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A review on bike-sharing: The factors affecting bike-sharing demand

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ABSTRACT

This paper aimed to address the need for a comprehensive review on the factors affecting bike-sharing demand to bridge the gaps by deepening the knowledge on weather, built environment and land use, public transportation, station level, socio-demographic effects, temporal factors, and safety. This article evaluates recent studies on station-based bike sharing in literature and seeks answers to two main research questions: First, how do the weather conditions, built environment and land use, public transportation, socio-demographic attributes, temporal factors, and safety affect the bike-sharing trip demand? Second, what are the most commonly used factors in literature affecting trip demand? For this purpose, an overview of the factors affecting trip demands has been established to evaluate the performance of Bike-Share Programs(BSPs) comprehensively. The results can provide reliable estimate for planners or decision-makers in understanding the key factors contributing to bike-sharing demand. The information obtained from this overview can also be a guideline for BSP planners, policymakers and researchers to improve the efficiency of BSPs.

1. Introduction

The necessity for shifting travel modes from motor vehicles to an eco-friendly bicycle has occurred over time because of traffic congestion and air pollution (Li & Kamargianni, 2018). Approximately 40% of the greenhouse gas emissions in Europe and about 20% in the US are due to the use of motor vehicles. Since fossil fuel consumption is the main cause of greenhouse gas, until now, the use of motor vehicles in transportation has been one of the most pollutant activity in the world (Agency, 2005; Gotschi & Mills, 2008). Air pollution and consumption of natural sources can be reduced for sustainable cities by adopting the Bike Share Programs (BSPs) into the city transportation systems (Bajracharya, Mulya, Purbasari, & Hwang, 2018; Cai et al., 2019; Lumsdon & Tolley, 2001; Zhang, Zhang, Duan, & Bryde, 2015). According to the survey conducted in Shanghai, the largest city in China, it has been determined that 8358 tonnes of fuel savings have been achieved by bike sharing. This led the decreasing of carbon dioxide and nitrogen oxide gas emissions and improved air quality (Zhang & Mi, 2018). In addition to the environmental benefits of BSPs, increased physical activity can have a positive impact on public health (Biking, 2016; Fishman, Washington, & Haworth, 2013). BSPs also have the benefits of reducing the travel times and costs of their users and space saving (Buehler & Hamre, 2014). In short, the use of BSP contributes to the creation of a greener environment, economic transportation and a healthier society, and BSPs can be used to promote the transition to cycling (Bauman, Crane, Drayton, & Titze, 2017).

In the past century, in the 1960s, the concept of "bikesharing" emerged with the increase in interest in bicycle usage and this development has led to the rapid spread of BSPs in European cities. The 1 st generation bike sharing programs emerged as "White Bikes", which were dedicated to the public in Amsterdam in 1965. But, the system ended in a short time because the bicycles were thrown into the channels. The 2nd generation bike sharing program' Nakskov" was born in Denmark in 1993. "Nakskov" which has 26 bikes at 4 station was closed due to bicycle theft. In the same period, it was realized the main problem was the lack of bicycle tracking and this idea was shed light on the development process of 3rd generation bike sharing programs. 3rd BSPs have telecommunication systems, smartphone accesses, smart cards, kiosks, computer-aided systems. In 2000s, the number of 3rd BSPs such as "Call a Bike" in Munich and "Velo'v" in France, have increased steadily during the decade. In addition, the BSPs started to be established in countries such as Brazil, China and USA. Finally, the 4th generation bike sharing programs are BSPs that include smart systems which target sustainability, efficiency and quality (DeMaio, 2009; Shaheen, Guzman, & Zhang, 2010; Shaheen, Guzman, & Zhang, 2012). BSPs have been spreading rapidly around the world for more than 20 years (Tang, Pan, & Shen, 2011). Every two years, the top 20 bike-friendly and sustainable cities, inspired by the new century, are ranked according to the Copenhagenize Index, which takes into account 14 different criteria, including the BSP (Design, 2014).

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BSPs have current two modes of sharing bicycles, i.e. dock-less and station-based. For example, in the US, dock-less BSPs such as Mobike, Ofo, Spin have started service in 2017. In the same year, although 44% of the shared bicycles in the US are dock-less, 96% of the trips in the US were realized using station-based bicycles (Guide, 2011). Dock-less BSPs are an extreme new bike-sharing mode, and they have some problems; bicycle theft, vandalism, lack of tracking bicycle (Sun, 2018). Thus, it would be more appropriate to consider the factors affecting dock-less BSPs as a separate research topic. Since may lead to great differences for factor identification, however, this article does not consider factor affecting dock-less BSPs and the difference between bicycles with and without docks.

Station-based BSPs have many stations and ready-to-use bicycles and can be provided for users to easily pick up and return bikes in the city (Lin & Yang, 2011). “Convenience” is the main factor motivating cycling and can include many facilities such as station accessibility, membership procedures and simplicity of payment, and helmet supply (Leister, Vairo, Sims, & Bopp, 2018; Zanotto, 2014). In recent years, studies to increase bike-sharing and to determine the factors facilitating bicycling have been included in the literature (Fishman, Washington, & Haworth, 2012; Hampshire & Marla, 2012).

Many factors affect the trip demand in BSPs (Leister et al., 2018). The number of trip may be increased if the incentive/disincentive factors affecting BSP use are better known by researchers, planners or BSP representatives. Fishman, Washington and Haworth (Fishman et al., 2013) stated that the determination of the efficiency of BSPs, is only possible by evaluating the performance of existing systems. In addition to increase the number of bike sharing of the existing BSPs, it is possible to use new BSPs to be established in a more effective way by considering the parameters affecting the system.

In this study, the factors which could be used for future research have divided into six main categories: weather, built environment and land use, public transportation, station level, socio-demographic effects and finally temporal factors and safety. A knowledge of these factors would allow planned or available BSPs that have been modified to have the desired number of trips for the future. This article evaluates studies on station-based bike sharing in the literature and seeks answers to two main research questions:

1) How do the weather conditions, built environment, public transport, socio-demographic attributes, temporal factors, and safety affect the bike-sharing trip demand?
2) What are the most commonly used factors in the literature affecting trip demand?

The most commonly used factors affecting bike-sharing demand are presented in the tables at the end of each main section with comparative evaluations. The aim of this study is to bring together the most commonly used factors affecting trip demand in the literature of BSPs to provide planners and researchers with factor suggestions that can be used in their studies and contribute the literature related to bike-sharing.

2. Factors affecting bike-sharing trip demand

2.1. Weather condition impact factors

It is a known fact that natural environment components such as weather and climate have a significant impact on both bicycle usage and frequency of usage (Sears, Flynn, Aultman-Hall, & Dana, 2012). In addition to the long-term seasonal effects of climate on bike-sharing, weather conditions change continuously in the short term and may affect the demand for trip generation. Whether a person prefers to use BSP is strongly determined by weather and climate. This section describes how weather conditions and climate affect bike-share. The effects of weather conditions such as temperature, precipitation, humidity / relative humidity, and wind speed on travel request are at the focal point of many studies (Fuller et al., 2013; Heinen, Van Wee, & Maat, 2010; Martinez, 2017).

2.1.1. Temperature and precipitation

The effect on temperature bike-sharing is one of the most investigated factors. It is determined that there is a positive correlation between the temperature increase and the bike sharing demand. When the weather temperature is between 0–20 °C, the trip production is positively correlated; bike sharing demand reaches a maximum level when the temperature is between 20–30 °C. The results of studies investigating the effect of temperatures above 30 °C on bike sharing are confusing (Heinen et al., 2010; Hyland, Hong, de Farias Pinto, & Chen, 2018; Kim, 2018; Wang, Akar, & Chen, 2018). In their study, El-Assi, Mahmoud and Habib (El-Assi, Mahmoud, & Habib, 2017) determined that bike-sharing demand in Toronto, where weather temperatures can reach a level of 42 °C, increases in temperatures of +30 °C. In contrast to this study, Kim Kim (2018) stated that in 2015, the temperature in South Korea was only 49 days +30 °C and the temperatures of +30 °C were considered as "scorching heat" for Tashu BSP. As a result, the trip demand was negatively affected by the scorching temperatures. But, Jing and Zhao Jing and Zhao (2015) found that the best weather temperature is between 30–35 ℃ for more bike sharing demand.

Furthermore, the effects of weather conditions on bike sharing demand were investigated different age cohorts. All age groups have a positive relationship with weather temperatures of 12–16 °C, while 27–32 °C temperatures are negatively related. In addition, it was observed that the travel production of young individuals between the ages of 16–27 was adversely affected by weather temperatures of 21–27 °C as opposed to other ages groups (Wang et al., 2018).

Low weather temperatures were found to be more disturbing by bicyclists than by high temperatures (Nankervis, 1999). Rain and snowfall at low temperatures are generally considered to be the most adverse weather conditions and there is a negative relationship between the rainy days and the bike sharing demand (Corcoran, Li, Rohde, Charles-Edwards, & Mateo-Babiano, 2014; Gebhart & Noland, 2014; Hyland et al., 2018; Kim, 2018; Sun, Chen, & Jiao, 2018). Moreover, precipitation decreases the travel demand far below the average and the demand for a trip after heavy rainfall is returned to normal again after 3 h (Reiss & Bogenberger, 2016). On the other hand, most research into bike-sharing demand identifies weather condition as a significant factor; Indeed, for unfavorable weather conditions such as low temperatures, rain, and snow, the researchers are all of one mind about lowing bike sharing demand (Saneinejad, Roorda, & Kennedy, 2012).

2.1.2. Wind speed, humidity / relative humidity

Wind, humidity/relative humidity are weather factors such as temperature and precipitation. These variables are important determinants of bike sharing behavior (Gallop, Tse, & Zhao, 2012). Kim Kim (2018) examined the temperature-humidity index, relative humidity and wind velocity weather variables every hour of the day to determine the combined effect of temperature and humidity dependence, and determined that all of the related variables had a negative effect on bike sharing. In addition, Miranda-Moreno and Nosal Miranda-Moreno and Nosal (2011) determined that an increase of 10% from 14.7 °C gives an average increase of 4% to 5% in the hourly volume. But, they observed it would reduce if the humidity exceeds 60% at weather temperatures higher than 28 °C. Gebhart and Noland Gebhart and Noland (2014) in their study showed that wind speed and relative humidity adversely affected bike sharing, using data from the BSP in Washington. Also, many researchers agree that travel generation decreases with increasing wind speed and humidity/relative humidity (Corcoran et al., 2014; Croci & Rossi, 2014; Sun et al., 2018; Wang et al., 2018).

2.1.3. The seasons and climate

The seasonal demand changes in bike sharing is the result of weather conditions and it is important to predict and develop models that are compatible with seasonal demand changes. In the long term, the positive/negative impact of seasons on bicycle usage necessitated the investigation of the annual data of bike sharing and even detailed analysis monthly (Fournier, Christofa, & Knodler, 2017; Wadud, 2014).

Some BSPs such as Great Rides, Capital, Boulder B-Cycle do not serve in winter because of lower trip generations compared to other seasons. In the US, a questionnaire was applied to understand the reasons for the wishes of potential passengers to use BSP in winter and to determine the factors affecting bicycling (Godavarthy & Taleqani, 2017). In the winter months, especially when there are rain and snow, it may be expected that bike sharing demand will decrease and "bikes idle duration" will increase (Kutela & Kidando, 2017). It is only allowed to rentable bikes continuously between April and November from BSP in Montreal, where most of its station is closed in winter. The survey results show that the number of bike sharing in the summer increased between 32% and 39%, according to the bike sharing in April (Miranda-Moreno & Nosal, 2011). Furthermore, as regards to the 2-year data of the Citybike Vienna system, the demand for cycling during the winter months decreased significantly even at the stations used intensively compared to the summer months (Rudloff & Lackner, 2014). Similarly, bicycle usage in Switzerland has increased continuously from "very cold to very hot" levels in all seasons except summer (Liu, Susilo, & Karlström, 2015). In Table 1, weather and climate factors, units, and their expected effects on the trip generation are given in light of the information obtained from the literature.

2.2. Built environment and land use factors

The urban environment, which has a greater density of population, job and retail density, provides a suitable environment for bicycle usage, combined with a strong bicycle infrastructure (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Ewing & Cervero, 1780; Moudon et al., 2005; Winters, Brauer, Setton, & Teschke, 2010). Bike sharing at BSP stations closer to city centers, recreation areas, attraction centers and transit points can be expected to increase. So far, many studies have identified the built environment and land use factor that promotes/prevents the use of BSP (Mateo-Babiano, Bean, Corcoran, & Pojani, 2016). This section describes how built environment and land use factors affect bike-share.

2.2.1. Built environment

Bicycle-friendly cities suggest that bicycle networks with strong infrastructure need to be built to increase bicycle usage (Schoner & Levinson, 2014). According to data from 43 cities in the United States, more bicycle usage was observed in cities with high levels of bicycle infrastructure (Dill & Carr, 1828). Bike paths/lanes separated from motor vehicle traffic create a more reliable space for cyclists and play an important role in promoting cycling (Gårder, Leden, & Pulkkinen, 1636; Howard & Burns, 1773). Continuous isolated bicycle paths/lanes support adult bicycle usage, particularly female bicyclists (Dill, 2009). The findings of Habib, Mann, Mahmoud and Weiss (Habib, Mann, Mahmoud, & Weiss, 2014) reveal that the isolated bicycle paths have the greatest positive impact on bicycle usage, as it increases driving comfort and safety. Akar and Clifton Akar and Clifton (2009) stated that the increase in bicycle lanes is an encouraging factor for bicycle user, even for non-cyclists. In addition, the placement of BSP stations into bicycle facilities has shown that it facilitates membership in BSPs for non-members (Faghih-Imani & Eluru, 2016). The proximity of the BSP stations to the bicycle lanes and the availability of bicycle lanes are associated with the desire to cycle more (Dill & Voros, 2007; Kabak, Erbaş, Çetinkaya, & Özceylan, 2018). Off-road is also an isolated bicycle

Table 1
Weather Condition Impact Factors.

Determinants	Factors	Usable Unit	Expected Impacts	References
Seasons	Winter	months	SNC	Fuller, Gauvin, Kestens, Daniel, Fournier, Morency and Drouin (Fuller et al., 2013), Heinen, Van Wee and Maat (Heinen et al., 2010),Martinez Martinez (2017), Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018), Kim Kim (2018), Wang, Akar and Chen (Wang et al., 2018), El-Assi, Mahmoud and Habib (El-Assi et al., 2017), Corcoran, Li, Rohde, Charles-Edwards and Mateo-Babiano (Corcoran et al., 2014), Sun, Chen and Jiao (Sun et al., 2018), Gebhart and Noland Gebhart and Noland (2014), Reiss and Bogenberger Reiss and Bogenberger (2016), Miranda-Moreno and Nosal (Miranda-Moreno and Nosal (2011), Croci and Rossi Croci and Rossi (2014), Wadud Wadud (2014), Fournier, Christofa and Knodler Jr (Fournier et al., 2017), Godavarthy and Taleqani Godavarthy and Taleqani (2017), Kutela and Kidando Kutela and Kidando (2017), Rudloff and Lackner Rudloff and Lackner (2014), Reiss and Bogenberger Reiss and Bogenberger (2017)
	Summer		SPC	
	Spring		PC	
	Autumn		PC	
Weather Type	Sunny	days	SPC	
	Partly Sunny		PC	
	Rainy		SNC	
	Windy		SNC	
	Cloudy		LPC	
	Foggy		UK-NC	
Precipitation	Snow	cm	SNC	
	Rain	cm	SNC	
	Light Rain	cm	LNC	
	Intermittent Rain	cm	LNC	
	Heavy Rain	cm	SNC	
	High chance of Precipitation	%	UK-NC	
	Low probability of Precipitation	%	UK-PC	
Wind	Light Wind	km/h	PC	
	High Wind		SNC	
Humidity	Relative Humidity	%	SNC	
Temperature	Temperature	°C	PC	
	Below Zero		SNC	
	0 - 10		LPC	
	10 - 20		PC	
	20 - 30		SPC	
	+30		CR	
	Scorching Heat		SNC	

LPC: Lowly Positive Correlation; PC: Positive Correlation; SPC: Strongly Positive Correlation
LNC: Lowly Negative Correlation; NC: Negative Correlation; SNC: Strongly Negative Correlation
CR: Confusing Results; UK-PC: Unknown- Positive Correlation; UK-NC: Unknown- Negative Correlation

path and strongly associated with its length and the use of stations within the 400 m (Mateo-Babiano et al., 2016). Wang, Akar and Chen (Wang et al., 2018) stated that the length of off-road within 500 m station buffer positively affects the trip generation. Additionally, Wang, Akar and Chen (Wang et al., 2018), in their study, concluded that the sidewalk length did not affect the use of BSP, although the length of the sidewalk had a positive effect on access to transit hubs (Ehrenfeucht & Loukaitou-Sideris, 2010; Griffin & Sener, 2016).

In the Portland city center, a two-way bicycle lane was installed by the Transport Office and the results of the survey showed that bicyclists, drivers, pedestrians and especially female users increased their comfort and safety perceptions (Monsere, McNeil, & Dill, 2012). The safety perception has an effect on the determination of the driving route (Hunt & Abraham, 2007). Roads with no bicycle infrastructure and mixed bicycle roads which is interactive with motor-vehicle traffic flows are the least preferred routes by bicyclists. The 10-minute travel time in route selection is the variable with the highest positive relationship (Caulfield, Brick, & McCarthy, 2012). In the SoBi BSP, bike-sharing was observed to be reduced in unmarked bicycling routes with high traffic volumes. It is also stated that users tend to prefer routes with isolated lanes instead of the shortest distance routes (Lu, Scott, & Dalumpines, 2018). In another study, the route selection of users tends to use stations that will provide a short deviation from the destination (Schoner & Levinson, 2013). It can be said that urban form, traffic volume and personal attitude affect bicycling safety (Aultman-Hall & Kaltenecker, 1999). Briefly, improvement of bicycle facilities are needed to maximize bicycle access, and "a minimum bicycle infrastructure" is required for safe and comfortable bicycle usage (Midgley, 2009).

The risk perception and safety in bicycle usage are important for night shift workers who use bicycles to access transit points. So, facilitating access to transit points with additional streetlight has increased bicycle usage and minimized crime prevalence near transit hubs (Chandra, Jimenez, & Radhakrishnan, 2017). As well, Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018) showed that bike sharing in the BSPs near the train stations increased, but the increase in the number of murders that occurred in 1.6-km station buffer decreased the use of BSP.Furthermore, the percentage of cycling as a mode of access to train stations in the Netherlands is less than the overall bicycle usage percentage due to the lack of bicycle and parking as well as the risk of cycling theft (Rietveld, 2000). Isolated bicycle paths, safe parking areas, rentable bicycle, docks, and racks are stated to be effective factors for access to the train stations by bicycle (Cervero, Caldwell, & Cuellar, 2013).

2.2.2. Land use

The land structure may differ from local, urban and regional, and may affect bike sharing demand (Cervero, 1989). A slope is one of the most important natural land variables affecting bicycle usage. In fact, in regions with a suitable slope for cycling, users tend to rent bicycles from the above stations and drop them to the below stations. Especially, female users and commuting generally do not prefer to use BSP stations in hills up-slope regions. Presence of high slope differences between stations on steep slopes and mountainous areas increases the amount of effort while cycling upwards and leads to unsafe high speeds when driving downwards (Frade & Ribeiro, 2014). Bike-sharing often decreases, when the slopes exceeds %4 slopes (Lu et al., 2018). Hood, Sall and Charlton (Hood, Sall, & Charlton, 2011), Jennings Jennings (2011), Bordagaray, dell'Olio, Fonzone and Ibeas (Bordagaray, dell'Olio, Fonzone, & Ibeas, 2016), all found that up-hill slopes reduced the bike sharing demand. In China's rugged and mountainous cities such as Chongqing, Guiyang, Dalian bicycle modal share is quite low. Tel Aviv BSP data. Research findings show an incentive reward policy in order to increase the return bike sharing demand in the up-hill stations (Fricker & Gast, 2016). Additionally, as with e-bikeshare systems, e-bikes can substitute smart bikes at stations in the mountainous region, and available e-bikes in stations can rent by users. Briefly, the e-bike that picked up / dropped from stations located in mountainous regions may contribute to bike sharing mobility in the respective area as it may reduce the effort to be exerted for users.

Depending on the terrain structure also, Frank and Pivo Frank and Pivo (1994) reported that employment, population density, and mixed land use are positively correlated with transport mobility. Kim, Shin, Im and Park (Kim, Shin, Im, & Park, 2012) conclude that for non-rainy weekdays, bike sharing demand is fifteen times higher for commercial areas than residential areas and also three or five times higher for parks than schools and subways. According to Cervero and Duncan Cervero and Duncan (2003), however, employment density within a radial distance of 8 km adversely affects bicycle usage, since intersections of highways and bicycle paths located near busy work centers create hazardous areas for users. This is a contradiction, in our opinion, it could be explained by the fact that conflict may because of the different study areas of these studies. Another reason for this could be the geographical distribution of the station, and its relationship with the built environment in the study area can affect the use of BSP. In other words, the proximity to green spaces and recreation areas, schools, universities, museums, shopping centers, sports areas, restaurants, hotels, bus/ subway/train/suburban/ ferry transit hubs has a positive effect on the use of BSP (Kabak et al., 2018; Kaltenbrunner, Meza, Grivolla, Codina, & Banchs, 2010; Wang et al., 2018). Table 2 shows the built environment and land use factors that affect bike sharing demand. In the literature, although the proximity of BSP stations to transit points is examined in the built environment or land use factors, this study argues that the factors that will enable the integration of BSPs with the public transport network should be investigated in detail. Therefore, Public Transport Impact Factors are discussed in the next section.

2.3. Public transportation impact factors

It is widely accepted that public transport planning and land use integration are necessary to reduce the use of motor vehicles and provide a suitable alternative means of transport, such as bicycles (Nigro, Bertolini, & Moccia, 2019). In the Netherlands, where its urban structure is known to be compatible with bicycle usage, although the bicycles are an option as a mode of transportation, 30% of business trips within 5 km are still carried out using motor vehicles (Engbers & Hendriksen, 2010). In recent years, in order to reduce the use of motor vehicles and to encourage bicycle use, the widespread use of BSPs in crowded countries such as China has gained considerable attention. In the studies carried out with the idea that increased passenger demand in the public transport network can be reduced by using BSP and an increase in flexibility of transportation systems has promoted the interest in determining the factors which influence users' decision to bike-sharing (Buehler & Pucher, 2011; Martens, 2007; Pucher, Garrard, & Greaves, 2011).

BSPs are "a form of public transport that provides bicycles for short-term use through the network of automatic bicycle parking stations" (Gleason & Miskimins, 2012). This is fully substituting public transport in cities with a three-phased trip: walk from origin to station, cycling between stations, and walk from station to destination. And also BSPs are systems that can be integrated with public transportation and provide sustainable transportation in cities. (Buehler & Pucher, 2011; DeMaio & Gifford, 2004). That kind of utilization is being complementary to public transportation, travel between hubs of which can be carried out by bike sharing. In other words, the first mile/last mile solution of bike-sharing usage can bridge the gap between multiple transit hubs (Fig. 1).

The results of the online survey with BSP users in the US and Canada showed that most of the members think the BSP strengthens public transport and improves their connections (Shaheen, 2012). The possibility of substitution or completion of bicycles to public transport was explained using the Tel Aviv BSP data. Research findings show that the bus completes bicycle for shorter trips whereas bus substitutes bicycle

Table 2
Built Environment and Land Use Impact Factors.

Determinants	Factors	Usable Unit	Expected Impacts	References
Bike Infrastructure	Bicycle Lane	km	PC	Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018), Wang, Akar and Chen (Wang et al., 2018), Mateo-Babiano, Bean, Corcoran and Pojani (Mateo-Babiano et al., 2016), Garrard, Rose and Lo (Garrard, Rose, & Lo, 2008), Habib, Mann, Mahmoud and Weiss (Habib et al., 2014), Akar and Clifton Akar and Clifton (2009), Faghih-Imani and Eluru Faghih-Imani and Eluru (2016), Dill and Voros Dill and Voros (2007), Kabak, Erbaş, Çetinkaya and Özceylan (Kabak et al., 2018), Ehrenfeucht and Loukaitou-Sideris Ehrenfeucht and Loukaitou-Sideris (2010), Griffin and Sener Griffin and Sener (2016), Lu, Scott and Dalumpines (Lu et al., 2018), Schoner and Levinson Schoner and Levinson (2013), Midgley Midgley (2009), Kim, Shin, Im and Park (Kim et al., 2012), Kaltenbrunner, Meza, Grivolla, Codina and Banchs (Kaltenbrunner et al., 2010)
	Bicycle Path	km	PC	
	Separated Pathway	%	SPC	
	Off-Road	km	PC	
	Sidewalk Length	km	No-Effect	
Built Environment	Population Density	% or pers./km^2	SPC	
	Employment Density	% or pers./km^2	CR	
	Office Density	%	PC- For attraction	
	Food Density	%	PC	
	Commercial	%	PC- For attraction	
	Residence	%	PC- With high trip generation	
	Green Areas	%		
	Street Light	%	PC- For safety	
BSP	Number of Docks on Station	count	PC-With high trip generation	
	Number of Racks on Station	count		
	Bike Sharing Age	years	NC-For non-member	
	Station Age	months	PC- With high trip generation	
	Station Capacity	docks	SPC- With high trip generation	
Land Use	Park Area	%	SPC-Weekend Pm	
	Hotel	count	PC	
	Restaurant	count, % or distance	PC	
	Shopping Center	count or distance	PC	
	Tourism Area	%	PC- For attraction	
	Recreation Area	%	PC- For attraction	
	School	distance	PC	
	University	distance	PC	
	Sports Center	count	PC	
	Lakeside	distance	SPC-Weekend	
	Seaside	distance	SPC-Weekend	
Natural Land	0 - 2	%	PC	
	2 - 4	%	SPC-For Pickup	
	4 - 6	%	SNC-For Return	

for longer trips (Levy, Golani, & Ben-Elia, 2017). Shifting from bus to bicycle depends primarily on travel length, travel time, travel comfort, and human effort (Campbell, Cherry, Ryerson, & Yang, 2016). Since close distances require allowable an effort and short-term exposure to unfavorable weather conditions can make bicycles replace buses for short trips, especially in cities with crowded public transport networks. For example, the potential impacts of BSP in Helsinki on travel time in public transport were investigated. It is observed that the use of BSP reduced the travel time in public transport by an average of 6 min (Jäppinen, Toivonen, & Salonen, 2013). Moreover, the faster trips have occurred at the stations of BSPs that are well integrated with the public transport network (McBain & Caulfield, 2018).

The "Vélo'v" in Lyon and the "Call-a-Bike" in Germany are examples of BSPs that have bikes at public transport stops (Borgnat et al., 2011; Buehler & Pucher, 2011). BSPs, which can integrate with railways, in particular, can reduce the use of motor vehicles in access to train stations by providing vacant space and available bicycles for potential passengers depending on station capacity (Wang et al., 2018). Martin and Shaheen Martin and Shaheen (2014) reported that in high-density regions with a network of railroad networks, BSPs can expand the public transport network and can also reduce the burden on public transport at peak hours in crowded cities. European cities follow a policy of supporting bicycle riding by providing safe parking at transit points, and additionally if the BSP stations are close to transit hubs such as trains, buses, and subways, travel generation at these stations may be positively affected (Pucher & Buehler, 2009). According to the data of Capital, Brisbane CityCycle and Paris Velib BSPs, the presence of BSP stations near the suburbs and railway stations is in high demand for rental or return during peak hours (Ahillen, Mateo-Babiano, & Corcoran, 2016; Etienne & Latifa, 2014). Six of the most used Capital BSP stations are close to the railway stations. Moreover, many parameters such as the train frequency per hour, the number of bus stops, employment density and residential density affect the use of Capital BSP. The model estimation represents that a 10% increase in bike sharing ends up with an 2.8% increase in transit use. Also, transit ridership is more affected by employment density in proportion to residential density (Ma, Liu, & Erdoğan, 2015).

The usage of public transport smart cards in bike rental increases the bike sharing demand. At night, especially when public transport is not available, between 22: 00 pm – 06: 00 a.m., they can encourage users to use BSP (Fishman et al., 2012). Fishman, Washington, Haworth and Mazzei (Fishman, Washington, Haworth, & Mazzei, 2014) found a positive correlation between the use of BSP stations and areas with poor public transport access in Melbourne. Between July 8-July 10, 2015, the total number of bike sharing increased by 86% to 72,503 trips and average travel time increased by 88% to a maximum of 43 min BSP in London throughout the strike (Fuller, Sahlqvist, Cummins, & Ogilvie, 2012; Saberi, Ghamami, Gu, Shojaei, & Fishman, 2018). BSPs can serve as a part of the public transport network or become a transportation alternative in areas where public transportation systems are weak (DeMaio, 2009). However, BSPs are not only used for transportation, but also for free time activity in recreational areas (Daley & Rissel, 2011; Gleason & Miskimins, 2012).

The main purpose of the section is determining factors that will facilitate the smooth integration of bike sharing with public transport and other alternative modes with evidence from the literature. The related factors are given in Table 3 for decision-makers, researchers and everyone who cares about integration BSPs into public transportation.

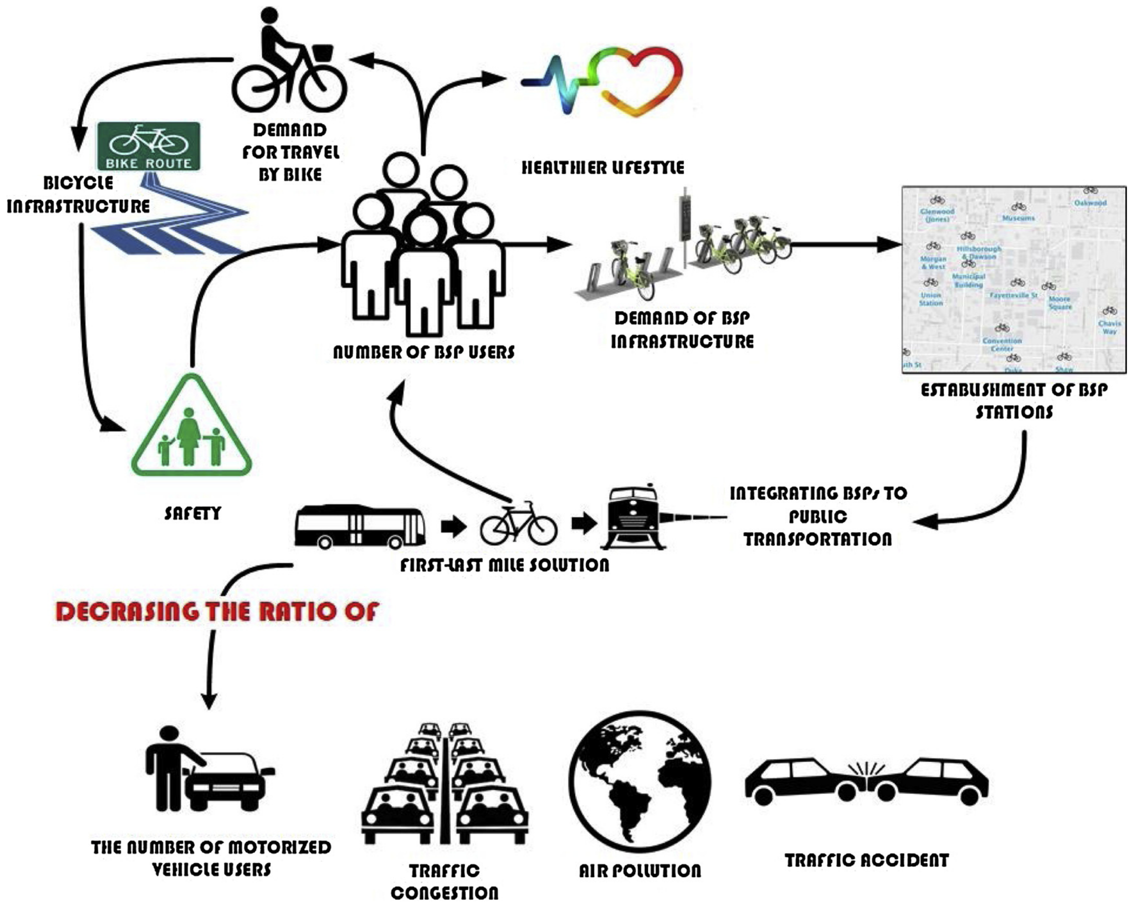

Fig. 1. Integrating BSPs to Public Transportation.

2.4. Station level impact factors

BSPs are one of the intelligent transportation systems that include bicycle rental stations, smart parking units and smart bikes (Raviv & Kolka, 2013). For all systems except for free-floating BSPs potential passengers need the bicycles available at the station to rent bikes and the empty smart parking unit in the station to place the rented bike (Froehlich, Neumann, & Oliver, 2008; Zhang, 2017). In both pick-up and return activities, access to the nearest station is preferably required (Shaheen, Zhang, Martin, & Guzman, 2011). Therefore, the stations should be deployed in the closest possible locations to reach their maximum coverage and the greatest number of people that could wish to rent a bike (MEng, 2011).

The proximity of BSP stations to each other and to the position of the cyclist increases bike-sharing demand (Bachand-Marleau, Lee, & El-Geneidy, 2012). The decision processes such as determination of optimum station location, addition/subtraction of new stations or increase / decrease in station capacities of BSP station network planning/editing phase have been included in the literature (Cetinkaya, 2017; Chen et al., 2015; Fuller et al., 2011; Rixey, 2013). However, in this section, the factors affecting the selection of optimum station location and station buffer distance are discussed.

Table 3
Public Transportation Impact Factors.

Determinants	Factors	Usable Unit	Expected Impacts	References
Public Transportation Network	Bus Stop	Distance to public transport hubs	SNC	DeMaio DeMaio (2009), Fishman, Washington and Haworth (Fishman et al., 2012), Wang, Akar and Chen (Wang et al., 2018), Engbers and Hendriksen Engbers and Hendriksen (2010), Gleason and Miskimins Gleason and Miskimins (2012), Shaheen Shaheen (2012), Levy, Golani and Ben-Elia (Levy et al., 2017), Jäppinen, Toivonen and Salonen (Jäppinen et al., 2013), McBain and Caulfield McBain and Caulfield (2018), Martin and Shaheen Martin and Shaheen (2014), Pucher and Buehler Pucher and Buehler (2009), Etienne and Latifa Etienne and Latifa (2014), Ahillen, Mateo-Babiano and Corcoran (Ahillen et al., 2016), Ma, Liu and Erdoğan (Ma et al., 2015), Fishman, Washington, Haworth and Mazzei (Fishman, Washington, Haworth, Mazzei et al., 2014), Fuller, Sahlqvist, Cummins and Ogilvie (Fuller et al., 2012), Saberi, Ghamami, Gu, Shojaei and Fishman (Saberi et al., 2018), Daley and Rissel Daley and Rissel (2011), Goodman, Green and Woodcock (Goodman, Green, & Woodcock, 2014)
	Metro Station		SNC	
	Train Station		SNC	
	Tram Stops		NC	
	Ferry Port		NC	
Public Transportation	Number of Bus Stops	count	PC	
	Number of Metro Station		SPC	
	Number of Train Station		SPC	
	Number of Tram Stops		PC	
Travel	Travel Time	Min.	NC	
	Travel Distance	Km	NC	
	Use of Public Transport Smart Cards	count	SPC	

2.4.1. Location optimization of BSP stations and selection station buffer distance

Determining the optimal station location in the station network is critical for the success of the BSPs (Vogel & Mattfeld, 2011). In optimal station location decision-making processes, spatial information that affects cycling sharing can be combined with using geographic information systems (Aultman-Hall, Hall, & Baetz, 1578; MEng, 2011). However, in order to establish a successful BSP station network, it is necessary to take into account the points of attraction such as restaurants, museums, metro/bus stops, schools, sports, and shopping centers (García-Palomares, Gutiérrez, & Latorre, 2012). For example, 12 different criteria were selected by Kabak, Erbaş, Çetinkaya and Özceylan (Kabak et al., 2018) in order to evaluate the site of 9 stations in İzmir / Karsıyaka and to determine the optimal station location among the alternatives. The existing and alternative stations were compared with using a 250-meter station buffer.

García-Palomares, Gutiérrez and Latorre (García-Palomares et al., 2012) point out two significant approaches to determine the optimal location of bike sharing stations in Madrid. The first approach is to minimize the impedance and maximize coverage, and the second is to maximize the total population covered within a 200 m station buffer. Although the first approach seems more advantageous in terms of spatial equality, the results of the study in London show that low-income areas are less likely to be close to Barclays Bike Rentals and travel frequency decreases as poverty increases (Ogilvie & Goodman, 2012). In addition, low-middle-income individuals in Phoenix account for almost 25% of the population and only 14.5% of bike-sharing stations are in the area where they live. The unbalanced distribution of the BSP station network was dealt with by Conrow, Murray and Fischer (Conrow, Murray, & Fischer, 2018) and they aimed to improve station accessibility and to show how to reach spatial and social equality.

Mateo-Babiano, Bean, Corcoran and Pojani (Mateo-Babiano et al., 2016) investigated 250 m buffer by taking into the consideration the distance between BIXI stations and convenient walking distance. Then, it was emphasized that increasing the number of stations without increasing buffer distance has a greater positive impact than increasing the level of station capacity. However, Wang, Akar and Chen (Wang et al., 2018) preferred the Citi bike station buffer as 500 m radial radius. O'brien, Cheshire and Batty (O'brien, Cheshire, & Batty, 2014) analyzed the data from 38 systems in Europe, the Middle East, Asia, Australia, and the United States by accepting the station buffer as 1000 m since geographic coverage of the 38 different systems varies between 20 km^2 and 200 km^2. However, Wang, Lindsey, Schoner and Harrison (Wang, Lindsey, Schoner, & Harrison, 2015) reported that the nearest station distance of 1000 m decreases travel generation by 90–95% on average.

Stations of BikeMi BSP in Milan were deployed less than 300 m from each other to allow access by walk (Croci & Rossi, 2014). In addition to other studies, El-Assi, Mahmoud and Habib (El-Assi et al., 2017) found that the production and attraction of the stations increased with the number of other PBS stations within 200 m. Moreover, users of 19 IT-based BSPs in the United States were interviewed and most of them indicated that the optimum distance between stations is 300 m to 400 m (Shaheen, 2012). Nielsen and Skov-Petersen Nielsen and Skov-Petersen (2018) also observed that the use of BSP increased when the distance to the stations was 3–4 km, according to the size of the region (Simons et al., 2013). Unlike other studies, Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018) tested combinations of 0.8 km, 1.6 km, 3.2 km, 4.8 km, and 8.0 km radii for the nearby stations variables by multilayered mixed-regression model. Then, they showed that the addition of a new BSP station within 800 m reduced bike sharing demand. To explain this, they pointed out that if the model does not include a larger buffer as the control variable, the effect of a buffer with a small radius on bike sharing can be considered positive in the estimated results.

Table 4 displays an overview of selected BSP station buffer distances and reasons for acceptance. In these studies, the BSP station buffer is used to examine the impact of land use and built environment components on bike sharing. Up to now, very little attention has been paid to the role of station buffer on control variables. On the other hand, most of these studies have predominantly ignored the effect of the station buffer on the research results. There is a current paucity of evidence-based literature describing the impact of the change of the station buffer in the range of 0–800 m and especially in the range of 300–800 m on bike sharing. Zhou Zhou (2015) utilized a flow clustering analysis to determine the optimal distance between 120 and 480 m and reported that the suitable buffer distance is approximately 400 m. Whilst several studies have shown that results related to station buffer are inconsistent, little if any empirical work has been done to investigate the effect of buffer distance.

2.5. Socio-demographic impact factors

To better understand the user profile of BSPs, it is necessary to identify the socio-demographic factors affecting the user's travel demand (Feng & Li, 2016). Bike sharing behavior studies have report that there is a strong correlation between the trip demand and gender, age, education, income, and vehicle ownership. BSP members generally represent male, young, educated, working, high income user profiles (Fishman, Washington, & Haworth, 2014; Ricci, 2015; Shaheen, 2012).

The results of the surveys conducted with 901 participants showed that members are men (52.8%), have post-secondary education (65.6%) and have an annual income of $ 50,000 or more (57.9%) compared to other customers (Zanotto, 2014). According to the results of an online survey conducted Melbourne BSP members in Australia: 76.6% of all users are male, and 16.9% between 30–34 years of age, 43% has 104,000 $ and more income, 81% of undergraduate or higher education (Fishman, Washington, Haworth, & Watson, 2015). Barclays Cycle Hire members, in London, are mostly men and men have tendency generation more trips than women (Ogilvie & Goodman, 2012). In another study, Citi Bike BSP's 30-day data for September 2016 of the 598 active stations in Manhattan were used to determine the effective factors of bike sharing for different age groups such as Milennials, Gen Xers, Baby Boomers. As a result, it is concluded that the 28–37 age group is the age cohort that uses the most BSP. For all generations using BSP, meteorological and temporal factors, BSP infrastructure, built environment, and public transport have been found to have a significant impact (Wang et al., 2018). Short travel time, low cost, ease of access to transportation facilities increase bicycle use in individuals aged 17–18 years, the fact that BSPs meet all the desired encouraging factors suggests that systems can encourage young people to use bicycles (Simons et al., 2013). Similarly, individuals in 18–34 age group are 3.3 times more likely to be BSP members than all other age groups (Fishman et al., 2015). The age range of BSP use is young, but especially adult (+18) individuals because of the age restriction imposed to become a member. Age limitation is applied to become a member since only adults can assume responsibility for the safety of bicycles. But the age-restriction to members of the BSP could be an obstacle to the promotion of bicycle use (Eren, Katanalp, Yıldırım, & Uz, 2018; Woodcock, Tainio, Cheshire, O'Brien, & Goodman, 2014).

Only 21% of Divvy BSP members in Chicago are female and the average distance between start and end-points for female users is 113.4 m and 210.3 m respectively on weekends and weekdays (Zhou, 2015). Similarly, Engbers and Hendriksen Engbers and Hendriksen (2010) reported in their study that female members prefer to travel less than 1 km on average when they go to work. The fact that less than 20% of London BSP members are women can be exemplified as the gender impact on bike sharing. Also, the impact of socio-economic characteristics can be exemplified that the sudden increase in ticket prices can reduce the use of BSP for residents living in low-income regions, unlike middle- and high-income people (Goodman & Cheshire, 2014). In addition, the middle-income variable is used not only to control the effects on bike sharing, but also to control the differences that may be due to

Table 4
Selection Station Buffer Distance.

References	Selected BSP Station Buffer / Reasons For Acceptance
Aultman-Hall and Kaltenecker Aultman-Hall and Kaltenecker (1999)	Within 200-meter
García-Palomares, Gutiérrez and Latorre (García-Palomares et al., 2012)	Within 200-meter / For high trip demand
Saibene and Manzi Saibene and Manzi (2015)	Within 200-meter
Kabak, Erbaş, Çetinkaya and Özceylan (Kabak et al., 2018)	Within 250-meter / According to distance between the stations
Faghih-Imani, Eluru, El-Geneidy, Rabbat and Haq (Faghih-Imani, Eluru, El-Geneidy, Rabbat, & Haq, 2014)	Within 250-meter / For convenient walking distance and according to distance between the stations
Croci and Rossi Croci and Rossi (2014)	Within 300-meter / For convenient walking distance and according to distance between the stations
Zhou Zhou (2015)	Within 400-meter / According to distance between the stations
Wang, Akar and Chen (Wang et al., 2018)	Within 500-meter / For convenient walking distance
Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018)	More than 800-meter / For all user types
Wang, Lindsey, Schoner and Harrison (Wang et al., 2015)	Less than 1000-meter / For increases trip generation
O'brien, Cheshire and Batty (O'brien et al., 2014)	1000-meter / Maximum distance for walking
Nielsen and Skov-Petersen Nielsen and Skov-Petersen (2018)	Within range of 3000 to 4000 meter

the credit card payment requirement of the CaBi system (Buck & Buehler, 2012). Research investigating the relationship between social inequality and low station access has shown that BSP stations are often established in areas with high income and densely populated areas, tourist sites, city centers, and recreation areas (Ricci, 2015).

Class, gender and ethnic identities are factors that are influential on bicycle usage (Steinbach, Green, Datta, & Edwards, 2011). Using the August 2010 trip data, various demographic and socioeconomic factors that were thought to affect bike-sharing demand were investigated in 65 stations of the BSP in Minneapolis. The relative effects on the BSP station, located within the 400 m, has been discussed using the factors such as race, employment intensity, medium, and high income, retail density, vehicle ownership (Muarer, 2011). In addition, population density is more significant for trip generation, while employment intensity is more decisive for trip attraction (El-Assi et al., 2017). Rixey Rixey (2013) also suggests that socio-demographic characteristics such as population, work intensity, mid-high income, and education have a positive relationship on bike sharing. Moreover, lower bike sharing demand can occur due to many reasons: while the main causes are as age and race, the other reasons are low retail sales opportunities and the BSP station buffer distance (Daddio & Mcdonald, 2012).

In Table 5, socio-demographic factors are divided into 5 groups as gender, age, education, income, and vehicle ownership. Researches shows that BSP members and candidate members have more car ownership than non-members (Shaheen & Guzman, 2011). The end of fuel costs, the decreasing of stress caused by traffic congestion, reduced travel time for the shorter trips and easy access to BSPs create to provide a convenient environment for car owners to use BSPs (Larsen, 2013; Martens, 2007; Murphy & Usher, 2015). Therefore, it was observed that car ownership did not diminish bike sharing demand (Shaheen & Guzman, 2011). Moreover, car ownership was found to be an attractive condition for the use of BSP (Shaheen et al., 2011). Interestingly, however, Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018) stated that driving license ownership has a negative impact on the use of BSP. This situation, it could be explained by the fact that the driving potential of individuals with driving licenses can be high.

2.6. Temporal factors and safety

2.6.1. Temporal factors

Different approaches or models and calendar events or time-based explanatory variables were used to identify factors affecting travel production. Kim Kim (2018) investigated effects of the factors such as the weekend, public holiday and school holiday, weather (temperature, humidity, precipitation, wind speed) data and spatial data (residential, commercial, industrial and green areas and university districts). In this study, results indicate that there was no noticeable difference in the number of bike rentals on weekends and weekdays, but during the weekend morning number of trips were reduced. Interestingly, the bike sharing on public holidays has decreased. The fact that school holidays do not have a significant impact on BSP usage is related to the fact that children under 17 cannot become members. Mateo-Babiano, Bean,

Table 5
Socio-Demographic Impact Factors.

Determinants	Factors	Usable Unit	Expected Impacts	References
Gender	Male	%	SPC	Ogilvie and Goodman Ogilvie and Goodman (2012), Zanotto Zanotto (2014), Hyland, Hong, de Farias Pinto and Chen (Hyland et al., 2018), Wang, Akar and Chen (Wang et al., 2018), El-Assi, Mahmoud and Habib (El-Assi et al., 2017), Engbers and Hendriksen Engbers and Hendriksen (2010), Shaheen, Zhang, Martin and Guzman (Shaheen et al., 2011), Shaheen Shaheen (2012), Rixey Rixey (2013), Zhou Zhou (2015), Ricci Ricci (2015), Fishman, Washington and Haworth (Fishman, Washington, Haworth et al., 2014), Fishman, Washington, Haworth and Watson (Fishman et al., 2015), Simons, Clarys, De Bourdeaudhuij, de Geus, Vandelanotte and Deforche (Simons et al., 2013), Ezgi Eren, Burak Yiğit Katanalp, Zeynel Baran Yıldırım and Uz (Eren et al., 2018), Goodman and Cheshire Goodman and Cheshire (2014), Buck and Buehler Buck and Buehler (2012), Steinbach, Green, Datta and Edwards (Steinbach et al., 2011), Muarer Muarer (2011), Daddio and Mcdonald Daddio and Mcdonald (2012), Shaheen and Guzman Shaheen and Guzman (2011)
	Female	%	LPC	
Age	< 16		Un-Known	
	16-21		SPC	
	22-27	%	SPC	
	28-37		SPC	
	38-51		LPC	
	51-70		LPC	
Education	Primary School	%	As the education level increases, the trip generation increases.	
	Secondary School			
	Completed			
	University			
	Bachelor Degree			
	Master Degree			
Income	Low Income		LPC	
	Middle Income	$	PC	
	High Income		SPC	
Ownership	Car	%	PC	
	Driving License	%	NC	
	Private Bicycle	%	PC	

Corcoran and Pojani (Mateo-Babiano et al., 2016) in their study suggest that CityCycle members prefer free short-term trips, and usually want to return to the stations where that not required to need to make more effort by bicycle. And they reported that recreation trips for the weekend increase the use of BSP in the afternoon, while work trips for the weekday increase the demand for BSP in the rush hours. Especially on weekends, the bike sharing demand in the parks is twice as much as on weekdays (Kim et al., 2012). Etienne and Latifa Etienne and Latifa (2014) reported that there is a high demand for trip at the stations that are close to the parking areas at weekend afternoons. In their study, Ahillen, Mateo-Babiano and Corcoran (Ahillen et al., 2016) showed that BSPs were most frequently used in the morning and afternoon that are "peak working hours" and also used in short-time travel. Froehlich, Neumann and Oliver (Froehlich et al., 2008) also showed that there was an increase in bike sharing demand from residential areas to commercial areas on weekdays at 7 a.m. and similarly there was increase the demand from commercial areas to residential areas after working hours. Furthermore, the cycling habits may increase the number of bike-sharing trips for commuting to and from work especially in the morning hours (Hampshire & Marla, 2012). The use of BSP is very common for short trips with high travel speeds. If Vélov BSP bikes use at 6:00 am during the weekdays, the travel speed can reach 14.5 km/h. If there is a short route for a destination by bicycle, then most of the bicycle trips will be shorter than the car trips in all hours during the week. In addition, the arbitrary travel speeds can decrease to 10 km/h on weekend afternoons (Jensen, Rouquier, Ovtracht, & Robardet, 2010).

2.6.2. Safety

High safety perception can be pointed out as a reason to cycle more. All people who are either user or not user can have different perceptions of feeling safe. For example, foreign tourists in countries where cycling is unsafe tend to supply helmets due to the high risk of an accident. Thus, the helmet can be an obstacle for tourists as BSPs do not have a rental unit to provide helmets (Kaplan, Manca, Nielsen, & Prato, 2015).

The use of the helmet by BSP users who interact with motor vehicle traffic at peak hours can reduce head injuries and even death (Bonyun, Camden, Macarthur, & Howard, 2012). But, it is clear that BSP users do not tend to wear helmets in comparison to private cyclists. For example, Kraemer, Roffenbender and Anderko (Kraemer, Roffenbender, & Anderko, 2012) conclude that members of the Washington, DC BSP were found to have much lower helmet wearing habits than private cyclists (Basch, Zagnit, Rajan, Ethan, & Basch, 2014). The research results in Toronto shown that 306 BIXI members and 6426 private cyclists were observed and BIXI members' helmet use rate was significantly lower than that of private cyclists (Bonyun et al., 2012). CaBi short-term users in Washington, D.C. are less likely to use helmets than long-term users (Buck et al., 2013). On the other hand, Citi Bike users in New York were observed for a total of 44 h on weekdays and weekend between 8:00 am - 2: 00 pm and 2:00 - 20:00 pm. Research results show that 85.3% of Citi Bike members did not wear helmets while cycling (Basch, Ethan, Rajan, Samayoa-Kozlowsky, & Basch, 2014). Also, Basch, Zagnit, Rajan, Ethan and Basch (Basch, Zagnit et al., 2014) reported that 21.7% of Citi Bike members and 15.3% of ordinary users wear helmets. Moreover, they point out that Citi Bike members are likely to use helmets when they go to work in the morning than in the evening. Furthermore, they found that the use of helmets in the recreation areas during the weekday is higher than at the weekend. Interestingly, another research findings show that although very few BIXI BSP members are women, most of the BSP members who use helmets are women (Bonyun et al., 2012). Of the 4789 cyclists observed in Montreal between 16 August and 31 October 2011, 46% have worn helmets. Also, Montreal BSP female users have more helmet usage level than male users. Young members have the highest rate of helmet use (73%), while young adults have the lowest use rate (34%) (Grenier et al., 2013). In contrast, Basch, Zagnit, Rajan, Ethan and Basch (Basch, Zagnit et al., 2014) reported that men use helmets more often than women.

There are conflicting results reported by previous studies on the impact of the mandatory helmet law on bike-sharing demand. Some researchers findings are consistent with each other; Fishman Fishman (2011), Shaheen Shaheen (2012), Fishman, Washington and Haworth (Fishman et al., 2013) found a negative connection between bike-sharing demand and helmet use as BSP bikes are rental for usually "unplanned" shorter trips. Fishman, Washington, Haworth and Mazzei (Fishman, Washington, Haworth, Mazzei et al., 2014), later in their paper on helmet wear, reported that the legal requirement introduced in Australia on helmet use reduced BSP usage. In fact, they pointed out that BSP users do not prefer to carry helmets rather than wear to helmets. it is considered that BSPs generally reduce the number of bicyclists using helmets. Therefore, providing helmets to BSP users; it can reduce horrendous injuries in accidents and prevent low bike-sharing demand in cities where helmet usage is mandatory.

3. Conclusion

Nowadays, the development of BSPs is thought to be necessary for a more livable environment. Over the last 50 years, BSPs have improved with the development of technology, and today, they have become an important new transportation option to solve problems such as excessive consumption of natural resources, traffic congestions, and sedentary lifestyles. BSPs offer various advantages over other modes of transport in terms of society, environment, and health. Therefore, in recent years, the number of researchers and planners which interest in studies that encourage the use of BSP have increased. To develop policies to improve bike sharing, the factors that affect bike sharing behavior need to be better understood. In this study the most commonly used factors affecting trip demand in the literature in researching the effectiveness of station-based BSPs have been gathered together. As explained in the tables, the basic evidence that can be extracted from the literature on bike-sharing is sorted in the following.

- Adverse weather conditions: rain, strong wind, high temperature, and humidity reduce bike-sharing demand. If there is no precipitation at 20–30 °C weather temperatures, it is more likely to increase the number of bike sharing according to other weather conditions.The temperatures that are upper than the maximum limit value according to the local climate negatively affect bike-sharing demand.
- The previous studies have often investigated built environment and land use factors that decrease/increase the safety perception of users. However, there is a need for objective studies investigating the effects of such paths on driving safety. Moreover, BSP members do not want to prefer bike lanes mixed with higher traffic, yet it remains unclear whether this affects bike sharing frequency.
- Station buffer distance is the determinant in the decision process such as optimum station location determination, new station addition/subtraction or increase/decrease the station capacity. First, the impact of the change of the station buffer distance in the range of 300–800 m on bike sharing should be more investigated. Furthermore, within the optimum station buffer distance, the benefits or comparative advantages/disadvantages of increasing station capacity or adding new stations can be determined.
- It is not possible to make a definitive finding on the effect of age groups on the expected travel demands. But young-adult individuals are more likely to use bike sharing than other age groups. In future studies, the investigation of the bike-sharing behavior of the older Z generation (18–22 age group) individuals may provide a better understanding of bicycle use habits and expectations of future adult individuals.
- An objective study has not been found on the severity of injury due to low helmet use, as there is no data on the accidents involving BSP

users. Few recent research studies have focused on BSP user safety, and even fewer studies have looked at driving safety. Additional research is needed to investigate the causes of accidents with BSP users, accident incidents, and safety measures to prevent accidents.

Most of the studies were carried out take into consideration some factors included in 6 main categories. For this reason, it remains unclear what factor has most affected bike sharing. However, it is clear that the most adverse weather condition that affects bike sharing demand is rain. In almost all of the studies, the rain factor has negatively affected all trip requests for the weekend and weekdays for members and non-members. Each of the few studies considering multiple factors investigated the built environment factors (residential, commercial, educational, recreational areas) and other important factors (duration, distance, weather, seasonality) related to the hour, day, month and year of the trip.

Finally, in the literature, there are a lot of review articles on bike sharing. However, to date, it is noteworthy that few studies (as far as our authors know) focus on factors affecting bike sharing demand. In contrast to other studies, our study has established a framework that shows the factors affecting bike sharing trip demands comprehensively to evaluate the performance of station-based BSPs. The evaluation results can provide reliable estimations for planners or decision-makers in understanding the key factors contributing to bike-sharing demand. BSP planners, policymakers and researchers can use the information obtained from this overview and the information provided in their work. This overview can be also a guideline to action plans to improve the efficiency of BSPs.

Declaration of Competing Interest

None.

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