocked using a monitor at the docking station or through a mobile app, with payment linked to the users' credit card. These are considered third generation bicycle sharing systems (Fishman, 2016), following earlier experiments where shared bicycle experiments were available for free or through coin-based payment systems. Third generation BSS produce different forms of data (Romanillos et al., 2016; 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 (the details of the route that users take between origin and destination on the street network; only for bicycles with GPS).

Previous BSS studies have looked at factors influencing the use of the system, on an aggregate level and on a station level. However, few studies have focused on behaviour by different types of users (Zhang et al., 2016), using their use of the system to try to classify the purpose of the trips. Travelling by bicycle is done for diverse purposes. Cycling for transport refers to cycle trips made for work, education and shopping. However, cycling is not always a means to an end, and is also done for leisure purposes, including cycling for sport, cycling as exercise, and cycling for recreation, including for holiday and tourism purposes (Handy et al., 2014). Analysis of spatial and temporal variation in BSS use has shown the influence of land use variables, weather variables and network variables. Factors such as the presence of retail and restaurants, cycling infrastructure, parks, university buildings, public transport connections, population density, weather, distance to the city centre / business district, and proximity to other BSS stations have been found to be associated with BSS use in different cities in the US and Canada (Buck & Buehler, 2012; Faghih-Imani et al., 2014, Wang et al., 2016). Data from BSS in e.g. Barcelona (Froehlich et al., 2009) and London (Beecham & Wood, 2014) showed that weekday use can be very different from weekend use. The influence of tourism numbers has not been evaluated in analyses of BSS use thus far, although the influence of points of interest and tourism destinations within a buffer zone around BSS stations have been assessed in case studies of Santander and Melbourne (Bordagaray et al., 2016; Jain et al., 2018). O'Brien et al. (2014) classified BSS based on temporal characteristics, aggregating diurnal hourly use to be able to identify dominant usage patterns, such as the 'weekday two peaks' characteristic of commuter dominated BSS, 'mainly weekend use' for leisure dominated BSS and 'single peak on all days', for BSS with high tourist usage. To understand and explain variation in system use, i.e. why certain stations and station pairs are more active than others, trips can be classified based on trip type (round trips, single trips), trip duration (short <20 minutes; longer >20 minutes) and land use at the station locations, to identify their purpose (e.g. for leisure or for transport) or the spatial and temporal variables influencing their use (Bordagaray et al, 2016; Borgnat et al., 2011; O'Brien et al., 2014).

3. Methodology

Trip and station data are used in this study to analyse and classify BSS usage. GPS data is not available for the BSS trips in Limassol, Las Palmas de Gran Canaria, and Malta, and is therefore not considered. Trip data of the three BSS was obtained from the operators, after negotiating and signing a data sharing agreement. The trip data describes the bicycle trips made from origins (O) to destinations (D), including the location 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 paper pertain to 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. 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 that these are likely the result of a mistake or malfunctioning 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.

Data on land use was extracted from the Copernicus Land Monitoring Service - Urban Atlas (UA) 2012 dataset (EEA, 2018) and the OpenStreetMap (OSM) dataset (OpenStreetMap contributors, 2019). A buffer of 300m was used around the stations, the most commonly used measure for a walkable distance to BSS stations (e.g. Jain et al., 2018). The spatial nature of stations is characterised by the land use and points of interest present within the 300m buffer around the station, in % (for residential and commercial/industrial land use), count (in the case of number of cafés/restaurants and hotels) or with a check mark for dummy variables (to indicate the presence of a park, cycling path, the beach/promenade, bus station or university building within the buffer). In order to determine the high and low tourist season for each of the case studies, data on tourist arrivals and weather were used. Tourism data was collected from the national statistical service CyStat for Cyprus, from the statistical institute for the Canary Islands (ISTAC) for Las Palmas de Gran Canaria and from the National Statistics Office (NSO) of Malta.

In order to better understand the BSS usage in the case study cities and what explains the variation in trip types, duration and use of stations, including seasonal influence, trips are classified based on trip type, duration and station location. The distribution of typical weekday and weekend temporal patterns is identified through the aggregation of daily frequency distributions, to elicit underlying trends and 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).

4. Case studies

Limassol is the second largest city in Cyprus, located on the island's southern coast, with 100,000 inhabitants in Limassol municipality, and around 200,000 inhabitants living in the greater urban conglomeration (CyStat, 2019a). Limassol is home to the largest port in Cyprus, it is one of the main industrial hubs, and it is also a well-known tourist destination. The campus of the Cyprus University of Technology is also located in the city centre. In 2018, the modal share by private car is 91.8%, by bus 1.8%, on foot 5.7% and by bicycle 0.7% (PTV, 2019). The majority of tourist arrivals (84%) in Cyprus are between April and October (CyStat, 2019b). The BSS was introduced in Limassol in 2012 and is managed by private operator Nextbike Cyprus, with 170 bicycles and 23 active stations, which are concentrated along the coastal promenade and the city centre. Users can opt for a subscription at €120/year with free 120 daily minutes of use, 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.

Las Palmas de Gran Canaria is the largest city and capital of Gran Canaria. The city is home to 379,925 inhabitants (INE, 2019). The city has two main city centres: firstly, the area around San Telmo and its bus station and secondly, the area around Las Canteras and Santa Catalina, including the bus station there. The main port area is located in the northeast of the city. The city has low elevation differences along the coast, but elevation differences of up to 300 meters further inland (Ayuntamiento de Las Palmas de Gran Canaria, 2015). The University of Las Palmas de Gran Canaria (ULPGC) is located around 10km south of the city, in the hills of Tafira. In 2012, the modal share by private car was 63%, by bus 13%, on foot 15% and by bicycle 0.5%. Due to year-round pleasant temperatures, mediated by the Gulf Stream, the majority of tourist arrivals (70%) in Las Palmas de Gran Canaria occur in the winter season, between October and April (ISTAC, 2020). SAGULPA, the municipal company responsible for parking management, introduced the BSS Sítycleta in April 2018, with around 375 bicycles and 37 stations, all located within the lower part of the city. The system is open daily throughout the year from 06:00 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), with daily free 30-minute use of the system, and a pay-as-you-go rate of €1.50 for every 30 minutes.

The Valletta conurbation in Malta refers to the urban area around the capital city Valletta, encompassing the Northern and Southern Harbour districts, which together are home to a population of 199.887 inhabitants (NSO, 2018).

The area includes the tourist town of St. Julian's, residential, commercial and employment centres in Msida, Gżira and Sliema and the University of Malta in Msida. In 2014, the modal share by private car was 75%, by bus 11%, on foot 7.5% and by bicycle 0.3% (Transport Malta, 2016). The majority of tourist arrivals (73%) in Malta are between April and October (NSO, 2019). In Malta, private operator Nextbike Malta introduced a bicycle sharing system in late 2016, with 60 stations and over 400 bicycles. The majority of the stations are located around the central urban area north of the capital Valletta. There are also some single and small clusters of stations in other parts of the island. 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.

5. Results

Figure 1 presents a visualisation of the flows between origin (O) and destination (D) stations in: a) Limassol (n=17,532), b) Las Palmas de Gran Canaria (n = 162,871), c) Malta (n = 37,306), where the varying thickness of the lines indicates the relative strength of the flow. Stations are numbered according to their station popularity ranking; the aggregate number of uses of the station as an origin or destination (O+D), i.e. LIM station 1 is the station with most aggregated rentals and returns in Limassol. Table 1 list the top 5 OD flows per city. In Limassol it is clear the OD flows are very much concentrated along the bicycle path on the promenade, as the top 5 OD connections are all between the top 5 O+D stations. All top 5 OD flows are roundtrips. In Las Palmas de Gran Canaria, the strongest OD flows are related to the city centre in the north of the city, around Santa Catalina park and bus station. Although there are also popular stations further south (e.g. LPA station 3, at San Telmo park and bus station), these show more diffuse connections with many other stations and are therefore not in the top 5 OD flows. In Malta, the top 5 OD flows are concentrated in the urban area around the harbour north of the capital city Valletta, which is an area with high population, employment and entertainment density. All stations are close to or on the coastal promenade.

Table 1. Top 5 OD flows in the three case study cities.

	Limassol	Las Palmas de Gran Canaria	Malta
1	LIM station 1 roundtrip (n = 1,503)	LPA station 4 → LPA station 9 (n = 1,475)	MAL station 2 → MAL station 1 (n = 582)
2	LIM station 2 roundtrip (n = 1,294)	LPA station 5 → LPA station 2 (n = 1,380)	MAL station 1 → MAL station 2 (n = 416)
3	LIM station 4 roundtrip (n = 1,132)	LPA station 2 → LPA station 5 (n = 1,352)	MAL station 7 → MAL station 1 (n = 406)
4	LIM station 5 roundtrip (n = 827)	LPA station 9 → LPA station 4 (n = 1,314)	MAL station 1 → MAL station 4 (n = 375)
5	LIM station 3 roundtrip (n = 772)	LPA station 1 → LPA station 11 (n = 1,147)	MAL station 5 → MAL station 3 (n = 355)

Table 2 presents the spatial characteristics of the top 5 OD flows stations, in an effort to understand what positively influences BSS use at the stations. Almost all stations have relatively high residential land use and low commercial/industrial land use. The presence of cafés and restaurants, indicative of entertainment and leisure areas, is important for BSS use, although hotels only to a lesser extent; they are not present in all top stations' buffer zones. The influence of the beach or promenade on cycling in these coastal island cities is very evident, as well as the provision of cycling paths. Whereas in Malta there are practically no cycling paths in the urban area where the BSS is present, the other two cities clearly show that all top 5 stations are in close proximity to cycling paths. The positive influence of parks is primarily clear in Limassol, indicative of leisure use. The presence of public transport connections shows importance as an origin in Las Palmas de Gran Canaria (LPA station 1), and as both origin and destination in Malta (MAL station 1). 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, a driver of BSS use in other cities (e.g. in Seville, Castillo-Manzano & Sánchez-Braza, 2013), does not show any correlation with the top 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 connected to the BSS.

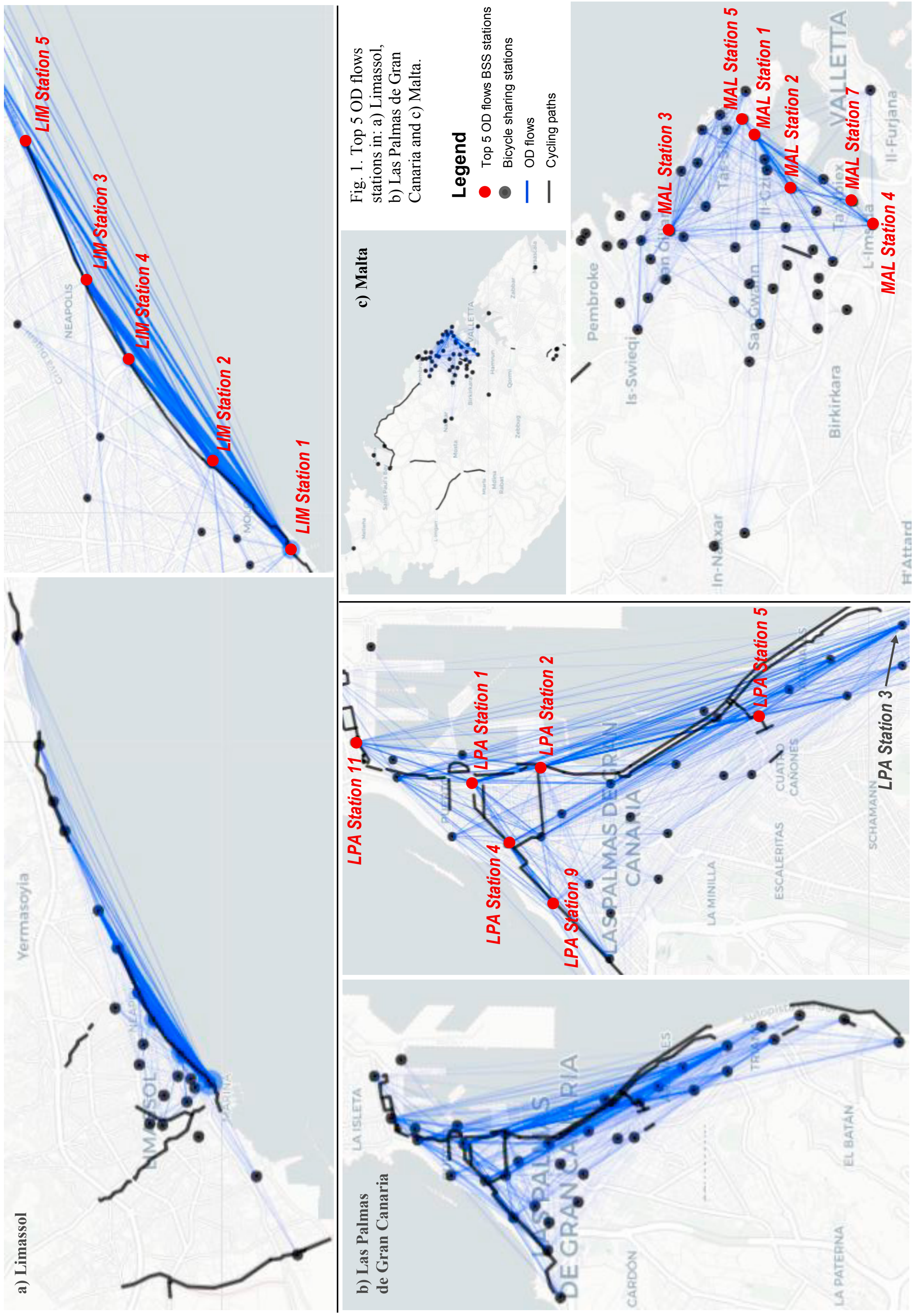


Fig. 1. Top 5 OD flows stations in: a) Limassol, b) Las Palmas de Gran Canaria and c) Malta.

Table 2. Spatial characterisation of stations in the top 5 OD flows

Station	% Residential	% Commerce /Industrial	# Hotels	# Cafés/ restaurants	Park	Cycling path	Beach/ promenade	Public transport*	University
Limassol									
LIM station 1	42%	33%	0	26	✓	✓	✓	-	-
LIM station 2	38%	22%	3	5	✓	✓	✓	-	-
LIM station 3	83%	0%	0	6	-	✓	✓	-	-
LIM station 4	43%	10%	3	21	-	✓	✓	-	-
LIM station 5	44%	9%	0	4	✓	✓	✓	-	-
Las Palmas de Gran Canaria									
LPA station 1	45%	9%	8	70	✓	✓	✓	✓ (B)	-
LPA station 2	30%	31%	1	31	-	✓	✓	-	-
LPA station 4	70%	0%	14	134	-	✓	✓	-	-
LPA station 5	72%	8%	0	20	-	✓	✓	-	-
LPA station 9	60%	8%	4	27	-	✓	✓	-	-
LPA station 11	45%	23%	4	13	✓	✓	✓	-	-
Malta									
MAL station 1	66%	0%	6	23	-	-	✓	✓ (B,F)	-
MAL station 2	53%	19%	3	13	✓	-	✓	-	-
MAL station 3	68%	13%	3	29	-	-	✓	-	-
MAL station 4	62%	12%	0	8	-	-	✓	✓ (B)	-
MAL station 5	68%	5%	9	22	-	-	✓	-	-
MAL station 7	74%	0%	0	3	-	-	✓	-	-

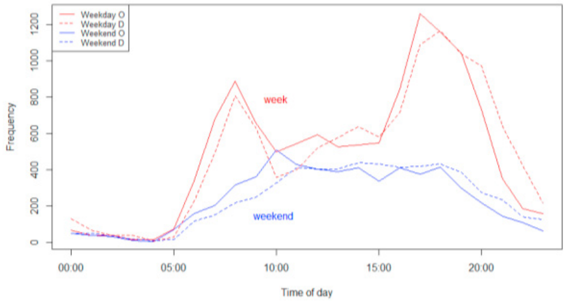
Notes: % percentage of land use in buffer; # number of establishments in buffer; * B: bus station; F: ferry landing site

Round trips, in which the origin of the trip coincides with the destination (O=D), are mainly associated with rides for recreation or for physical exercise (Bordagaray et al., 2016). In Limassol, of the total 17,532 trips, 42% (7,288 trips) constitute round trips. In Las Palmas de Gran Canaria, of the total 162,871 trips, only 5% (8,611 trips) constitute round trips. In Malta, of the total 37,306 trips, 13% (4,698 trips) are round trips. In comparison, Bordagaray et al. (2016) found that around 19% of total trips with the BSS in Santander (Spain) were roundtrips.

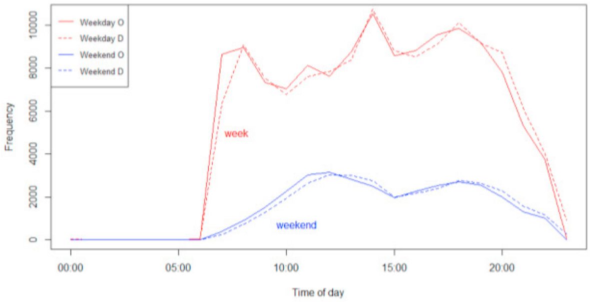
The aggregated diurnal hourly use, split by weekdays and weekend days, is shown in Figure 2, allowing the identification of dominant usage patterns. Limassol's BSS shows a double weekday peak, which is usually indicative of commuting, but here more likely to be related to before and after work exercise and leisure behaviour rather than solely for commuting trips. Weekend use is high, with trips throughout the day, typically related to leisure activities (Fishman, 2016; Pfrommer et al., 2014). Las Palmas de Gran Canaria's BSS shows a morning and evening peak, but also high use throughout the day. These observations are concurrent with observations in other Southern European cities, where next to the morning and evening commuting peaks, a lunch hour or afternoon peak can be observed, e.g. in Lyon and Seville (Borgnat et al., 2011; Castillo-Manzano & Sánchez-Braza, 2013). Malta's BSS shows a strong double peak on weekdays, associated with commuting behaviour, as well as some leisure use on weekend days.

Trips can also be classified as being for transport or for leisure based on the trip time. Trips under 20 minutes are typically associated with commuting or cycling for transport, whereas longer trips are for recreational purposes, such as fun or physical exercise (Fishman, 2016). Table 3 presents the median, mean and standard deviation (SD) of the trip duration in minutes. When comparing the three cities, Las Palmas de Gran Canaria and Malta have shorter median trip durations. The higher median and mean trip duration 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 the first 2 hours free 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; Pfrommer et al., 2014).

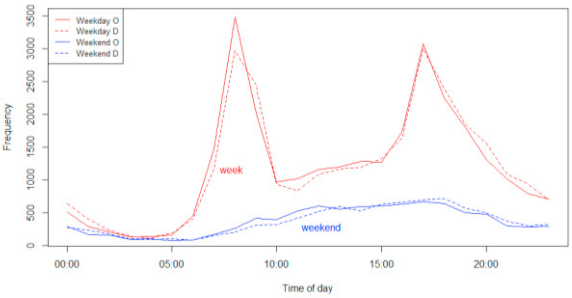
Looking at the distribution of trips and their duration between the high and low seasons, in Limassol, 73% of total trips take place in the high season (April to October). In Las Palmas de Gran Canaria, 61% of total trips take place in the high season (October to April) and in Malta, 74% of total trips take place in the high season (April to October). In none of the cities there is a large difference in the use of the BSS in terms of trip duration between the high and low season; the median trip duration varies by maximum 1 minute between different seasons.



a) Limassol



b) Las Palmas de Gran Canaria



c) Malta

Table 3. Descriptive statistics of trip duration (minutes).

	Limassol	LPGC	Malta
Median	39	13	14
Mean	61	19	30
SD	66.97	29.08	51.11

Fig. 2. Temporal daily usage patterns of the BSS in: a) Limassol, b) Las Palmas de Gran Canaria, c) Malta.

6. Discussion and conclusion

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. This is however not necessarily due to increased use by tourists, as the presence of hotels do not show a clear influence on the top OD flows stations, but rather by the high season signifying the months characterized by outdoor leisure and exercise, for residents and tourists alike. 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, the expansion of the system, and the provision of electric bicycles, can 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.

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 the predominant use 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. Leisure use can be a predecessor for cycling for transport, as people feel comfortable riding a bicycle and cycling is normalized. Improvements to the connections between public transport and BSS in Limassol, as well as collaborations with employers and the university, could promote cycling for transport.

The presence of cycling infrastructure, particularly next to the beach or on promenades in these coastal cities, clearly contributes to the use of BSS stations as origins and destinations. 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 paths are provided in the urban area.

Further work will focus on a deeper analysis of the influence of spatial and temporal characteristics in regression models, to understand in more detail how BSS use is influenced by land use variables, socio-economic characteristics, network variables and temporal variables related to tourism and weather factors.

The comparative analysis between the three cities shows that despite sharing commonalities, the cities exhibit differences in their shared bicycle use. The BSS in Limassol is dominated by leisure use, whereas in Las Palmas de Gran Canaria and Malta, use is more related to cycling for transport. There are lessons for promoting both BSS use for transport and for leisure. Investing in connections between the BSS, public transport network and cycling infrastructure can promote cycling for transport, whereas connecting leisure areas, such as beaches, parks and cafés, with cycling infrastructure can promote BSS use for leisure.

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