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Doctoral Thesis

The contribution of bike-sharing to sustainable mobility in Europe

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Abstract

Traffic congestion and air pollution are common and current concerns of urban areas. To solve these problems, municipalities have implemented sustainable mobility plans. Bike-sharing schemes (BSSs) have been promoted as an additional tool to encourage sustainable mobility.

Bike-sharing is a bicycle rental system that allows, without additional charge, to take a bicycle in one point and to return it in a different one, where the bicycle can be rented by another user.

Despite the first BSS was implemented in 1968 in Amsterdam, bike-sharing is a recent way of urban mobility because its real expansion did not take place until the 21st Century. The first high-technology scheme was introduced in 1996 in Portsmouth (United Kingdom). In 2005 the first large scale project providing a high amount of bike-sharing stations was implemented in Lyon (France). However, the current largest BSS in Europe was initiated in 2007 in Paris (France). Numerous European cities that were impressed by the high use of these systems have followed the example and they have implemented a BSS.

The success of BSSs achieving sustainability goals have been evaluated in this dissertation based on 51 case studies. The positive and negative effects of BSSs on European cities are assessed in terms of mobility, environment, health, traffic safety and economy to obtain their contribution to sustainable mobility.

Furthermore, this dissertation defines the city factors and bike-sharing factors that may increase the success of BSSs and quantifies their influence on the final level of use of BSSs. On the other hand, barriers that can arise when operating BSSs are identified and likely solutions are suggested.

Kurzfassung

Verkehrsprobleme und Luftverschmutzung sind Problemen städtischer Räume. Nachhaltige Mobilitätsmasterpläne sollen diese Probleme lösen, aber auch die Implementierung von Fahrradverleihsysteme (FVS) kann eine effektive Strategie sein um nachhaltige Mobilität zu fördern.

FVS sind Systeme, welche NuzerInnen ermöglicht, ohne zusätzliche Kosten, ein Fahrrad an einer Verleihstation auszuleihen und an einer anderen Station wieder zurückzugeben, an der wiederum andere NutzerInnen das Leihrad wieder ausleihen können.

Das erste FVS wurde 1968 implementiert, dennoch sind FVS ist ein junges urbanes Verkehrsmittel, da die reale Umsetzung des Systems erst im 21. Jahrhundert erfolgte. Das erste High-Tech-FVS wurde 1996 in Portsmouth (Vereinigtes Königkeit) initiiert und seit 2005 gibt es das erste große städtische FVS mit vielen Fahrrädern und Stationen in Lyon (Frankreich). Seit 2007 wird das größte FVS Europas in Paris (Frankreich) betrieben. Viele europäische Städte folgten, da sie die hohe Anzahl der NutzerInnen der Leihräder beeindruckte und implementierten ebenfalls FVS.

Diese Dissertation erforscht den Erfolg der FVS anhand ihrer nachhaltigen Ziele. 51 Case-Studies werden untersucht. Positive und negative Auswirkungen der FVS auf Mobilität, Umwelt, Gesundheit, Verkehrssicherheit und Wirtschaft der ausgewählten Städte werden analysiert.

Weiters werden städtische Faktoren und FVS-Faktoren, die auf den Erfolg von FVS Auswirkung haben definiert und deren Einfluss auf die Nutzung der FVS quantifiziert. Mögliche Problemen werden identifiziert und Lösungen vorgeschlagen.

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1 INTRODUCTION

1.1 Rationale

Urban population rate has highly increased in the last decades and currently European population concentrates mainly in cities. Cities generate a considerable part of environment and socio-economic impacts and most people that could be potentially affected by these impacts live in urban areas. Urban mobility is one of the most relevant human activities in cities. Individuals produce numerous trips with diverse purposes e.g. for working, for education, for shopping or for social relationships. The excessive use of cars for covering these routes causes significant negative impacts. Pollution emitted by vehicles is harmful for environment and public health, and traffic congestions lead to loss of time and money for individual and collective economy.

Consequences of climate change due to greenhouse gasses have special relevance nowadays in our society. Motor vehicles, as a result of the combustion of fuel, emit CO_2, which is one of the main originators of climate change. New fuels, gasoline-electric hybrid vehicles and even total electric vehicles have been developed to reduce air pollutants. These “green vehicles” have started to be introduced in European cities. Nevertheless, they still represent a small part of the car fleet and air pollution caused by cars is still nowadays a general concern.

Electro-mobility might contribute to reduce pollution in urban areas, but it will not solve traffic congestions. Low occupancy of cars together with limited space availability in cities cause traffic jams that make urban transport inefficient. To solve these and other collateral problems generated by car traffic, sustainable development, and specifically sustainable mobility, has become a priority in urban areas. City councils have implemented new mobility plans and policies that promote the use of other more efficient transport modes in terms of energy and space such as public transport, cycling and walking. However, these actions have not been totally successful and people still seem to be reluctant to shift from car to other more sustainable transport modes. Therefore, new strategies are searched to achieve the goals of sustainability.

At the end of 20th century, bike-sharing schemes (BSSs) emerged as a likely solution for mobility problems. Many cities were persuaded to implement BSSs and the number of these schemes in Europe augmented exponentially. It has been assumed that BSSs contribute to sustainable urban mobility. However, so far very few researches have actually investigated them and have measured and studied consequences, benefits and troubles, associated to the operation of these systems.

This dissertation analyzes and quantifies the success of BSSs in terms of sustainability comprising mobility, environment, health, traffic safety and economy aspects. Moreover, the influence of certain driving forces (city factors and bike-sharing factors) on the success of BSSs has been evaluated. These findings clarify the effects are BSSs for European cities and contribute to increase the success when introducing a BSS respectively. Furthermore, this dissertation provides a review of likely barriers for success and solutions that may avoid fails of bike-sharing projects.

1.2 Structure

This dissertation can be structured in two blocks as follows:

The first block comprises sections 1 to 5 and describes the main characteristics of bike-sharing as transport mode. After the introductory section 1, section 2 provides an overview of relevant topics such as sustainable transport, cycling and conception of bike-sharing that will help the reader to understand this thesis work. Section 3 shows the objectives and the methodology of this research. Section 4 describes in detail the case studies analyzed in this dissertation. And finally, section 5 describe the diversity of models and elements of BSSs through the 51 case studies of this dissertation

The second block of the dissertation comprises section 6 and section 7. They describe the quantitative outcomes of the data processing. Concretely, section 6 analyzes the success of BSSs in terms of sustainability and section 7 studies the main factors that influence the success of BSSs.

2 OVERVIEW

2.1 Introduction

The goal of this chapter is to provide the background knowledge to understand the topic discussed in this doctoral research. The chapter is divided in three sections that go from a rather more general scope to a more specific scope: sustainable mobility (section 2.2), cycling (section 2.3) and bike-sharing (2.4).

In the first section, the meaning of sustainable transport (section 2.2.1) as well as the main goals of sustainability (section 2.2.2) are discussed. The second section will focus on explaining the benefits of cycling in terms of sustainability (section 2.3.1) and the favourable and negative conditions for the bicycle use (section 2.3.2). Finally, the third block will define the concept “bike sharing” (section 2.4.1), justify the choice of this term (section 2.4.2), describe the historical evolution of the system (section 2.4.3), explain the expansion of BSSs (section 2.4.4) and expose the advantages of bike-sharing compared to private bicycles (section 2.4.5).

2.2 Sustainable mobility

2.2.1 Definition

The title of this dissertation is: “The contribution of bike-sharing to sustainable mobility in Europe”. Thus, defining “sustainable mobility” is the first step to assess the real contribution of bike-sharing in the framework of this doctoral research.

In 1987, the World Commission on Environment and Development of the United Nations published the report entitled “Our Common Future”, also known as “Brundtland Report” because of the name of its Chairwoman: Gro Harlem Brundtland (Wikipedia 2010b). The Brundtland report defined sustainable development as “development, which meets the needs of the present without compromising the ability of future generations to meet their own needs” (UNO 1987).

In 2005, the United Nations through the World Summit Outcome Document, emphasized the difference between the three "interdependent and mutually reinforcing pillars" that hold sustainable development: economic development, social development, and environmental protection (UNO 2005). From then on, sustainability has been generally understood as the conjunction of the environmental, social and economic dimensions (Figure 1).

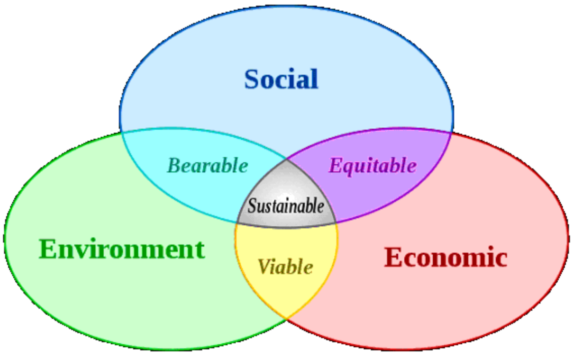


Figure 1: Scheme of sustainable development as a confluence of three dimensions: environment, social and economic aspects (IUCN 2006; Wikipedia 2010g)

If we focus on the term “sustainable transport”, The Centre for Sustainable Transportation has identified three types of definitions (Gilbert 2005).

- Literal economist definitions such as the following: “Transport where the beneficiaries pay their full social costs, including those paid by future generations, is sustainable” (Schipper 1996)
- Environmentally sustainable definitions like the one proposed by the Organization for Economic Cooperation and Development (OECD): “An environmentally sustainable transport system is one that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes” (OECD 2000).
- Comprehensive definitions such as the one proposed by the Ministers of Transport of the 15 European Union (EU) countries: “A sustainable transport system is defined as the one that (a) allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations; (b) is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development; (c) limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes while minimising the impact on the use of land and the generation of noise” (SUMMA 2005).

This last definition is preferred by many experts, including the Sustainable Transportation Indicators Subcommittee of the Transportation Research Board, the European Council of Ministers of Transport and the Canadian Centre for Sustainable Transportation; since it is comprehensive and it clearly expresses that sustainable transportation must balance economic, social and environmental goals, which are also called the “triple bottom line” dimensions (Litman 2010).

2.2.2 Goals

Since one of the aims of this dissertation is to analyze the success of bike-sharing on increasing sustainable mobility, apart from “sustainable mobility”, “success” is another key term to be specified. According to the Oxford Dictionary, “success” is “the accomplishment of an aim or purpose” (Oxford Dictionary 2010). It means that no success can be achieved without an aim to be accomplished. Therefore, when analyzing the success of bike-sharing in terms of sustainability, as this dissertation does, a previous set of goals is required. Todd Litman, director of the Victoria Transport Policy Institute, appeals for the distinction between the following four terms: “goal”, “objective”, “target” and “indicator”. “Goal” is what one wants to achieve; “objective” is a way to achieve this goal; “target” is a specified realistic and measurable objective and “indicator” is a variable selected and defined to measure progress toward the objective (Litman 2010).

Litman defines “indicator set” as “a group of indicators selected to measure comprehensive progress toward goals”. Diverse institutions have built different indicator sets to achieve the most convenient method to evaluate the sustainability of transport systems or transport modes. For example, the Centre for Sustainable Transportation of Canada, the Organization for Economic Co-operation and Development (OCDE), the World Business Council’s Sustainable Mobility project, the United States Environmental Protection Agency (USEPA), the Transport and Environmental Reporting Mechanism of the EU (TERM) and Sustainable Mobility Measures and Assessment project (SUMMA) manage their own indicator sets for the study of the sustainability of transport.

Since this dissertation focuses the research on Europe, it pays special attention to European organisms related to sustainability such as the TERM and SUMMA. The European Environmental Agency (EEA) elaborated the indicator set of the TERM in 2002. However, the TERM program directly concerned environmental performance while sustainable transport only indirectly. In contrast, the SUMMA project focused rather more on sustainable transport than TERM (Litman 2010).

The SUMMA project was funded by Directorate-General for Energy and Transport of the European Commission and its indicator set was published in 2005 (Gilbert 2005). The mission of SUMMA was a) to define sustainable mobility and develop indicators for the monitoring of sustainability, b) to assess the scale of sustainability problems associated with transport and c) to identify policy measures to promote sustainable transport (SUMMA 2005).

SUMMA distinguishes between two types of indicators: system indicators and outcome indicators. The system indicators are proxies that describe what is happening inside the system and the outcome indicators represent the impacts of the transport system. Outcome indicators are also called “outcomes of interest”.

The outcomes of interest of SUMMA were selected to cover the main elements of the definition of sustainable transport and the three dimensions of sustainability: social, environmental, and economic dimension. The outcomes of interest correspond with the goals that a transport system has to fulfil to achieve the sustainability. Each one of these goals may require one or more than one indicator to be measured, calculated and assessed. The SUMMA project suggested the following list of goals: Accessibility, transport operation costs, productivity, cost to economy and benefits to economy are goals that belong to the economic dimension of sustainability. Resource use, direct ecological intrusion, emission to air, soil and water, as well as noise and waste are part of the environmental dimension. And finally, affordability, safety and security, health, liveability, equity and social cohesion belong to a social dimension. More details about these goals of sustainable transport are shown in Table 1[1,2].

Economic	Environmental	Social
EC1: Accessibility Economic accessibility has two aspects: (1) local access of goods and people to services, work, industrial plants, etc., and (2) long distance links among regions.	*EN1: Resource use* The use of materials, energy and other resources by the transport sector.	*SO1: Accessibility and affordability* The time and cost required to reach basic services. Lower income individuals generally have poorer accessibility to basic services than those well off.
EC2: Transport operating costs The costs to the user of the transport system, both direct user costs (fuel, ticket prices, transport equipment), and indirect costs, such as the costs of congestion.	*EN2: Direct ecological intrusion* Impacts of transport on flora and fauna caused infrastructure (building, using, and maintaining) rather than pollution.	*SO2: Safety and security* Safety implies freedom from danger. Security concerns freedom from fear (of crime or other undesired actions).
EC3: Productivity/Efficiency Providing conditions for an expanding, productive and efficient economy and therefore for inceased social welfare. Inefficiencies increase resources needed to achieve benefits.	*EN3: Emissions to air* Emissions of pollutants, etc. into the air, which affect health and harm buildings. Also the emission of greenhouse gasses, which contributes to global warming.	*SO3: Fitness and health* The trend to perform short trips by car decreases fitness and increases the threat to health (through increased pollution).
EC4: Costs to economy All costs of transport (except for the individual user), i.e. infrastructure investments, maintenance, public subsidies, final energy consumption and external costs of transport.	*EN4: Emissions to soil and water* Emissions of pollutants to soil and water, wastewater from manufacture and maintenance, runoff from roads, discharges of oil and wastewater by ships, etc.	*SO4: Livability and amenity* Transport influences our *quality of life*. It concerns an individual's direct surroundings and the impact transport has on it. It concerns not only measurable aspects (noise, pollution) but also perceptions and attitudes.
EC5: Benefits to economy The gross value added generated by the transport sector, national revenues from taxes and traffic system charging, and economic growth induced by transport.	*EN5: Noise* Transport is one of the most significant sources of noise in urban areas. There is evidence that noise is related to human and animal health and wellbeing.	*SO5: Equity* This concerns the fair distribution of costs and benefits among different groups in society, among income classes, among regions, and among generations.
	EN6: Waste Transport vehicles and infrastructure create large amounts of waste during their life cycle, which can partly be recycled or reused, but is otherwise disposed of by incineration and in landfills.	*SO6: Social cohesion* The ongoing process of developing a community of shared values, challenges and opportunities based on trust, hope and reciprocity. Is related to *social capital*, social organisation and social trust features that facilitate co-operation for mutual benefit.

Table 1: Analysis of the sustainability of transport systems suggested by the SUMMA project (Litman 2010)

[1] Although impacts are grouped in a way that each one belongs to one dimension of sustainability, some impacts can actually affect more than one dimension. For example, traffic accidents (SO2) could also be understood not only as a social problem but also as an economical cost. And pollution could be interpreted not only as an environmental issue but also as an economical and social issue, because pollution leads to investments against climate change and damage of public health.

[2] The SUMMA project mentioned "working conditions in transport sector" as goal of social dimension of sustainability. However, this dissertation will consider the goal as contained within the "social cohesion" goal.

2.3 Cycling

2.3.1 Sustainability of cycling

Cycling has been widely considered as a sustainable transport mode and public organisms support policies that encourage their daily usage to achieve the goals of sustainable mobility. Ralph Buehler, Virginia Tech and John Pucher, Professors of the Rutgers University, in New Jersey (USA), summarize the contribution of cycling to the three dimensions of sustainable mobility as follows: “Cycling causes virtually no noise or air pollution and consumes far less non-renewable resources than any motorized transport mode. The only energy cycling requires is provided directly by the traveller, and the very use of that energy offers valuable cardiovascular exercise. Cycling requires only a small fraction of the space needed for the use and parking of cars. Moreover, cycling is economical, costing far less than both the private car and public transport, both in direct user costs and public infrastructure costs. Because it is affordable by virtually everyone, cycling is among the most equitable of all transport modes. In short, it is hard to beat cycling when it comes to environmental, social and economic sustainability” (Buehler et al. 2010).

According to the classification of goals for sustainable transport suggested by the SUMMA project in Table 1, the statement of Buehler and colleges is right. From the perspective of economy, cycling is sustainable:

- Firstly, cycling improves economic accessibility by reducing travel costs (goal EC1 of SUMMA). For example, in the city of Groningen (The Netherlands) it has been estimated that cycle trips are 35% faster than car trips and between 60,000 and 90,000 travel hours are saved thanks to cycling.
- Secondly, bicycles can contribute to increase economic sustainability by reducing transport operation costs (goal EC2) and cost of transport (goal EC4). Actually, staff is not needed for cycling since users drive by their selves and bicycles do not consume any fuel and consequently they do not imply any operation cost. Moreover, cycling infrastructure consist basically in a network of cycle ways, racks for parking and signposting. A study of the World Health Organization / Regional Office for Europe (WHO/Europe) has estimated that benefits of cycling are between four and five times higher than these investments costs[3] (Dehaye 2007).
- Finally, cycling industry can contribute to incentive the national economy (goal EC5). For example, a study of the Austrian Ministry of Environment concludes that the direct and indirect economic effects of the cycling industry generate €882,500,000 of added value and 18,328 equivalent jobs (Thaler & Eder 2009). Although these figures correspond only to Austria, similar benefits might be found in other European countries.

[3] The study takes into account external costs derived from the reduction of health, accidents, environmental and parking cost associated to cycling.

Cycling is environmental sustainable due to the following reasons:

- The amount of material required to build a bicycle is much lower compared with motor vehicles (goal EN1 of SUMMA).
- In addition bicycles do not cause impact in flora and fauna (goal EN2), do not emit any air pollutant (goal EN2) or any water and soil pollutant (goal EN4), cycles do not produce noise (goal EN5) or waste (goal EN6).

Cycling can be socially sustainable since it meets the requirements below:

- Firstly, cycling guarantees the accessibility of their users in terms of time and cost (goal SO1 of SUMMA). It is assumed that urban trips up to 5 kilometres long are affordable with a bicycle. Since 50% of car trips in Europe are shorter than 5 kilometres and urban trips below 5 kilometres might be faster by bicycle than by car, it would mean that 50% of car trips could be made faster by bicycle. In addition, bicycles have not operation costs for users apart from repairs and maintenance (WALCYNG 1997; Dekoster & Schollaert 1999).
- Secondly, bicycle theft is still a current concern of cyclists (Bikeoff 2008a) but it has been demonstrated that cycling increases traffic safety in different ways (goal SO2). Cycling is a safe transport mode and cycling reduces general accident risk of all modes. The risk of a fatal injury per kilometre is about 2½ times higher for cyclists than for passengers of motor vehicles. Nevertheless, taking the time instead of distance as reference shows that cycling seems to be safer because risk of dying in a bicycle trip is above 2 times lower than in a motor vehicle trip (Kifer 2000). Moreover, the higher the number of pedestrians and cyclists, the lower the risk of accident is. According to Jacobsen, the number of motorists that collide with pedestrians or cyclists increases at about 0.4 power of the number of existing people walking or bicycling. It means that if a city doubles its walking and cycling share, a 32% of increase of injuries can be expected. However, taking into account the amount of walking and bicycling trips, the probability that a motorist will strike an individual person walking or bicycling declines 66% (Jacobsen 2003).
- Thirdly, cyclists improve their individual health by doing a physical exercise as a consequence of the pedalling, and the collective health by avoiding the emission of harmful air pollutants (Cavill & Davis 2007) (goal SO3).
- Finally, cycling contributes to make cities more liveable since bicycles do not emit noise or pollution (goal SO4). Bicycle use increases the equity of the society in the mobility since bicycles occupy less public space and they are cheaper than motor vehicles and consequently economically affordable for low incomers too (goal SO5).

2.3.2 Determinants of bicycle use

As section 2.3.1 shows, cycling meets most of the requirements for sustainability by contributing with numerous environmental, economic and social benefits. Cyclists seem to be convinced about advantages of bicycles. According to several surveys, cyclists declare that they ride a bicycle because it is "healthy, environmental friendly, funny, flexible, relaxing, cheap, controllable, predictable, free, quick, exciting, relaxing and convenient" (Wiersma 2010). Despite all these advantages of cycling, only 5% to 10% of European trips are covered by bicycle (WALCYNG 1997). If bicycles are so beneficial and the cyclists agree, why is the rest of the society not persuaded to cycle?

Heinen and her colleges of the Delft University of Technology carried out one of broadest and most comprehensive literature review concerning the determinants of bicycle use. They compiled and listed the main factors that affect bicycle use and evidences found in studies worldwide. According to the conclusions of this review, the reasons that induce people to use or not to use a bicycle as a frequent transport mode can be classified in four groups: Built environment, natural environment, socio-economic variables and psychological factors (Heinen et al. 2010)[4].

Determinants of bicycle use concerning the first group, built environment, are the following:

- Smaller cities, higher population densities and mixer land uses lead to shorter urban trips. Since short distances benefit the daily use of bicycles, the presence of these three city factors may increase cycling modal share.
- Safe bicycle parking facility is a crucial condition for bicycle use according to most of studies.
- The risk of accident is other frequent reason argued by non-cyclists to refuse using bicycles. Therefore, the higher the risk of accident, the lower the possibility to persuade people to cycle is. We should take into account that safety can be an objective and measurable data or a subjective perception. Although people tend to say that they would cycle more often if they would have more accessible and well connected bicycle paths and although separated bicycle paths provide higher levels of subjective safety, the impact of density, segregation grade, quality and continuity of the cycle network on the levels of bicycle use might be rather moderate.
- Cyclists have a negative perception of traffic lights, dense traffic and wide streets and generally avoid them when choosing a route, but there is no general agreement whether this really affects the frequency or modal choice.

The natural environment has a large influence on cycling share levels:

- It has been found that hilliness has an evident negative effect on bicycle use.
- On the other hand, beauty of routes has been mentioned in some researches as likely attractive factor but it has not been demonstrated yet.

[4] Heinen originally consider a fifth miscellaneous group comprising transport costs, safety and travel time as well as effort as affecting aspects. Nevertheless, in this dissertation transport costs have been included in the group of socio-economic aspects and safety, travel time and effort have been included in the group of built environment.

- Many studies state that the rain, low temperatures and darkness discourage cycling and although little literature studies the effect of wind on bicycle use, it is demonstrated that wind raises the effort when pedalling. The hostility towards these weather factors seem to confirm other research results that affirm that summer is perceived as more attractive to ride than winter.

The relationship between socio-economic factors and cycling is uncertain:

- Most researches conclude that men cycle more than women but as the cycling rate increase, both men and women seem to cycle the same.
- There is no consensus concerning the connection between age and bicycle use.
- The same occurs to the influence of income on cycling; while some studies confirm the causality, others do not find any relevant effect.
- Regarding the household structure, individuals without children, students and part-time workers seem to be more willing to cycle though this relationship have not been widely demonstrated.
- On the other hand, two factors that clearly influence cycling levels are car and bicycle ownership. High car presence use to decrease the use of bicycle while high bike ownership is a relevant indicator of usage.
- Finally, transport costs are relevant when encouraging people to use the bicycle. Although the bicycle is a cheap transport mode, not only the usage costs of bicycle influence but also the costs of other transport modes. For example, although there is no consensus concerning the influence of fuel price, free public transport may lead to decrease cycling and monetary incentive for cyclists may be effective for the bicycle use.

Psychological factors influence the decision of individuals to use the bicycle.

- Attitude, defined by Heinen and her colleges as “the expectation of all the outcomes of an activity, and the personal value of these outcomes”, seems to be crucial. People that have a positive attitude towards cycling are more likely to commute cycling than those that have a negative attitude.
- Social norms and public image play an important role in the level of cycling. For example, individuals that perceive more public support for cycling and those who realized that work-colleagues cycle are more willing to use the bicycle.
- Ideological beliefs count when choosing the transport mode. Thus, for instance people with strong environmental awareness are more likely to cycle.
- Perceived behavioural control, defined as a “personal evaluation of the ability of performing certain behaviour”, results relevant. For instance, individuals who do not commute by bicycle perceive more barriers and dangers in commuting by bicycle than frequent users of bicycles.
- Finally, one of the strongest psychological factors is the habit or repetition of certain behaviour. It has been found that people do not take every factor into consideration

when making a transport choice. They just repeat a habit disregarding likely disadvantages. If the tendency is changed and the individual starts using a different mode, perception can change. Thus, for instance, leisure oriented cycling may contribute to initiate people to use more frequently bicycles as transport mode.

2.4 Bike-sharing

2.4.1 Definition

Bike-sharing is a relative new way of urban mobility. Although the first bike-sharing scheme was implemented in 1968 in Amsterdam, the real expansion of the system did not take place until the beginning of 21st Century. Since then, not only the number of BSSs but also the variety of models has extremely grown all over Europe (section 2.4.4). Nowadays, the existence of such a diversity of schemes has made difficult to build a general accepted definition. Early publications have contributed to outline some of the main characteristics of bike sharing and differences with traditional bike rental (Beroud 2007; SpiCycles 2008; NICHES 2007; Sassen 2009). Nevertheless, very few accurate definitions of bike sharing have been formulated so far (IDAE 2007; MetroBike 2011; NYC Department of City Planning 2009; Wiersma 2010; Büttner et al. 2011).

A definition of bike-sharing should comprise common features of different types of BSSs and particularities that make the concept unique and different in comparison to similar concepts. The core of the definition is rather overall accepted: bike-sharing is basically a bicycle rental, i.e. a lending of bicycles to customers who need their use, but not their property, for a specific goal and period of time (MetroBike 2011; DeMaio 2004; IDAE 2007; Beroud 2007; NICHES 2007; Sassen 2009). However, the main challenge of a bike-sharing definition is to find out the limits of the meaning, i.e. the key distinctions that make bike-sharing different to traditional bike rental.

The vice-president of the agglomeration Grand Lyon, Gilles Veso, who supported the implementation of Vélo'v, the local BSS, stated that they "invented the public individual-transport" (Bührmann 2008). Invention is "something which has never been made before" (Cambrigde University 2009). Since bike-sharing is in essence bike rental and since bike rental existed previously, why is bike sharing an invention?

Three primary attributes define all bike-sharing models as innovative, unique and different to traditional bike rental:

- One-way trips are allowed
- Unidirectional trips involve no additional charge
- Bicycles can be rented where other users returned them

Normally bike rental companies do not allow the return of a bicycle out of the shop. If unidirectional rents are allowed, a truck of the company transports the bicycle again to the shop to be rented again and the customer has to pay for the service. In contrast, most of bikes-sharing rents are unidirectional and do not imply any additional charge. For example, 95% of trips of the scheme Call a Bike start and finish in different places (Sassen 2009).

Considering the above mentioned aspects, a likely definition of bike-sharing would be the following: “Bike-sharing is a bicycle rental system which allows, without additional charge, to take a bicycle in one point and to return it in a different one, where the bicycle can be rented by another user” (Castro, Büttner, et al. 2010).

The three primary attributes included in the definition are valid of all BSSs. Nevertheless, some secondary attributes that are not valid for all models of BSS but are applicable for most of them can help to complete the meaning. Quasi-common features of BSSs are the following:

- Easy and unattended rental process (Sassen 2009; NICHES 2007)
- Round-the-clock service (Beroud 2007; Sassen 2009)
- Location in public space (Sassen 2009)
- Low usage fee (Beroud 2007) (NYC Department of City Planning 2009)
- External funding from public subsidies or advertisement (Sassen 2009)
- Daily mobility oriented (SpiCycles 2008; IDAE 2007)

Several BSSs are provided with only one point where bicycles can be taken and returned. Thus, they lack one essential characteristic of bike-sharing: the possibility to make one-way trips. These schemes with only one station are not really BSSs but rather more “public bicycle rentals”, since their only difference with traditional bike rental is that they are usually funded by public subsidies instead of private companies (DeMaio 2009b). Nevertheless, they are generally considered as BSSs either because they plan to implement more stations and they will become then real BSSs or because secondary attributes make the rental indirectly similar to bike-sharing. For example, some rental programs with only one station that offer very inexpensive fees make long rental times convenient. In this way unidirectional trips and free of charge returns through provisional stops within the whole rent are possible.

2.4.2 Naming

As mentioned in section 2.2, bike-sharing is a relative new concept of urban mobility and there is no general agreement about the naming yet. Numerous different terms have been used so far to refer to the same concept. Below are shown some examples collected from existing publications in English.

- Self-service bike rental program (Fietsberaad 2009)
- City bikes (The new mobility agenda 2008)
- Smart bikes[5] (Noland & Ishaque 2006; DeMaio 2003)

[5] “Smart bike” is the common name of all BSSs provided by Clear Channel. Since Clear Channel was the first company that introduced this third generation of systems, bike-sharing was named “smart bikes” by some authors (Sassen 2009).

- Cycle hire scheme (Dector-Vega et al. 2008)
- Public use bikes (DeMaio 2001; NICHES 2007)
- Public bicycles (Bührmann 2008; Snead & Dector-Vega 2008)
- Bike-sharing, bike sharing or bike share (DeMaio 2004; Nadal 2007; Beroud 2007; Mlasowsky 2008; NYC Department of City Planning 2009; MetroBike 2011; Castro & Emberger 2010; DeMaio 2009b)

Most of publications seem to use the term “bike-sharing” to refer this new mobility concept. Significant precedents are the two last EU-projects [6] focused on bike-sharing (SpiCycles[7] and OBIS) and one of the most visited blogs in this field (“The Bike-sharing Blog” by Paul DeMaio). This dissertation will follow this tendency and will overall use the term “bike-sharing”.

2.4.3 Historical evolution

To summarize history and evolution of bike-sharing, Paul DeMaio, MetroBike LLC (USA), has grouped all existing and extinct schemes in three generations (DeMaio 2001). This way of classification has been generally adopted by most of authors.

2.4.3.1 First generation

“Provo” was an anarchist Dutch movement (1965-1967) that had as a main goal “to provoke violent responses from authorities using non-violent bait” (Wikipedia 2010f). Luud Schimmelpennink, one of their activists, initiated the “White bicycle plan”, a set of actions focused to reduce traffic congestion in Amsterdam (the Netherlands). One of them was the so called “Witte Fietsen” or White Bikes. In July 1965, donated and painted white bicycles were distributed throughout the city for free use. Everyone was allowed to use a bicycle without any charge and to return it somewhere else where it could be taken by another user. The action ran only for several days, since the bicycles were quickly stolen, damaged or confiscated (DeMaio 2009b; Wikipedia 2010a). Despite the apparent fiasco of the plan, the White Bikes became an inspiration for a new concept of mobility: bike-sharing. Actually the White Bikes are considered as the first known BSS.

[6] Intelligent Energy Europe Funds, 6th Framework Programme, European Commission

[7] Sustainable Planning & Innovation for Bicycles

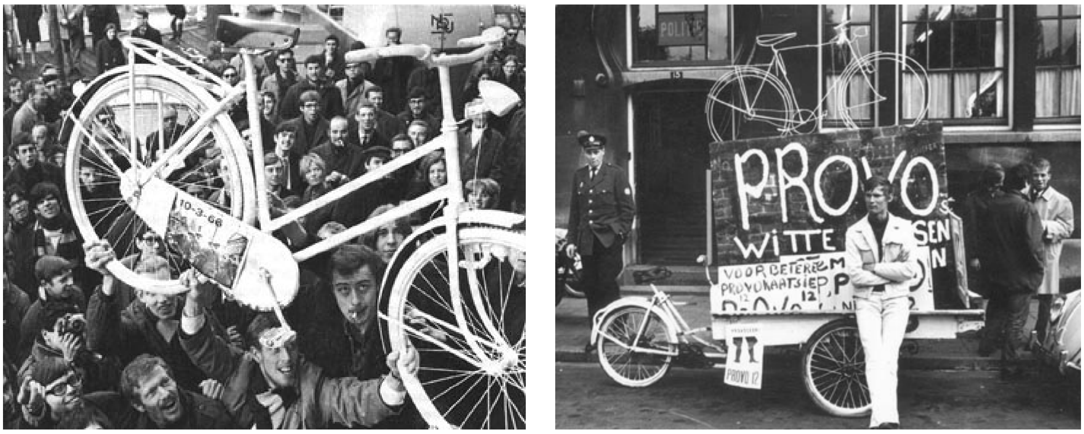


Figure 2: White Bikes of Amsterdam (Austinyellowbike 2010)

Some other BSSs in Europe followed the trail of the White Bicycles. The implementation in 1973 of the “Vélos Jaunes” (Yellow Bikes), in La Rochelle (France), was the second experience implementing a BSS (Beroud 2007). The “Kommunal Fahrrad” (Communal Bicycle) was launched in Bremen (Germany) in 1978. The city council and stores to introduce a park & ride concept in the centre of the city funded the system. After three months the number of red-white bicycles of “Kommunal Fahrrad“ decreased from 300 to 55 and the scheme stopped operating (Sassen 2009). Afterwards, in the 80s, 1,000 bicycles were provided for free use in Milan (Italy) and in 1993 300 free Green Bikes were introduced in Cambridge (United Kingdom) (DeMaio 2001; Sage 2007). The result was the same in all these cases: in short time the bicycles were damaged or stolen and the scheme was modified or closed (DeMaio 2001; Beroud 2007; Sage 2007; Beroud 2007; Sassen 2009).

Similar projects were developed out of Europe. Until 2001 about 25 first generation BSSs had been implemented in the USA with different results. One of the first programs of the USA was launched in the 90s in Portland, Oregon. An environmental group supplied about 1,000 Yellow Bikes without any restriction. The scheme operated during three years, but finally it became more restrictive due to vandalism and resultant economic problems (Sage 2007; O’Keefe & Keating 2010; Wikipedia 2010a). In Madison, Wisconsin, the Red Bike was victim of thefts and as a consequence the scheme started locking the bicycles and asking for a deposit.

The main common feature of all first generation schemes seems to be the lack of rules. The most relevant characteristics of this type of BSS are summarized below.

- No registration: Users do not have to register before taking a bicycle.
- No identification: Users do not have to show any identification before borrowing a bicycle.
- No fee: There is no pricing policy. The service is unlimited free of charge.
- No locks: Bicycles are not locked and everyone has free access to pick them in any moment.
- No specific locations: There are no fixed locations to return the bicycles. They can be left wherever another user can pick them up.

- Donated and painted bicycles: Normally bicycles are donated. They are ordinary commercial bicycles painted with a recognisable colour to make them distinct to the private ones.
- Administrated by associations: These programs use to be managed by associations which have as a goal not only to promote cycling but also to encourage citizens to think about the socio-economic model. BSSs are normally self-funded, although some of them were supported by public authorities.

First generation BSSs present the following advantages as a result of their characteristics:

- The lack of rules regarding registration, identification, fees and return of bicycle make easy and flexible the rent and therefore attractive for users.
- Very few staff, only for repairing, and no infrastructure are needed. This makes the scheme inexpensive.

On the other hand, these programs present also disadvantages:

- Unrestricted and uncontrolled lending cannot punish unacceptable usage of the bicycles. Thus, vandalism grows dramatically and the bicycles disappear because of theft.
- First generations schemes are funded with limited budget. High investments, such as the replacement of theft bicycles, are not affordable for these systems.

Experiences implementing first generation BSSs seem to show that their negative aspects are crucial. Most implemented schemes have been modified or closed. Costs derived from vandalism are excessive and incomes very limited what make the BSSs economically unsustainable.

2.4.3.2 Second generation

The birthplace of the second generation was Denmark. The first scheme was launched in 1991 in Grenå and the second one in 1993 in Nakskov, both of them in Denmark and both rather small programs (DeMaio 2009b).

In 1995 the inventors of the BSS of Nakskov transfer the idea to Copenhagen (Denmark). The program provided up to 5,000 bicycles and it is still working, but with only 2,000 bicycles due to theft. The bicycles can be locked from 110 specific stations in the same way as a shopping cart. Users just have to insert a 20-crown or a 2-euro coin in a mechanical device. The coin is recovered automatically when the bicycle is correctly returned in another station. Bicycles can only be ridden inside a delimited area of the city and police supervises accomplishment of this rule. Unlike the first generation bicycles, the pieces are different to the commercial ones, i.e. they cannot be installed in ordinary bikes to avoid vandalism. Moreover, bicycles are specially designed to be durable and advertising plates are installed on wheels. The BSS is funded by the companies that sponsor these plates and the municipality. The maintenance and repairs of the bicycles are carried out by a department of the Rehabilitation

Agency of Copenhagen together with a non-profit organisation called Incita. For this task they hire persons with risk of social exclusion and they provide them vocational training (Sassen 2009).

The good results and the big media impact of the City Bikes of Copenhagen gave as a consequence that other numerous cities copied the idea. Very similar BSSs were implemented in Trondheim (Norway), in Vienna (Austria), in Helsinki (Finland), in Arhus (Denmark), in Aveiro (Portugal), and in German cities such as Lübeck, Hannover, Minden, Ingolstadt, Trier, Koblenz and Chemnitz.

The BSSs of Trondheim was launched in 1996 and despite the good results it was substituted by a third generation system (Sassen 2009). In April 2002, the "Klimaschutzprogramm der Stadt Wien" (Program of Climate Protection of the City of Vienna) together with the association Viennabike launched the second generation system Viennabike to improve the daily urban mobility. Viennabike was provided with 1,540 bicycles and 235 stations and as the Copenhagen's scheme also worked with €2 deposit within the downtown. The system collapsed just in one month because of vandalism. However, Viennabike increased awareness of bike-sharing and it was the basement of a third generation BSS implanted one year later in the city: Citybike Wien (ManagEnergy 2010; Sassen 2009; Stadt Wien 2010).

Figure 3: Bycyclen in Copenhagen (left) (Svenningsen 2010) and bicycle of Viennabike being rescued from the Danube Canal (right) (Der Standard 2010)

In summary, the main features that define the second generation BSSs are the following:

- No registration: As in first generation systems, users can use the bicycles without previous subscription.
- No identification: Users do not have to show any identification before borrowing a bicycle. They just need a coin.
- Deposit: The coin inserted when borrowing a bicycle works as deposit. It is automatically refunded when the user returns the bicycle in a station.
- Locked: Unlike first generation programs, second generation bicycles are locked.
- Stations: Bicycles are taken and returned from/to fixed locations.

- Specific durable bicycles: Bicycles are compounded by durable, recognisable and unique pieces that cannot be installed in ordinary bikes.
- Advertising incipient: Advertising appears in second generation BSSs as a way of funding. Municipalities also increase their role and invest more money in this generation than in the first one. The improvement of social problems such as unemployment seems to appear as secondary goal of these systems.

As a consequence of these characteristics second generation BSSs have the following advantages compared with first generation:

- The number of damaged and stolen bicycles decreases: Four factors influence the increase of security and the reduction of vandalism: 1) the bicycle pieces become more durable to reduce breakdowns caused by vandalism, 2) the design of bicycles become more exclusive to dissuade theft and exchangeability with commercial bicycles and 3) the bicycles are locked instead of be placed on the street for free rental and 4) the usage is limited to an specific area within the city.
- The revenues are higher because of the access of advertising as a way of funding and the more relevant role of public authorities, which allows larger infrastructure and public campaigns.

Some important negative aspects are still to be solved.

- The lack of registration and identification as well as the low value of the deposit make the bicycles still very accessible for vandalism.
- The investment is higher than in first generation schemes but still insufficient to balance the elevated costs motivated by theft.

Second generation BSSs seem to be economically more sustainable and better prepared against vandalism than first generation one. However, these improvements are not enough. BSSs are able to “survive” but they are not really “efficient” since a big amount of resources is needed to counteract the cost of bicycle theft and damages caused by vandalism (Sassen 2009). Therefore, sooner or later most of existing second generation BSSs tend to disappear or to be substituted by third generation systems. Even the City Bikes of Copenhagen, the most representative second generation program, is planning to be upgraded to a third generation system (MetroBike 2009).

2.4.3.3 Third generation

The first third generation BSS was developed in 1996 in the Portsmouth University (United Kingdom). The campus is divided in two areas situated three kilometres away from each other, and the goal of the BSSs was to connect both places in an ecologic and rapid way. The Portsmouth University launched the BSS called Bikeabout, as part of its Green Transport Plan. The project was funded by the ENTRANCE program[8]. The system was totally automated. After an obligatory subscription, users received a smart card. This card was asked when renting a

[8] Energy Saving in Transport through Innovation in the Cities of Europe

bike to identify the user and it opened the depots where bicycles were available. The opening of the depots to pick up and return bicycles was automatically registered. Thus, if a bicycle was too late returned, damaged or even stolen, the card holder could be punished by the operator. The subscription fee was low and the use of the 100 available bicycles located in two stations was free of charge (Black & Potter 2010).

Despite the progress of Bikeabout, some farther steps were done by later BSSs. In 1998 the American company Clear Channel introduced in Rennes (France) the system Vélo à la Carte. Vélo à la carte, in contrast to Bikeabout, provided a higher number of terminals and the bicycles were locked outdoors instead of inside depots. The system was equally automated but the smart card unlocked the bicycles from a specific rack on the street (Clear Channel 2010).

One of the competitors of Clear Channel in the current bike-sharing market is the French company JCDecaux. The first BSS of JCDecaux was launched in Sandnes (Norway) in 2000. The company together with a local foundation operated 30 bicycles. The way of working was very similar to the model in Rennes. However, the annual subscription was not for free but cost €15. Usage was free of charge. The BSS was mainly funded by an advertising contract between JCDecaux and the municipality. The company obtained the rights of 20 billboards from the city council as consideration for the free service (Sassen 2009).

In 2001 the system Call a bike was introduced in Berlin (Germany) as a new variant of bike-sharing. Users had to make a phone call to obtain a code that unlocks the bicycle. The code has to be inserted in an electronic display on the bicycle. Fixed location for stations did not exist and bicycles could be picked and returned everywhere inside the operating area (Sassen 2009).

This flexible model was later implemented in more European cities but the station-linked systems spread out more quickly (section 5.3.2). Furthermore, the increasing scheme-size became a challenge for operators. In 2003 Citybike Wien, a third generation BSS, was satisfactory implemented in Vienna. The operator, JCDecaux, transferred this system to Lyon (France) and launched Vélo'v, the first large-scale 3rd generation scheme with 1,500 bicycles. The first 30 minutes of use were free of charge but longer rents had to be paid to encourage short-term rents. Revenues from billboards were assigned to the operator as a result of a parallel advertising contract signed with Greater Lyon, the public authority of the agglomeration. In the same way was funded Vélib', in Paris (France). 7,000 bicycles were distributed throughout the whole city at the inauguration in 2007. Later, the scheme was extended up to 20,600 bicycles becoming the largest BSS of Europe (DeMaio 2009b).

Figure 4: Bike-sharing stations of Vélo à la carte in Rennes (left) (Vyi 2007) and Vélo'v in Lyon (right)

Taking into consideration the above mentioned features, the main characteristics of the third generation BSSs are:

- Registration: Users require a subscription before renting a bicycle for the first time. Subscription fee can be charged.
- Identification: Users have to identify themselves each time that they rent a bike.
- Pricing: Some BSSs are totally for free but others can ask for a usage fee.
- Locked: Bicycles have to be unlocked for hiring them.
- Stations: Stations can exist or not in third generation BSSs.
- Specific durable bicycles: Bicycles are compounded by durable and recognisable and unique pieces that cannot be installed in ordinary bikes.
- Advertising relevant: If advertising was a secondary source of revenues for the second BSS generation, advertising contracts becomes the main way of funding of third BSS generation.

Compared to the second generation, third generation BSSs achieve some improvements:

- Control over customers increases as a result of the obligatory registration and identification. Moreover, the usage fee contributes to limit the duration of rents. All together results in a reduction of bicycle theft, which makes operation costs affordable and the system economically more sustainable. The consequent higher availability of bikes also increases the trust of customers on the service.
- Billboard contracts make possible high investments on large-scale BSS.

On the other hand, some troubles difficult the progress of BSSs:

- Although advertising companies made possible big projects, third generation BSSs might be too dependent on the high revenues of billboards contracts to survive economically.
- Despite all the measures implemented to control the rents, vandalism is still currently an important issue that affects the economic viability of the BSSs.

2.4.3.4 Fourth generation

There is none generalized consensus concerning a hypothetic fourth generation of bike-sharing. While some authors support that BSSs that work with one integrated card valid for bike-sharing and public transport might be the 4th generation (DeMaio 2001), others think that BSSs without fixed stations (Snead & Dector-Vega 2008) or schemes that provide bicycles powered by electricity (Sassen 2009) should be consider as forth generation systems.

The above mentioned divergence of opinions shows that no clear definition of fourth generation exists yet and it is recommended being expectant to next developments of BSSs.

2.4.4 Expansion

New BSSs are continuously launched. According to Paul DeMaio, “a new BSS is inaugurated in the world every each month” (DeMaio 2009b). At the same time, existing schemes are closed or substituted by new models. Therefore, the list of existing BSSs is very changeable and figures can be very inaccurate. However, a tendency in the increase of the number of schemes can be appreciated. In 2003 only 11 third generation BSSs existed worldwide, all of them in Europe (DeMaio 2004), while in 2010 there were 238 BSSs (Figure 5).

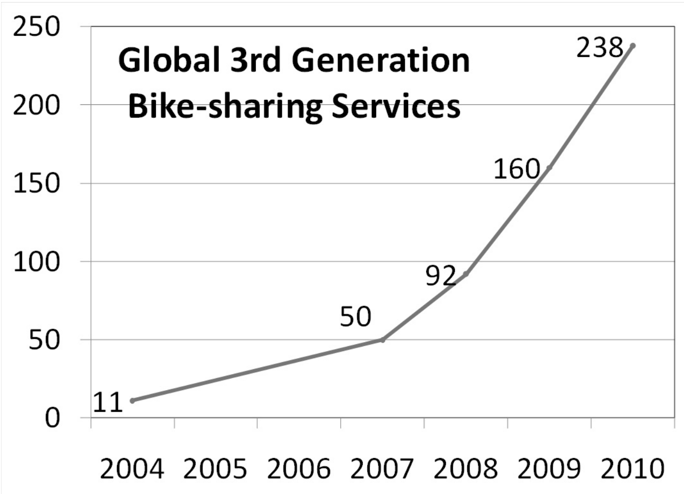


Figure 5: Evolution of the number of third generation BSSs worldwide between 2004 and 2010 (DeMaio 2009a)

If we focus our analysis on Europe instead of on the world, on the number of cities provided with BSSs instead of their number of BSSs, and on all generation BSSs instead of third generation systems, different figures are obtained. In 2009 it was estimated that approximately 300 European cities were provided with BSSs (Castro, Büttner, et al. 2010). If we consider residual the number of cities provided with first and second generation schemes compared to the number of cities provided with third generation schemes in 2004 in Europe, it would mean that the number of European cities with BSSs multiplied by 30 in only six years. As Figure 6 reveals, this increase has been especially relevant in Western Europe. Taking Spain as representative example of the expansion of bike-sharing[9], we can observe in Figure 7 that the growth of the number BSSs have been exponential.

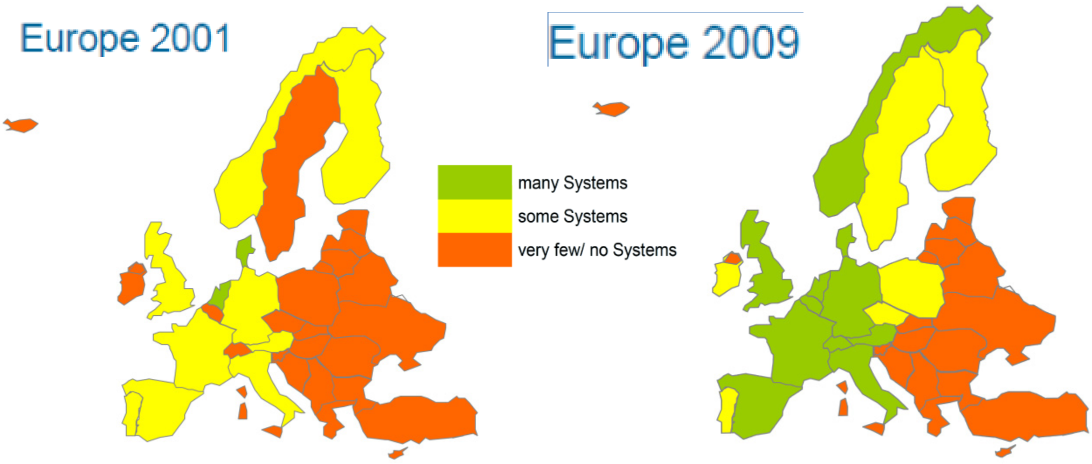


Figure 6: Expansion of BSSs in European countries between 2001 and 2009 (Büttner 2010)

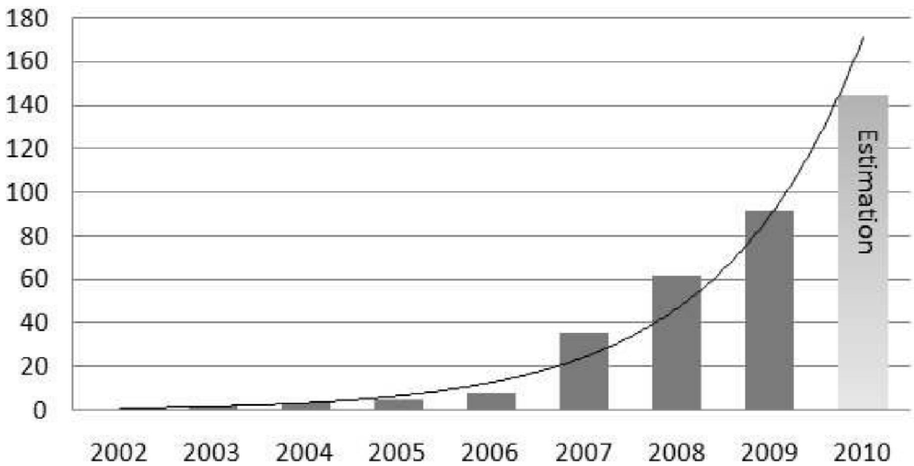


Figure 7: Evolution of the number of BSSs in Spain between 2002 and 2010 (Sanz & Kisters 2010)

Concerning the location of existing BSSs, a quick overview over the current world bike-sharing map in Figure 8 shows that although most of existing systems are still concentrated in Europe, China and Korea in Asia, USA and Canada in North America and Brazil in South America have started being active implementing BSSs. If we focus our attention on Europe, Figure 9 shows that BSS seem to be more numerous in Spain, France and Italy and Germany.

[9] Spain is nowadays one of the European countries with more schemes (see Figure 9).

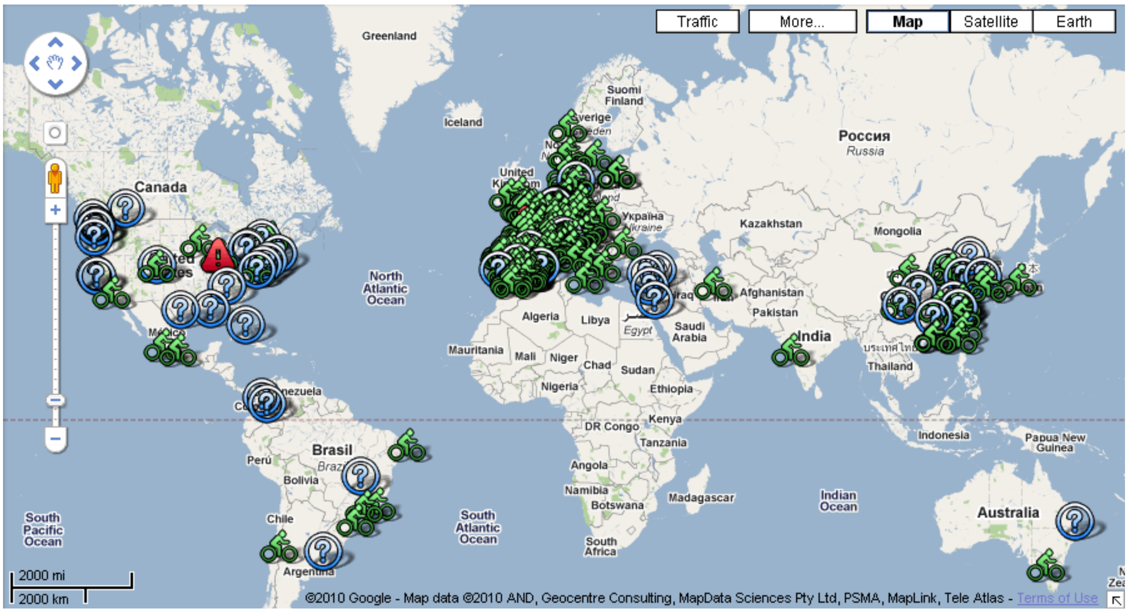


Figure 8: Bike-sharing World Map in 2010 (MetroBike 2011)

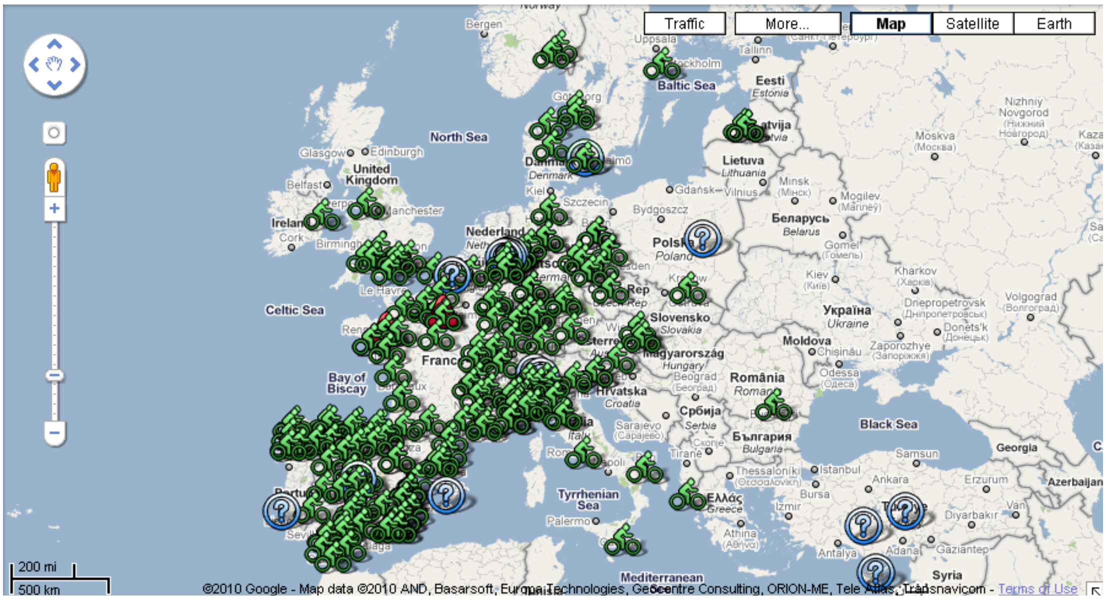


Figure 9: Bike-sharing European Map in 2010 (MetroBike 2011)

Gilles Vesco, Vice President of Grater Lyon, stated: “there are two types of Mayors: those who have bike-sharing and those who want bike-sharing” (DeMaio 2009b). The current distribution and exponential growth of the number of BSSs mentioned above seem to confirm the statement of Gilles Vesco.

2.4.5 Advantages for users

Section 2.4.1 has explained what bike-sharing exactly is and what their main properties are. However, some questions concerning the attributes of bike-sharing are still to be answered: Which target groups take benefit of using bike-sharing? What advantages does bike-sharing offer to them?

When non-cyclists are directly asked about the reasons for not cycling several negative aspects are argued. Non-cyclists mainly perceive cycling as "slow, tiring, dangerous, uncomfortable, uncharacteristic and inconvenient". The major worries concerning cycling are "traffic, safety, weather, daylight, long distances, sufficient fitness, trip-chain, carry of loads, and storage, equipment and maintenance of the bicycle" (Heinen et al. 2010; Wiersma 2010). Bike-sharing can contribute to solve some of these worries and barriers toward cycling by offering several advantages compared to private bicycles:

- Bike-sharing enables easier intermodality with public transport.
- Bike-sharing provides an energy efficient transport mode for unsupplied public transport routes.
- Bike-sharing avoids inconveniences associated to bicycle property such as maintenance and vandalism.
- Bike-sharing provides a convenient transport mode for tourism.
- Bike-sharing provides bicycles for unexpected cycle trips.

Public transport (PT) has as disadvantage that it normally cannot provide a "door-to-door" mobility. As a result, an additional transport mode is required to cover the distance between the origin and the initial PT station ("first mille") and to reach the destination from the final PT station ("last mille"). The bicycle is a convenient transport mode to combine with public transport because it is environmentally friendlier than motor vehicles and faster than walking, which increases the area of influence of the PT stations and the number of likely destinations (Figure 10).

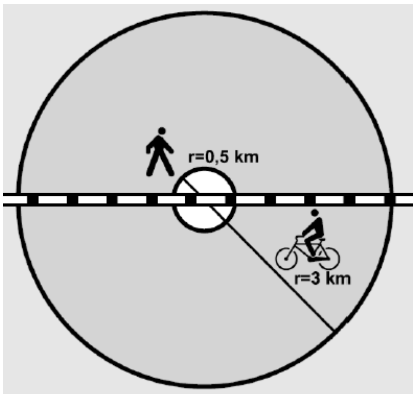


Figure 10: Enlargement of the influence area of a public transport station through bike & ride (Sassen 2009)

If an individual decides to use a bicycle to cover the first and the last mille of the trip, he/she has two options.

- The traveller can ride with the bicycle to the PT station, take it with him/her inside the vehicle and transport it until the final PT station, where he/she can use it again to afford the last mille of the trip. The problem of this option is that carrying a bicycle inside PT vehicles can be forbidden or restricted within certain timetables due to lack of space or appropriate equipment for transport of bicycles. Even if it is allowed, bicycles could be heavy and the get on and get off would require a considerable effort for the traveller. Therefore, this option may be unattractive and can dissuade people to cycle in such intermodal trips.

- The traveller can ride with the bicycle to the PT station and there he/she can leave the bicycle in a parking place. In this way he/she can travel avoiding inconveniences regarding the transport of the bicycle inside PT vehicles. At the destination the traveller could walk or use a second bicycle that he/she previously left parked there to cover last mille of the trip. The main troubles of this option are two: 1) unavailability of parking places and 2) vandalism risk due to unattended parking during the day at the origin of the trip. If the person has a second bicycle, it is more costly and the second bicycle stays unattended during the night in a parking place at the final PT station. Since one of the main barriers of non-cyclists to cycle is the worry about bicycle theft or vandalism, this option could also dissuade potential cyclists to ride.

BSSs offer a third option when undertaking intermodal trips. The bike-sharing users can rent a bicycle at the origin of the trip and return it in bike-sharing terminal close to the initial PT station. After undertaking the main part of the trip by public transport, he/she can rent an additional bicycle at the final PT station and undertake the last mille of the trip using again a bike-sharing bicycle. Coming back to the primary attributes of bike-sharing (section 2.4.1) and unlike private bicycles, BSSs enable unidirectional trips. This advantage can solve at the same time the two main troubles associated to urban intermodality: the problematic transport of bicycles in PT vehicles and the risk of bicycle theft.

Apart from more convenient intermodal trips, bike-sharing offers additional advantages. For example, if a route is not supplied with public transport and a person does not own any motor vehicle or bicycle (or has no intention to use it), then in principal he/she can just walk or avoid the route. However, bike-sharing offer the possibility to cover this unsupplied route in a faster way than by foot.

Moreover, since bike-sharing is a rental service, it does not imply property of the bicycle and avoids several inconveniences associated to bicycle ownership. Apart from the already mentioned worry about bicycle theft and vandalism, non-cyclists are afraid about their aptitude to keep the bicycle well maintained or the consequent maintenance costs. Since bike-sharing users do not own the bicycle that they use, they do not have to take care about these two dissuading concerns. In this way people might find more convenient cycling using a BSS.

Tourists may also find convenient BSSs. Since they usually do not have any available vehicle in the city that they visit, tourists mainly use public transport. However, active people may prefer to cycle instead of using public transport because they can enjoy the scenery when pedalling. Traditionally active tourists have rented bicycles in bike rental shops for visiting a city. Nevertheless, usage fees for short rental periods of some bike-sharing models can be cheaper than the tariffs offered by traditional shops (section 7.2.12) and this motivates that some customers prefer to use BSSs.

Finally, BSSs provide a needed bicycle in unexpected situations. For instance, if an individual decides to join a group of friends that will ride by bicycle and if he/she does not have any available bicycle, a BSS can provide a bicycle solving to this specific trouble.

2.5 Summary

In 2005 the United Nations emphasized the difference between the three "interdependent and mutually reinforcing” pillars or dimensions that hold sustainable development: “economic development, social development, and environmental protection” (UNO 2005).

Every dimension comprises, in the case of a transport system, a list of goals that have to be fulfilled to achieve the sustainability. Each one of these goals of sustainability may require one or more than one indicator, to be measured, calculated and assessed. The SUMMA project suggests the following list of goals and their classification inside categories to evaluate the sustainability of a transport system (Table 2).

	Dimensions of sustainability		
	Economical	**Environmental**	**Social**
Goals	Accessibility	Resource use	Accessibility and affordability
	Transport operation costs	Direct ecological intrusion	Safety and security
	Productivity / Efficiency	Emissions to air	Fitness and health
	Costs to economy	Emissions to soil and water	Livability and amenity
	Benefits to economy	Noise	Equity
		Waste	Social cohesion

Table 2: Dimensions and goals of sustainable transport. Data source: (SUMMA 2005)

Bicycles meet most of the above mentioned goals from the economic, environmental and social dimension, therefore they can be considered as a sustainable transport mode. Despite all advantages associated to cycling, only 5% to 10% of European trips are covered by bicycle (WALCYNG 1997). Determinants for cycling are listed in Table 3 and can be grouped in four categories: 1) built environment, 2) natural environment, 3) socio-economic and 4) psychological factors. All these factors seem to affect the decision of taking a bicycle when undertaking an urban trip.

Built environment	Natural environment	Socio-economic factors	Psychological factors
City-size	Hilliness	Gender	Attitude
Population density	Beauty of the route	Age	Social norms
Mixed land use	Temperature	Income	Public image
Trip distances	Rain	Household structure	Ideological belifs
Bicycle parking	Wind	Car ownership	Perceived behavioural control
Density of cycle network	Darkness	Bicycle ownership	Habits
Segregation grade of cycle ways	Season	Costs of transport	
Quality grade of cycle ways			
Continuity of cycle ways			
Safety			
Road width			
Traffic lights and stops			

Table 3: Determinants of cycling. Data source: (Heinen et al. 2010)

Bike-sharing is a bicycle rental system which allows, without additional charge, to take a bicycle in one point and to return it in a different one, where the bicycle can be rented by another user (Castro, Büttner, et al. 2010).

Several attributes make bike-sharing different to traditional rental bike. Primary attributes are common for all bike-sharing models while secondary attributes are not valid for all models but applicable for most of them. They can be summarized as Table 4 shows.

Primary attributes	Secondary attributes
One-way trips are allowed	Easy and unattended rental process
One-way trips are free of charge	Round-the-clock service
Bicycles can be rented where other users returned it	External funding from public subsidies or advertisement
	Low usage fee
	Location in public space
	Daily mobility oriented

Table 4: Primary and secondary attributes of bike-sharing

Bike-sharing was created in 1965. From then on BSSs have considerably changed. To see the evolution of bike-sharing throughout the time, BSSs can be grouped in three generations. Table 5 shows the main comparable features of these three generations. 1st generation and 2nd generation BSSs are in disuse, while 3rd generation systems develop and expand enormously.

1st Generation	2nd Generation	3rd Generation
Since 1965	Since 1991	Since 1996
No registration	No registration	Registration required
No identification	No identification	Identification required
No pricing	Deposit	Pricing
No lock	Locked bikes	Locked bikes
Painted bicycles	Exclusive design	Exclusive design
No advertising	Incipient advertising	Relevant advertising

Table 5: Overview of the three BSS generations

The number of BSSs has increased exponentially in the last years. In 2003 only 11 third generation BSSs existed worldwide and all of them were installed in Europe (DeMaio 2004), while in 2009 approximately 300 European cities were provided with BSSs (Castro, Büttner, et al. 2010).

BSSs present several advantages that can persuade customers to use a bike-sharing bicycle instead of a private bicycle. Target groups that may appreciate the advantages of BSSs are:

- Commuters that want to make intermodal trips connecting bicycle and public transport.
- People that need to cover a route without public transport supply.
- Potential cyclists that do not cycle because of their fear of bicycle theft or of their concern about bicycle maintenance and consequent costs.
- Tourist that need a transport mode for sightseeing.
- People that unexpectedly need a bicycle.

3 RESEARCH OBJECTIVES AND METHODOLOGY

3.1 Objectives

Taking into account the state of the art of section 2, the aim of this doctoral dissertation is to enumerate and quantify the main benefits and inconveniences of BSSs in terms of sustainability and to suggest strategies to make bike-sharing more efficient and sustainable. Therefore, the main questions to be answered in this dissertation are the following:

- What are the likely positive (or negative) impacts of bike-sharing for urban sustainability? (section 6)
- Which driving forces influence the success of BSSs? (section 7.2)
- What are the barriers that hinder the success of BSSs and how could these barriers be minimized or solved? (section 7.3)

The final purpose of answering all these questions is to find out the role that bike-sharing should play in urban mobility to optimize its contribution to sustainability.

3.2 Methodology

3.2.1 Bottom-up approach

To achieve the objectives of this dissertation, a bottom-up approach has been used. According to this approach, the state of the art has motivated the research objectives. These objectives have required a certain methodology that answers the questions in the most accurate way. The methodology used can be summarized in the three next research steps: 1) the selection and description of case studies, 2) the analysis of success of bike-sharing and 3) the analysis of factors that influence success. The data collected from the case studies have been processed in both analyses and they have provided the final results and conclusions. These research findings have answered the questions listed in the objectives of the dissertation. Figure 11 shows this bottom-up approach.

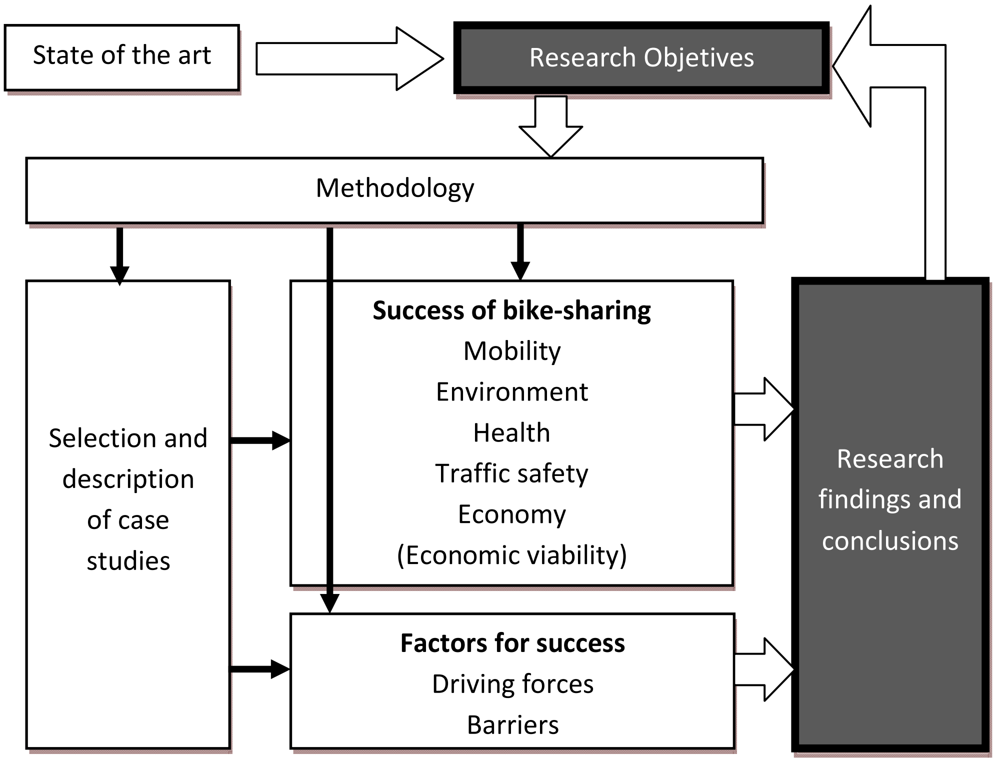


Figure 11: Bottom-up approach of this dissertation

3.2.2 Case studies and data collection

To analyze the success and the factors that influence bike-sharing, a sample of 51 case studies has been selected from more than 300 European existing cities provided with BSSs. The list of case studies coincides with the one elaborated by the EU-project OBIS[10]. The 51 BSSs from 48 cities and 10 countries studied in the project are a representative spectrum of the European status quo of bike-sharing and its diversity of models and cities[11].

The research undertaken in this dissertation has required a compilation of numerous data. The information collected for the OBIS project has been the foundation of the database of this dissertation. However, the author of this dissertation has compiled more than 300 additional data that update and complete the information provided by the OBIS project. The resulting database is a comprehensive cross-section of 51 case studies in 2009. The data compilation has required an intensive literature review that has comprised diverse sources such as journals articles, academic thesis, books, reports, conference presentations, data bases, websites, blogs and press articles, most of them available on the Internet. The data basis of the 51 cases studies is shown in annex 10.1.

[10] Optimising Bike Sharing in European Cities (OBIS) is a project funded by the Intelligent Energy Europe program of the European Commission from 2008 to 2011.

[11] Additionally to the 51 case studies, key facts of other BSSs have been collected and shown to provide qualitative framework and support to the result of the numeric analysis.

Apart from the lack of previous research focused on bike-sharing, the three main difficulties of the data collection have been the following: 1) inexistence of information, 2) opacity of informants and 3) unreliability of data.

Firstly, it was not possible to compile all required data because information was not available. Those case studies without enough information to complete calculations had to be removed from data processes. Lack of data may be motivated by the short lifetime of the bike-sharing concept. Since bike-sharing is a newly implemented transport mode, it is still under development. Therefore, some operators did not standardize a systematic collection of data yet and this might cause the current absence of data.

Secondly, in some cases data exist but they can neither be published nor used for researches because of the privacy policy of their owners. A considerable part of BSSs operate in private hands and these companies use to consider some data as commercial secrets.

Finally, the two previous difficulties lead to a low reliability of information. For example, certain figures can be contradictory just depending on the source. To discern the most suitable data in case of contradiction of sources, criteria such as confirmation in a third publication, feasibility considering the framework and reliability of the source were applied in this dissertation.

The collected data have been processed using Microsoft Excel® 2003-2007 and IBM SPSS® Statistics version 19.0 to calculate and represent the analysis of success in section 6 and the analysis of factors in section 7.

3.2.3 Analysis of success

As section 2.4.4 has explained, BSSs have quickly spread over Europe and currently numerous cities are provided with bike-sharing services. Many municipalities and bike-sharing operators have reported the success of their BSSs in terms of the increasing number of rents or bike-sharing bicycles. However, a high number of rents or bicycles do not mean itself “success”. According to the Oxford Dictionary, “success” is defined as “the accomplishment of an aim or purpose” (Oxford Dictionary 2010) and according to the Cambridge Dictionary success is “the achieving of the results wanted or hoped for” (Cambrigde University 2009). Therefore, “success” obligatory implies the statement of previous goals and only BSSs that achieve these initial goals should be considered as “successful”.

Which are these goals? There are different reasons to implement a BSS. Section 2.4.5 has shown that bike-sharing offers several advantages for individuals but bike-sharing can also be a mechanism to improve the whole city. For instance, a user survey carried out in Paris in 2009 revealed that 93% of users agreed that Vélib’ contributes to improve the image of the city, 90% stated that the BSS improves environment, 90% mobility, 85% health and 69% economy (Vélib’ 2009a). If we take into account existing literature about the benefits of bike-sharing (Beroud 2007; Sassen 2009; IDAE 2007; DeMaio 2004; DeMaio 2003; SpiCycles 2008) and we assume that the aim of any municipality when implementing a BSS is to ameliorate the conditions of life of the citizens, some likely reasons that could be argued to introduce a BSS are the following:

- To reduce car traffic
- To increase PT attractiveness
- To increase cycling
- To reduce pollution
- To improve air quality
- To increase fitness level
- To reduce traffic accidents with cyclists involved
- To create jobs
- To reduce transport costs for households
- To improve city image
- To increase city attractiveness for tourism

The municipalities that have as a goal reducing car traffic, increasing PT attractiveness or/and increasing cycling in their cities have all of them a common goal, which is to improve urban mobility in terms of reduction of traffic congestions as well as optimization of travel time and urban space. Other municipalities could have as a priority to reduce pollution that implies an environmental improvement as a goal[12]. Cities that have as a goal to increase fitness of people and quality of air have in common the wish to improve public health. A reduction of accidents with cyclists involved as a result of the introduction of a BSS leads actually to increase general traffic safety. And finally, those municipalities that implement a BSS with the primary goal to increase job opportunities, to reduce travel costs for citizens, to improve the city image or/and to promote tourism have in common the goal of improving local economy.

The achievement of any of these primary goals implies the success of a BSS. However, no BSS can be considered successful if it is not economically sustainable. For instance, if a BSS obtains very good results reducing CO_2 but it has to close several months after the launch because of insufficient funding, it cannot be considered successful. Success must be long-term maintained. Therefore, together with the achievement of goals, the requirement of economic viability must be always met.

This dissertation has grouped the likely goals of bike-sharing into five categories (Figure 12):

[12] Although a reduction of car traffic and an increase of public transport and cycling (mobility goals) give as a result a reduction of pollution (environmental goals), both goals have been considered as different in this dissertation since municipalities may set priority goal without considering side effects. For instance, there might be municipalities that set as a goal to improve mobility because there are continuous traffic jams in their cities. Although these municipalities might appreciate the consequent reduction of pollution, it is not their priority. In contrast, other municipalities might set the improvement of environmental conditions as a priority goal because e.g. few traffic congestions take place and the implementation of the BSS is integrated in a national policy to fight against climate change.

- Mobility
- Environment
- Health
- Safety
- Economy

The achievement of these five final goals associated to bike-sharing implies in fact five “categories of success”. These categories of success together with the requirement of economic viability represent the areas of study that this dissertation has analyzed for the evaluation of success of bike-sharing in European cities.

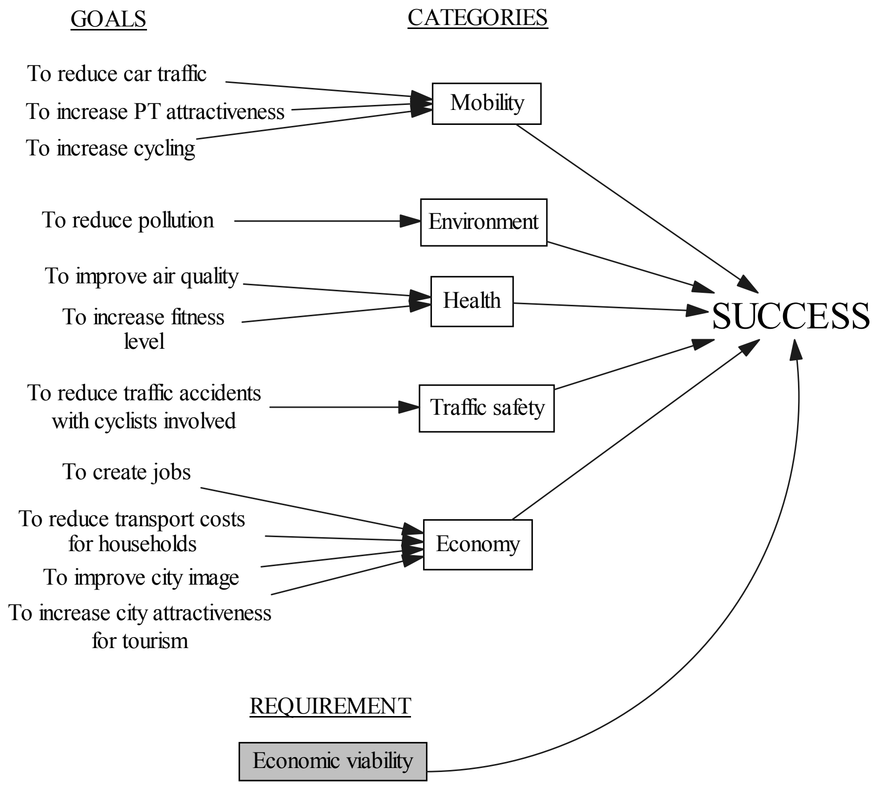


Figure 12: Goals of bike-sharing

As Figure 13 shows, the five categories of success or fields of study mostly cover the three dimensions of sustainability explained in section 2.2.2: environmental, social and economic sustainability. Environmental and economic goals concerning the implementation of BSSs assess their environmental and economic sustainability. Safety and health goals can be included in social sustainability. And finally, mobility issues can be considered as the central goal, which originates the other four goals and is contained in the three dimensions of sustainability[13]. Therefore, since the main aim of this dissertation is to evaluate the contribution of bike-sharing to sustainability, the fields of study selected for the research are sufficiently

[13] Environmental and health effects have implications in terms of economy because reduction of pollution and public health imply costs. Safety could be considered as a kind of health. Hence, these goals share common areas.

representative for the target. It is relevant to remark that the framework of every goal represented in Figure 13 is limited under the condition of meeting long-term economic viability.

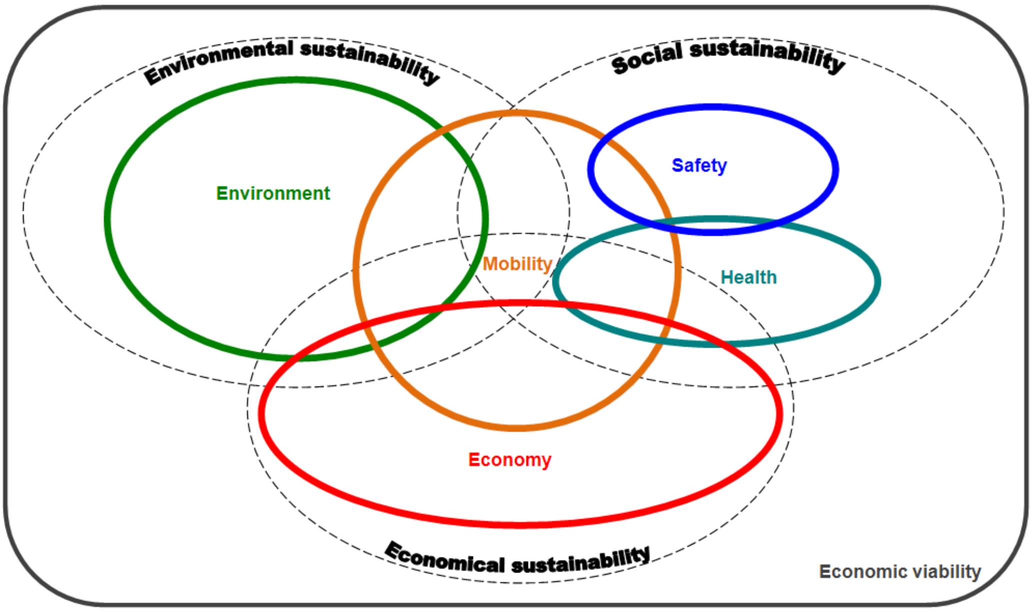


Figure 13: Sustainability of the categories of success used in this dissertation to analyze bike-sharing

Success achieving the primary goals that may motivate the introduction of the BSSs will be evaluated based on a cross section analysis of data collected in 2009[14]. As a result of treatment of data and calculations, the main quantitative outputs (section 6) will be the following:

- Absolute values normalized by population (or total trips in case of mobility indicators) to assess the real "impact" of the BSSs in the cities and by the number of bike-sharing bicycles to assess the "efficiency" of the infrastructure installed[15].
- Rankings of the most successful cases studies and their values. Although comparisons between BSSs might be "unfair" because of their different lifetime, these rankings will help to identify the most relevant "good practices" to be imitated. Furthermore, the numeric results will be later used in section 7 to analyze the influence of affecting factors in the level of success obtained.
- Averages and statistical medians of the final results that will measure the success of bike-sharing as a global movement in Europe.

[14] If not enough data have been available to analyze a case study, this case study will not appear in the final figures. Therefore, a case study can appear at the beginning of a calculation process and disappear in a specific middle step of this calculation due to unavailability of a certain data.

[15] As section 7 will reveal city size and BSS size are two determinant parameters that affect the absolute values of rents. BSSs located in large cities may have more rents since they have more inhabitants and consequently more demand and vice versa. The same occurs with the number of bicycles. BSSs with more available bicycles are more likely to catch more customers.

3.2.4 Analysis of factors

Two kinds of factors that influence success of BSSs have been identified in this section: 1) driving forces and 2) barriers. Driving forces catalyze the achievement of established goals, while barriers hinder the success or motivate the failure of the system. Apart from the positive and negative connotation of these terms, there is another difference between them. Driving forces are given or designed attributes of the BSSs and the cities, but barriers arise as result of non-favourable attributes.

Section 7.2 will focus on the analysis of the correlations between driving forces and success. The study of the isolated influence of each driving force and the success indicator (sections 7.2.1 to 7.2.14) will comprise three elements.

The first element is the diagram of the model. Depending on the type of variable, the diagram can be a scatter plot or a box plot. Metric variables are represented by a scatter plot and by a (linear or logarithmic) model that fit the data. The X axis of the scatter plot diagram corresponds to the driving force (independent variable) and the Y axis to the success indicator (dependent variable). In contrast, ordinal and dichotomous variables are represented by box plots. Box plots show the distribution of data through the minimum, lower quartile, median, upper quartile, maximum and outliers (when existing) of each category of the variable. The bottom and top of the box represent the lower and upper quartiles and the band near the middle of the box is the median. The ends of the whiskers represent the minimum and the maximum values. Outliers are observations that lay 1.5 times the interquartile range above or below the lower and the higher quartile.

The second element is a table that summarizes the main parameters of the model such as the coefficient of determination (represented as “R square”), the p-value (“sig.”), the variable of the function (“b”) and its constant (“constant”). The coefficient of determination shows goodness of fit of the model. The p-value shows the reliability of the result. The null hypothesis (H_o) is that the result of the statistical test occurred by chance. If a p-value is lower than the significance level (also called critical p-value), it implies the null hypothesis is rejected, i.e. the result is statistically significant and unlikely to have occurred by chance. The minimum significance level chosen is 0.1. It means that only results with a p-value lower than 0.1 will be considered as statistically significant. Linear models have the following function: Y=bX+constant, while logarithmic functions have this other function: Y=constant+b*Ln(X).

The third element is a table with information about the level of correlation between the success indicator and the driving force. Three parameters are shown in the table: 1) The Spearman coefficient (“correlation coefficient”), 2) the p-value (“sig. 2-tailed”) and 3) the number of cases of the sample (“N”). Correlation can be measured by two coefficients: Pearson’s coefficient (for parametric data) and Spearman’s coefficient (for non-parametric data). Since data may not fit a linear function and consequently they may not have normal distribution and since the Spearman’s coefficient reduces the probability of obtaining Type I error (false positive), Spearman correlation analysis has been used. Spearman’s coefficients from 1 to 0.7 will be considered as high correlation, from 0.7 to 0.5 as medium correlation, from 0.5 to 0.3 as low correlation and below 0.3 as no correlation. The information about the model is less relevant when no significant correlation between the variables is found. The meaning of the p-value is the same as explained above for the summary of the model.

After the study of single correlations between one driving force and the success indicator, the final section 7.2.15 will present a multiple regression analysis. The multiple regression analysis reveals the influence of the driving forces on rotation integrated in a system that considers interactions between driving forces. The meaning of parameters regarded in the multiple regression analysis will be explained in section 7.2.15.

Table 6 lists the 24 driving forces that will be analyzed[16]. The driving forces will be grouped into the below listed categories that correspond with the sections 7.2.1 to 7.2.14. There are two groups of driving forces depending on their origin: bike-sharing factors and city factors.

- Bike-sharing factors are those that describe the features of a BSS and they can be decided before the implementation or modified during the operation of the BSS.
- City factors are those that describe the features of the city where a BSS is located and they are more costly or slower to change since they are intrinsic to the location.

Bike-sharing factors	
Category	Driving force
Bicycles & stations	Number of bicycles
	Number of stations
	Distance between stations
	Stations per city km^2
Technology	Technology of the docking device
	Way of identification
Availability of service	All-year-around service
	Round-the-clock-service
Subscription & usage fee	Validity of long-term subscriptions
	Rental period free of charge
Integration with PT	Metro stations provided with BSS
	Advantageous fee for PT passengers
City factors	
Category	Driving force
Population	Population
	Population density
Topography	Topography
Climate	Average yearly temperature
Car use	Car modal share
Public transport use	PT modal share
	Permission to carry bikes in trains
Bicycle use	Cycle network density
	Cycling modal share
Tourism	Tourism density
Vandalism	Theft per cycle trip
Traffic safety	Accidents per cycle trip

Table 6: Bike-sharing factors and city factors

[16] The election of these affecting factors has been based on the two following criteria: 1) hints of determinants of cycling described in section 2.3.2 and 2) availability of data in the case studies.

Figure 14 summarizes the key variables that determine the success of a BSS according to section 6. Since the number of bike-sharing rents determines directly or indirectly most of the success categories, the study of section 7.2 will be mainly focused on the correlation of driving forces and this success indicator.

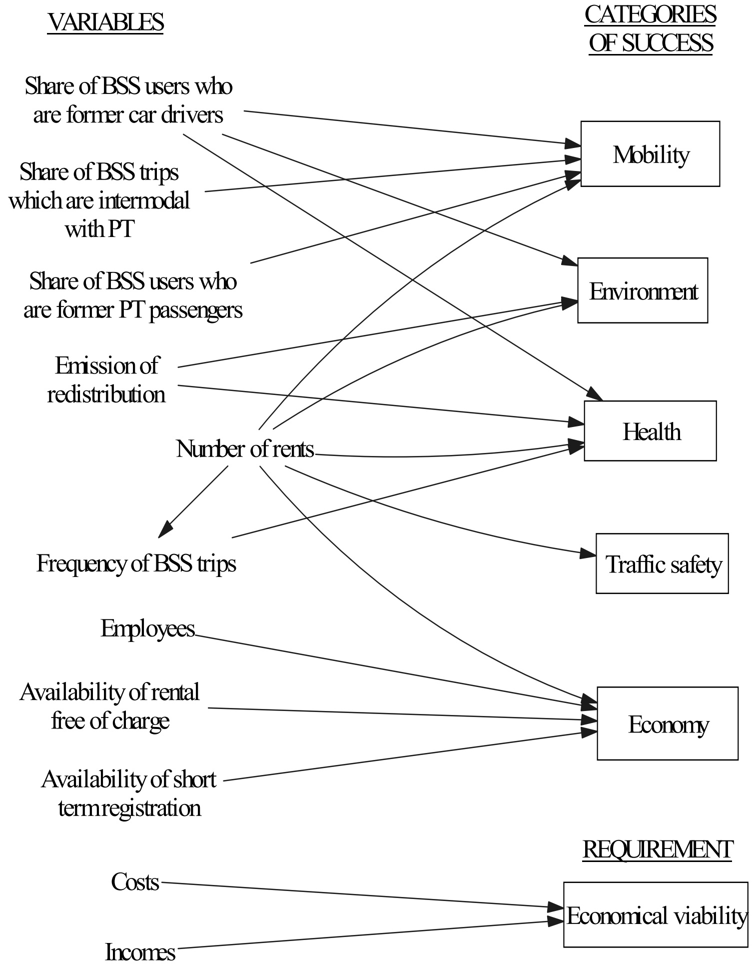


Figure 14: Main variables affecting success

According to section 6, success of bike-sharing has to be evaluated in terms of impact (normalized by population or municipal trips) and efficiency (normalized by bicycles). Therefore, if the intention of section 7 is to analyze the influence of driving forces on success, in theory, both rents per inhabitant (impact) and rents per bicycle (efficiency) should be taken into consideration. Nevertheless, only influences of driving forces on efficiency have been studied in this dissertation, because according to Figure 15, the number of rents is higher correlated with the number of bicycles (Spearman's coefficient 0.818) than with population (0.507). A linear relation has been assumed and Figure 16 and Figure 17 show the linear model of both relationships. Although the extreme case of Paris has been removed in Figure 16 to avoid distortions of results, the adjustment of data to a linear model is high (R^2 =0.915).

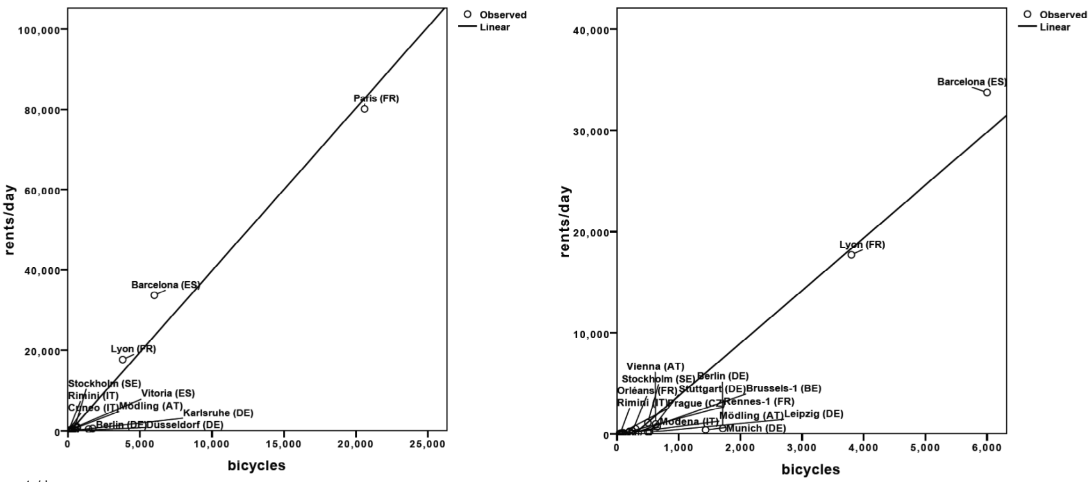
Correlations

rents/day

		Spearman's rho
rents/day	Correlation Coefficient	1.000
	Sig. (2-tailed)	.
	N	28
bicycles	Correlation Coefficient	.818**
	Sig. (2-tailed)	.000
	N	28
inhabitants	Correlation Coefficient	.507**
	Sig. (2-tailed)	.006
	N	28

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 15: Correlation of the number of rents per day with the number of bike-sharing bicycles and with population. Data source: Annex 10.1



rents/day

	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.975	1010.016	1	26	.000	-744.663	4.052

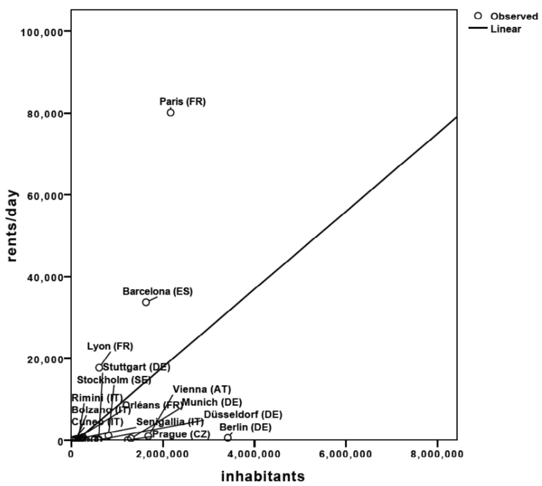
The independent variable is bicycles.

Dependent Variable:rents/day

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.915	268.123	1	25	.000	-1439.597	5.207

The independent variable is bicycles.

Figure 16: Linear model of the number of bike-sharing bicycles and the number of daily rents with all case studies (left) and without Paris (right). Data source: Annex 10.1



Dependent Variable:rents/day

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.208	6.848	1	26	.015	-1144.265	.010

The independent variable is inhabitants.

Figure 17: Linear model of city population and the number of daily rents. Data source: Annex 10.1

The number of rents per bicycle and day is also called “rotation”. In other words rotation means the number of times that a bike-sharing bicycle is rented during a day. Figure 18 shows the values of rotation in each one of the 28 BSSs of the sample with available data. The values range from 0.1 to 5.6 rents per day and bicycle. Barcelona, Lyon and Paris reach the highest values of rotation with 5.6, 4.7 and 3.9 rents per day and bicycle while the average is 1.2.

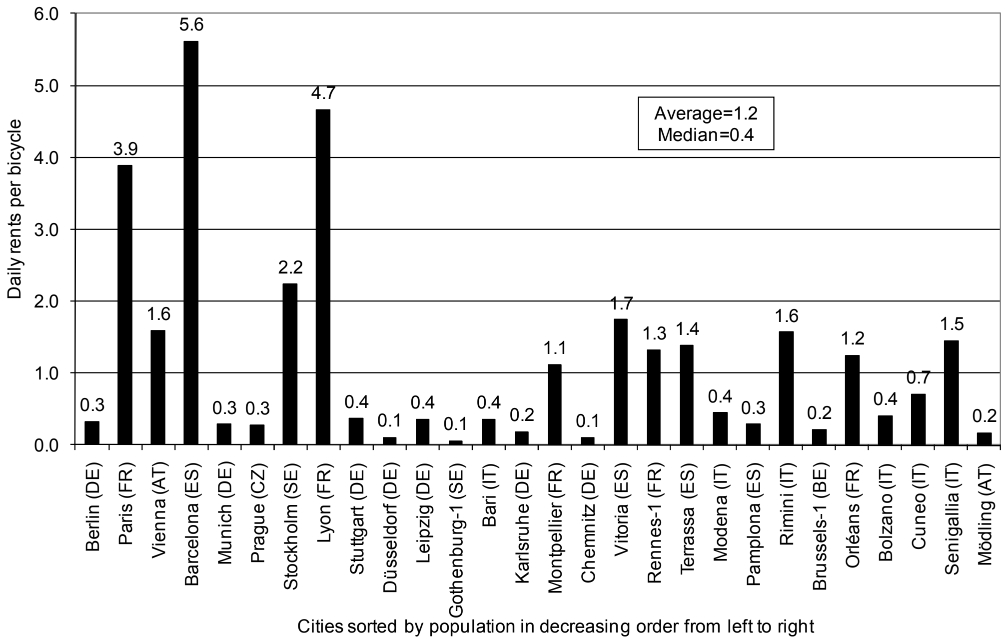


Figure 18: Rotation in the BSSs studied. Data source: Annex 10.1

Finally, section 7.3 will analyze in a qualitative way the barriers for success associated to bike-sharing operation. The likely causes, consequences and solutions of these barriers will be identified and explained.

4 CASE STUDIES

As section 2.4.4 has explained, more than 300 European cities were provided with a BSS in 2009. A sample of 51 BSSs located in 48 cities from 10 different countries was selected by the EU-project OBIS as case studies to investigate the optimisation of bike-sharing. This dissertation adopts the same list of case studies as sample. The high number of case studies and their diversity offers a wide and representative overview of the bike-sharing reality in Europe.

Numerous available data from the 51 selected cases studies have been collected and processed in this dissertation to analyze the success of BSSs in terms of sustainability (section 6) and the influence of factors affecting this success (section 7). Table 7 shows the main features of the BSSs selected. As it can be observed, the 48 cities studied belong to the following ten countries: Austria, Belgium, Czech Republic, France, Italy, Germany, Italy, Poland, Spain, Sweden, and United Kingdom. Italy with eleven schemes, France with eight, Spain and Germany with seven BSSs are the countries with a higher representation in the sample.

In each city only one BSS was analyzed, with the exception of Rennes, Gothenburg and Brussels, where two schemes were studied. In Rennes and Brussels two BSSs were analyzed because during the research one of them was closed and substituted by a new one, while in Gothenburg both BSSs operate at the same time[17] (Robert 2009a; Robert & Richard 2009; Petersen & Robèrt 2009).

Only two BSSs of the list of case studies were introduced in the 20th century, Cyklestaden in Gothenburg in 1978 and Vélo a la Carte in Rennes in 1998. In contrast, the other 49 systems were implemented in the 21st century. The most modern BSSs of the list were introduced in 2009 in Rennes and Brussels.

Apart from Vélo a la Carte and Cyclocity, the schemes located Rennes and Brussels respectively, other two BSSs studied in this research are currently closed and do not operate anymore. They are Freiradl in Mödling and Oybike in London. Both were substituted by upgraded BSSs (Castro & Emberger 2009; Williamson 2009a).

Regarding the number of available bicycles, the list of case studies shows the wide variety of models that the selected sample contains. The largest BSS, Vélib' in Paris, offer 20,600 bicycles. Other relevant BSSs in terms of size of bicycle fleet are Bicing in Barcelona with 6,000 and Vélo'v in Lyon with 3,800 bicycles.

These case studies are described in more detail through the characterisation of their elements in section 5.

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[17] BSSs located in cities where more than one BSS operate or have operated are named with the number 1 and 2. For instance: Rennes-1 and Rennes-2.

Country	City	BSS name	Start	Status quo	Bicyles in 2009
Austria	Mödling	Freiradl	2004	Closed in 2009	47
	Lake Neusiedl	nextbike	2007	Operating	100
	Salzburg	Citybike	2005	Operating	15
	Vienna	Citybike	2003	Operating	626
Belgium	Brussels-1	Cyclocity	2006	Closed in 2009	250
	Brussels-2	Villo!	2009	Operating	1,000
Czech Republic	Prague	Homeport	2005	Operating	(**) 30
France	Chalon-sur-Saône	Réflex	2007	Operating	100
	Dijon	Velodi	2008	Operating	350
	Lyon	Vélo'v	2005	Operating	3,800
	Montpellier	VéloMagg	2007	Operating	(*) 650
	Orleans	Vélo +	2007	Operating	250
	Paris	Vélib'	2007	Operating	20,600
	Rennes-1	Vélo à la carte	1998	Closed in 2009	200
	Rennes-2	Vélo Star	2009	Operating	900
Germany	Belin	Call a Bike	2002	Operating	1,715
	Chemnitz	Chemnitzer Stadtfahrrad	2006	Operating	(*) 130
	Düsseldorf	nextbike	2008	Operating	(*) 300
	Karlsruhe	Call a Bike	2007	Operating	343
	Leipzig	nextbike	2005	Operating	500
	Munich	Call a Bike	2000	Operating	1,436
	Stuttgart	Call a Bike	2000	Operating	525
Italy	Bari	Bari in Bici	2007	Operating	80
	Bolzano	Noleggio bici Bolzano	2003	Operating	100
	Brescia	Bicimia	2008	Operating	120
	Cuneo	Bicincittà	2004	Operating	50
	Milan	bikeMi	2008	Operating	1,400
	Modena	C'entro in bici	2004	Operating	224
	Parma	Punto Bici	2006	Operating	48
	Rimini	Rimini in Bici	2008	Operating	52
	Rome	Atac Bike Sharing	2009	Operating	120
	Senigallia	C'entro in bici	2007	Operating	68
	Terlizzi	Terlizzi by bike	2008	Operating	(*) 20
Poland	Krakow	BikeOne	2008	Operating	100
Spain	Barcelona	Bicing	2007	Operating	6,000
	Pamplona	Nbici	2007	Operating	(*) 101
	Ribera Alta	Ambici	2009	Operating	350
	Seville	Sevici	2007	Operating	2,000
	Terrassa	Ambiciat	2007	Operating	(**) 100
	Vitoria	Servicio Municipal de Préstamo de Bicicletas	2004	Operating	300
	Saragossa	BiZi	2008	Operating	400
Sweden	Gothenburg-1	På cykel i Lundby/Lånecyklar i Göteborg	2006	Operating	125
	Gothenburg-2	Greenstreet	2005	Operating	57
	Örebro	Cykelstaden	1978	Operating	1,400
	Stockholm	City Bikes	2006	Operating	500
United Kingdom	Bristol	Hourbike	2008	Operating	16
	Cambridge	OYBike	2008	Operating	3
	Cheltenham	OYBike	2008	Operating	26
	Farnborough	OYBike	2007	Operating	10
	London	OYBike	2004	Closed in 2010	108
	Reading	OYBike	2007	Operating	13

(*) Last confirmation of these data in 2008. (**) Last confirmation of these data in 2007

Table 7: List of case studies sorted by countries and alphabetic order

5 ELEMENTS AND VARIANTS

5.1 Introduction

Bike-sharing has not the same appearance everywhere. A wide diversity of BSSs is currently operating all around Europe and BSSs can be totally different from one city to another. The aim of this chapter is, 1) to explain how BSSs work from an operational and organisational perspective, 2) to describe the case studies and the elements that compose the schemes, 3) to present the likely variants of these elements and 4) to show the proportion of each variant in the existing bike-sharing market.

From an operative point of view, section 5.2 will explain what users have to be aware before using the system for the first time. After the previous obligations, section 5.3 will describe the tangible infrastructure that enables users to recognise and access the service. The periods of time when BSSs are operative and opened to customers will be described in section 5.4. The rental procedure as well as conditions concerning the usage of bike-sharing bicycles will be described in section 5.5. Finally, obligations after a bicycle rent, such as payment of fees, will be described in section 5.6. From an organisational point of view the different stakeholders and roles in bike-sharing management will be presented in section 5.7.

5.2 Registration

Before using a bike sharing service for the first time, customers can be obligated to become members of the BSSs through the fulfilment of a registration. The main goal of registrations is to provide operators with a way of contact with customers for charging fees or fines. Data of customers for statistical purposes as well as signed acceptance of usage conditions are also registered by mean of registrations. The data to be fulfilled in registration forms depend on the BSS, but some of the most usual ones are shown below:

- Contact data, e.g. name, post address, e-mail address and telephone number.
- Other personal data for statistical purposes, like e.g. gender or birthday.
- A username and a password to unlock the bicycle or to have access to the personal website profile.
- Way of payment selected for subscription fee and usage fee (when several options are available) as well as bank data (when a bank payment is available).
- The approval of usage and payment conditions to enforce the contract between operator and customer.

When the form is fulfilled, it has to be delivered. While some BSSs require registrations in person, either in a bike-sharing office or in a bike-sharing station, others allow sending the form by Internet, telephone or post. Some BSSs combine both possibilities and allow pre-registration online but the registration has to be confirmed in a bike-sharing station.

5.2.1 Obligation

Depending on the bike-sharing model, registration can be required or not. For example, first and second generation systems do not require any registration. However, these kinds of BSSs are currently in disuse (section 2.4.3.1 and 2.4.3.2). To avoid vandalism and to provide a way to charge fees, registrations became mandatory with third generation systems (section 2.4.3.3). Most of current schemes and all BSSs analyzed in this dissertation require registration.

5.2.2 Age restriction

Bike-sharing can be an open service for all ages, but actually 70% of the 51 BSSs studied are age-restricted (Table 8). Customers of these schemes have to be at least 12, 14, 15, 16 or even 18 years old to fulfil the registration form and to become members. The most usual minimum age is 16 years old, which is asked in 24% of cases studies.

MINIMUM AGE		
	N	%
No min age	15	30%
12 years old	4	8%
14 years old	9	18%
15 years old	1	2%
16 years old	12	24%
18 years old	9	18%
Sum	*50*	
NA	1	

Table 8: Minimum age allowed for using bike-sharing

5.2.3 Target group

The trip purposes of bike-sharing users can be grouped in two main categories: 1) working and education and 2) leisure. Working and education mobility implies daily trips in working days, while leisure activities (e.g. tourism, going to a cinema…) take place less frequently and during weekends. Each type of trip purposes has a different type of user with different necessities. For example, users of working and education mobility may require long-term subscriptions, low usage fees and integration with public transport, while users of leisure activities may require short-term subscriptions and flat rates for long rents.

BSSs can be strategically addressed to a certain target group. Nevertheless, most of BSSs are formally open to every likely user to reach as many rents as possible. Although the BSSs are normally mixed used, some parts of the operating area can concentrate more individuals of a certain target group. For instance, in Lower Austria a study revealed that the regional BSS, Leihradl-nextbike, is mainly used for commuting in some towns and for leisure in other towns. In one of these groups of towns the implementation of 30 minutes free of charge (instead of the initial €1 per hour fee) was identified as a reason for the increase of the share of daily mobility trips (Castro 2011).

BSSs can not only concentrate their efforts in a specific target group, but also allow the access to the service to an exclusive target group. However, experience shows this instrument of restriction is rarely implemented. In almost all BSSs studied in this dissertation, 98%, all likely target groups are allowed to use the system (Table 9). The only restriction found in the case studies was geographical. In one BSS only local residents were allowed to use the system.

TARGET GROUP		
	N	%
All target groups allowed	50	98%
Certain target group not allowed	1	2%
Sum	*51*	

Table 9: Target group allowed using bike-sharing

Although some BSSs theoretically allow the bicycle rental to all kind of customers, they can implement policies that indirectly dissuade certain customers groups to use the system. For example, those BSSs that only accept national debit cards as way of identification indirectly exclude foreign visitors as customers and flat rates are especially convenient for tourist and leisure mobility (section 6.6.4).

5.2.4 Period of validity

Bike-sharing memberships can expire after some time. Depending on the different length of validity, subscriptions have been grouped in this dissertation in two categories (Table 10):

- short-term subscriptions and
- long-term subscriptions.

Subscriptions valid up to one week are considered in this doctoral thesis as short-term subscription. 41% of case studies offer the possibility to subscribe for short-term membership. This kind of memberships may be especially attractive for intensive users such as potential customers that want to try the system for a while or for tourists who visit the city for a short time. One day or one week subscriptions are available in 38% of the BSSs, while in 52% of the cases both options are available[18].

In contrast to short-term subscriptions, long-term subscriptions can be valid for one year or forever. All BSSs studied in this dissertation offer long-term subscriptions. 61% of them offer one-year memberships, while 39% offer unlimited valid memberships. The target group of long-term subscriptions use to be residents because fees become more convenient for extensive usage. Unlimited valid memberships, even when charged, might be more economical than one-year memberships because customers only pay once to obtain and keep the usage right. A particular case of long-term subscription is the one linked to seasonal PT cards. PT card holders can benefit with more favourable conditions such as longer rental periods free of charge or lower fees when renting a bicycle by mean of this specific subscription. 24% of the BSSs analyzed provide this type of subscription that has as target group PT commuters.

[18] One-day, three-days and one-week subscriptions have been highlighted in this section, but there are other validities below one year. One-month, 90-days and 6-months memberships are also available in few BSSs with residual usage.

TYPES OF SUBSCRIPTION					
	N		%		
Short-term	21		41%		
Long-term	51		100%		
PT	12		24%		
Short-term			**Long-term**		
Duration	N	%	Duration	N	%
1 day	4	19%	unlimited	20	39%
1day&1week	11	52%	1 year	31	61%
1 week	4	19%	*Sum*	*51*	
3 days	2	10%			
Sum	*21*				

Table 10: Validity of bike-sharing subscriptions

5.2.5 Subscription fee

The amount of money that gives users the right to use a BSS for a certain period of time is the subscription fee. Subscriptions fees are different depending on the period of validity (Table 11).

Subscription fees of short-term memberships such as daily subscriptions go from €0 to more than €5. Subscriptions without charge are rare, only 7% of the cases studies offer it. On the contrary, most of daily subscriptions, 47%, cost less than €1. Weekly memberships, also considered as short-term subscriptions, can cost from €1 to €7, but 60% of them cost from €4 to €6.

Long-term subscription fees such as the ones of unlimited subscriptions go from €0 to about €12. 40% of them are free of charge and 55% cost €1 or less. In contrast yearly fees can be more expensive. Their price go from €0 to 36€, being 27% free of charge and 46% from €20 to €30.

SHORT-TERM SUBSCRIPTIONS					
1 day			1 week		
Fee interval	N	%	Fee interval	N	%
€ 0	1	7%	€ 0	0	0%
(€0,€1]	7	47%	(€0,€1]	1	7%
(€1,€2]	1	7%	(€1,€2]	1	7%
(€2,€3]	1	7%	(€2,€3]	3	20%
(€3,€4]	0	0%	(€3,€4]	0	0%
(€4,€5]	0	0%	(€4,€5]	3	20%
(€5,€6]	5	33%	(€5,€6]	6	40%
Sum	*15*		(€6,€7]	1	7%
			Sum	*15*	
LONG-TERM SUBSCRIPTIONS					
unlimited			**1 year**		
Fee interval	N	%	Fee interval	N	%
€ 0	8	40%	€ 0	8	27%
(€0,€5]	11	55%	(€0,€5]	0	0%
(€5,€10]	0	0%	(€5,€10]	5	17%
(€10,€12]	1	5%	(€10,€15]	2	7%
Sum	*20*		(€15,€20]	1	3%
			(€20,€25]	10	33%
			(€25,€30]	4	13%
			(€30,€36]	1	3%
			Sum	*31*	

Table 11: Subscription fees sorted by period of validity

5.2.6 Deposit

A deposit is a quantity of money, which can be retained by operators of BSSs at the moment of the registration. Deposits are returned to their owners when the subscription expires. The purpose of deposits is to have quick access to money of users to charge fines if a bicycle is stolen or damaged.

Most of the BSSs (58%) do not ask for any deposit to become a member. When deposits are required, they can reach up to €200. 16% of the cases charge €150, but 24% of the total require between €10 and €30 (Table 12)[19].

DEPOSIT		
	N	%
No deposit	29	58%
[€10,€30]	12	24%
€ 150	8	16%
€ 200	1	2%
Sum	*50*	
NA	1	

Table 12: Deposit required at the registration

[19] Figures of long-term subscriptions.

5.2.7 Insurance

According to the sample analyzed, 72% of BSSs do not include any traffic insurance covering the liability of customers when riding a bike-sharing bicycle (Table 13). When insurance is offered, it is mostly a third-party one (20%), i.e. if customer causes some material or personal damage to other person (but not him/herself), the insurance pays the cost.

INSURANCE		
	N	%
No insurance	34	72%
User insurance	2	4%
Third-party insurance	10	21%
All-risk insurance	1	2%
Sum	*47*	
NA	4	

Table 13: Insurance coverage included in the subscription of bike-sharing members

5.3 Infrastructure

The infrastructure is the external, physical and recognisable part of a BSS, i.e. it is the element that users search on the street when they wish to have access to the service. The bike-sharing infrastructure comprises basically two elements: bike-sharing bicycles and bike-sharing stations.

5.3.1 Bicycles

“Public bicycles” (NICHES 2007; SpiCycles 2008), “BSS bicycles” “bike-sharing bicycles” (Castro & Emberger 2010) as well as just “bicycles” (SpiCycles 2008; Castro, Büttner, et al. 2010) are usual terms to refer to bicycles used in BSSs.

The bicycle is the only element common to all BSSs. However, bicycles can be different depending of the bike-sharing model.

Bike-sharing bicycles can be conventional bicycles or differ from them. If they differ, not only their external appearance is different and but also their mechanisms. Exclusivity of design of bike-sharing bicycles has three aims:

- To make them easily recognisable by customers for finding the service.
- To help operators to identify bicycles, when they are stolen.
- To avoid theft and re-usage of pieces in conventional bicycles.

Three examples of bicycle components that contribute to increase comfort of customers when riding are gears, tyres and brakes, but there are not available in every bike-sharing bicycle (Table 14).

Multi-gear bicycles make possible to regulate effort pedalling uphill and downhill and therefore reduces the inconveniences of bike-sharing in hilly cities. 80% of the BSSs studied provide bicycles with gears. However, gears can produce often breakdowns and consequently increase the maintenance costs of BSSs. Hence, 20% of BSSs offer public bicycles without different speeds.

Bicycles can be equipped with rim brakes, like in Bicing, or with disc brakes, like bikes of Vélo'v (Vidal n.d.). In both cases frontal and rear break are controlled from the handlebar. 80% of BSSs, according to the case studies of this dissertation, are provided with these both types of brakes. In contrast, pedal brakes are available in bicycles of 20% of BSSs. In these cases only the frontal brake can be controlled from the handlebar, while the back brake is executed with the pedal.

88% of BSSs provide bike-sharing bicycles with inner tube filled with air, as commercial bicycles. However, 12% of schemes opted to introduce tyres filled by other materials, such as gum. Full gum tyres absorb less shocks, hence ride is less comfortable. Nevertheless, wheels of gum avoid flat tyres and therefore reduce maintenance costs. "Citybike Wien" in Vienna is one example of BSSs provided with this kind of tyres (Castro 2009).

Gears availability			**Both brakes on handelbar**			**Tyres with innertube**		
	N	%		N	%		N	%
Yes	40	80%	Yes	40	80%	Yes	45	88%
No	10	20%	No	10	20%	No	6	12%
Sum	*50*		*Sum*	*50*		*Sum*	*51*	
NA	1		NA	1				

Table 14: Bicycle equipment

The existence, typology and materials of gears, tears and brakes, together with other elements of equipment such as lighting, basket and frame, determine the different weight of bicycles. For instance, the bicycles of Vélib' in Paris weights about 22 kilograms, while bicycles of Bicing in Barcelona weights 16.8 kilograms (NYC Department of City Planning 2009; Bikeoff 2008b). Weight is a determinant characteristic of bike-sharing bicycles because heavy bicycles can cause discomfort at riding.

5.3.2 Stations

Bike-sharing stations are the fixed places where users take and return bike-sharing bicycles. In the bike-sharing field, "Bike-sharing station", "BSS station" (Castro & Emberger 2010), "docking station" (Dector-Vega et al. 2008) or just "station" (Beroud 2007) are accepted terms for referring to this concept.

88% of the BSSs studied in this thesis operate with stations (Table 15). Nevertheless, there are BSSs without stations as well. First generation schemes and phone call oriented BSSs like Call a bike or nextbike are examples of bike-sharing models that operate without stations. Both Call a bike and nextbike are flexible systems based on the freedom to take and return the bike in any visible cross inside the operation area of the city. Users just have to inform the operator about the location of the returned bicycle (DB Bahn 2009; nextbike 2010).

Fixed location of stations			Protection of stations			Lock of bicycles in stations					
	N	%		N	%		N	%		N	%
Yes	45	88%	Depot	3	6%	Electronic	37	73%	Docking post/bar	26	51%
No	6	12%	Out-door but covered	3	6%	Mechanic	8	16%	Bike lock	19	37%
Sum	*51*		Out-door without roof	45	88%	Staff	6	12%	Staff	6	12%
			Sum	*51*		*Sum*	*51*		*Sum*	*51*	

Table 15: Station equipment

The main advantage of systems without stations is that bike-sharing customers save time. Users can return the bicycle directly on their final destination instead of do it in a station and walk to the destination. Furthermore, stations have a limited space for bicycles. When a station is full, users cannot return the bicycle and when the station is empty they cannot pick a bicycle up. In both cases customers must walk or ride to the nearest bike-sharing station to take or return the bicycle what is time-consuming.

On the other hand, BSSs without stations have cons too. Users of these schemes, in contrast to customers of models with stations, do not know where to find the bicycles when departing because it depends on where previous users returned them. Therefore, users have to make a phone call or to access Internet to find out the accurate position of the bicycles. Other handicap of BSSs without stations is that the phone call or the SMS can imply an additional cost for users when renting the bicycle.

Figure 19: Bike-sharing station of C'entro in bici in Modena (left) and bike-sharing bicycle of Call a Bike in Berlin (right)

Apart from bicycles, bike-sharing stations can provide: information for users, protection against vandalism and meteorology and locks for bicycles.

Bike-sharing stations provide instructions about service and the nearest bike-sharing stations. This information can be shown through panels and screens. Panels made of wood or metal show static information in less technologically developed systems. In contrast, high-technology systems are equipped with a touch-screen that provides real time information such as availability of bikes and docking points at stations.

Bike-sharing bicycles can be located indoor in depots or outdoor in the public space. If they are in depots, they are protected against vandalism and meteorology but then they are less visible and the scheme reaches lower awareness (Castro, Lackner, et al. 2010). If they are outside, they can be protected against meteorology through a roof and against vandalism and meteorology by bike boxes, like for example in OV-fiets in The Netherlands (Wikipedia 2010e) or in Bikey in Germany (Bikey n.d.). In practice, most of BSSs, 94% of the case studies, locate their stations on public space. 88% do not provide any protection for bicycles, 6% store the bicycles in public space but covered with a roof and 6% of schemes locate their stations inside private or semi-private areas such as inside buildings (Table 15).

Locking of bicycles is required in bike-sharing stations to avoid theft. Depending on the technology available, stations can be equipped with electronic devices (73% of case studies), mechanical devices (16%) or staff (12%) to deliver the bicycle (Table 15). Depending on the typology lockers can be: docking posts and bars, independent locks and staff.

Docking posts and docking bars are electronic devices where bicycles can be locked. They are implemented in 51% of the BSSs studied (Table 15). Docking posts are individual and independent locking points for only one bicycle. They have to be connected to a computer in the station by subterranean cable network. Therefore, pavement removal and underground work can be required for the installation. Vélib' in Paris is one example of this kind of lock. Docking bars are horizontal bars provided with several docking points. The connexion with the station's computer is by a cable with goes inside the bar. In this way less breaking of the pavement is needed but the physical barrier for pedestrians in sidewalks is more evident. Bicing in Barcelona is one example of this system. Energy of both, docking posts and docking bars, can be supplied through two ways in electronic stations: with cable excavated and with solar powered stations. The first one, used in almost all models, requires longer installation; in Paris for instance it took 6 months to build 700 stations. In contrast solar powered stations do not need so much excavation and therefore the installation time is shorter, about 20 minutes per station (NYC Department of City Planning 2009).

The classical and mechanical bicycle lock is the device used by 37% of the case studies e.g. those operated by nextbike (Table 15). Depending on the BSS, locks are opened by keys or codes. However, bicycle locks can be electronic, like the ones used by systems such as Call a Bike. They have a small touch-screen where the code must be keyed in.

In low-tech BSSs, users access indirectly to bicycles through staff, who actually lock and unlock the bicycle and who take and deliver it from/to the customer. 12% of the BSSs studied require staff (Table 15).

Figure 20: Docking posts of Vélib' in Paris (left) and docking bar of Bicing in Barcelona (right)

5.4 Availability of service

BSSs do not have to be always in operation. They can close during some hours in a day or during some months in a year.

5.4.1 Throughout the year

BSSs can operate all the year round. In fact, 75% of the case studies of this dissertation do it (Table 16). However, there are also systems that stop operating during several months. Climate is the main reason for this seasonal closing. People cycling and walking have no protection against weather conditions and therefore they are very affected by meteorological conditions such as rain and cold. Consequently, demand of bike-sharing may decrease in colder cities so that operation becomes uneconomical and hence operators decide to make winter breaks (Castro & Emberger 2010).

Availability throughout the year		
	N	%
All the year round	38	75%
Limited operation	13	25%
Sum	*51*	

Table 16: Availability throughout the year

5.4.2 Throughout the day

63% of cases in this study offer round-the-clock service, while 37% operate within limited opening hours that can be different depending on the day of the week (Table 17). Wideness of the opening hours seems to be affected by the level of technology of bike-sharing stations. Those systems that require staff to deliver bicycles, i.e. those provided with lower technology, stop operating at night. In contrast, automatic systems enable non-stop service (Castro & Emberger 2010).

Availability throughout the day		
	N	%
Round-the-clock	32	63%
Limited operation	19	37%
Sum	*51*	

Table 17: Availability throughout the day

5.5 Rent

Rents start when users pick up a bicycle and end when they notify its return. It means that one rent could comprise more than one trip, if users decide to stop in intermediate destinations. During the rent customers have to respect usage rules. If they do not do it, operators can fine them.

5.5.1 Identification

Just before taking a bicycle, users of third generation systems have to identify themselves in a bike-sharing station if they want to have access to the service. Depending on the technology available, there are several means of identification. 51% of the systems studied require a smart card to identify users. Smart cards can be bank cards, PT cards and even specific bike-sharing cards. Customers of 27% of BSSs need a mobile phone to rent a bicycle. Smart cards and phone calls are asked in automatic systems. In contrast, in manual systems operated by staff, 20% of the BSSs studied, identity cards (ID) can be asked to check the identity of users. A residual 2% of BSSs require a code given when subscribing to identify customers (Table 18).

Additionally to the smart card or a phone call, some BSSs can also ask customers to provide a code for the identification. In case of card-oriented systems the code is a personal password chosen by the customer in the moment of the registration and it has to be typed in the bike-sharing terminal. Phone oriented schemes communicate customer a one-use code that unlock the mechanism and release the bicycle.

Way of identification		
	N	%
Smart Card	26	51%
Phone	14	27%
ID	10	20%
Code	1	2%
Sum	*51*	

Table 18: Way of identification of bike-sharing users

5.5.2 Return of the bike

In card-oriented systems, rents do not finish until the bike is correctly introduced in a docking device of a station. After that, a light signal can confirm the successful return of the bicycle. Phone-oriented schemes can need a phone call not only to unlock but also to return the bike to inform the operator about the exact location of the bicycle. If users want to do intermediate stops without returning the bicycle, it is normally possible. Bicycles of card-oriented systems can be equipped with an additional locking mechanism and a key while users of phone-oriented systems just need to close the normal bicycle lock. Electronic bicycle locks of Call a Bike have an option on the display to lock the bike without finishing the rent.

5.5.3 Operating area

Those BSSs that have no fixed stations, e.g. Call a bike, or second generation systems, e.g. City Bikes of Copenhagen, do not allow the ride of bike-sharing bicycles outside of a delimited area smaller than the municipality. However, customers of most of systems can ride bicycles in the whole city, even when stations do not cover the whole municipal area (IDAE 2007).

In contrast, the operating area of some BSSs, 14% of case studies, is larger than the city (Table 19). In other words, the scheme can cover several cities. In these cases users can take a bicycle in one city and return it in a different one. The limits of the operating area can exceed municipal limits because of overexpansion of the BSS, as Bicing planed to do in Barcelona expanding to other 17 municipalities (20 minutos 2010) or because of collaboration between several towns, like nextbike in Burgenland (Castro & Emberger 2009).

Operating area		
	N	%
Comprising only one city	43	86%
Comprising more than one city	7	14%
Sum	*50*	
NA	1	

Table 19: Operating area

5.5.4 Limit of rental period

Rental periods can be limited by operators to encourage short rents and to avoid vandalism. 32% of case studies fix this limit to 24 hours; while 34% ask for shorter rents and 10% allow longer rents. If a BSS has no limit of rental time, 24% of the cases studied, excessive rental time can be dissuaded by mean of exponential tariff models that make such long rents uneconomical for users (Table 20).

Limit of use		
	N	%
<24 hours	17	34%
24 hours	16	32%
>24 hours	5	10%
No limit	12	24%
Sum	*50*	
NA	1	

Table 20: Limit of use

5.5.5 Fine

Bike-sharing operators can fine customers if the rental time is exceeded or the bicycle is damaged or stolen. 46% of the BSSs analyzed in this dissertation apply economic sanctions. The most usual amount of money is €150 (24% of case studies). However, 54% of BSSs do not impose economic fines. These BSSs may punish users by mean of the cancellation of memberships (Table 21).

Fine		
	N	%
No fine	22	54%
<€150	5	12%
€150	10	24%
>€150	4	10%
Sum	*41*	
NA	10	

Table 21: Fine

5.6 Payment of service

The relationship between BSSs and users do not finish when the rented bicycle is returned. After the return, usage fees are charged. There are many different fees and ways of payment available in Europe.

5.6.1 Usage fee

There is a very wide diversity of tariff models in the bike-sharing market. Even BSSs of the same provider can ask for a different usage fee depending on the city where the system is implemented. However, a strategy seems to be gradually adopted by most operators: the offering of rental periods free of charge. Only 24% of BSSs analyzed[20] charge the service from the first minute of the rent. If free rental time is available, what happens in 76% of the cases, the most common period without charge is 30 minutes (35% of the case studies). Unlimited free rents are also quite common in European BSSs since they represent 27% of the cases (Table 22). A transferability study carried out within the OBIS project reveals that the city-size has influence on the tariff model (Castro & Emberger 2010).

After the free rental period, usage fees can be charged per minute, per 30 minutes or per hour. Only 10% of schemes analyzed, charge usage fees per minute, while 20% charge per 30 minutes, 18% per hour and 20% a combination of both. The amount of money to be charged depends on the provider and the city. Call a bike systems, which comprise most of case studies that charge per minute, ask for 8 cents per minute (DB Bahn 2009). BSSs with initial free rental period charge up to €1 for the following 30 minutes or one hour. The tariff usually increases as the rental time rises to make inconvenient long rents and consequently to encourage rotation of bicycles between different customers. Nevertheless, there are also BSSs that offer flat rates to give the opportunity to rent bicycles for longer periods of time. There are three kinds of systems offering flat rates: 1) BSSs that charge the whole rent with a fix amount of money, 2) BSSs with unlimited free rental and 3) BSSs with an initial rising rate that becomes flat. An example of this third category is nextbike Burgenland in Austria, where the rent is charged with €1 per hour till

[20] Bike-sharing usage fees differ depending on the length of validity of subscriptions. The figures represented in this section correspond exclusively to usage fees of long-term subscriptions, because they are the most usual ones.

the fifth one. Then the fee becomes constant and from the 5th hour till the 24th hour the rent costs €5. In total, 67% present any flat rate in its tariff model (Table 22).

Rental time free of charge			Usage fee period			Flat rate		
	N	%		N	%	Flat rate	33	67%
No free rental	12	24%	€/minute	5	10%	No flat rate	16	33%
30 minutes	18	35%	€/30minutes	10	20%	*Sum*	*49*	
1 hour	4	8%	€/hour	9	18%	NA	2	4%
Miscellaneous	3	6%	€/30minutes&€/hour	10	20%			
Unlimited	14	27%	€/rent	3	6%			
Sum	*51*		Unlimited free	14	27%			
			Sum	*51*				

Table 22: Rental time free of charge, usage fee period and flat rate availability

5.6.2 Way to pay

BSSs can offer different ways to pay the service. The most common means are: bank transfer, bank card (credit or debit card), specific bike-sharing pre-paid card and cash. Cash is normally allowed only in low-tech systems and they represent 18% of schemes analyzed in this dissertation. 22% of the systems enable the payment through pre-paid cards, while bank transfers and bank cards are admitted in 43% and 63% of cases (Table 23). A BSS can allow several different means of payments to make the system more accessible for customers.

Available payment options		
	N	%
Bank transfer	22	43%
Bank card	32	63%
Pre-paid card	11	22%
Cash	9	18%

Table 23: Available payment options (systems can allow more than one way of payment)

5.7 Management

Sections from 5.2 to 5.6 have described the variety of BSSs from the point of view of customers. In this section bike-sharing variety is showed from the organisational point of view. Several authors have contributed to make classifications of existing organisation forms of bike-sharing (Beroud 2007; NYC Department of City Planning 2009; DeMaio 2009b; SpiCycles 2008; Petersen 2009) and these publications have inspired this doctoral thesis to suggest the following hierarchy of three different roles involved in the management of bike-sharing: investor, operator and provider.

5.7.1 Investor

The investor is the entity that funds a BSS. As section 6.7 will show, usage and subscription fees coming from customers are not enough to maintain economically BSSs. Therefore, BSSs usually need external funding. The main revenues of schemes are public subsidies, citywide billboard contracts and advertising showed in bike-sharing infrastructure such as bicycles or stations.

Stakeholders that act as investors in BSSs are: private companies and public authorities. 57% of the BSSs analyzed are funded by private companies, while 43% of them are funded by public authorities. Private funding can come from outdoor advertising companies (e.g. JCDecaux or Clear Channel), transport companies (e.g. Veolia) and other particular enterprises (e.g. C'entro in Bici or nextbike).

Although in some cases the initiative of implementing a BSS in a city is born from public authorities, it does not necessary mean that they support economically the system. In these cases they cannot be considered as investors. Public authorities that fund BSSs comprise national, regional as well as municipal governments, energy agencies such as the Spanish Agency of Diversification of Energy (IDAE) and Climate Alliance of Lower Austria, railways operators such as Deutsche Bahn in Germany, municipal public transport operators such as ATAC in Rome or departments of city councils are nowadays funding the introduction and the maintenance of BSSs (Table 24).

Investor		
	N	%
Association	0	0%
Public authorities	22	43%
Private companies	29	57%
Sum	*51*	

Table 24: Kind of stakeholders in the role of investor

5.7.2 Operator

Investors provide funding to support economically implementation costs or/and running costs of BSSs. Nevertheless, some of them, mainly public authorities, are not interested or are not able to manage operational issues. In these cases investors delegate the responsibility of the project to operators. Although operators can subcontract some services, they are in charge of most of strategic and running tasks such as election the most suitable bike-sharing model, construction of bike-sharing infrastructure, registration, pricing, charge of services, redistribution, repair of bicycles, and evaluation of BSSs.

18% of bike-sharing operators are public authorities. In contrast, 74% of operators are private companies. Apart from public authorities and private companies, associations also play the operational role. Inside the category of associations we can find stakeholders as NGOs, environmental organisations, residents' associations and similar non-profit societies. 8% of operators of the case studies are associations (Table 25).

Operator		
	N	%
Association	4	8%
Public authorities	9	18%
Private companies	37	74%
Sum	*50*	
NA	1	

Table 25: Kind of stakeholders in the role of operator

5.7.3 Provider

While operators plan and execute the strategy of BSSs, providers supply the infrastructure that enables this strategy, i.e. stations and bicycles. Operators choose the provider regarding the system that they can offer and the suitability of this system with the existing city.

Stakeholders can play one of the roles, investor, operator, provider, or a combination of some of them. Leihradl-nextbike, a BSS in Lower Austria, is a good example that illustrates the differences between these three roles. The government of Lower Austria supports economically the BSS. After a call for tenders, an environmental association, “die Umweltberatung”, is in charge of the project and therefore it is the operator. Nextbike was the provider chosen to introduce its bike-sharing model (Castro, Lackner, et al. 2010)

Other relevant example is Bicing in Barcelona. The city council, or more accurately, the department of municipal services, assumes the role of investor and operator. The company Clear Channel plays the role of provider for supplying its system and the municipality pays for the service.

A different case is Paris, where the company JCDecaux play the role of investor, operator and provider after a call for tenders and an outdoor advertisement contract with the city council. Therefore, the company assumed all risks of implementing and running the BSS (Sassen 2009).

In practice most of providers, 90% of cases studied, are private companies. They previously spent money creating the system and need to recover the investment introducing their models in cities. Public authorities and associations represent 8% and 2% respectively (Table 26).

Nowadays, many BSSs are created by the same provider. These schemes can look apparently different and have different commercial names, but they present some common characteristics and stay “under the umbrella of the same franchise”. The group of BSSs implemented by only one provider conforms a unique product with a specific name and image. For instance, Smart Bikes is the general name of the model provided by Clear Channel and Cyclocity is the denomination of BSSs of JCDecaux, which are the two biggest provider companies (Sassen 2009). Their BSSs have the largest representation in the list of case studies, 14% (Table 27).

Provider		
	N	%
Association	1	2%
Public authorities	4	8%
Private companies	45	90%
Sum	50	
NA	1	

Table 26: Kind of stakeholders in the role of provider

Provider companies		
	N	%
Veolia	6	12%
Call a bike	5	10%
Bicincittà	5	10%
Clear Channel	7	14%
JCDecaux	7	14%
C'entro in bici	4	8%
Vipre	1	2%
Nextbike	3	6%
CEMUSA	1	2%
EFFIA	2	4%
Other	10	20%
Sum	*51*	

Table 27: Companies playing the role of providers

5.8 Summary

A wide diversity of BSSs is currently operating all around Europe and systems can be totally different from one city to another. The elements that make up and explain the way of working of bike-sharing systems can be grouped in six categories:

- how to start using the system, i.e. the registration (Figure 21);
- how to find the system, i.e. the physical infrastructure (Figure 22);
- when to access to the service, i.e. the availability (Figure 23);
- how to rent a bicycle, i.e. the rental process (Figure 24);
- how to pay the service, i.e. the payment (Figure 25);
- and from an organisational point of view, how to make the system operative, i.e. the management (Figure 26).

Going through these six aspects the following figures below summarize the different variables that are currently available in the bike-sharing market. The diversity of models is shown by mean of qualitative and quantitative variables. All existing qualitative variables are listed, while only the minimum and maximum values of quantitative variables are shown. The most common cases of both qualitative and quantitative variables, i.e. the statistical mode, are highlighted in bold.

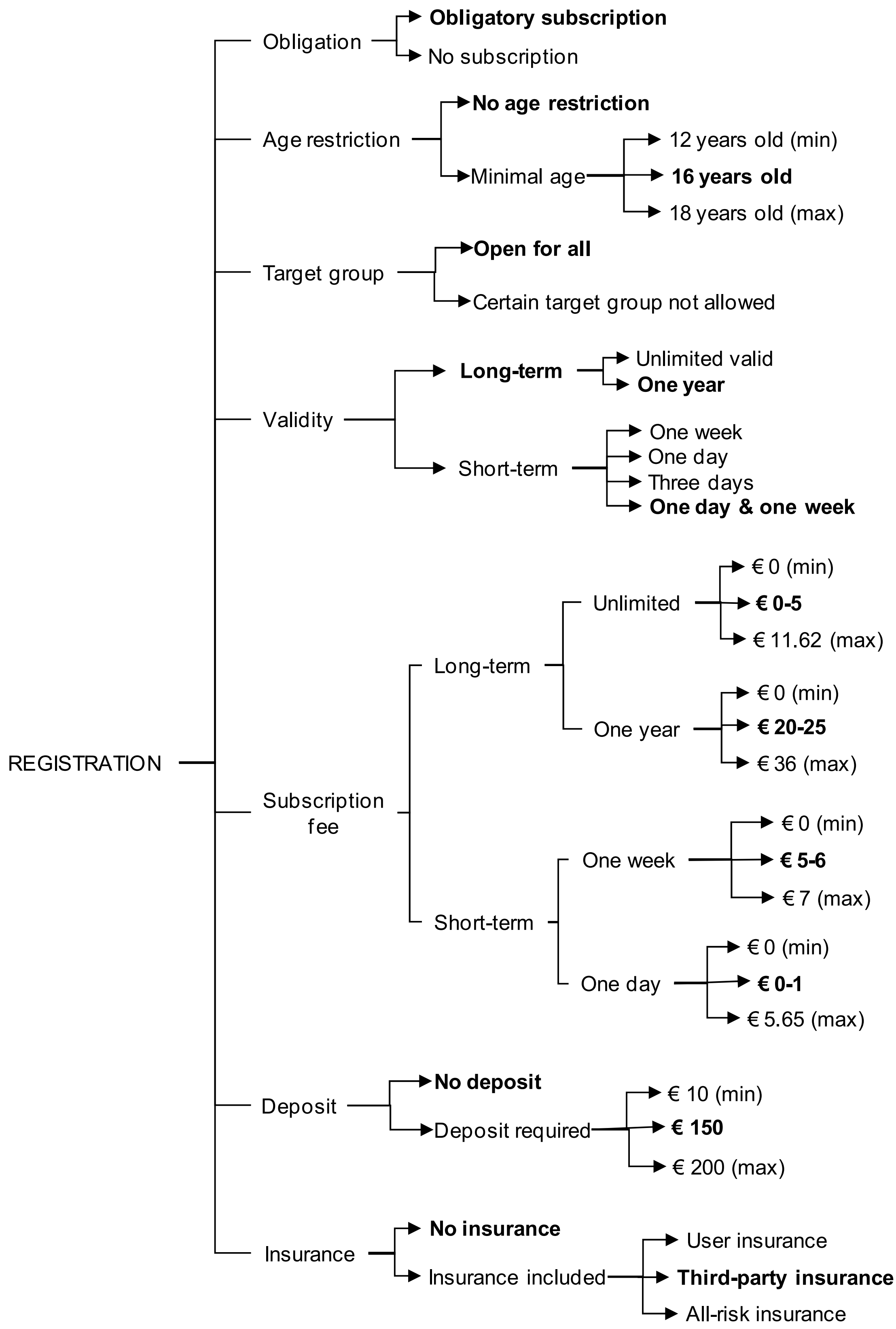


Figure 21: Variants concerning registration (bold means most frequent case)

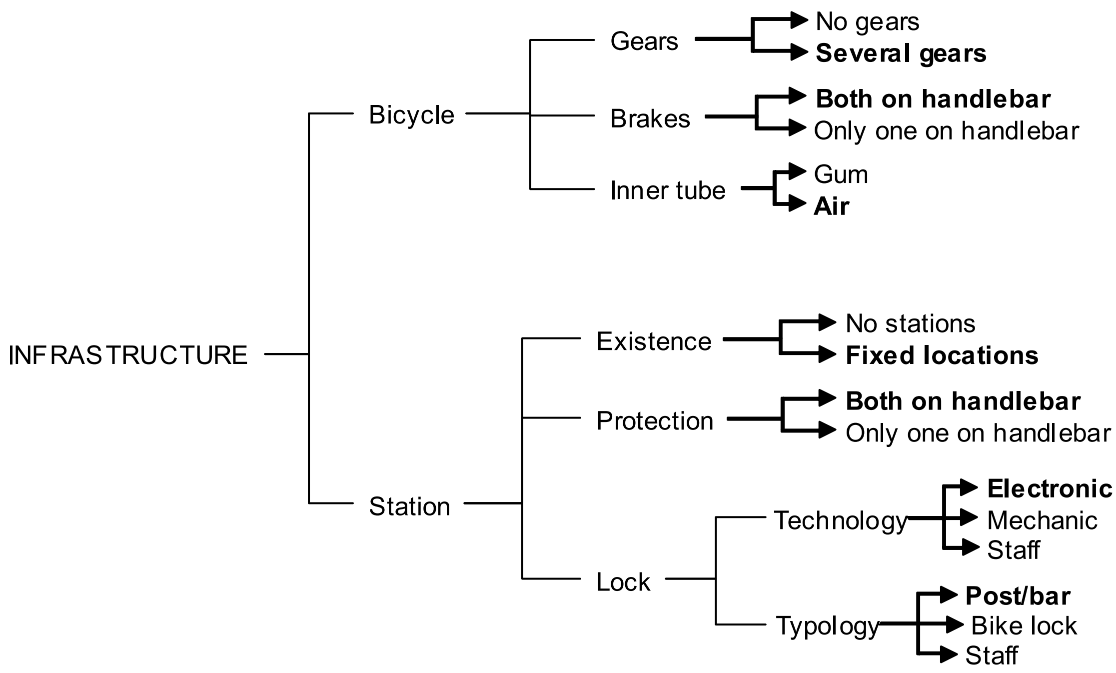


Figure 22: Variants concerning infrastructure (bold means most frequent case)

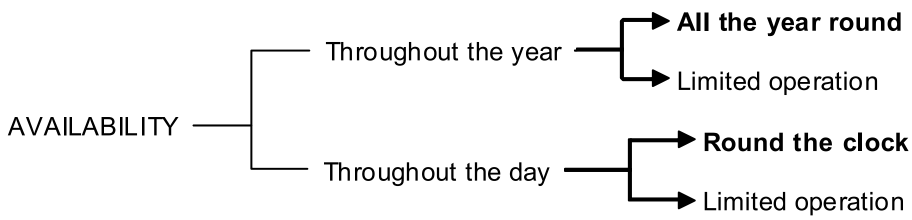


Figure 23: Variants concerning availability of service (bold means most frequent case)

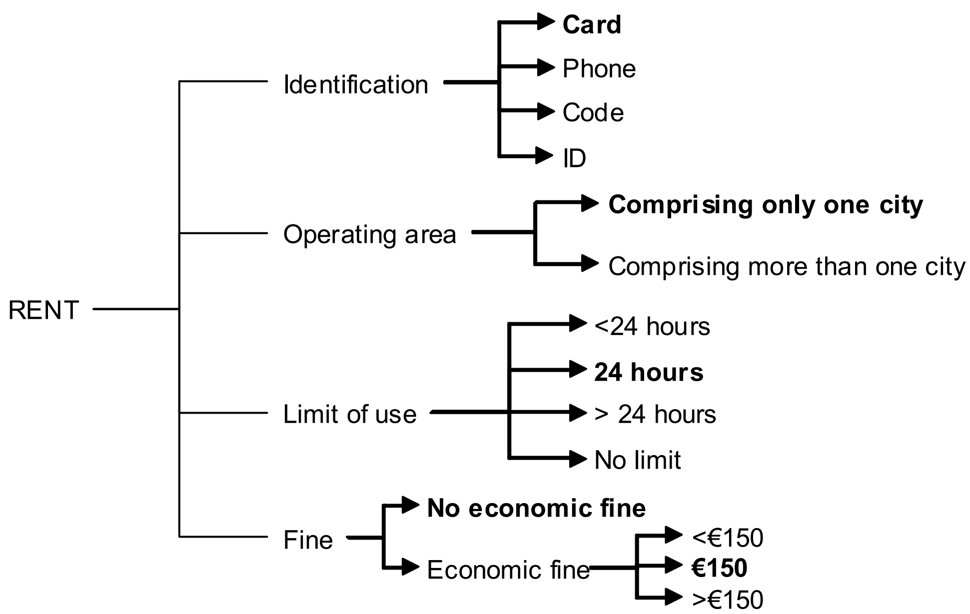


Figure 24: Variants concerning rental process (bold means most frequent case)

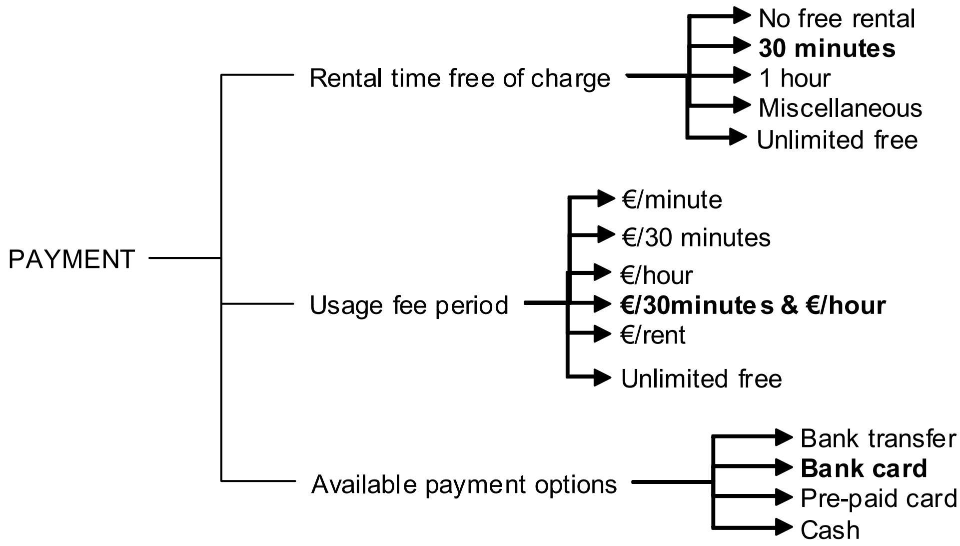


Figure 25: Variants concerning payment (bold means most frequent case)

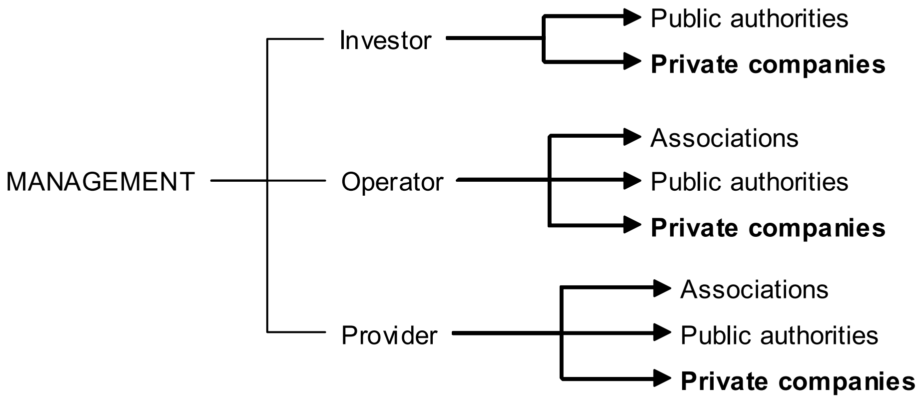


Figure 26: Variants concerning management (bold means most frequent case)

6 SUCCESS OF BIKE-SHARING

6.1 Introduction

The aim of section 6 is to analyze the success of BSSs in terms of sustainability. Success means the achievement of a goal and this dissertation has grouped the likely goals of bike-sharing into five categories: mobility, environment, health, traffic safety and economy. Additionally, success requires durability. Therefore, economic viability is needed to preserve the success.

This section is divided in six subsections (6.2, 6.3, 6.4, 6.5, 6.6 and 6.7) that correspond with the five categories of success plus the requirement of economic viability. The approach and methodology used in this section have been explained in detail in section 3.2.3.

6.2 Mobility

6.2.1 Introduction

Limited space availability in city centres and over-use of cars have caused traffic congestions all around Europe. According to the European "Green Paper" (European Commission 2007), "every year nearly 100 billion Euros, or 1% of the EU GDP, are lost to the European economy as a result of traffic congestions". To avoid these negative impacts derived from transport, municipalities have developed new mobility concepts that try to reduce car use and promote softer modes such as public transport, cycling and walking.

Section 6.2.2 will show the role that bike-sharing plays in changing mobility behaviour. The following three sections will analyze the impact and efficiency of bike-sharing in the achievement of three likely goals in terms of mobility:

- Reduction of car traffic (section 6.2.3)
- Increase of attractiveness of public transport (section 6.2.4)
- Increase of cycling (section 6.2.5)[21].

6.2.2 General impacts on mobility

The irruption of bike-sharing as a new alternative of urban transport has motivated changes in mobility behaviour. For instance, in Paris 89% of bike-sharing users state that "it is easier to move inside the city thanks to Vélib'", 54% travel more often as a consequence of the

[21] Although traffic jams emit air pollutants that generates environmental, health and economic problems, this section focuses on a primary impact of car congestions: traffic flow. It means, in terms of this dissertation, cities that have as a goal to improve mobility by mean of a BSS have as a priority to speed up traffic flow and consequently to reduce duration of trips.

BSS and 18% undertake trips that they could not do before the introduction of the BSS (NYC Department of City Planning 2009; Vélib' 2009a).

Those bike-sharing users that travelled before the implementation of a BSS have substituted a previous transport mode by bike-sharing bicycles. Figure 27 shows that on average 15% of bike-sharing users state that they currently rent a bike instead of travelling by car, 33% declare that they used public transport before the launch of the bike-sharing system, 8% covered their trip previously with their own bike and 22% by walking.

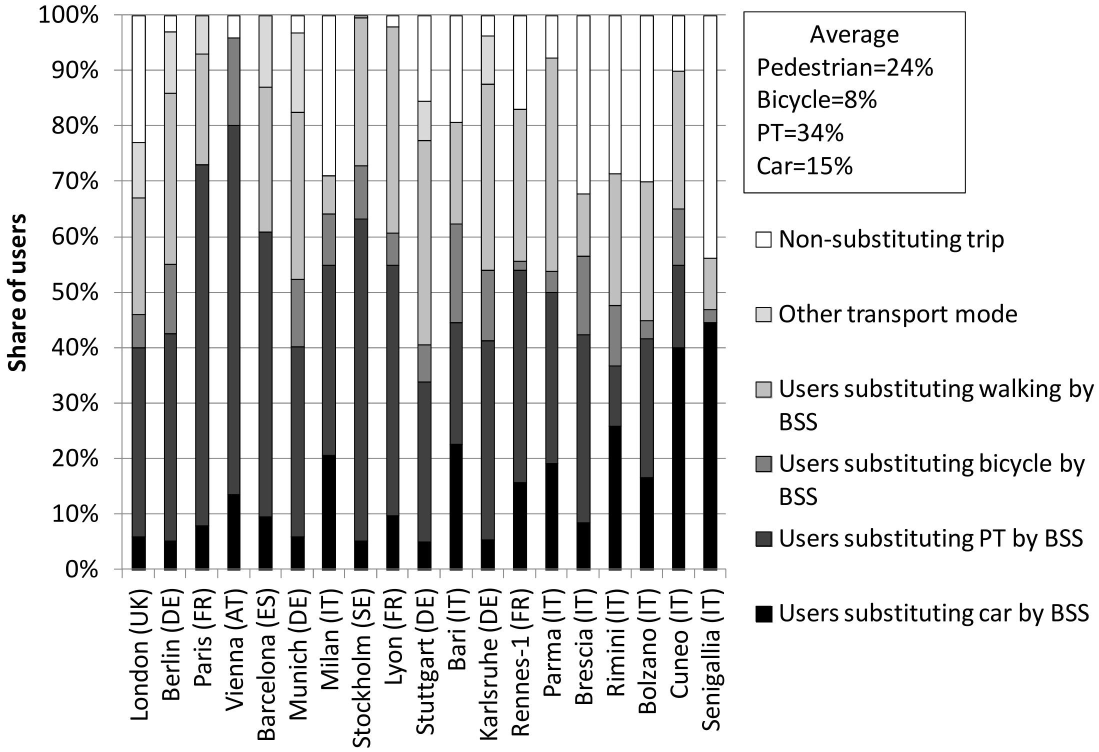


Figure 27: Former way of transport used by bike-sharing members before using bike-sharing. Data source: Annex 10.1

If a BSS is implemented to support daily mobility, a likely indicator to test the effectiveness of the BSS is the share of customers who use it for trips to work and education. As Figure 28 shows, the contribution of bike-sharing in terms of daily mobility is significant in the cases studied. On average, the destinations of 46% of trips of European BSSs are work places and education centres. As a consequence of the advantages of bike-sharing for commuters, not only residents of the cities where a BSS is implemented subscribe to the service, but also people from near towns. For example, in Paris 33% of annual members of Vélib' lives in the suburbs of the agglomeration (NYC Department of City Planning 2009).

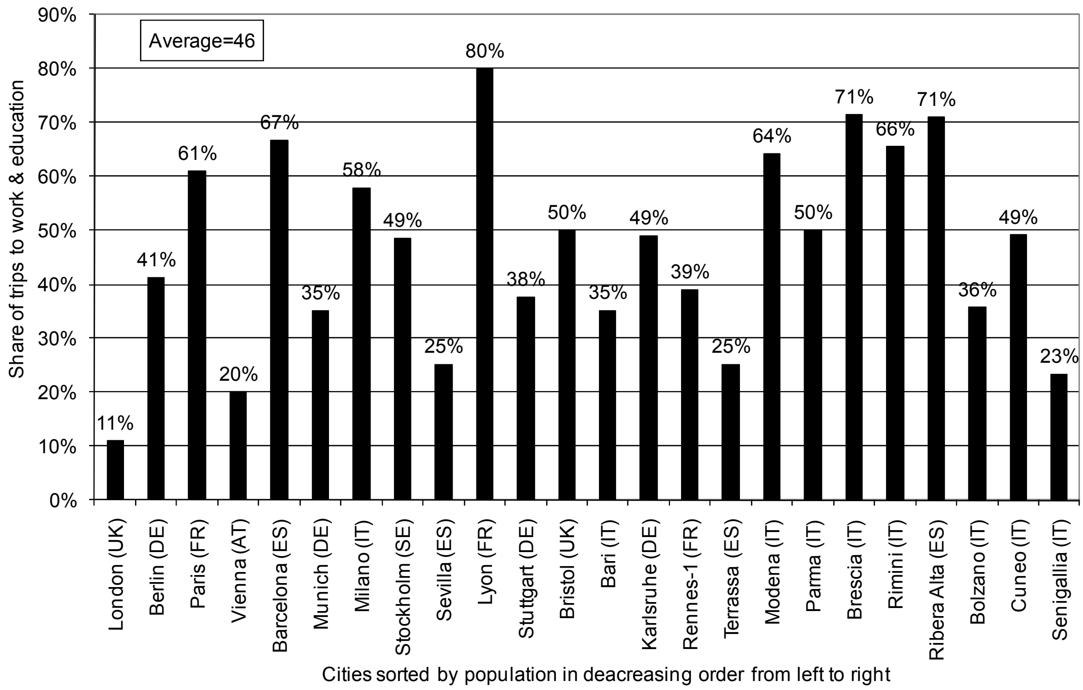


Figure 28: Share of bike-sharing trips that have as purpose working and education. Data source: Annex 10.1

Citizens who enjoy night leisure have experienced a relevant change of travel behaviour as a result of the operation of bike-sharing services. In cities where public transport is closed during the night and bike-sharing services are offered round-the-clock, bike-sharing bicycles have been prominently ridden during the inactivity of public transport as a convenient alternative mobility mode. For instance, in Paris 25% of bike-sharing rents takes place between 9 p.m. and 3 p.m. (NYC Department of City Planning 2009). Figure 29 shows that in Vienna, apart from the classical rush hours of commuters on working days in the morning and in the afternoon, BSSs can register evident peaks of demand during late night hours at weekends.

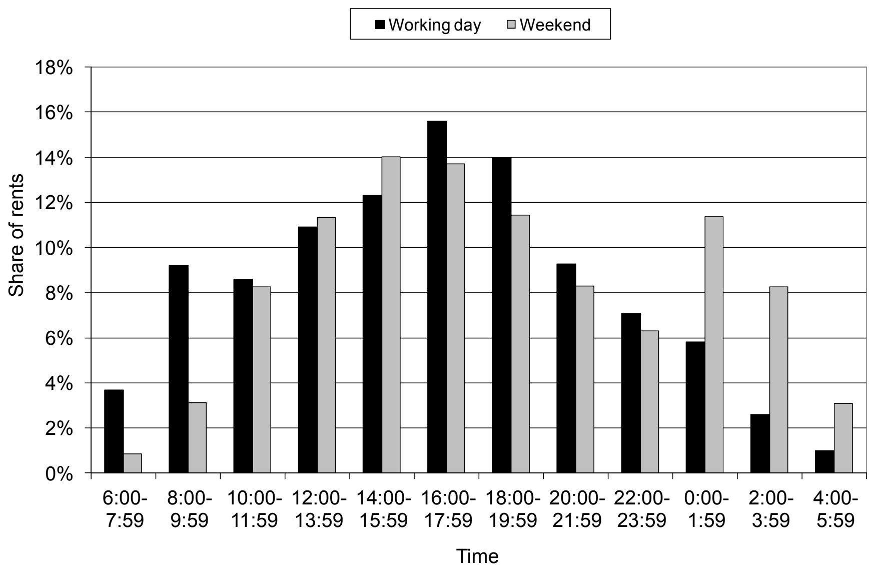
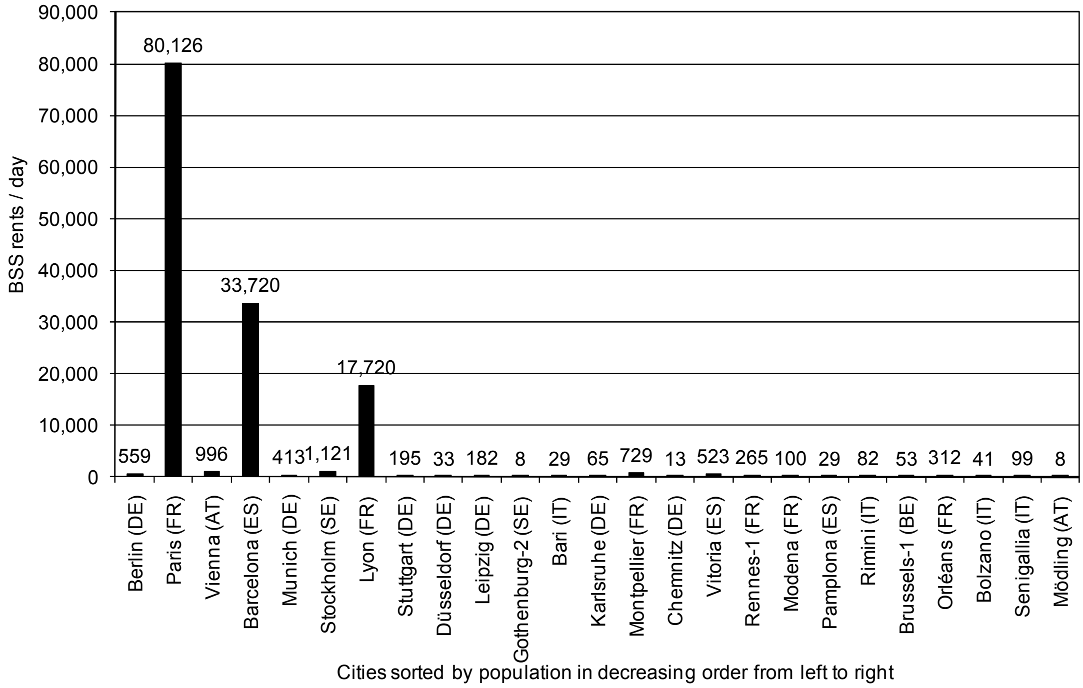


Figure 29: Share of rents throughout the day in Citybike Wien, Vienna. Data source: (Castro 2009)

The average number of bike-sharing trips per day can be calculated by dividing annual rents of the case studies and their annual days of operation. Figure 30 shows the result.



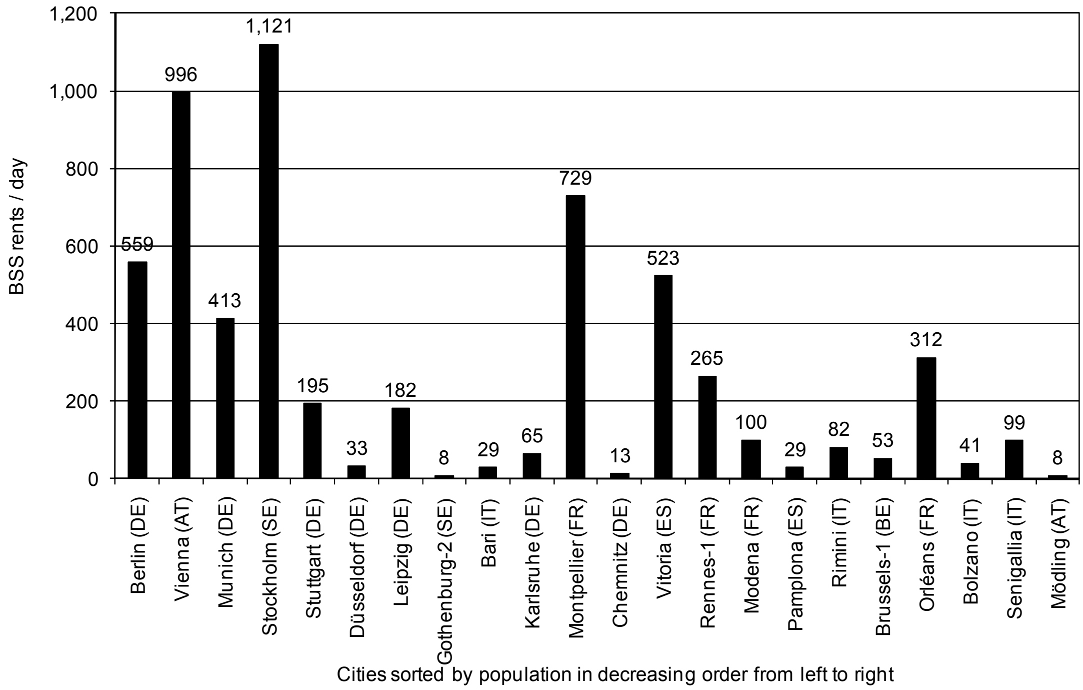


Figure 30: Daily bike-sharing rents in 2008 in all case studies with available data (above) and without Paris, Barcelona and Lyon (below). Data source: Annex 10.1

How relevant is the influence of these bike-sharing trips in the whole urban mobility of the cities? The bike-sharing modal share, i.e. the share of bike-sharing trips regarding the total municipal trips, is an indicator that helps to answer this question (Figure 31). In only three cities the trips covered by bike-sharing bicycles represent more than 0.4% of the total municipal trips.

In Barcelona 0.43% of trips are covered by bike-sharing bicycles, in Paris this share reaches 0.76% and in Lyon Vélo'v influences the modal split with 0.92% of trips. The rest of the systems studied are still very far from these results and their shares do not represent in any case more than 0.15% of municipal daily trips. As a result of these figures, one could state that on average bike-sharing represents 0.11% of the daily trips of the cities where a BSS is implemented. The statistical median reaches 0.02%.

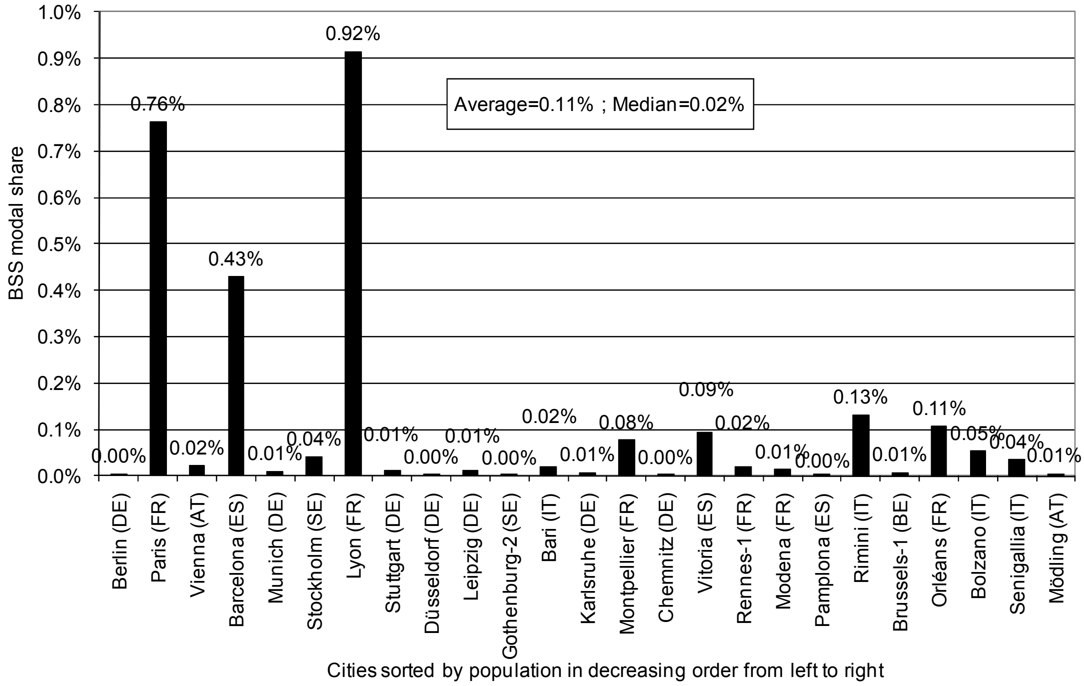


Figure 31: Bike-sharing modal share. Data source: Annex 10.1

6.2.3 Reduction of car traffic

Cars are the most abundant and less space efficient mobility mode (Dekoster & Schollaert 1999). Therefore, a reduction of the number of cars on streets is crucial to avoid traffic jams in cities. Bike-sharing has contributed to decrease car traffic in some European cities. In Paris, for instance, from 20% to 46% of users state that they drive less their cars since they became members of Vélib' (NYC Department of City Planning 2009; Vélib' 2009a) and one year after the launch of the BSS, a decrease of around 5% of car traffic was reported in the city. In Lyon 28% of bike-sharing users were less willing to use their own car in 2008 and this share increased up to 46% in 2009 (DeMaio 2009b). 20 months after the implementation of the bike-sharing system in Lyon car traffic decreased by 4% (Sassen 2009).

Nevertheless in none of these cases the reduction of car traffic can be exclusively attributed to bike-sharing but also to other affecting reasons. For example, in Paris a new Master Mobility Plan that gave priority to pedestrians, cyclists and public transport was implemented in 2001. The introduction of the BSS was just one of the several different actions carried out in the framework of this new mobility plan. This fact brings us to the main question of this section 6.2.3: how heavy is the real influence of bike-sharing on the reduction of car traffic in European cities? The success indicators to evaluate reducing car traffic are the two following:

- The reduction of car trips observed in the city normalised by the number of municipal car trips (indicator of impact)
- The reduction of car trips per bike-sharing bicycle installed (indicator of efficiency)

The process of calculation starts with the shift of car trips to bike-sharing produced by BSSs. Figure 32 shows the share of bike-sharing trips that come from cars in the cities studied. On average 15% of users of European BSSs are former car drivers and the median is 10%. In large-scale schemes such as the ones located in Barcelona, Lyon or Paris this share is even lower: below 10%. In contrast, from 20% to 45% of users of Italian schemes stated that before the launch of the scheme they used cars. As section 7.2.9 will clarify, elevated ratio of car trips shifted to bike-sharing is motivated by existing car modal share which is high in Italian cities compared with other cases studied.

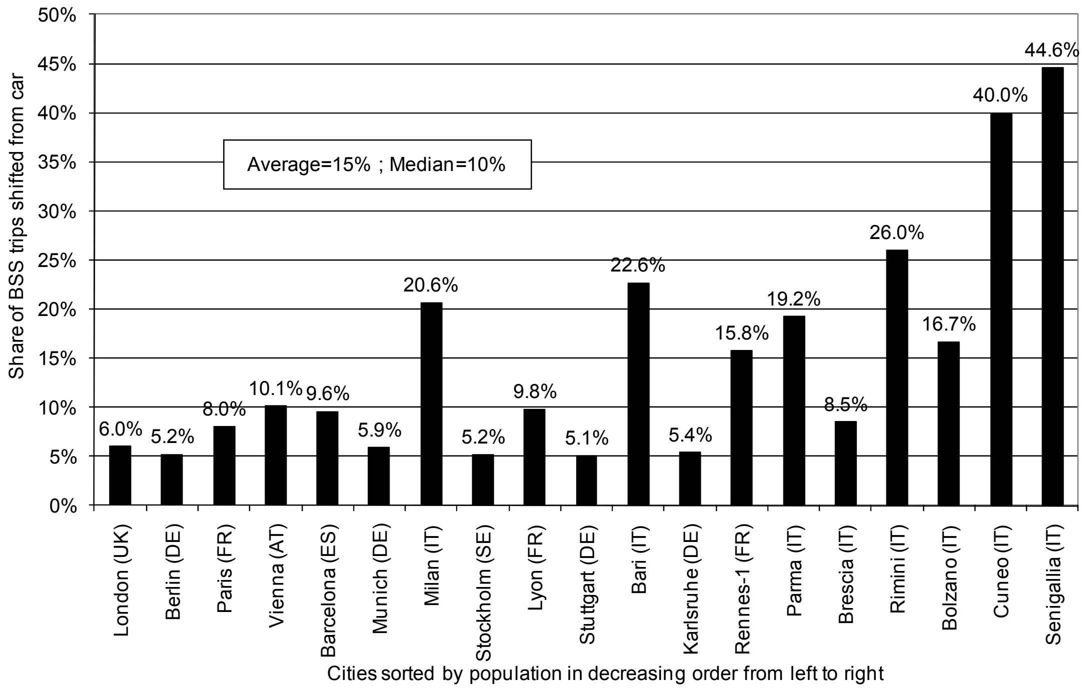
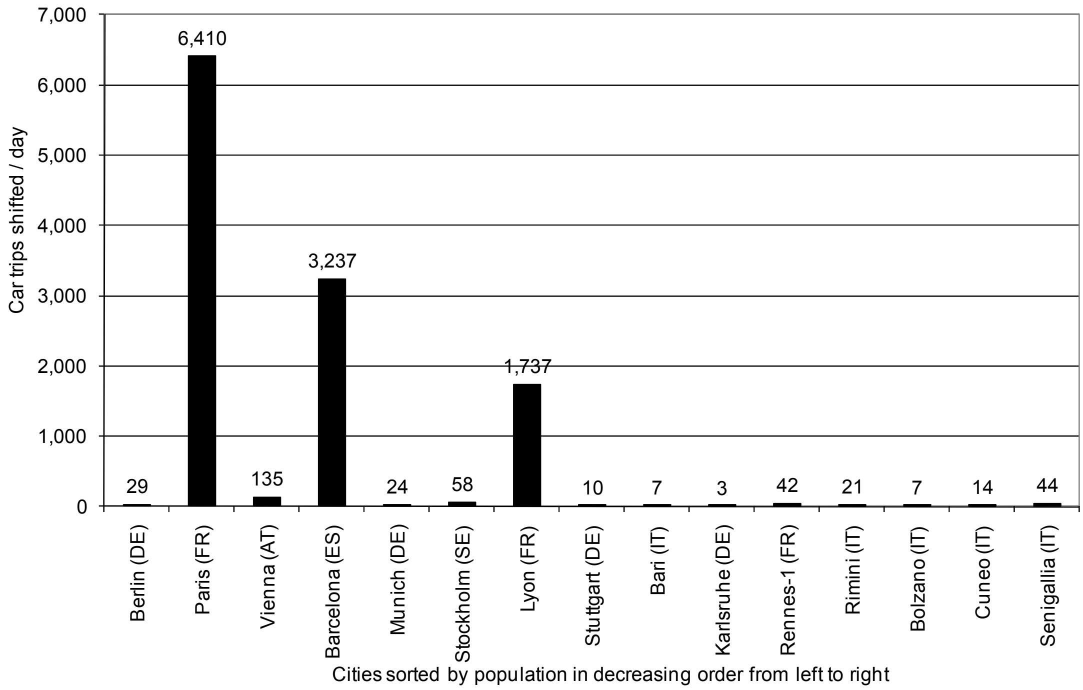


Figure 32: Share of bike-sharing trips shifted from car. Data source: Annex 10.1

By multiplying the share of bike-sharing trips that was covered previously by car of Figure 32 by the number of daily rents of the scheme of Figure 30, the number of daily car trips that are replaced thanks to bike-sharing can be obtained. As Figure 33 reveals, the schemes in Paris, Barcelona and Lyon shifted the greatest number of car trips in Europe. More than 6,000, more than 3,000 and nearly 2,000 daily car trips were replaced respectively in these cities.



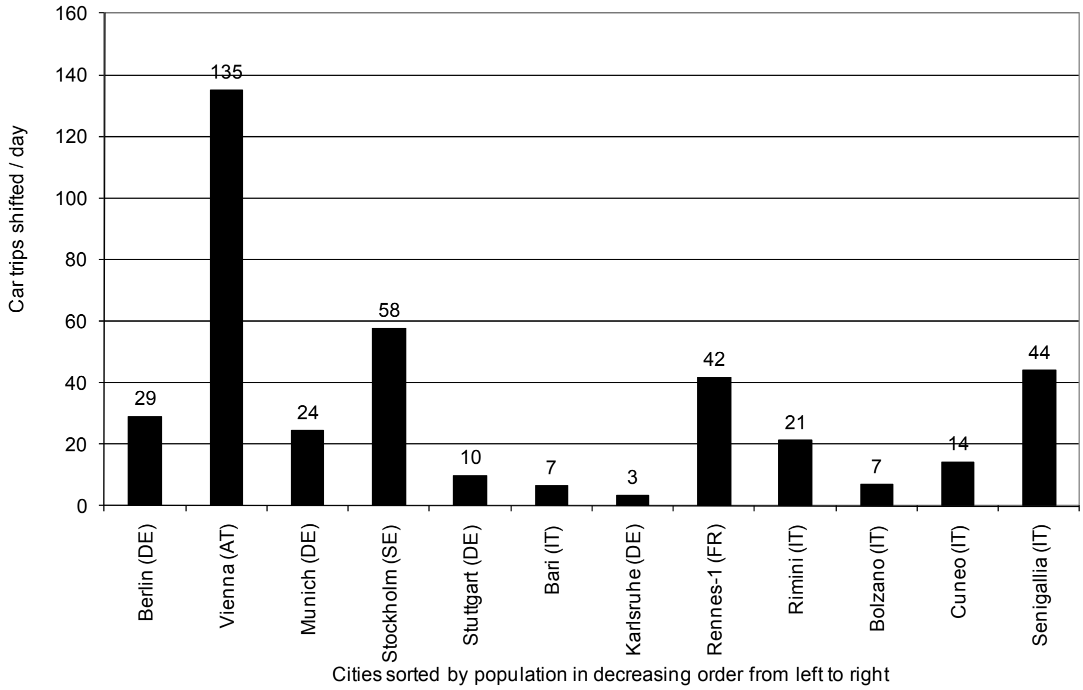


Figure 33: Number of municipal daily car trips shifted to bike-sharing in all case studies with available data (above) and without Paris, Barcelona and Lyon (below). Data source: Annex 10.1

There exist at least two factors that explain the apparent success in Paris, Barcelona and Lyon: 1) they are large cities and 2) large scale BSSs where installed there. As sections 7.2.1 and 7.2.6 will show, large cities and large scale BSSs are more likely to report more bike-sharing trips than small ones, therefore the absolute figures of the diagram need to be normalized by municipal car trips and by bike-sharing bicycles to know the real impact and efficiency of this success.

Figure 34 shows the impact of bike-sharing in the total car mobility, i.e. the normalized decrease of car traffic regarding the municipal daily trips. The figure was calculated by dividing the results of Figure 33 by the number of daily car trips of the municipality. From this approach Paris, Barcelona and Lyon are the most successful BSSs in Europe in terms of impact. They substitute from 0.15% to 0.18% of urban daily car trips. The impact of the rest of case studies is far below these numbers. In fact, although BSSs remove on average 0.04% of municipal car trips, 50% of BSSs do not shift more than 0.01% of car trips.

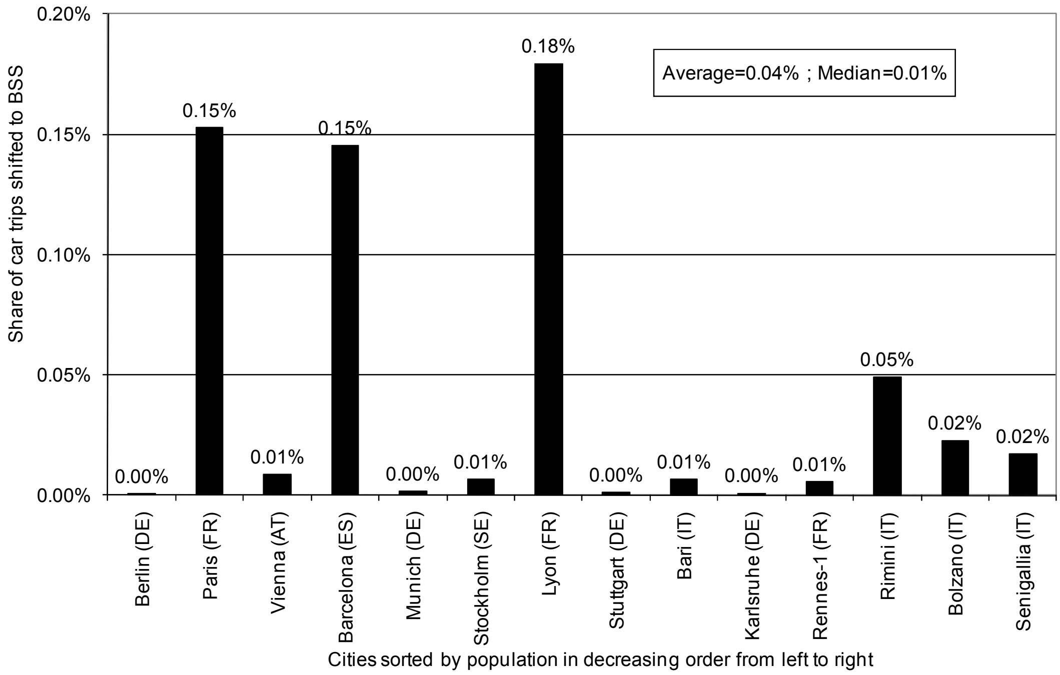


Figure 34: Share of municipal car trips shifted to bike-sharing. Data source: Annex 10.1

The success of bike-sharing decreasing car traffic can be also evaluated in terms of efficiency, it means, by normalizing shifted car trips with the number of available bike-sharing bicycles. As Figure 35 reveals, no large-scale BSS is the most efficient system decreasing car traffic, but an Italian small BSS located in Senigallia. The BSSs of Barcelona and Lyon are the second and third most efficient, while the BSS of Paris is the 5th position, after the BSS in Rimini. 0.65 daily car trips per bike-sharing bicycle are shifted in Senigallia, while 0.54, 0.46, 0.41 and 0.31 are shifted in Barcelona, Lyon, Rimini and Paris respectively. On average 0.2 daily cars per bicycle are replaced due to bike-sharing in European BSSs. In others words, BSSs remove 20 daily car trips per each 100 bike-sharing bicycles implemented in a city and at most 65 daily trips per 100 bicycles. The median is 0.2 daily rents per bicycle.

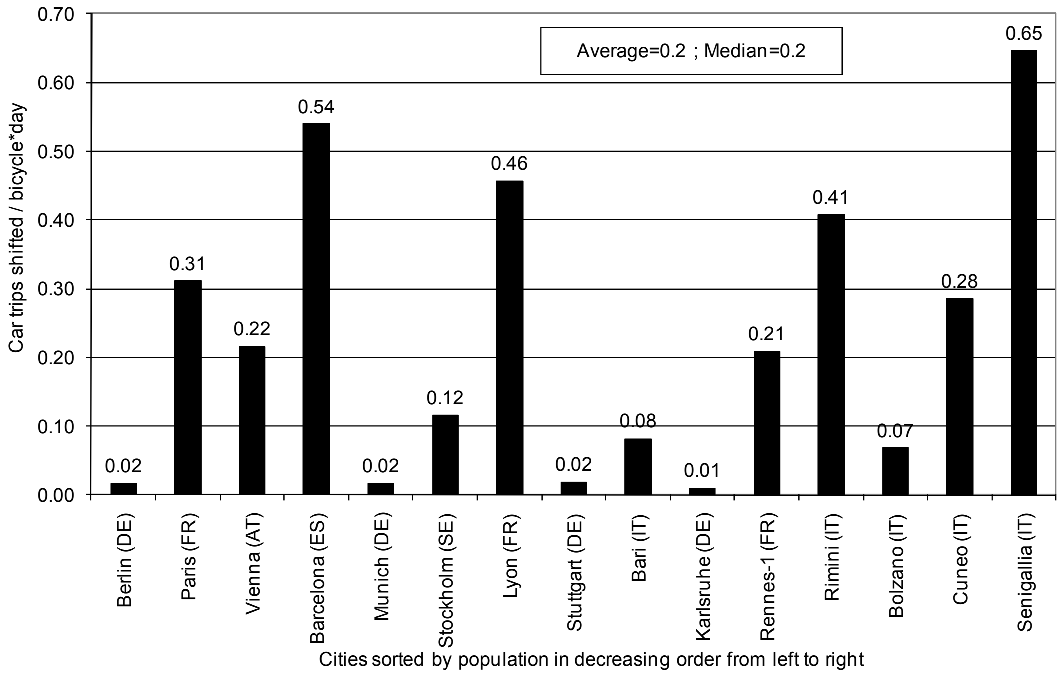


Figure 35: Daily car trips shifted to bike-sharing per bicycle. Data source: Annex 10.1

6.2.4 Increase of public transport attractiveness

BSSs can improve mobility by replacing car trips with bike-sharing trips, but also by convincing people to travel by public transport. Two likely ways to increase public transport attractiveness are the following:

- Reducing congestion in PT vehicles
- Increasing intermodality as a faster way to cover the “last mile” of the trip.

Public transport congestion in rush hours is a big concern nowadays. Cities like New York have even planned to gain space in carriages by removing seats (NYC Department of City Planning 2009). Passengers who replace PT trips with bike-sharing trips may leave free space in vehicles and this might increase the comfort of existing passengers and enable the access of new ones.

The indicator that shows the success in reducing congestion in public transport is the number of PT trips shifted to bike-sharing. This indicator has to be normalized by the number of public transport trips and the number of bike-sharing bicycles to obtain the impact and the efficiency respectively. Figure 36 represents the share of bike-sharing trips that were previously made by public transport. As we can see the result has been very different depending on the city and the share fluctuates from circa 0% to almost 80%. The average value is 35%.

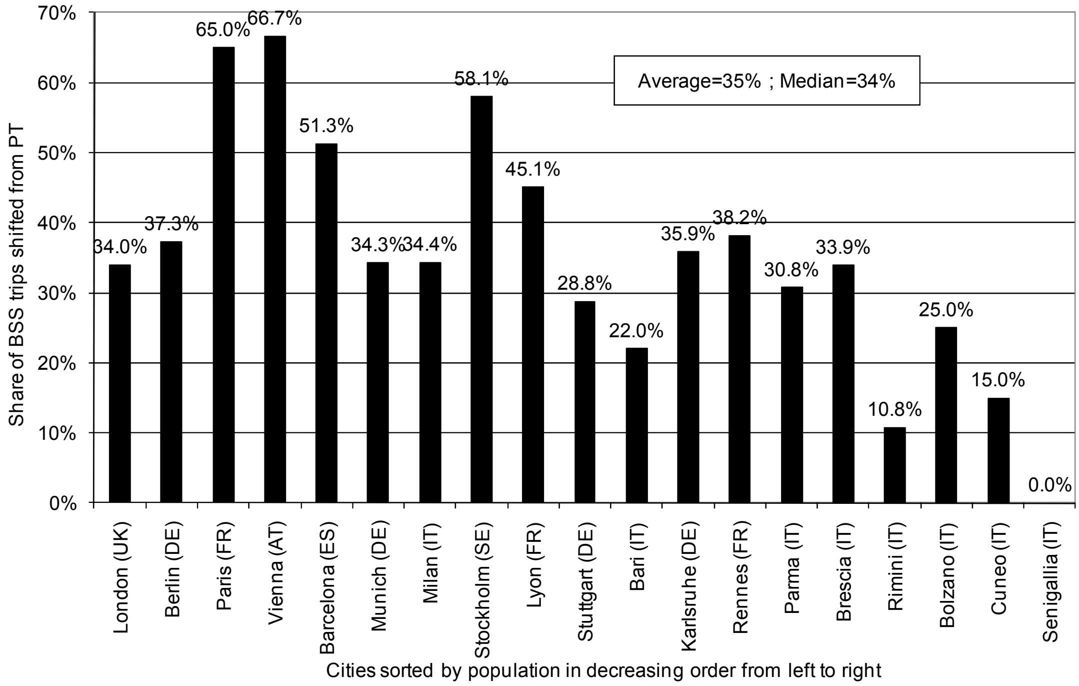
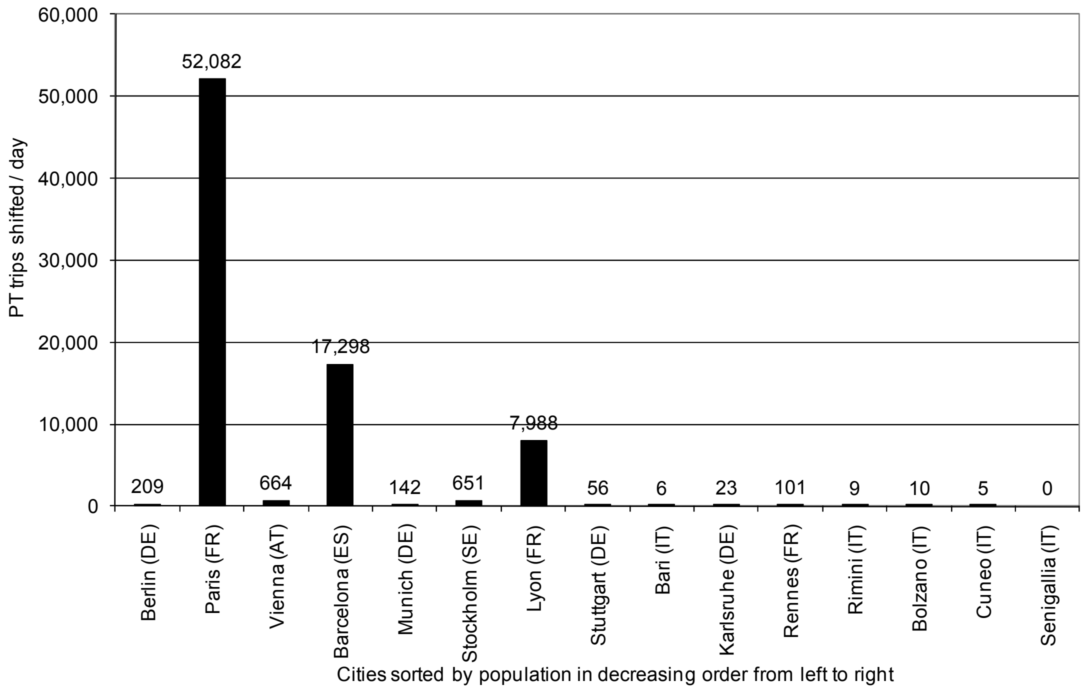


Figure 36: Share of bike-sharing trips shifted from PT. Data source: Annex 10.1

Figure 37 shows the number of PT trips that were removed as a result of the introduction of bike-sharing. It has been calculated by multiplying the share of bike-sharing trips that are former PT trips (Figure 36) by the number daily rents of the scheme (Figure 30).



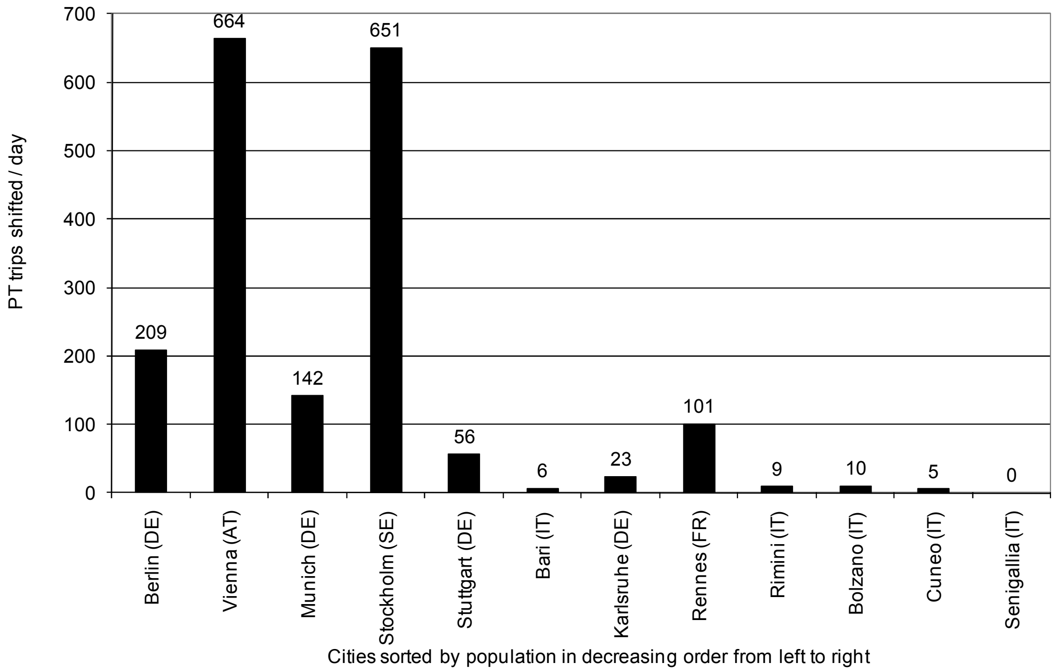


Figure 37: Number of municipal public transport trips shifted to bike-sharing in all case studies with available data (above) and without Paris, Barcelona and Lyon (below). Data source: Annex 10.1

In a following calculation step, the values of Figure 37 have been divided by the number of total daily PT trips of the cities. The result is the share of municipal PT trips shifted regarding the whole PT mobility (Figure 38). On average 0.5% of bike-sharing trips come from public transport, but the median is 0.1% because apart from Paris, Barcelona and Lyon, no city shifted more than 0.5% of PT trips to bike-sharing. In Lyon 2.8% of daily PT trips were replaced by bike-sharing trips, in Paris 2.5% and in Barcelona were 0.5%.

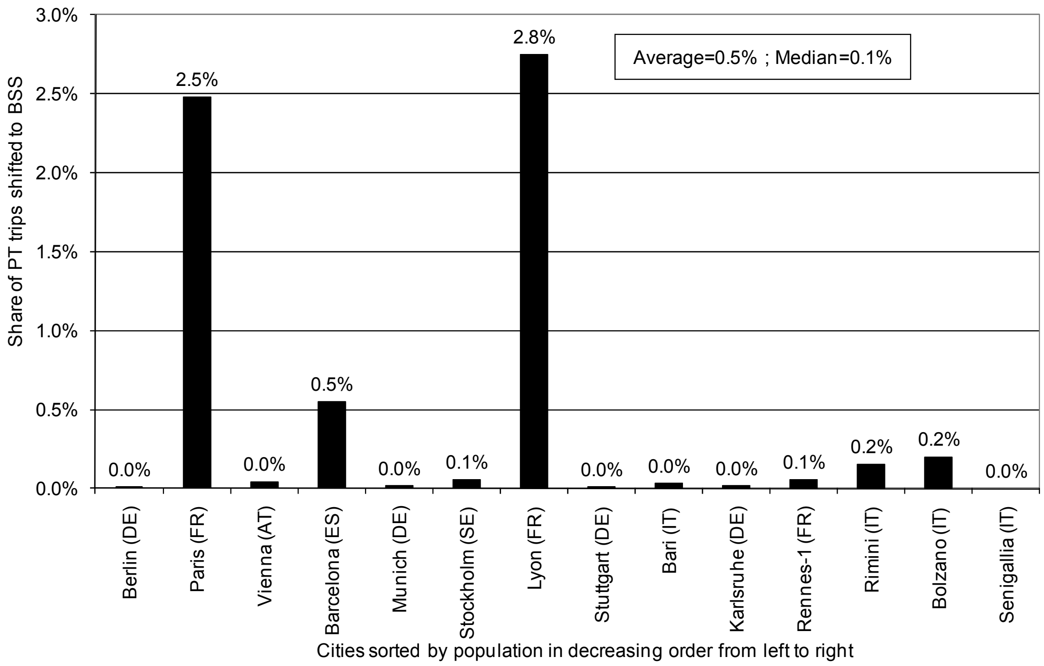


Figure 38: Share of municipal PT trips shifted to bike-sharing. Data source: Annex 10.1

In terms of number of PT trips shifted per bicycle, the BSSs in Barcelona, Paris and Lyon are the three most successful cases (Figure 39). 2.9, 2.5 and 2.1 PT trips per bike-sharing bicycle are daily substituted in these cities. In contrast, the average ratio reaches 0.7 PT trips per bicycle and day and the median is 0.1.

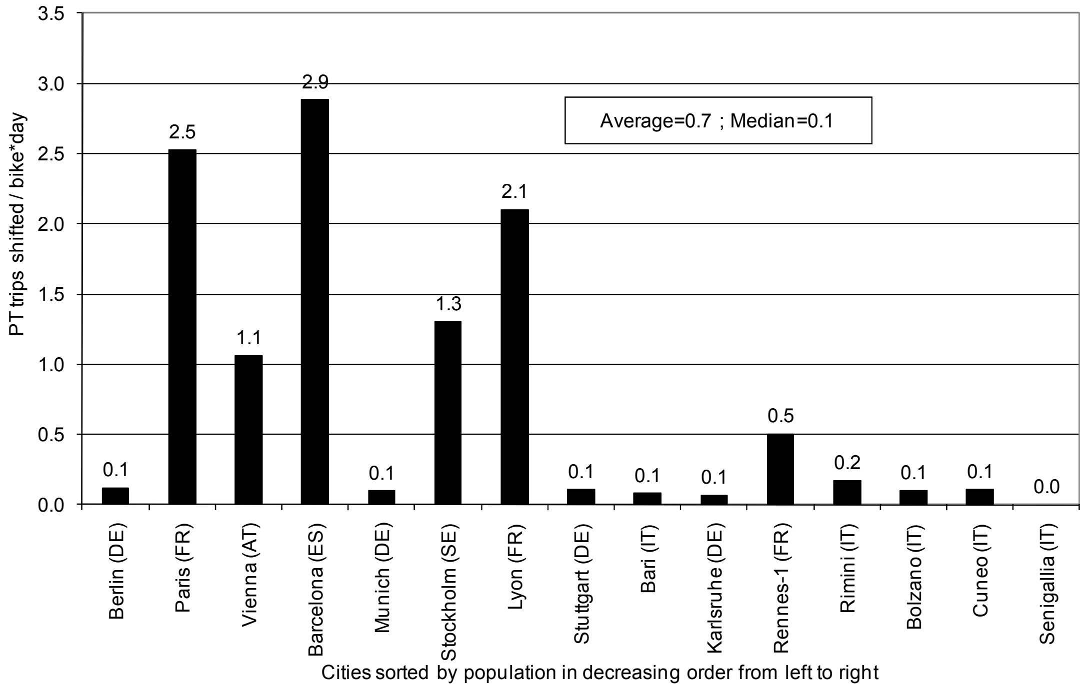


Figure 39: Number of daily former PT trips shifted to bike-sharing per bicycle. Data source: Annex 10.1

Cycling plays a relevant role in public transport intermodality. Since public transport can very rarely offer door-to-door trips, PT passengers need a complementary transport mode to cover the distance from the origin to the initial PT station and from the final PT station to the destination. This “first mille” and “last mille” of mobility can be made by walking or by bicycle but cycling is faster than walking, which enables to reach further distances. However, as section 2.4.5 has explained, the combination of public transport and bicycles can causes some troubles. Limited space and permission in PT vehicles as well as lack of cycle racks and vandalism are barriers for intermodality. Bike-sharing represent a convenient solution for these cases. Bicycles do not have to be carried inside vehicles neither parked at PT stops and bike-sharing users do not need to own two bicycles neither leaving them unattended.

Two rates have been selected as indicators to asses the achievement of this goal: 1) the impact and efficiency of the amount of bike-sharing trips connected with PT trips and 2) the share of bike-sharing users that hold a PT seasonal card.

The share of bike-sharing trips connected with public-transport ranges from 20% in Vienna to 79% in Paris (Figure 40). The average rate reaches 34% of bike-sharing trips while the median is 40%.

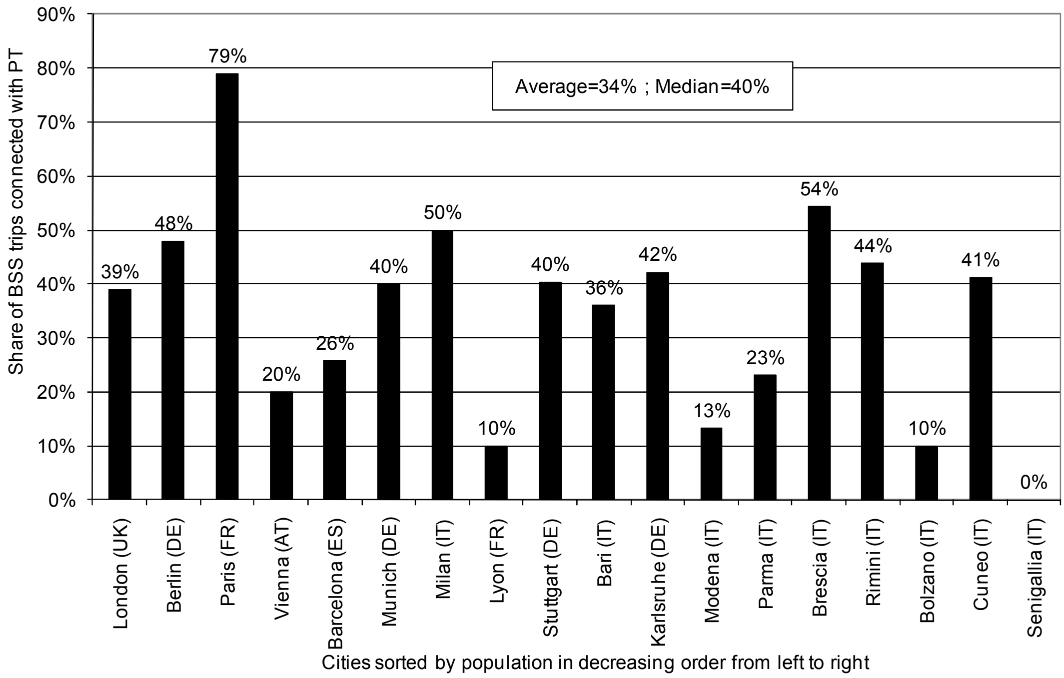


Figure 40: Share of bike-sharing trips connected with public transport. Data source: Annex 10.1

If we multiply the share of bike-sharing trips connected with public transport by the daily rents of the BSSs, we obtain the number of daily intermodal trips. The impact of bike-sharing promoting intermodality has been calculated by normalizing this number of intermodal trips by the number of municipal PT trips per day. Up to 3% of PT trips are connected with bike-sharing, while on average rate is circa 0.37%; the median is 0.03%.

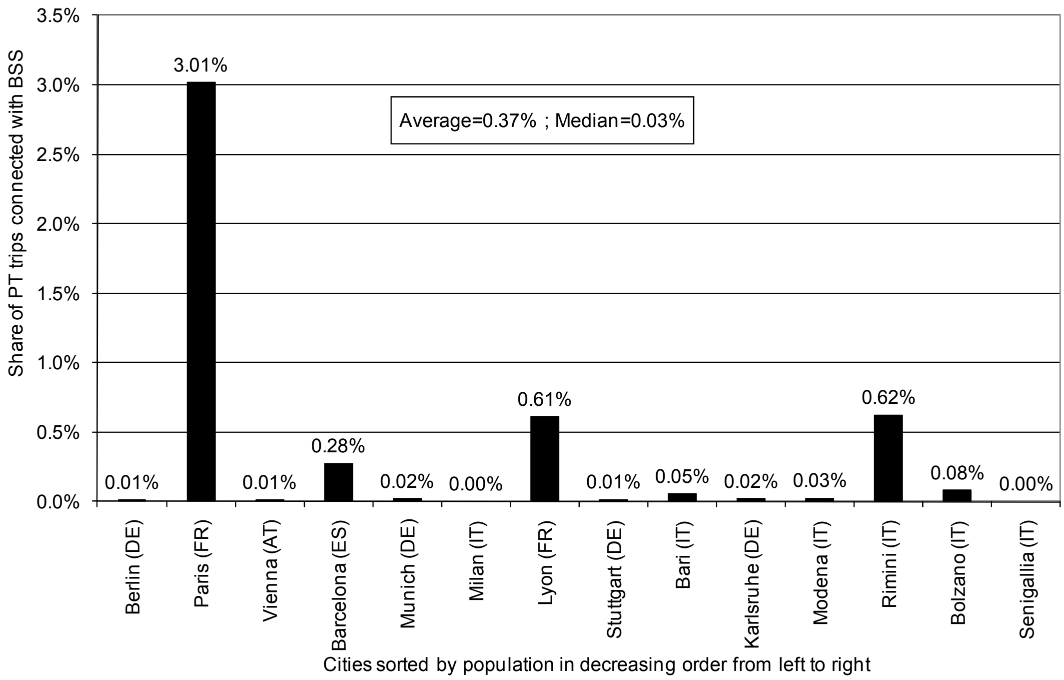


Figure 41: Share of PT trips connected with bike-sharing. Data source: Annex 10.1

Concerning the efficiency of the bike-sharing infrastructure (Figure 42), up to 3.07 daily bike-sharing trips per bicycle are connected with public transport. On average, this ratio reaches 0.5 daily trips per bicycle and in 50% of cases it does not exceed 0.1 daily trips per bicycle.

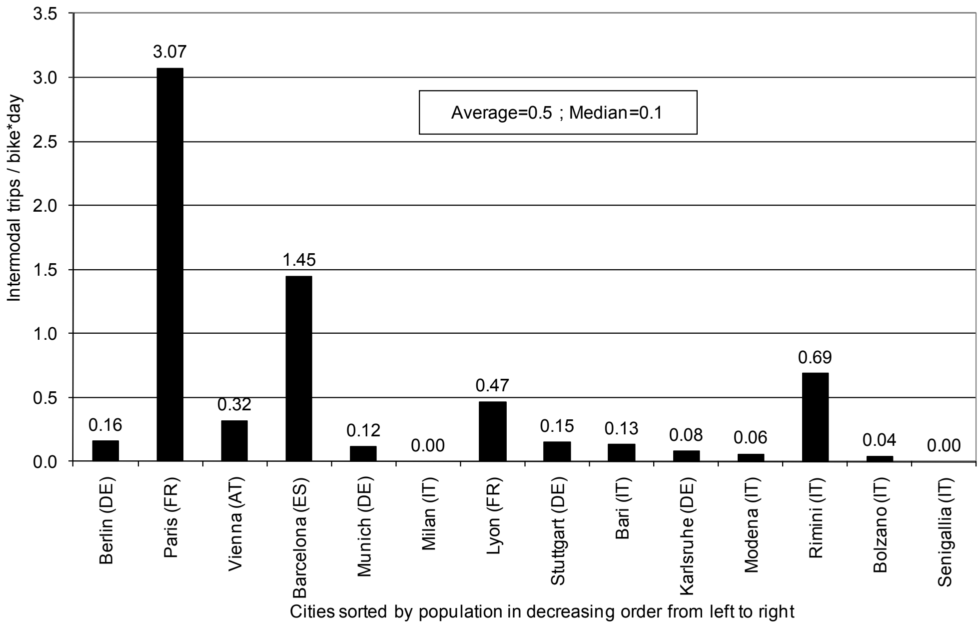


Figure 42: Yearly bike-sharing trips connected with PT per bike. Data source: Annex 10.1

The second indicator of success promoting intermodality, i.e. the share the bike-sharing users holding a seasonal PT card, presents values from 9% to 56% (Figure 43). On average, 40% of bike-sharing users hold a PT card, what means that they are still frequent PT passengers. The statistical median of this rate is 42%.

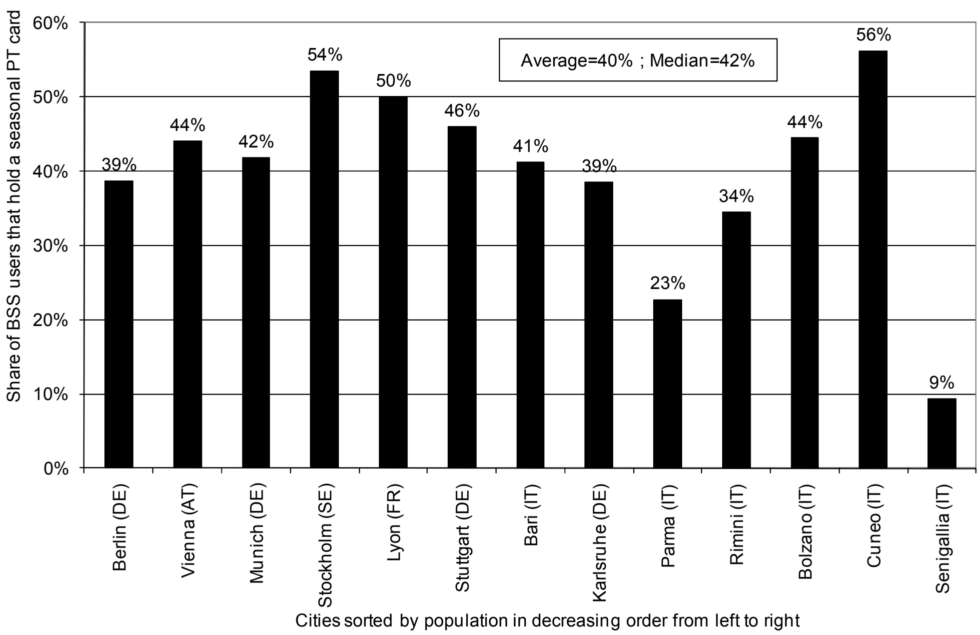


Figure 43: Share of bike-sharing users holding a seasonal PT card. Data source: Annex 10.1

6.2.5 Increase of cycling

Some cites have high expectations on bike-sharing regarding promotion of cycling. For example, the initial goal of Vel'oh, the BSS implemented in Luxemburg, was to contribute to increase cycling modal share from 1% to 10% in 2015 (Sassen 2009). This section shows the actual success of bike-sharing goal in Europe.

Firstly, as introduction, we see how BSSs have changed habits of bicycle owners and people that do not own any bicycle. From the perspective of bicycle owners, theft is one of the main concerns of cycling. Bike-sharing offers the possibility to use a bicycle but without owning it; therefore fear of vandalism is minimized. This advantageous circumstance might have contributed to persuade bicycle owners to start riding. In Lyon, 96% of Vélo'v customers who registered the first year of operation stated that they did not ride their own bicycle before (NYC Department of City Planning 2009). Moreover, 33% of customers of the pilot project of Leihradl-nextbike, a BSS located in several towns of Lower Austria, declared that they ride their bicycles more often since they became members of the system (Castro, Lackner, et al. 2010)

On the other hand, BSSs also influence people that do not own any bicycle. Figure 44 shows that on average, 57% of bike-sharing customers own a private bicycle. In other words, 43% of users who had no opportunity to ride a bicycle are cycling today thanks to BSSs.

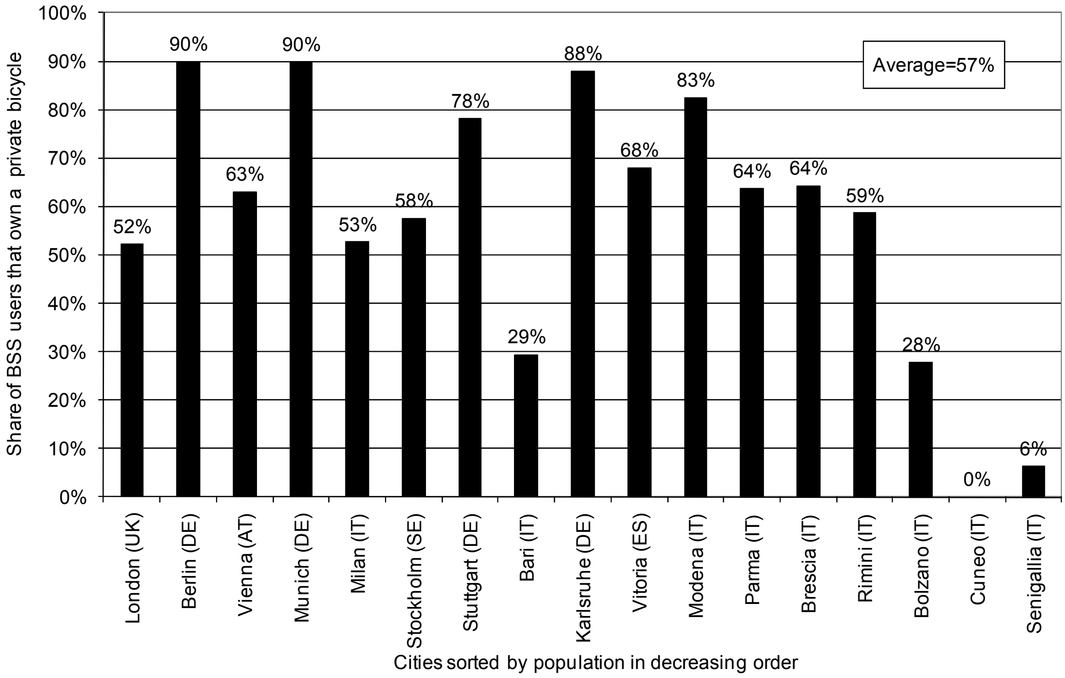


Figure 44: Bicycle ownership of BSS users. Data source: Annex 10.1

Bike-sharing contributes to increase cycling in two different ways: directly and indirectly. The direct increase of cycling generated in a city as a result of the operation of a BSS is indeed the number of bike-sharing trips reported. To represent the impact of this direct increase of cycling regarding the previous cycling level, the average number of daily bike sharing trips in 2008 has been normalized by the number of daily cycling trips before the implementation of the

BSS[22]. The result (Figure 45) reveals that on average bike-sharing have contributed till 2008 in Europe to increase cycling directly by 8.5%. The median is 0.3%. In only three cities the activity of the BSS is higher than 10% of the previous bicycle use. In Paris this share reached around 38%, in Barcelona 57% and in Lyon 92%. In other words, in Lyon the number of bicycles on road in 2008 almost doubled regarding the launch of the BSS because of the presence of bike-sharing bikes.

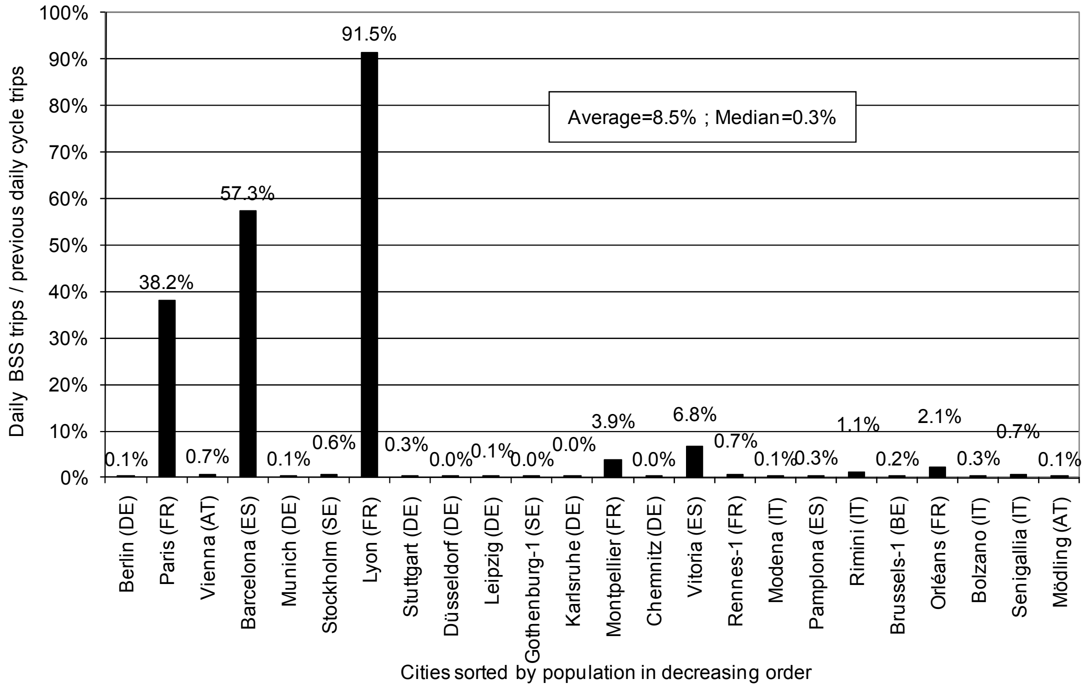


Figure 45: Daily direct increase of cycling (bike-sharing trips) in 2008 compared to level of cycling before the start of the BSS. Data source: Annex 10.1

If we assume that the direct increase of cycling caused by BSSs is the number of bike-sharing rents, then just dividing this value by the number of bike-sharing bicycles available, we are able to figure out the efficiency of BSSs directly increasing cycling. As Figure 46 shows, Barcelona, Lyon and Paris are the most efficient BSSs increasing bicycle trips. 5.6 daily cycle trips per bike-sharing bicycle were generated in Barcelona as a result of the operation of Bicing. The average ratio reaches 1.2, but the statistical median does not exceed 0.4 cycle trips per bike-sharing bicycle.

[22] It has been assumed that all municipal daily trips and private bicycle trips remained constant after the start of the BSS.

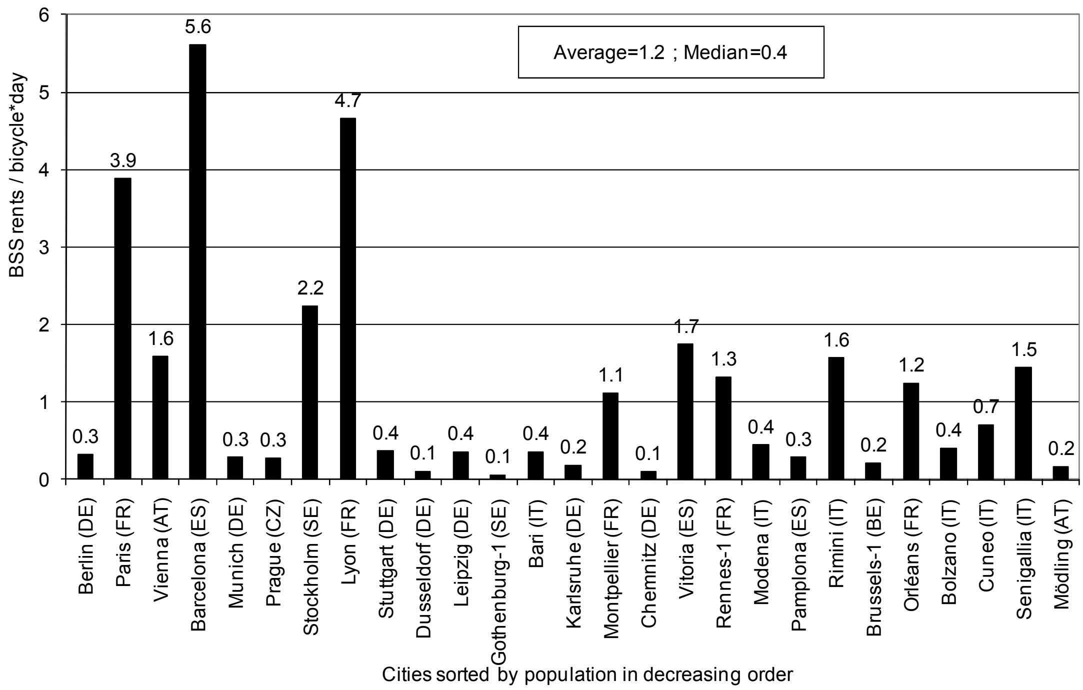


Figure 46: Daily direct increase of cycling (bike-sharing trips) per bike-sharing bicycle in 2008. Data source: Annex 10.1

As seen above, the new cycle trips made with bike-sharing bicycles represent the direct increase of cycling caused by BSSs. However, it exist also an indirect increase of cycling as a result of the “critical mass effect” of the bike-sharing bicycles. Some people might be convinced to ride their own bicycle because they see more cyclists on the streets and this may produce on them a subjective feeling of safety or being fashionable. Unfortunately, there was not enough data in the case studies to make a cross section analysis of the indirect increase of cycling due to bike-sharing. Nevertheless, relevant facts of several single cases are described in this section to figure out the impact of this side effect.

In Figure 45 it has been assumed that the number of traditional bicycle trips did not change after the launch of the BSSs, but actually it did. In Lyon the total number of bicycle trips increased by 44% after two years of operation of Vélo’v (Cyclocity 2008) and by 80% after four years (Grand Lyon 2009a) (Figure 47). In Paris and Barcelona one year after the start of the BSS the total number of cycle trips rose by 70% (Bremner 2008) and 27% (López 2009) respectively. In the case of Lyon around 30% of the new bicycle trips reported in 2010 regarding the start of the BSS were made by bike-sharing (Beroud 2010), while in Barcelona this share reached 46% in 2008 (López 2009). Furthermore, bike-sharing represent 31% of the cycle trips of Lyon in 2009 (Beroud 2010), 33% of the Parisian ones (Sassen 2009) and 30% of the cycle trips of Barcelona (Sanz & Kisters 2010).

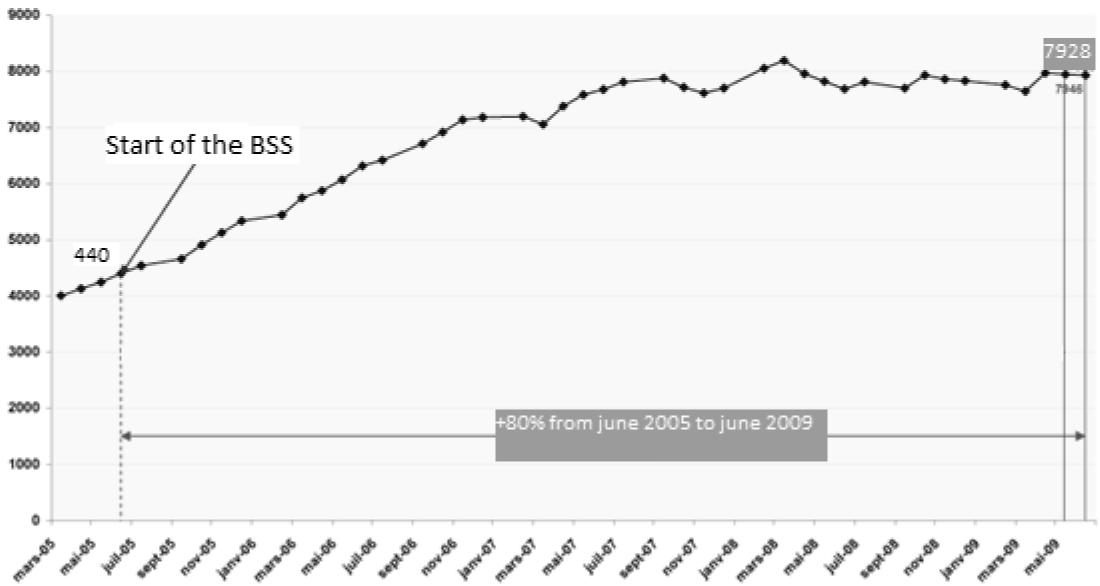


Figure 47: Monthly evolution the number of bicycles counted in 16 points of the city of Lyon after the launch of Vélo'v (Grand Lyon 2009a)

It seems to be clear that cycling increased after implementing BSSs in some European cities, but what was the real influence of bike-sharing in this augment of private bicycle use? To evaluate properly the impact of bike-sharing on cycling, it is recommended to see the evolution of bicycle use not only after but also before the launch of the BSS.

For example, in Lyon, Paris, Barcelona and Vienna cycling modal share increased after the start of the BSS, but the cycling level was in a rising tendency before the introduction of the BSS. Vélo'v was launched in Lyon in 2005 and within 1995 and 2006 cycling rose from 0.5% to 4% (Sassen 2009)[23]. In Paris a similar phenomenon was observed. 360 kilometres of new cycling network were built before the implementation of the BSS, from 1997 to 2007 and cycling modal share increased 48% from 2001 to 2006 (one year before the launch of Vélib') (Dector-Vega et al. 2008).

Therefore, bike-sharing seems not be the only reason that influences the current increase of bicycle use in European cities. Indeed it seems to be initiated by a longer and previous process. In Barcelona the cycling modal share was increasing since before the launch of the BSS. In 2005 cycle modal share was 0.75%, while in 2007 (year of launch of Bicing) was 1.76% (Romero 2008). This increase of cycling may be motivated by the expansion of the cycle infrastructure that was taking place in the city since 1990. As Figure 48 shows, the length of cycle lane network has continuously increased for more than 15 years before the launch of Bicing, what may influence in the current increase of bicycle use. In Vienna the higher level of cycling may be due not only by the launch of the BSS, but also to the parallel expansion of cycle ways network according to Figure 49.

[23] The period shown overlaps the launch of the BSS; hence bike-sharing might have influence on the final figure. Nevertheless, the impact is presumably residual since the first months of operation the number of bicycles and rents are low.

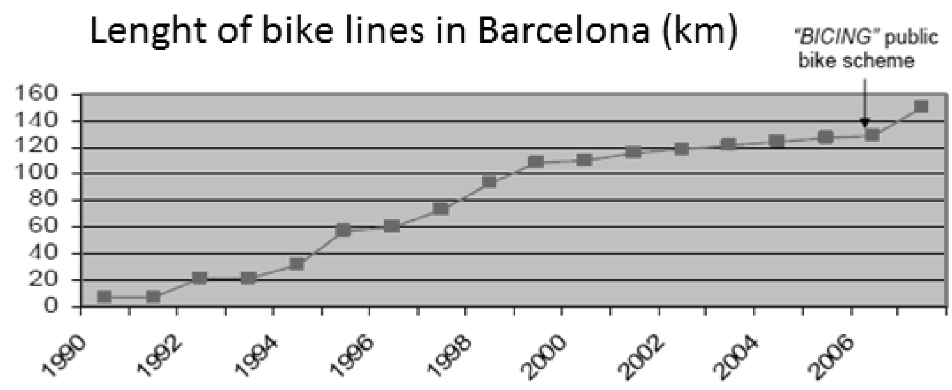


Figure 48: Yearly evolution of the length of available bicycle lanes in Barcelona from 1990 to 2006 (Romero 2008)

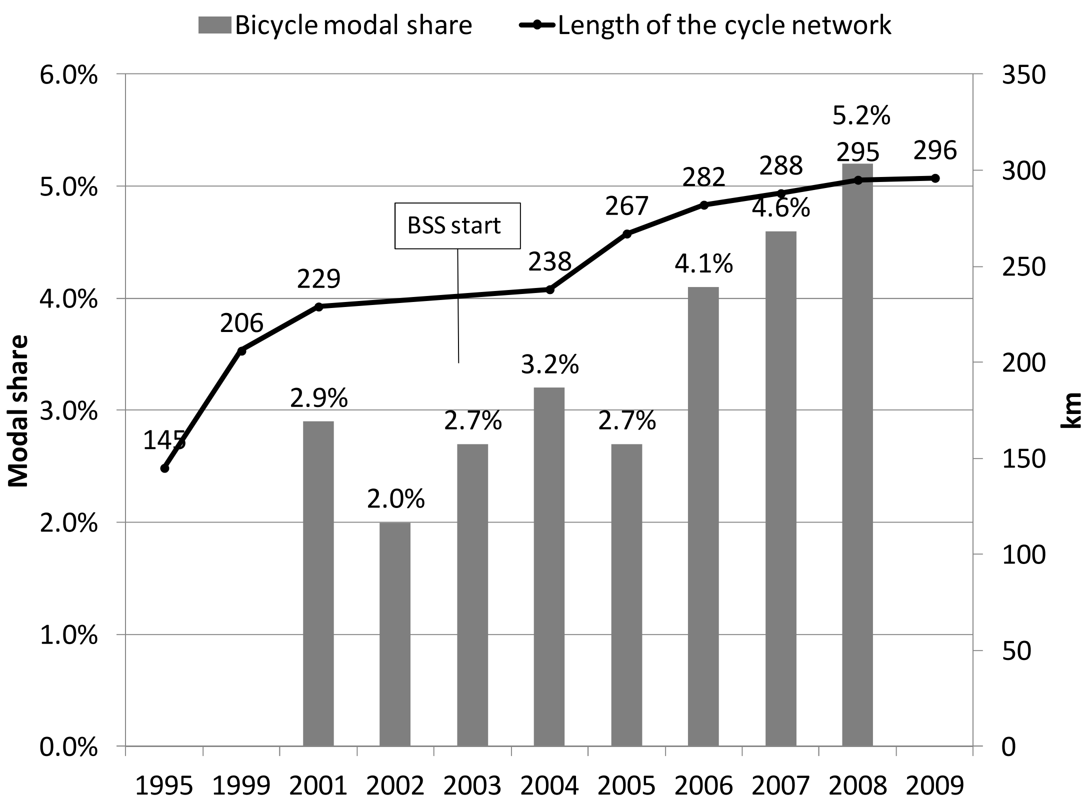


Figure 49: Evolution of the bicycle modal share and length of the cycle network in Vienna (BSS launched in 2003). Data source: (BMVIT 2010)

Therefore, it is difficult to identify the real impact of bike-sharing on increasing cycling. In some cities, BSSs were implemented together with other actions to promote cycling and in other cases BSSs were launched at the time that the first achievements of these cycling policies started arising. Despite this collateral effect, the impact of bike-sharing increasing indirectly cycling is perceptible. Figure 50 shows the increase of municipal cycle trips in two Spanish cities: Seville and Barcelona. The BSS of Seville was launched in August 2007 and the BSS of Barcelona in March 2007. Although bicycle use started increasing before the implementation of bike-sharing, a remarkable "jump" of cycling can be observed in both cases by 2008 compared to 2007. From these two figures one could conclude that bike-sharing accelerated the process of cycling promotion in these cities.

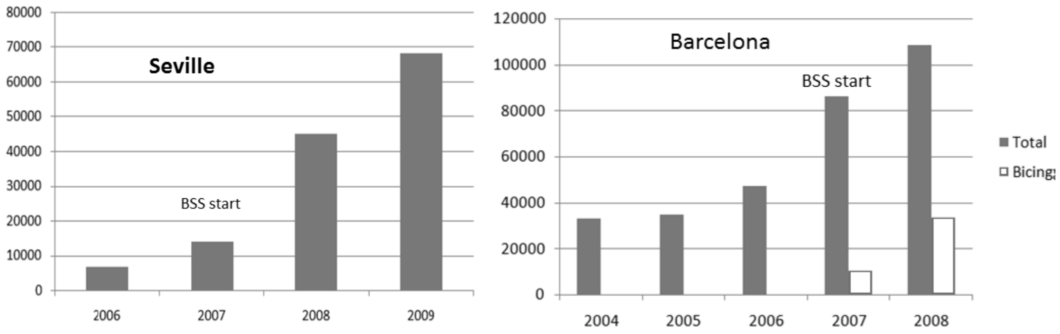


Figure 50: Yearly evolution of the number of municipal cycle trips in Seville from 2006 to 2009 (left) (García Jaén n.d.) and yearly evolution of the number of municipal cycle trips and BSS trips in Barcelona from 2004 to 2008 (right) (Sanz & Kisters 2010)

A similar acceleration of the level of cycling could be observed immediately after the launch of Vélo'v in Lyon (Figure 51).

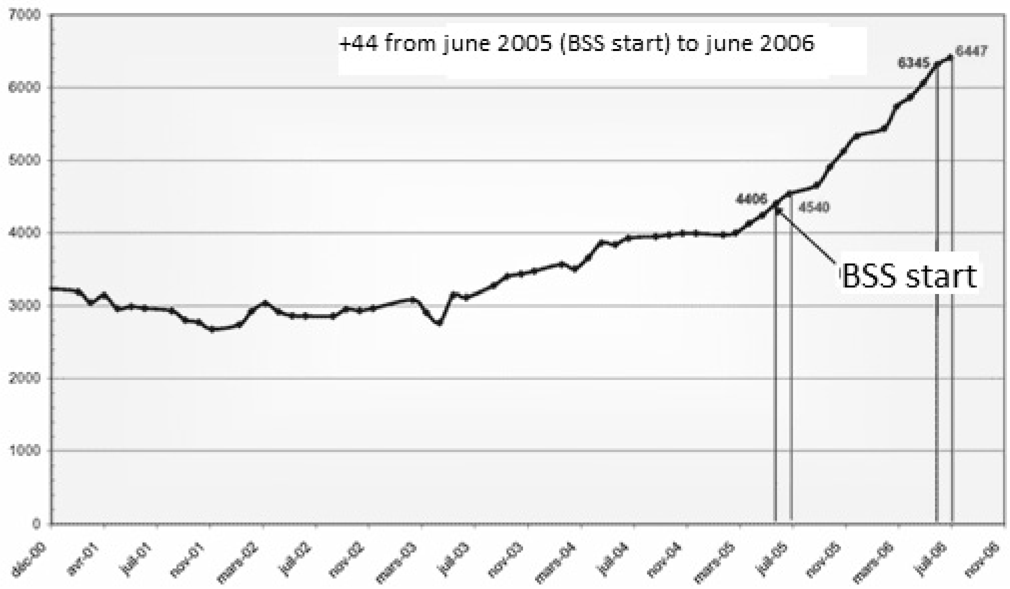


Figure 51: Monthly evolution of the average number of cycling trips registered by 16 counters in Lyon before and after the implementation of Vélo'v (Beroud 2007)

In this section we have seen that enlargement of cycle infrastructure may affect positively bicycle modal share. However, as other authors have supported (Wiersma 2010), BSSs might influence the construction of this infrastructure. In some cities, the presence of bike-sharing riders and new cyclists overcrowded the capacity of existing cycle facilities and city councils have been encouraged expanding and improving cycle infrastructure. For instance, in Barcelona, as a result of the popularity of the BSS and the new cyclists, the city council implemented new sustainable mobility policies and expanded the bicycle network from 128 km in 2007 (BSS start) to 150 km in 2008 (Midgley 2009). In Lyon the first cycle master plan was introduced in 2009, i.e. four years after the launch of the BSS (Beroud 2010).

6.2.6 Summary

The main goals of implementing a BSS in terms of urban mobility can be: 1) reducing car traffic, 2) increasing public transport attractiveness and 3) increasing cycling in a city. Figure 52, Figure 53 and Figure 54 show the goal (in a square), the main indicators used in this dissertation to evaluate the success of bike-sharing achieving this goal and the data required for their calculation. Table 28 summarizes the value of the main indicators of bike-sharing success in terms of mobility calculated in this section.

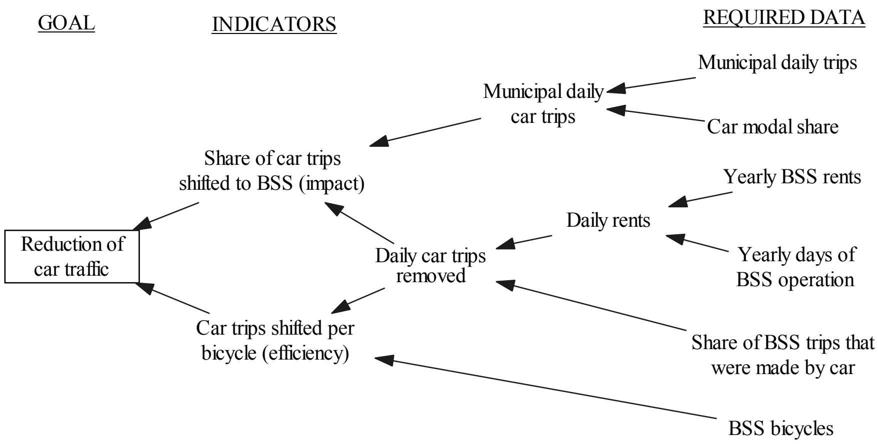


Figure 52: Indicators and data required for evaluating the reduction of car traffic

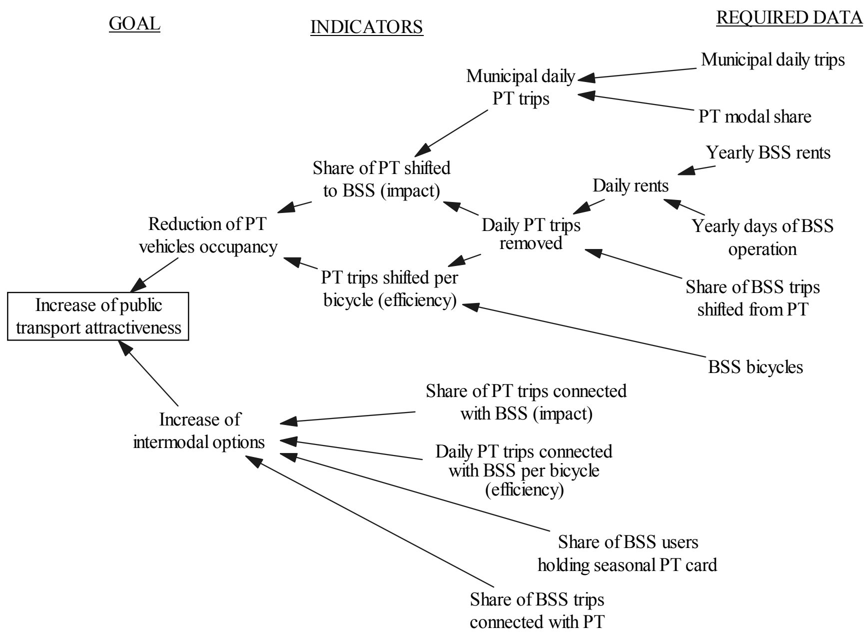


Figure 53: Indicators and data required for evaluating the increase of public transport attractiveness (discontinuous lines represent less accurate but still complementary helpful indicators)

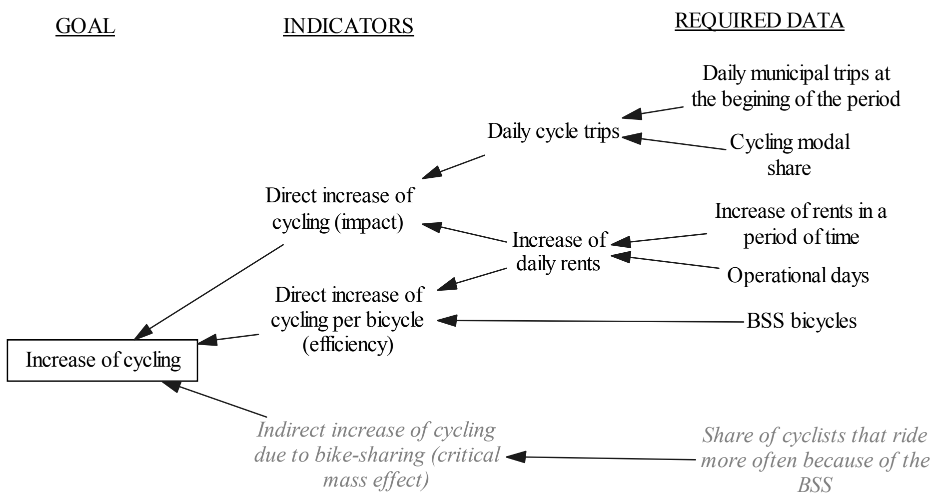


Figure 54: Indicators and data required for evaluating the increase of cycling (items highlighted with grey and italic characters are necessary for the evaluation but they were not calculated because of unavailability of data)

Indicator	Average	Median	Maximal	Unit	N
(General implications)					
BSS modal share	0.11	0.02	0.92	%	25
Users that use BSS instead of car	15	10	45	%	19
Users that use BSS instead of public transport	35	34	67	%	19
Users that use BSS instead of cycling	8		18	%	17
Users that use BSS instead of walking	24		38	%	18
Decrease of car traffic					
Car trips shifted to bike-sharing (impact)	0.04	0.01	0.18	%	15
Car trips shifted to bike-sharing (efficiency)	0.2	0.2	0.6	trips/bicycle*day	15
Increase of public transport attractiveness					
PT trips shifted to BSS (impact)	0.5	0.1	2.8	%	14
PT trips shifted to BSS (efficiency)	0.8	0.1	2.9	trips/bicycle*day	15
BSS trips combined with PT	34	40	79	%	18
PT trips combined with BSS (impact)	0.37	0.03	3.01	%	13
Intermodal PT-BSS trips (efficiency)	0.5	0.1	3.1	trips/bicycle*day	13
BSS users holding a seasonal PT card (impact)	40	42	56	%	13
Increase of cycling					
Direct increase of cycling (impact)	8.5	0.3	91.5	%	24
Direct increase of cycling (efficiency)	1.2	0.4	5.6	trips/bicycle*day	27

Table 28: Key values of the bike-sharing success in terms of mobility

Bike-sharing trips represent on average 0.11% (at most 0.92%) of the whole urban mobility of those cities where BSSs have been implemented (Table 28). Only 15% of these trips are former car trips. As a result, BSSs remove on average 0.04% of urban car trips and 20 daily car trips per each 100 bike-sharing bicycles available in a city (at most around 0.2% of daily car trips and 60 trips per 100 bicycles).

Bike-sharing can increase public transport attractiveness in two ways: by reducing congestion of PT and by increasing intermodality. On average 35% of bike-sharing trips were made previously by public transport and as result 0.5% of daily PT trips are shifted to BSSs. Concerning intermodality, 40% of bike-sharing users still hold a PT card, which means that they are still frequent PT passengers and although 0.5% of PT mobility is intermodal with BSSs, the average share of bike-sharing trips connected with public transport is 34%.

An acceleration of the number of private bicycle trips has been observed after the implementation of some BSSs. However, it has not been possible to quantify the indirect influence of bike-sharing increasing cycling by mean of the “critical mass effect”. Effects of complementary cycling promoting actions that were implemented together with BSSs (e.g. cycle network expansion) have made difficult the calculation of the indirect influence. Therefore, only direct increase of cycling caused by bike-sharing bicycles could be quantified. Without taking into consideration indirect effects of BSSs and complementary policies, it has been found that bike-sharing bicycles have directly increased daily cycle trips in European cities with BSS up to 91.5% till 2008 (8.5% on average).

6.3 Environment

6.3.1 Introduction

The EU representatives agreed in March 2007 a common and comprehensive pollutant emission and energy consumption policy to combat climate change and decrease energy dependency. The targets planed are known as “20-20-20 targets” and they have to be reached by 2020. The three targets are the following:

- To reduce at least 20% greenhouse gas emissions below 1990 levels in the EU.
- To reduce 20% primary energy consume by improving energy efficiency.
- To reach at least the 20% of the share of energy coming from renewable resources.

In January 2008 the European Commission proposed enforcing the 20-20-20 targets through legislation. Thus, this “climate and energy package” became a law in June 2009 after the green light of the European Parliament (European Commission 2010b). CO2 is one of the main greenhouse gases that cause climate change. 23.1% of European CO2 emissions are caused by transport activity and this share has continuously increased from 1990 (European Commission 2010a).

Bike-sharing has been widely conceived as a way to reduce CO_2 emissions originated by urban mobility, but very few and raw calculations have demonstrated the real impact and efficiency achieving this goal. This section will evaluate the success of bike-sharing from an environmental approach focusing on CO_2 reduction. Direct CO_2 decrease associated to operation of BSSs in European cities will be estimated in three steps: 1) CO_2 saved due to motor vehicle trips substituted by bike-sharing trips will be calculated in section 6.3.2, 2) CO_2 emissions produced as a result of the bike-sharing operation will be considered in section 6.3.3 and 3) a balance of saving and emission will show the impact of BSSs fighting against climate change in section 6.3.4. Other kind of harmful pollutants such as CO, NOx and PM are evaluated in section 6.4.2 (category health).

6.3.2 CO_2 saving

Not all bike-sharing users emitted CO_2 before using BSSs. To calculate the direct CO_2 saved as a result of bike-sharing operation, it has been assumed in this dissertation that those bike-sharing customers that are former pedestrians, cyclists or PT passengers did not emit any CO_2 before using BSSs. In other words, only bike-sharing trips shifted from car really contribute to save CO_2. The process used to calculate the CO_2 saved has been the following: the number of bike-sharing trips that are shifted from car trips has been multiplied by the distance covered in bike-sharing rents. The result is the car distance covered before the implementation of the BSS. The CO_2 saved due to bike-sharing operation has been obtained multiplying this distance by the average emission of the substituted cars.

Figure 55 reveals that bike-sharing trips go from 0.8 up to 3.1 kilometres, while on average the distance is 2 kilometres long.

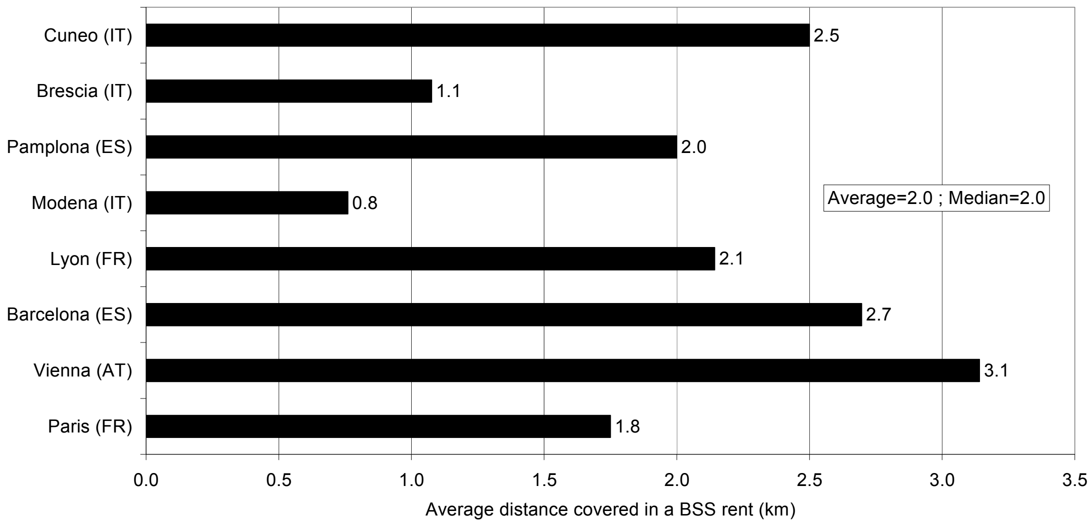
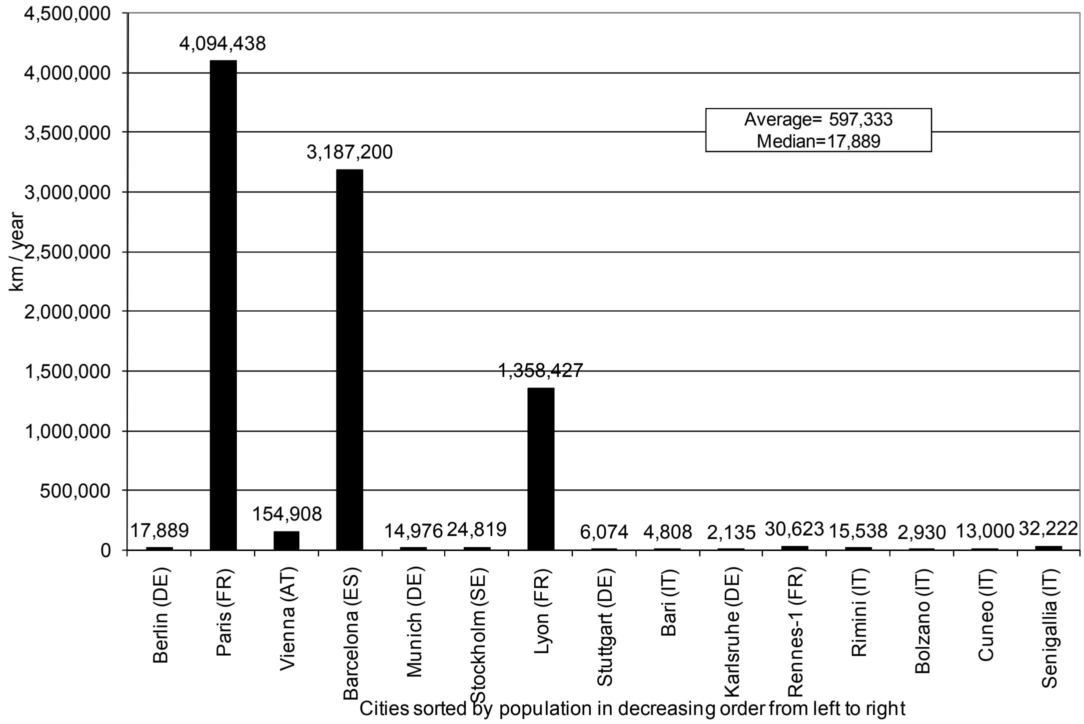


Figure 55: Average distance covered in a BSS rent. Data source: Annex 10.1

The number of annual car trips shifted to BSSs is obtained by multiplying the number of daily municipal car trips shifted to bike-sharing (Figure 33) by the number of days in a year that the studied BSSs are operative. The multiplication of this number of annual car trips by the distance per rent of Figure 55 results in the total distance covered by bike-sharing rents per year formerly covered by car[24]. Figure 56 reveals that Paris, Barcelona and Lyon are the cities where more car kilometres were replaced directly by bike-sharing.

[24] Since very few case studies have available data concerning distance of trips, in order to continuous the calculation with a significant number of case studies, it has been assumed that bike-sharing trips in Berlin, Munich, Stockholm, Stuttgart, Karlsruhe, Rennes, Rimini, Bolzano and Senigallia are 2 kilometres long (the average value).



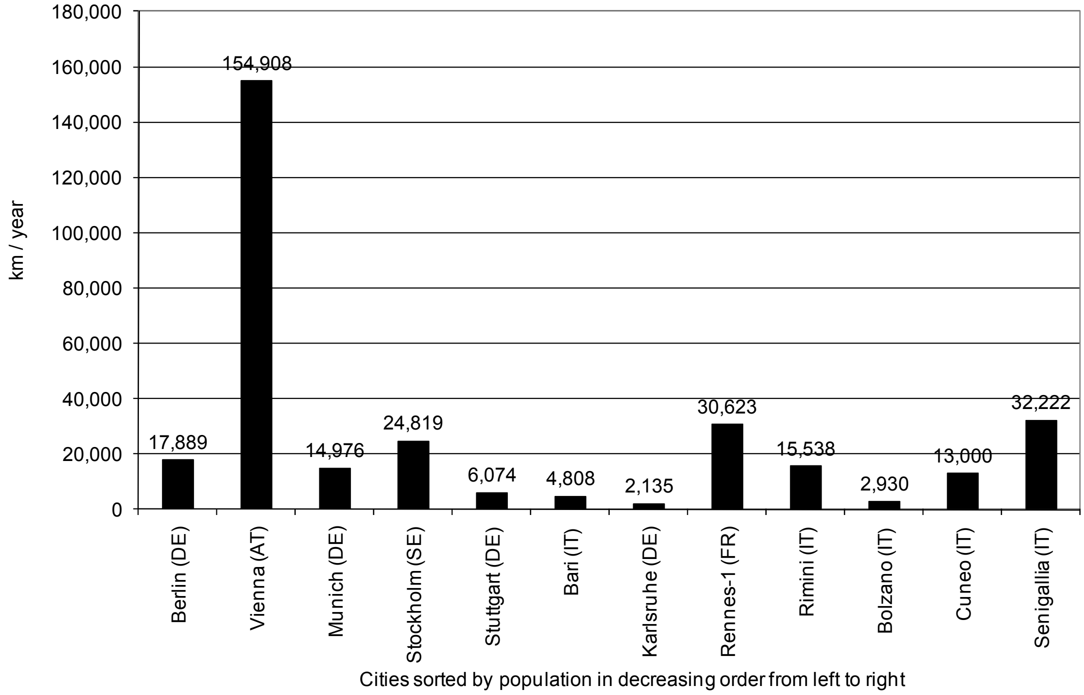


Figure 56: Former annual car trip distance replaced by bike-sharing in all case studies with available data (above) and without Paris, Barcelona and Lyon (below). Data source: Annex 10.1

The average CO_2 emission of cars in the EU is 160 grams per kilometre, according to the pan-European association Transport and Environment (Planet Ark 2007). If former car distance of Figure 56 is multiplied by standard emissions of cars, the yearly CO_2 saving due to BSSs is finally obtained. As Figure 57 illustrates only the BSSs located in Paris, Barcelona and Lyon reach appreciable CO_2 saving. 655, 510 and 217 CO_2 tonnes per year are not emitted anymore respectively in these cities since car passengers changed their habits and start riding a bike-sharing bicycle. In contrast, the CO_2 saving of the rest of case studies does not exceed 18 CO_2 tonnes per year. On average, BSSs save 96 CO_2 tonnes per year, i.e. around 600,000 car kilometres[25], in the cities where they operate, while the half of the analyzed case studies do not save more than 3 CO_2 tonnes per year.

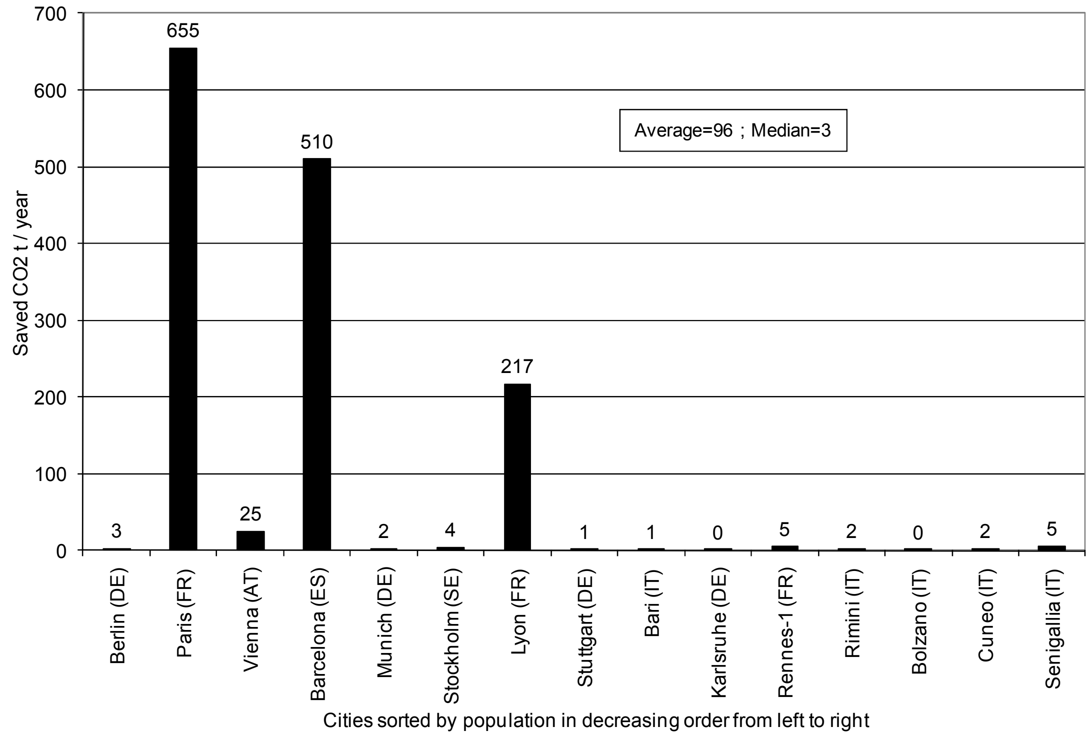


Figure 57: Annual CO_2 tonnes saved by bike-sharing. Data source: Annex 10.1

How much does Figure 57 represent compared with the total emissions of these cities? For instance, while the BSS in Lyon saves 217 CO_2 tonnes per year, the whole municipal mobility emits 577,171 CO_2 tonnes per year (Coparly 2009). Therefore, the CO_2 saving of Vélo'v represent a reduction of 0.04% of CO_2 emissions in Lyon.

Taking the population as reference for normalizing, it can be found that Vélo'v, Bicing and Vélib' are the BSSs with higher impact, as Figure 58 shows. In Lyon around 357 CO_2 yearly kilograms per 1,000 inhabitants are not emitted anymore thanks to the BSS. In Barcelona the saving reaches 313 kilograms and in Paris 302 kilograms. In the rest of case studies the contribution is below 116 yearly CO_2 kilograms per 1,000 inhabitants. On average, 80 CO_2 yearly kilograms per 1,000 inhabitants, equivalent to 500 car kilometres, are not emitted anymore due to bike-sharing operation in European cities. As the statistical median reveals, one half of the case studies save up to 15 CO_2 yearly kilograms per 1,000 inhabitants.

[25] One CO_2 Ton is equivalent to 6,250 car kilometres because as mentioned above the average CO_2 emission of cars in the EU is 160 grams per kilometre.

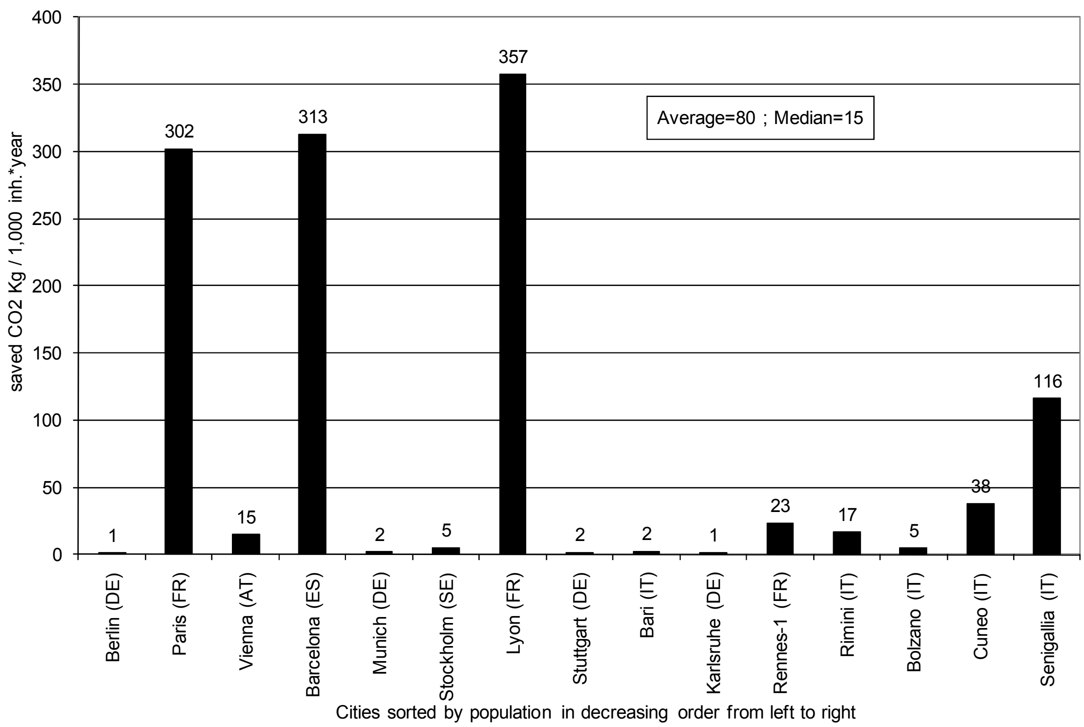


Figure 58: Annual CO_2 tonnes saved per 1,000 inhabitants. Data source: Annex 10.1

When studying not the impact but the efficiency of BSSs, the results are different. Figure 59 shows, modest schemes seem to be more competitive compared with large-scale BSSs. In Senigallia about 103 CO_2 kilograms are saved per bike-sharing bicycle and year, while in Barcelona this value reaches 85 CO_2 kilograms per bicycle. The third place in the ranking is for Vélo'v in Lyon with nearly 57 CO_2 kilograms per bicycle. According to this analysis the Parisian BSS is less efficient reducing CO_2 per bike-sharing bicycle (32 CO_2 kg/bike*year) than other smaller BSSs such as the ones located in Rimini (48), Cuneo (42) and Vienna (40). One could say that European BSSs save on average 31 CO_2 kilograms per bike-sharing bicycle, equivalent to 194 car kilometres per bicycle. The statistical median is 24 CO_2 kilograms per bike-sharing bicycle.

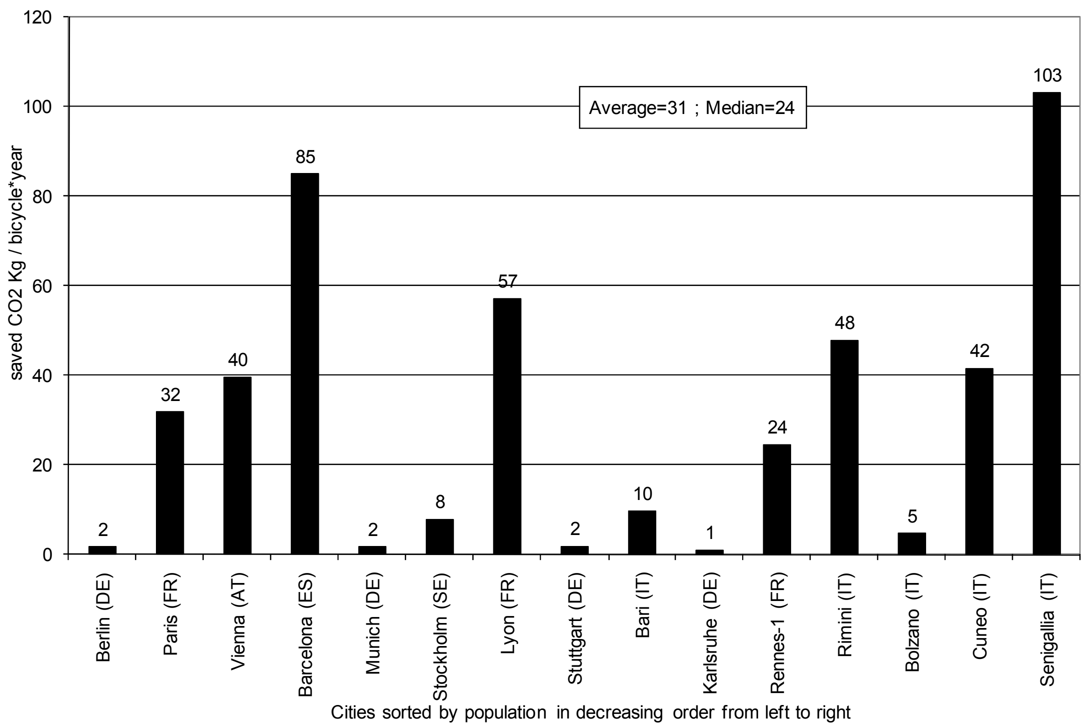


Figure 59: Annual CO_2 tonnes saved per bicycle. Data source: Annex 10.1

The real CO_2 saved through bike-sharing operation might be higher than the results showed by Figure 57, Figure 58 and Figure 59. As section 6.2.5 has explained, bike-sharing may also contribute to increase cycling in an indirect way, by the “critical mass effect”. This collateral shift of car trips may also have an impact on CO_2 saving. Nevertheless, there are unfortunately not available data about the share of these new private bicycle users coming from car that changed their mobility habits because of the introduction of a BSS. Therefore, only direct CO_2 saved, i.e. only car trips shifted to BSSs, has been considered in this section.

6.3.3 CO_2 emission

BSSs can emit CO_2 by mean of different activities related with their operation. The energy consumption of making the bike-sharing bicycles, the emission of employees going to the work place and the distance covered by vans for the redistribution and repair of the bicycles are some environmental impacts caused by bike-sharing (Beroud 2007). In this dissertation the first two factors are considered marginal, while the impact of redistribution is in detailed studied.

When bike-sharing stations are empty or full, bicycles have to be redistributed to recover the balance of parking and bicycle availability. As section 7.3.5 explains, in Lyon redistribution of bicycles represents 20% of all bike-sharing movements between stations (voluntary user trips plus mandatory user trips from a full station to an available one plus redistribution carried out by the operator) (Snead & Dector-Vega 2008).

The fleet of vans for redistribution varies widely depending on the BSS, as Figure 60 illustrates. Paris requires 200 vehicles for redistribution and Barcelona 46, while the rest of case studies with available data do not need more than 3. As section 7.2.1 and 7.3.5 show redistribution efforts depends on BSS-size and hilliness of the operation area.

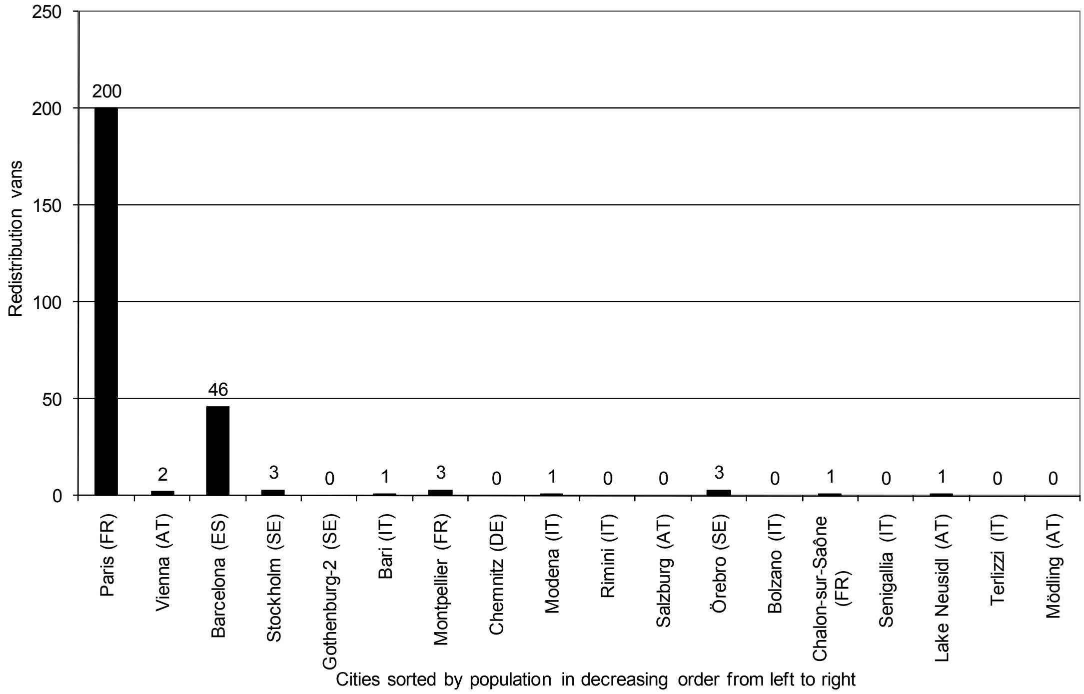


Figure 60: Number of redistribution vans. Data source: Annex 10.1

The distance that each redistribution van covers per day has been estimated in this dissertation by dividing the total daily distance covered by the number of vans. As we see in Figure 61, the average daily distance that each van covers for the redistribution of bicycles can fluctuate from 10 to 100 kilometres. On average redistributions vans cover about 39 kilometres per day.

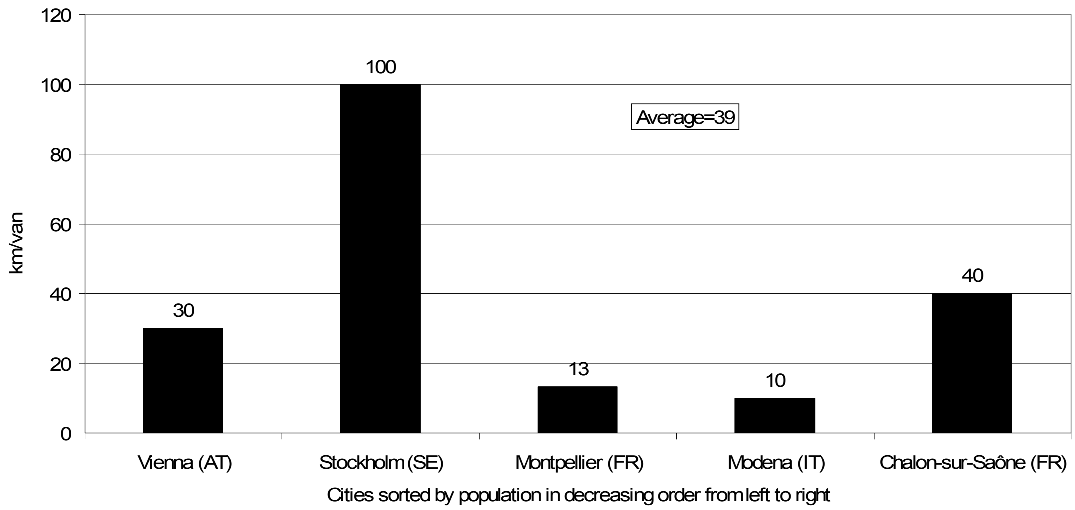
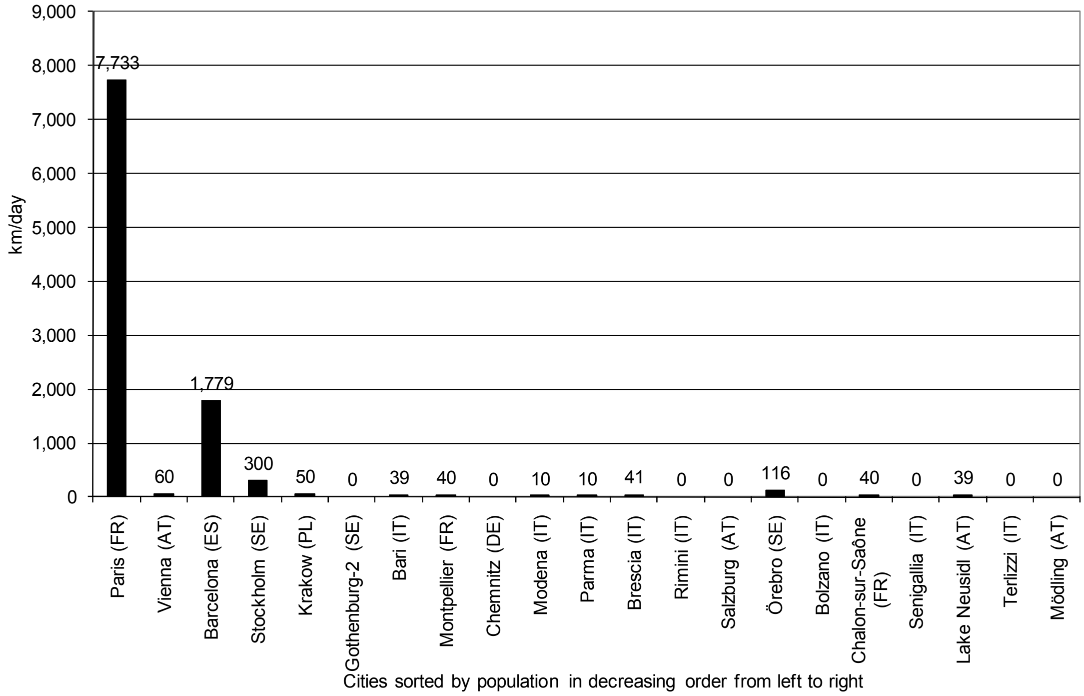


Figure 61: Daily distance covered per van. Data source: Annex 10.1

If we multiply daily distance covered by all redistribution vans[26] by the number of yearly days of operation of BSSs, yearly distance due to redistribution is obtained (Figure 62).



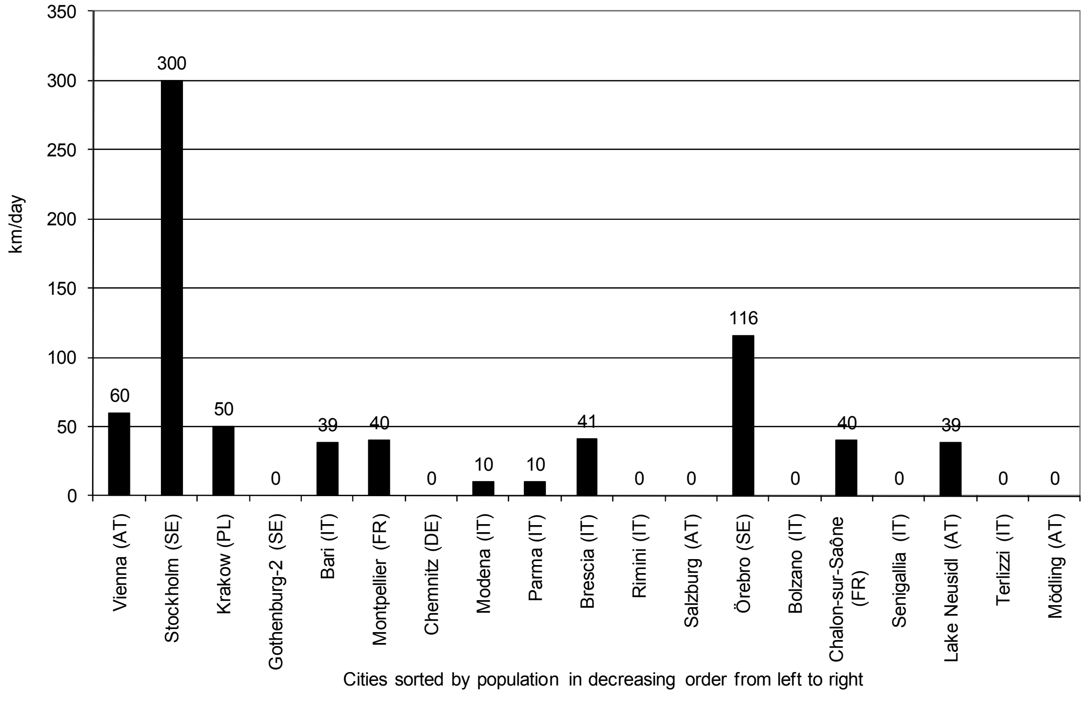


Figure 62: Daily distance covered by all redistribution vehicles in all case studies with available data (above) and without Paris and Barcelona (below). Data source: Annex 10.1

[26] Since very few case studies provide information about the distance covered by redistribution vans and in order to continue the calculation with a significant number of case studies, it has been assumed that the redistribution distance of the cases without data is the average value of the BSSs with available data, i.e. 39 km.

If redistribution vans are motor vehicles propelled by fossil fuels, they emit pollution[27]. By multiplying the yearly distance of all redistribution vehicles by their CO_2 emission per kilometre, the total CO_2 emission of the BSSs can be estimated. As Figure 63 reveals, due to redistribution, Bicing, in Barcelona, emits around 140 CO_2 tonnes per year, while in Stockholm the emission is 10 CO_2 tonnes per year. The rest of case studies with available data do not exceed 4 CO_2 tonnes per year. Cases studies of Figure 63 that are represented with 0 CO_2 tonnes are actually BSSs with only one station, hence they do not need any redistribution. Considering these "public bicycle rental systems" with only one station, one could say that BSSs emit on average in Europe 10 CO_2 tonnes per year, while if we exclude them from the calculation we obtain that BSSs emit actually 19 CO_2 tonnes per year.

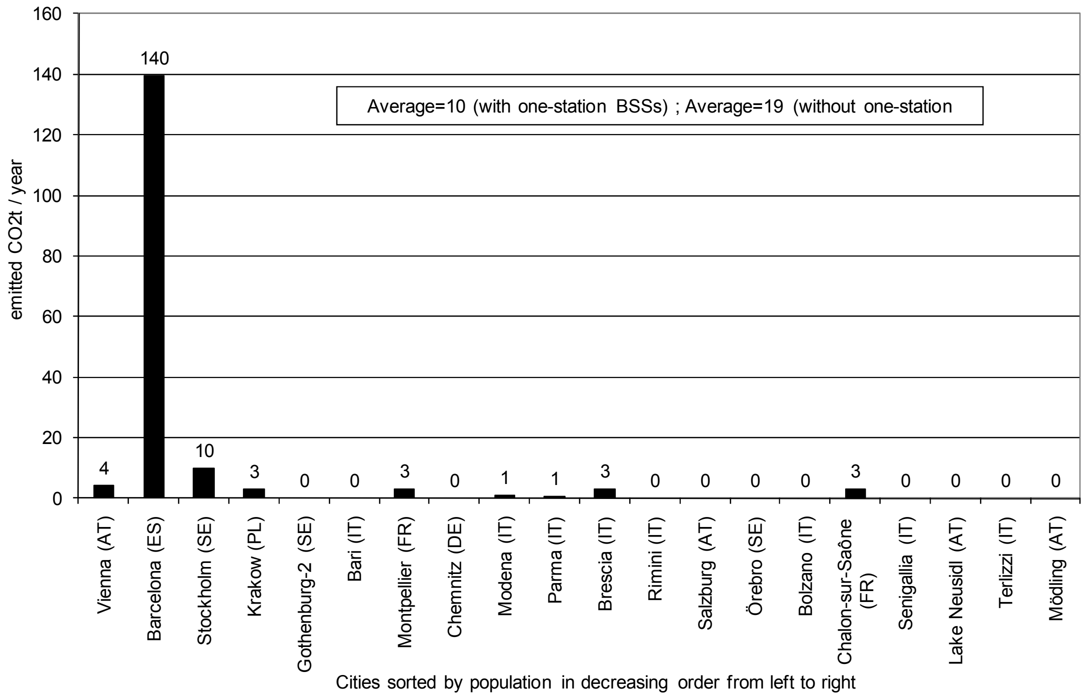


Figure 63: Annual CO2 tonnes emitted by bike-sharing redistribution. Data source: Annex 10.1

Concerning the environmental impact on the population, Figure 64 reveals that the top of CO_2 emissions per inhabitant takes place in Barcelona and Chalon-sur-Saône (86 and 63 CO_2 kilograms per 1,000 inhabitants), while the rest of case studies do not exceed 17 kilograms per 1,000 inhabitants. The average impact of BSSs with more than one station is 23 kilograms per 1,000 inhabitants (12 as statistical median).

[27] Only cases studies with the whole redistribution fleet propelled by fossil fuels were considered. Three case studies provide information about the emission of these vehicles. In Vienna they emit 190 CO_2 grams per kilometre, in Stockholm 155 and in Modena 300. For the rest of case studies, the average emission of the three available data, i.e. 215 CO_2 grams per kilometre, has been assumed.

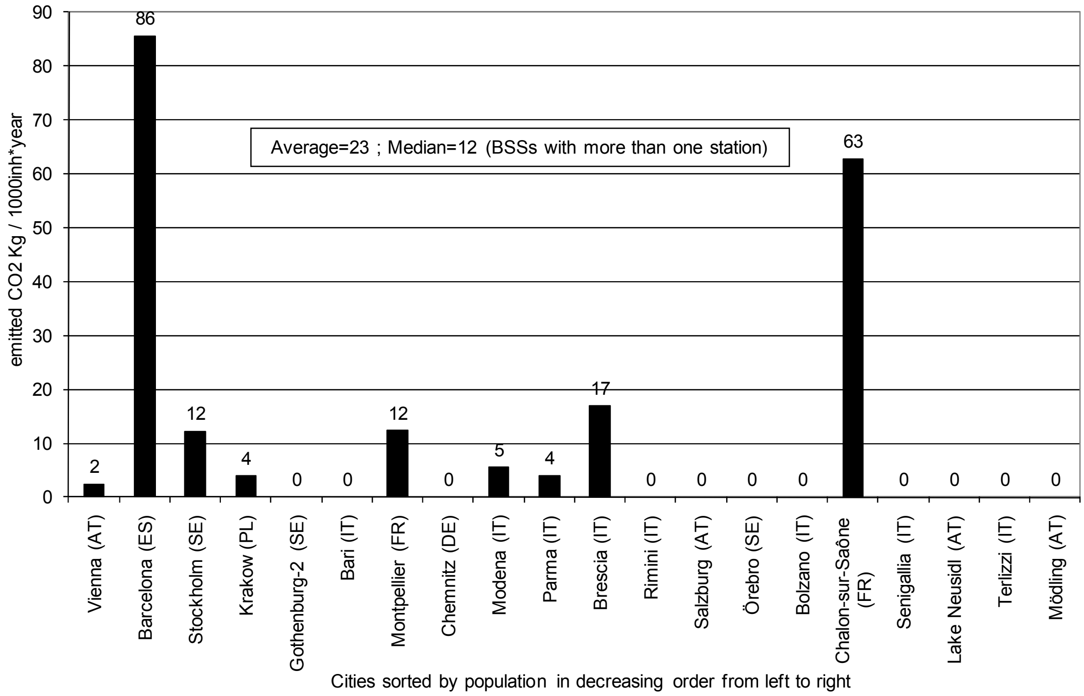


Figure 64: Annual CO2 kilograms per 1,000 inhabitants emitted due to bike-sharing redistribution. Data source: Annex 10.1

Emissions per bicycle seem to be rather more similar between case studies than emissions per inhabitant (Figure 65). The highest emission per bicycle is reached in Chalon-sur-Saône, Krakow and Brescia with 31, 29 and 27 CO_2 kilograms per bicycle respectively. On average, the BSSs emit 17 CO_2 kilograms per bicycle (20 as median).

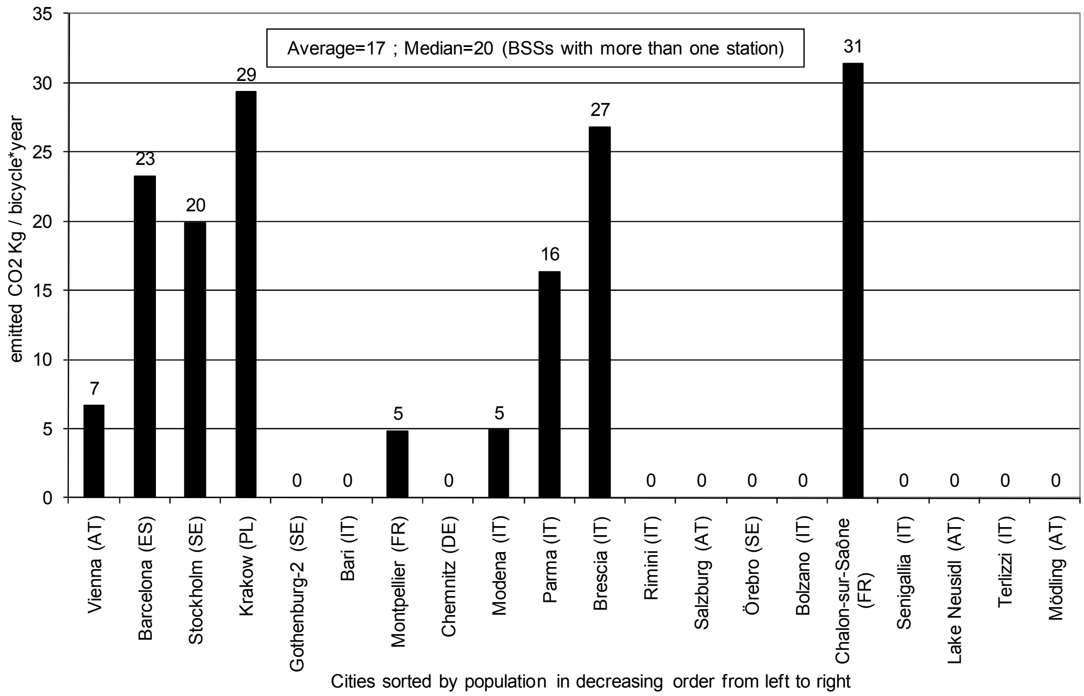


Figure 65: Annual CO2 kilograms per bicycle emitted due to bike-sharing redistribution. Data source: Annex 10.1

6.3.4 Balance

Figure 66 draws up a balance between the distance of motor vehicles saved thanks to bike-sharing (Figure 56) and the distance covered as a result of redistribution vans (Figure 62).

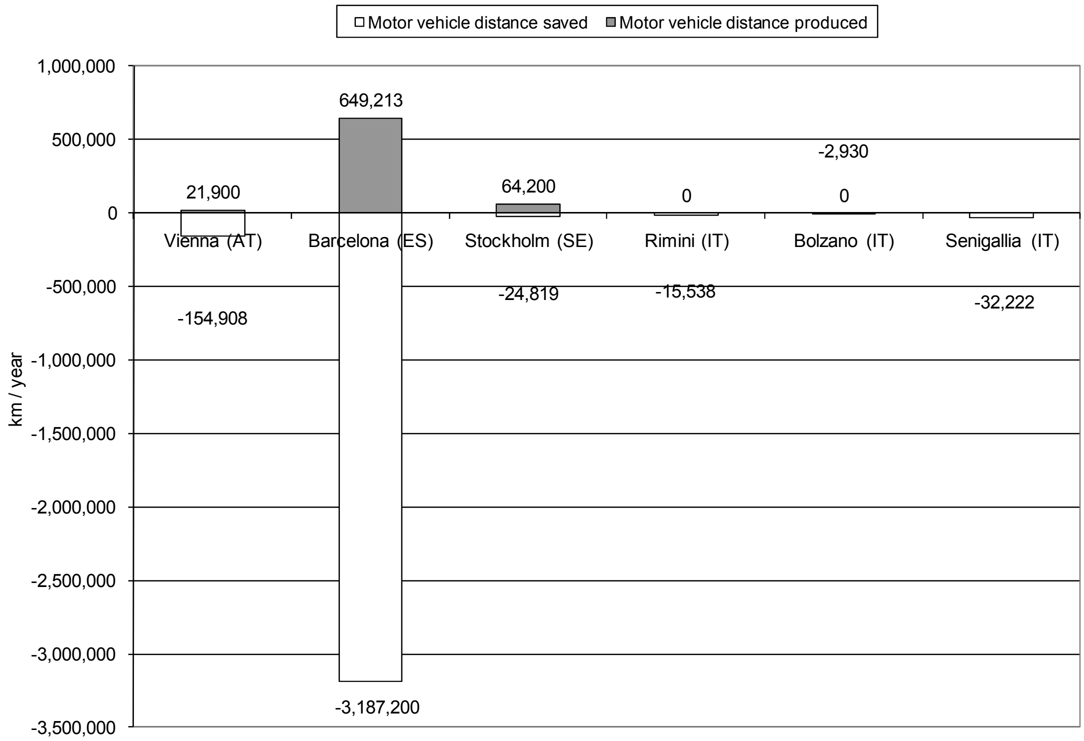


Figure 66: Balance of annual motor vehicle kilometres. Data source: Annex 10.1

Figure 67 is the translation of Figure 66 to CO_2 emissions and it reveals the net contribution of bike-sharing in reducing CO_2. In Vienna the net CO_2 reduction does not exceed 21 tonnes per year while in Barcelona reaches 370. In both cases, CO_2 emission due to redistribution represents around 25% of CO_2 saved (22% in Vienna and 27% in Barcelona). In contrast, according to the information available and calculations described in this dissertation, the BSS of Stockholm instead of reducing CO_2 increases the level of this pollutant. As a result of the direct substitution of car trips by bike-sharing trips 4 tonnes per year are saved, but the BSS emits 10 CO_2 tonnes per year due to an intensive work of redistribution. Therefore, the balance is that 6 CO_2 tonnes per year are emitted because of the bike-sharing operation.

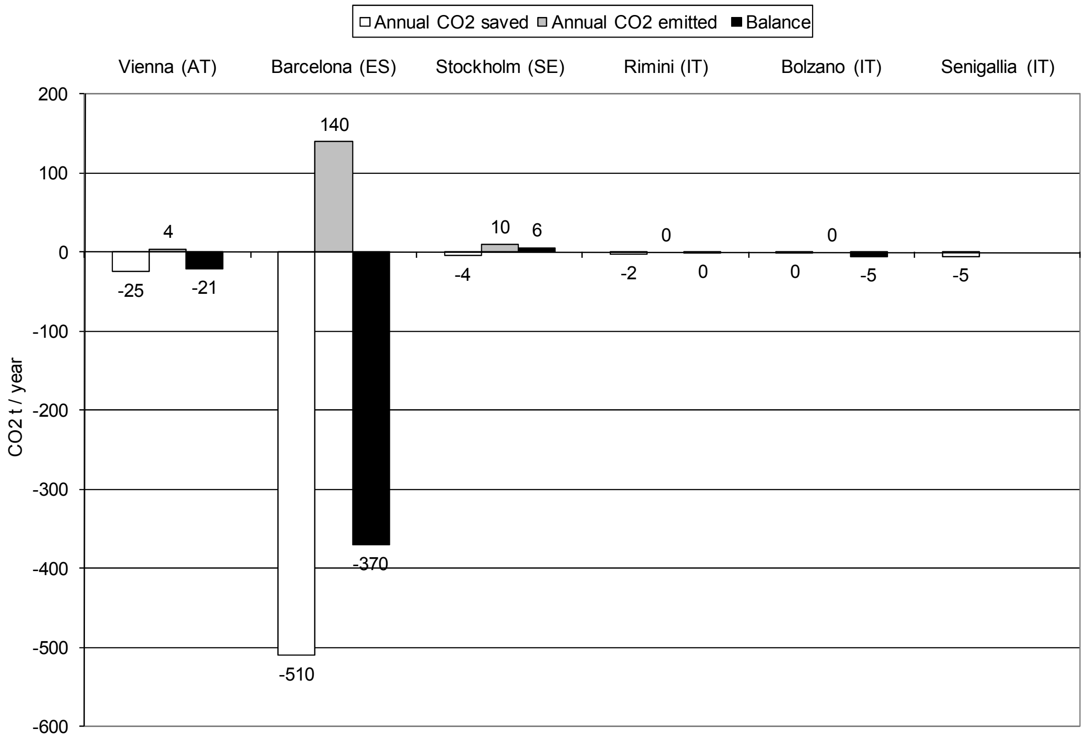


Figure 67: Net CO2 reduction of bike-sharing. Data source: Annex 10.1

6.3.5 Summary

Figure 68 summarize the main indicators and data used in this dissertation to evaluate the success of BSSs in terms of environment. Table 29 summarizes the main resulting figures of this calculation.

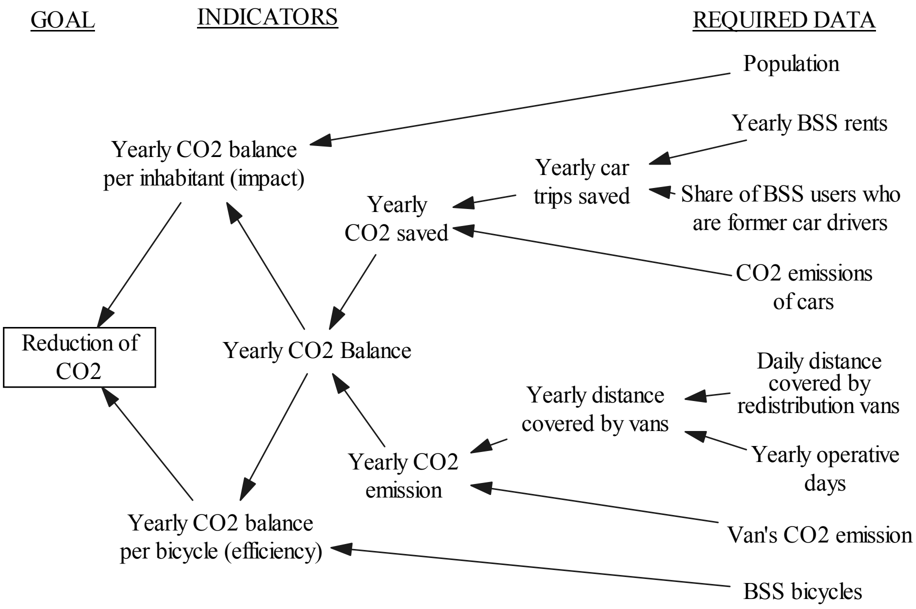


Figure 68: Indicators and data required for evaluating the reduction of CO_2 reduction

Indicator	Average	Median	Maximal	Unit	N
Reduction of CO_2 emissions					
Gross CO_2 reduction (impact)	80	15	357	kg/1,000inh*year	15
Gross CO_2 reduction (efficiency)	31	24	103	kg/bike*year	15
CO_2 kg emissions (impact) [BSSs >1station]	23	12	86	kg/1,000inh*year	9
CO_2 kg emissions (efficiency) [BSSs >1station]	17	20	31	kg/bike*year	9
Net CO_2 saving			-370	t/year	6

Table 29: Key values of the bike-sharing success in terms of environment

Paris, Barcelona and Lyon save appreciable gross quantities of CO_2 as a result of the transfer of trips from cars to bike-sharing bicycles: 217, 510 and 655 CO_2 tonnes per year respectively. In contrast, the rest of case studies do not save more than 25 CO_2 tonnes per year. Concerning the impact of the CO_2 reduction on population this research concludes that BSSs enable an average gross saving of 80 CO_2 kilograms per 1,000 inhabitants and per year in European cities. Large-scale BSSs such as the ones in Barcelona, Paris and Lyon reach higher levels of impact compared to other BSSs. However, modest BSSs seem to be as competitive as large-scale BSSs when analysing the efficiency of the gross CO_2 reduction. On average European BSSs save 31 CO_2 kilograms per bike-sharing bicycle and year.

As a result of the bicycle redistribution from full to empty stations, Bicing in Barcelona emits more than 140 CO_2 tonnes per year. The rest of case studies with available data do not exceed 10 CO_2 tonnes per year. In terms of “impact”, BSSs emit on average 23 CO_2 kilograms per 1.000 inhabitants and per year, while 17 CO_2 kilograms per bike-sharing bicycle and year are emitted.

Only six case studies had sufficient data to make a balance between CO_2 saved and emitted. In Vienna and Barcelona CO_2 emission due to redistribution represents from 22% to 27% of the gross CO_2 saved. These two BSSs can be considered successful in terms of environment. In contrast, according to information available and calculations described in this dissertation, the BSS of Stockholm instead of reducing CO_2 increases the level of this pollutant.

6.4 Health

6.4.1 Introduction

Decision makers of municipalities may be interested in implementing a BSS to improve health of their citizens. Bike-sharing can affect health in two different ways:

- increasing air quality and
- increasing fitness level.

By the first way, bike-sharing customers who are former car drivers contribute to reduce car traffic and consequently air pollution, what brings public health benefits. By the second way, only customers who ride the bike-sharing bicycle become fitter and consequently healthier, hence benefits are individual.

6.4.2 Increase of air quality

As section 6.3 has explained, former car drivers who decide to make their trips by bike-sharing bicycles stop emitting CO_2, a greenhouse gas that plays a relevant role accelerating climate change. Nevertheless, fossil-fuel motor vehicles do not only emit CO_2 but a collection of air pollutants such as ozone (O_3) nitrogen oxides (NO_x: NO_2 and NO_3), suspended particular matter (PM_{10} and PM_{25}), lead (Pb), carbon monoxide (CO), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC), ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4) (EAA 1999; EPA 2010).

According to the Environmental Protection Agency of the United Stated some of these components can produce diverse harmful effects in public health. "Exposure to ozone for 6 to 7 hours, even at relatively low concentrations, significantly reduces lung function and induces respiratory inflammation in normal, healthy people during periods of moderate exercise. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. Major concerns for human health from exposure to particulate matter are: effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. Excessive exposure to lead may cause anaemia, kidney disease, reproductive disorders, and neurological impairments such as seizures, mental retardation and/or behavioural disorders. Exposition to elevated CO levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks. The health threat from CO is most serious for those who suffer from cardiovascular disease" (EPA 2010). The effects of the above mentioned air pollutants in European public health damage can be observed in Table 30.

Estimated health impact of ambient air pollution in Europe		
Indicator of health deficiency	Proportion of the health deficiency attributed to the pollution	Estimated number of cases (annual)
Cough and eye irritation in children	0.4-0.6%	2.6-4 million
Lower respiratory illness in children	7%-10%	4-6 million
Lower respiratory illness in children causing a medical visit	0.3%-0.5%	17-29 thousand
Ambulatory visits due to respiratory disease	0.2-0.4%	90-200 thousand
Decrease of pulmonary function by more than 5%	19%	14 million
Incidence of chronic obstructive pulmonary disease	3-7%	18-42 thousand
Hospital admissions due to respiratory disease	0.2%-0.4%	4-8 thousand

Table 30: Estimated health impact of ambient air pollution in Europe (EAA 1999)

This dissertation has evaluated the reduction of three relevant pollutants, PM, CO and NOx, in European cities due to bike-sharing operation. The yearly car kilometres saved because of BSSs have been taken as start basis of the calculations (Figure 66). Additionally, it has been assumed that former car trips emitted previously 0.005 PM grams per kilometre, 0.5 CO grams per kilometre and 0.18 NOx grams per kilometre, which are the EU standards of emission of PM, CO and NOx of diesel cars[28] in 2009 (Wikipedia 2010c). By multiplying these two parameters,

[28] The values of pollution of diesel engines have been taken in this section as assumption because most of new car registrations in Europe are diesel powered cars (DieselNet 2008). The EU standards of emission of PM, CO and NOx of gasoline cars are 0.005 PM grams per kilometre, 1.0 CO

the yearly net reductions of PM, CO and NOx have been obtained and are represented in Figure 69.

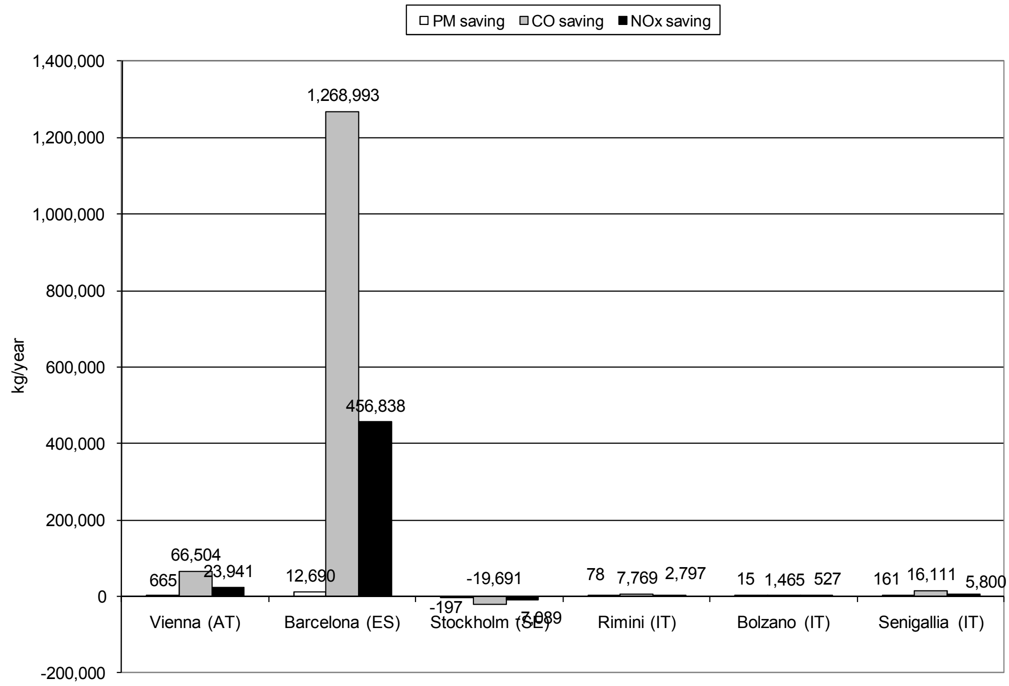


Figure 69: Annual net PM, CO and NOx reduction due to bike-sharing. Data source: Annex 10.1

The normalization of Figure 69 by population and bicycles give as a result Figure 70 and Figure 71, which illustrate the impact and efficiency of the six cases studies with sufficient data for the analysis. According to these two figures, BSSs located in Barcelona and Senigallia are the two case studies with highest levels of net reduction of pollutants in terms of impact and efficiency. Bike-sharing reduces up to 7.8 PM grams, 778.7 CO grams and 280.3 NOx kilograms per 1,000 inhabitants and year (in Barcelona) and up to 2.4 PM grams, 236.9 CO grams and 85.3 NOx grams per bicycle and year (in Senigallia)[29].

grams per kilometre and 0.06 NOx grams per kilometre (Wikipedia 2010c). Therefore, if the reader wants to know the outputs of this section for gasoline powered-cars, he/she just has to multiply the CO results by two and to divide the NOx results NOx by three.

[29] Unfortunately, these results regarding emissions cannot be expressed in term of air pollution concentration. Concentration depends on several factors such as meteorological conditions, physical and chemical properties of the pollutant, location of the emission and turbulence grade of the atmosphere (Arzate Echeverría 2004). Therefore, collective health benefits as a result of bike-sharing operation could not be estimated.

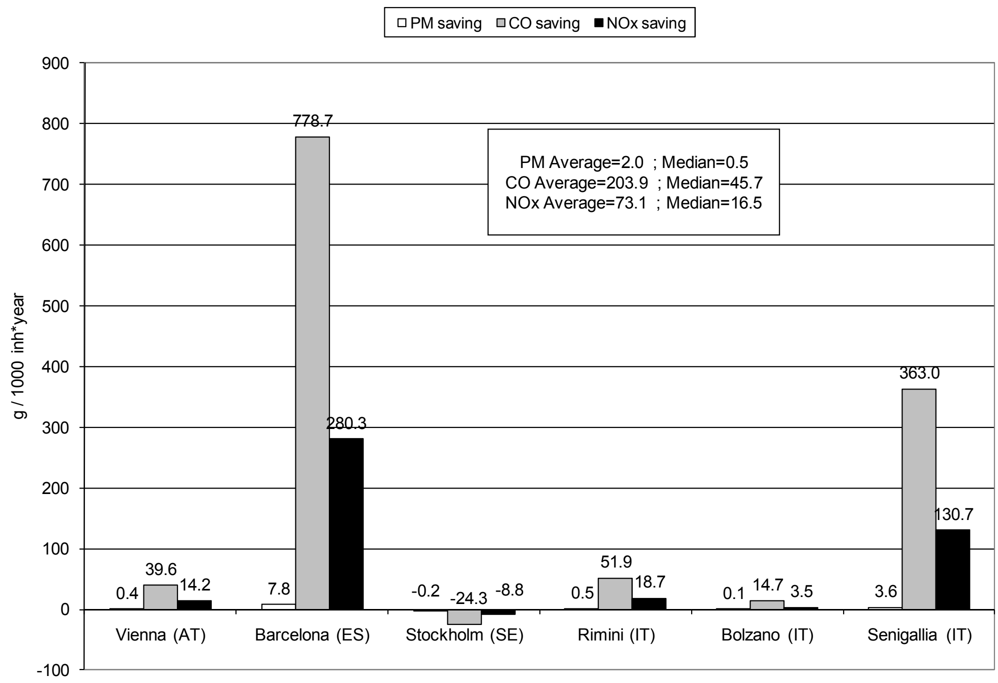


Figure 70: Impact of the annual net PM, CO and NOx reduction due to bike-sharing. Data source: Annex 10.1

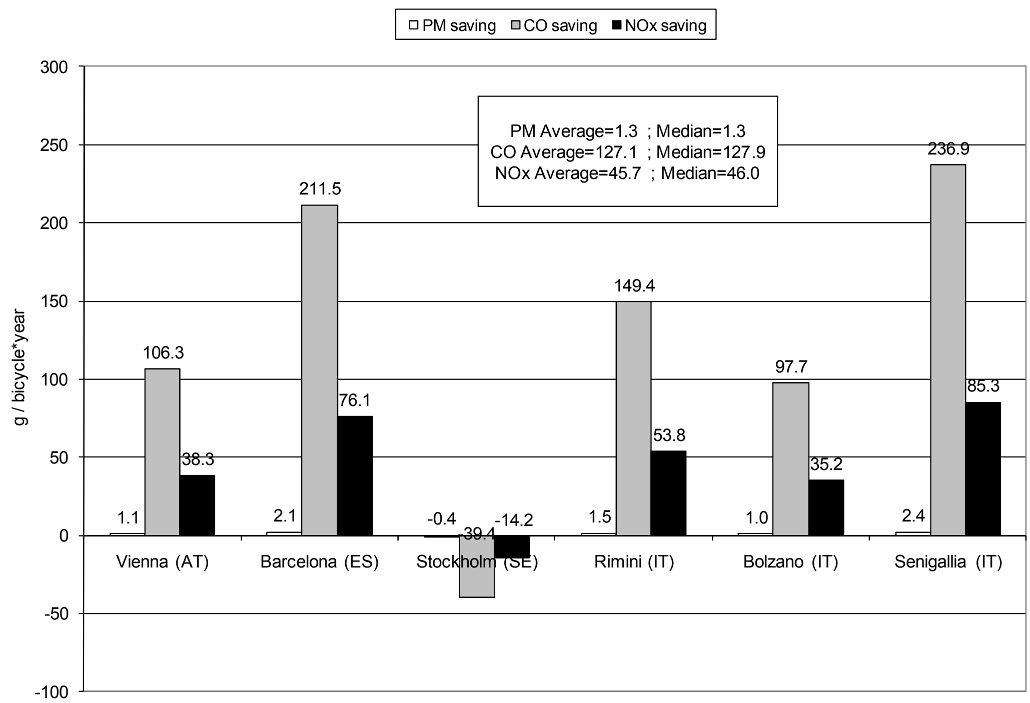


Figure 71: Efficiency of the annual net PM, CO and NOx reduction due to bike-sharing. Data source: Annex 10.1

6.4.3 Increase of fitness level

70% of illnesses are due to a sedentary life stile, according to a study of the Sport College of Cologne (Sassen 2009), and direct health care costs motivated by inactivity have been estimated in USA between €19,766 million and €30,278 million per year. This represents between 2.4% and 3.7% of the total health care costs of the country (Cavill & Davis 2007).

Cycling can cause knee injuries when the saddle is too low and the gears too high, back pain and urethritis or genital anaesthesia for rides longer than 3 hours per day and by poor saddle design and posture. However, researches have stated that “injuries sustained while riding tend to be minor, not require medical attention and where these occur, riding position and correct adjustment of the machine can ameliorate, if not stop, such problems”. Indirect injury through traffic accidents can happen but it has been estimated that “cycling fatalities are overweight by the health benefits by a factor of 1:20” (Cavill & Davis 2007).

The first study that linked physical activity with health improvement was carried out in the 1950s. From then on, a collection of researches have demonstrated the different benefits of physical exercise on all-cause mortality, cardiovascular diseases, blood pressure, diabetes, cancer, obesity, muscles and bones and mental health (Cavill & Davis 2007). But how much exercise is necessary to experiment such positive effects? A study of the London School of Hygiene and Tropical Medicine has revealed that people 45-64 years old who cycle one hour in a week experience less than half coronary heart diseases. On the other hand, the World Health Organization (WHO) has established that people of all kind condition require at least 30 minutes of physical daily activity, i.e. around 3 to 3.5 hours in a week, to acquire relevant health benefits[30] (Cavill & Davis 2007). In fact, according to the Institute for Exercise and Sport Sciences of the University of Copenhagen, cycling 3 hours in a week to go to work reduces all-cause mortality by 39% (L. Andersen et al. 2000). Furthermore, the German Cycling Association has determined that 10 daily minutes of cycling has positive effects on muscles and joints, 20 minutes on immune system, 30 minutes on heart functions, 40 minutes on long-term capacity, 50 minutes on lipid metabolism and 60 minutes on obesity (Sassen 2009)[31]. In terms of energy consumption, although it depends on several factors, especially on body weight of the cyclist, it can be stated that cycling burns at least 5 kilocalories per minute (Cavill & Davis 2007).

Taking into consideration all these facts and figures, this dissertation has evaluated health benefits that bike-sharing users may experience as a result of riding bike-sharing bicycles. Figure 55 has shown in section 6.3.2 the average trip length of bike-sharing rents. Figure 72 shows the period of time that users are riding the bicycle to cover these distances. As we can see, values fluctuate from 12 to 23 minutes per trip, being 18 minutes the average and median value.

[30] These 30 minutes per day can be divided in two or three periods of 15 or 10 minutes respectively.

[31] Regular but not-daily exercise may also have positive effects. For instance, a study of the Cooper Institute for Aerobics Research showed that cycling 3 kilometres in a day three times per week improve physical conditions (Cavill & Davis 2007).

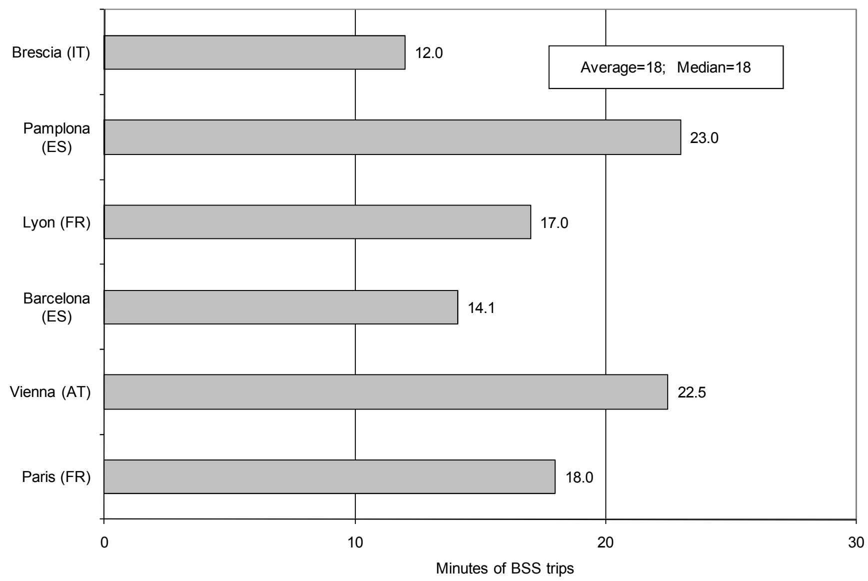


Figure 72: Daily duration of physical activity associated to bike-sharing[32]. Data source: Annex 10.1

If we assume that customers travel by bike-sharing everyday and that they make at least two trips (one to go toward their destination and another one to come back), it would mean that bike-sharing users ride on average 36 minutes per day. Therefore, users that ride everyday the average time might improve muscles and joints, immune system and heart functions thanks to bike-sharing. In two of the six BSSs studied the time riding bike-sharing bicycles exceed 40 minutes, thus those users might improve even long-term capacity as a result of the physical exercise associated to bike-sharing (Figure 73).

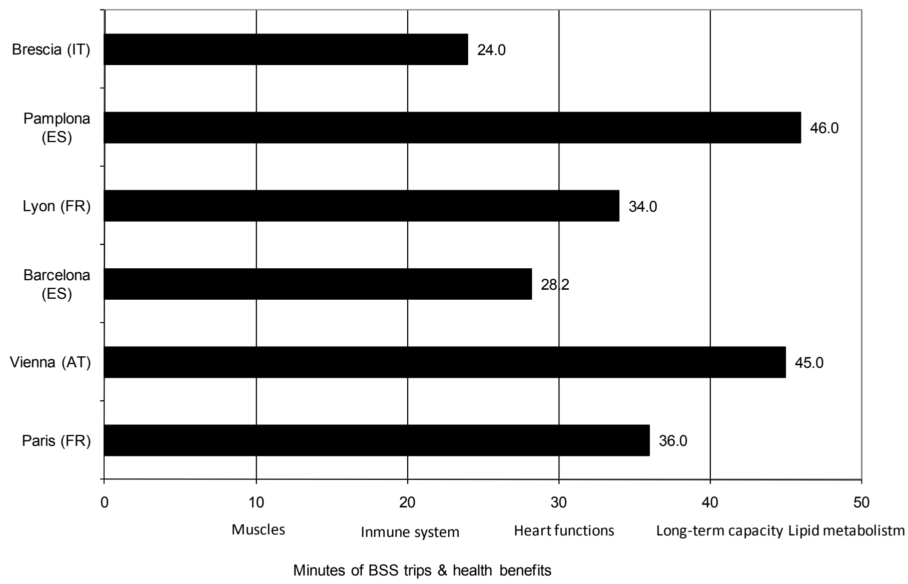


Figure 73: Daily duration of round bike-sharing trips and health benefits associated. Data source: Annex 10.1

[32] Rental time can be longer than trip time because one rent can comprise several trips. For instance, if a user makes a break before returning a bicycle, the time dedicated for the rent is longer than the real time pedalling to cover the distance. We require for this section real time pedalling.

Bicycles of Citybike Wien in Vienna are designed to cover distances no longer than 3 kilometres according to its operator (Sassen 2009). Despite a hypothetic lower level of comfort of bike-sharing bicycles, length of municipal cycling trips seems to be similar to bike-sharing trips. Bike-sharing trips are 18 minutes long; while according to Figure 74 private bicycle trips take on average 19 minutes.

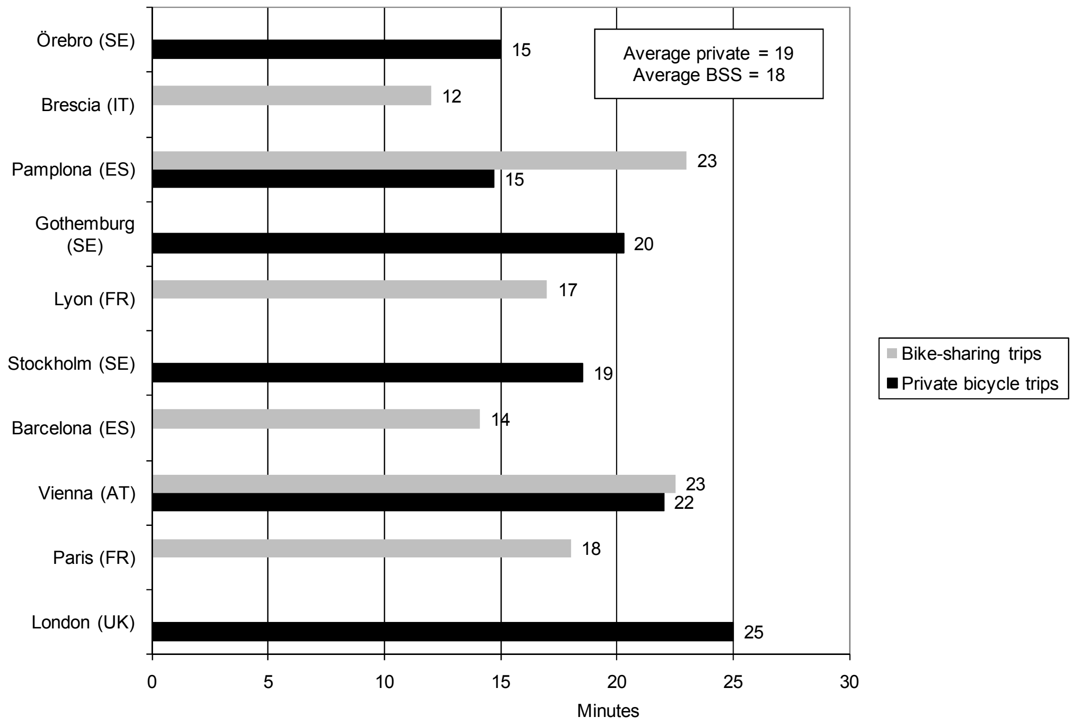


Figure 74: Duration of private bicycle trips. Data source: Annex 10.1

Speed of bike-sharing trips might be slightly lower on bike-sharing bicycles than on private bicycle trips. Figure 75, calculated by dividing the results of Figure 55 by Figure 74, shows the average velocity of bike-sharing trips. The average velocity in bike-sharing trips is only 7 km/h, while the European Cyclist Federation estimates that private bicycles ride in cities have values from 15 to 25 km/h (The European Network for Cycling Expertise n.d.). The lower velocity of bike-sharing trips can be caused by the time that users spent finding a bike-sharing station with available docking point or by the likely inexperience of some users cycling.

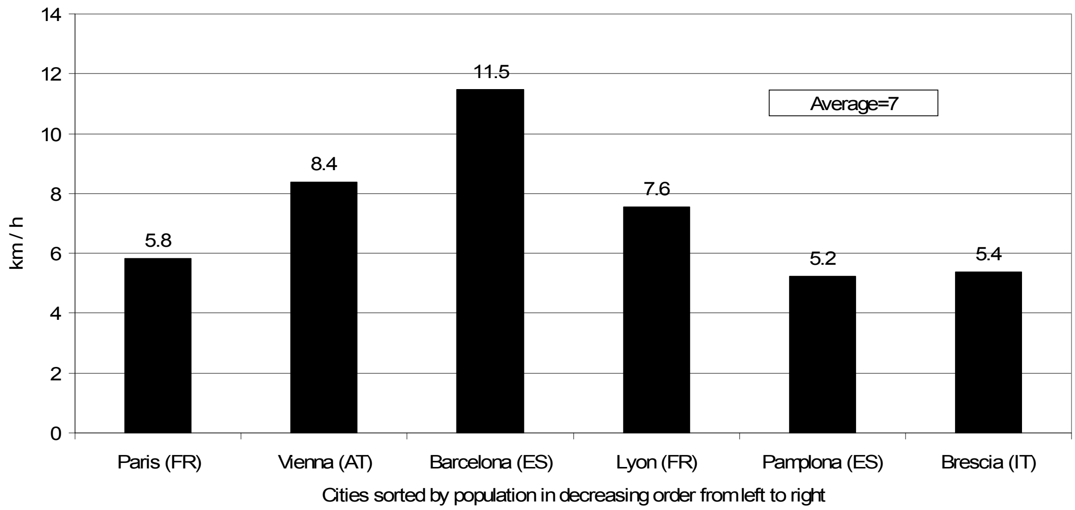


Figure 75: Speed of bike-sharing trips. Data source: Annex 10.1

Apart from the general positive health effects of riding a bike-sharing bicycle, it is interesting to analyze which share of the city population is really affected by this individual benefit of increasing fitness. Figure 76 reveals that on average 3.5% of inhabitants of the case studies are members of the BSSs located in their cities. In 50% of cases this share does not exceed 1.5%.

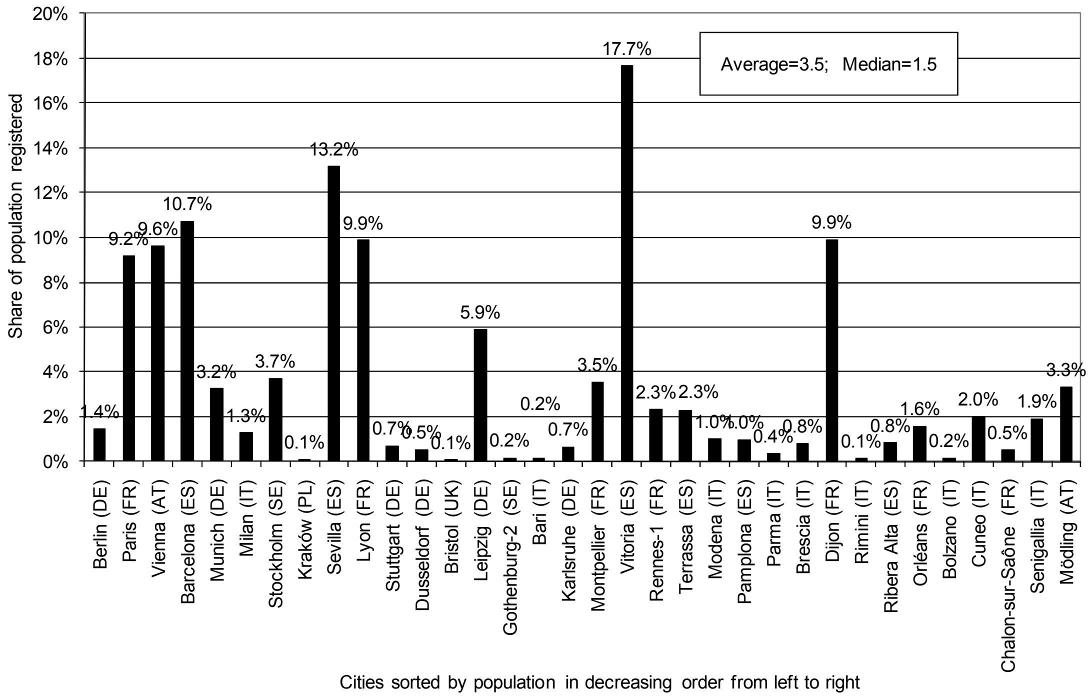


Figure 76: Share of population registered in the BSS. Data source: Annex 10.1

Furthermore, on average 25% of bike-sharing members state that they use the scheme everyday, 20% as median (Figure 77). All this means that 0.9% of population of the cities studied are members who use the system everyday. Therefore, they might be benefited by the individual health effects of physical exercise linked to bike-sharing, assuming that all daily users cycle at least the minimal time described in this chapter (10 minutes).

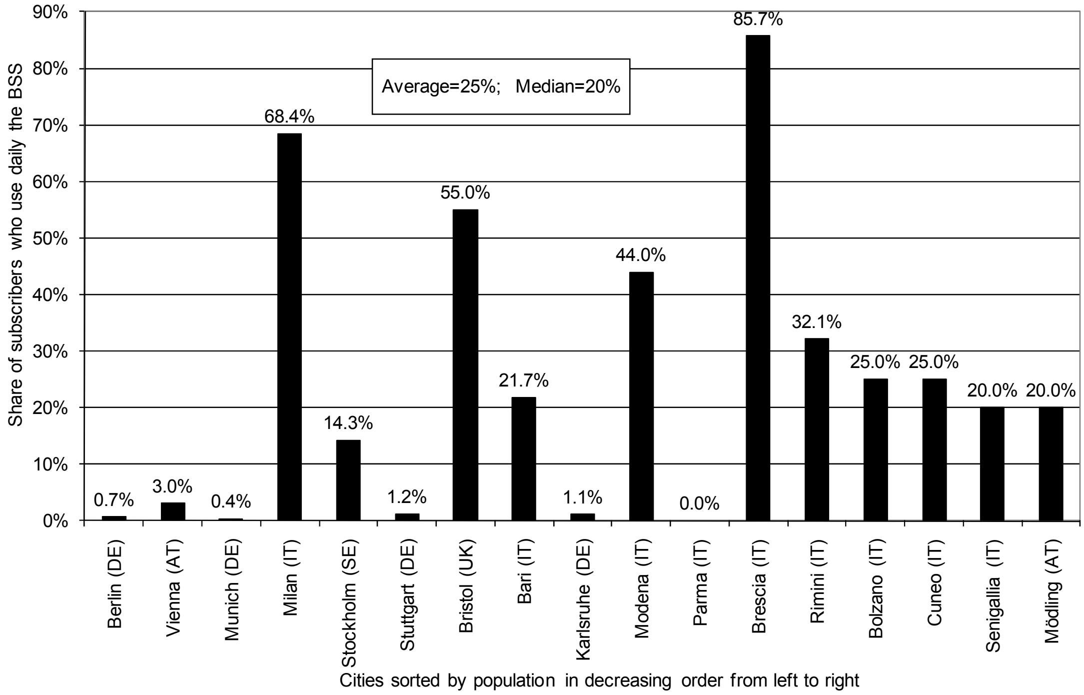


Figure 77: Share of bike-sharing subscribers who use daily the BSS. Data source: Annex 10.1

Bike-sharing improves directly health conditions of their users but this might also has indirect effect on new cyclists that were convinced to travel by bicycle thanks to the “critical mass” created by bike-sharing users, as section 6.2.5 has described. Unfortunately, there are not sufficient data to evaluate this indirect effect.

Those people who improve their physical conditions by mean of bicycles are not the only beneficiary of the promotion of healthy habits, but also public authorities. Healthy citizens require less medical treatments and they are consequently less costly for city councils and ministries. For instance, a Norwegian research found out that the reduction of social cost of the each inactive person that start cycling 30 minutes per day can reach from €3,000 to €4,000, being the social cost of an active person in Norway from €500 to €1,500 (ADFC 2006). Moreover, a study carried out in Odense (Denmark) demonstrates that the increase of 24% of the cycling modal share occurred in the city from 1999 to 2002 caused a decrease of 20% of general mortality among 15-49 years old inhabitants and a decrease of 6% of social security cost, what caused a municipality saving of about €4,500,000 in terms of health costs (T. Andersen & Edrén n.d.). Regarding bike-sharing, in Barcelona a medical study determined that the implementation of Bicing, helps to avoid more than 12 deaths in a year, considering the benefits of physical exercise and the negative impact of the traffic accidents and pollution (Rojas-Rueda et al. 2011).

6.4.4 Summary

Figure 78 shows the main indicators and data used in this dissertation to evaluate the success of bike-sharing in terms of health and Table 31 summarizes the value of most relevant outcomes of the calculations.

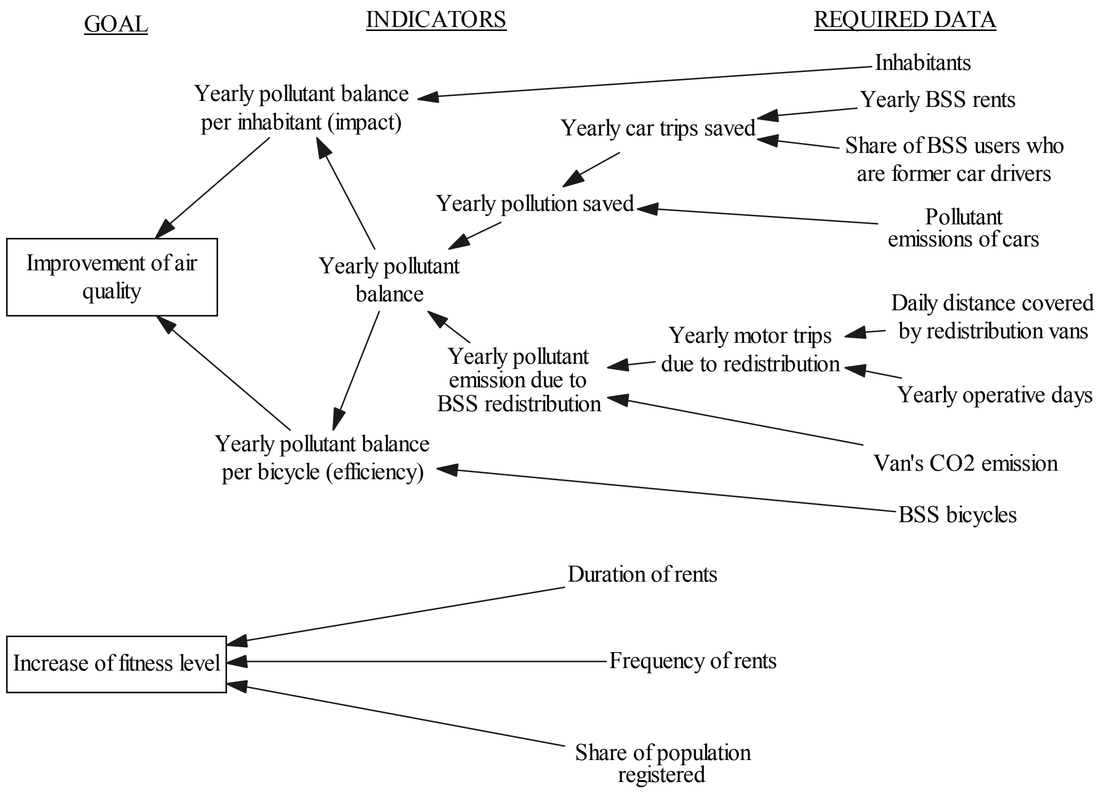


Figure 78: Indicators and data required for evaluating the improvement of health (discontinuous lines represent links of less accurate but relevant complementary indicators)

Indicator	Average	Median	Maximal	Unit	N
Reduction of harmful pollutants					
Net PM saving (impact)	2.0	0.5	7.8	g/1000inh*year	6
Net CO saving (impact)	203.9	45.7	778.7	g/1000inh*year	6
Net NOx saving (impact)	73.1	16.5	280.3	g/1000inh*year	6
Net PM saving (efficiency)	1.3	1.3	2.4	g/bike*year	6
Net CO saving (efficiency)	127.1	127.9	236.9	g/bike*year	6
Net NOx saving (efficiency)	45.7	46.0	85.3	g/bike*year	6
Increase of fitness					
Duration of bike-sharing trips	18	18	23	minutes	6
Population registered in BSS	3.5	1.5	18	%	34
Users who ride daily bike-sharing bicycles	25	20	86	%	17
Population registered and using daily BSS	0.9			%	

Table 31: Key values of the bike-sharing success in terms of health

Bike-sharing contributes to improve public health by improving quality of air. BSSs in Europe reduce up to 7.8 PM grams, 778.7 CO grams and 280.3 NOx grams per 1,000 inhabitants and year and up to 2.4 PM grams, 236.9 CO grams and 85.3 NOx grams per bicycle and year.

BSS can also contribute to improve individual health through fitness of users. Bike-sharing customers ride on average 18 minutes per rent. It means 36 minutes for round trips. Consequently, if these users ride everyday this distance, they would improve muscles and joints, immune system and heart functions thanks to bike-sharing. However, 18% of bike-sharing members use the BSS everyday and 3.5% of population are members of BSSs (on average). Therefore, only 0.9% of population of the cities studied might experience the positive effects derived of physical activity in bike-sharing trips.

6.5 Traffic safety

6.5.1 Introduction

As section 6.2.5 has explained high levels of bicycle use may lead to low number of accidents involving cyclists. Since BSSs can increase directly and indirectly levels of cycling modal share, it could be concluded that they contributes to enforce traffic safety. Thus, those city councils concerned about high levels of accidents involving cyclists can plan to install a BSS to make the municipality safer for soft mobility modes such as bicycles.

This section will study the observed effects of bike-sharing on traffic safety. Not only positive but also negative effects will be analyzed and the success of existing BSSs achieving this hypothetic goal will be evaluated.

6.5.2 Increase of traffic safety

Several studies have affirmed that available data concerning traffic safety contain high levels of under-reporting and misclassification of injuries (Cavill & Davis 2007). Less than half of existing accidents involving pedestrians and cyclists are actually reported and accidents that are reported by the police use to have mistakes in the assessment of the severity of injuries due to lack of medical knowledge (Spence 2003). A “Comparison of Hospital and Police Casualty Data” carried out in United Kingdom in 1996 by the Transport Research of Laboratory assured that if accidents would be right recorded, the real number of serious casualties will increase by 52% (Cavill & Davis 2007). A study of the Traffic Safety Board of Austria (Kuratorium für Verkehrssicherheit) shows that data concerning accidents differ very widely depending on the source (BMVIT 2010). If data are collected in hospitals the number of cyclists involved in accidents can be up to five times higher than the ones reported by police (Figure 79). A likely reason for this is that accidents reported by police imply a traffic offence, while accidents reported in hospitals can be caused out of roads in leisure trips.

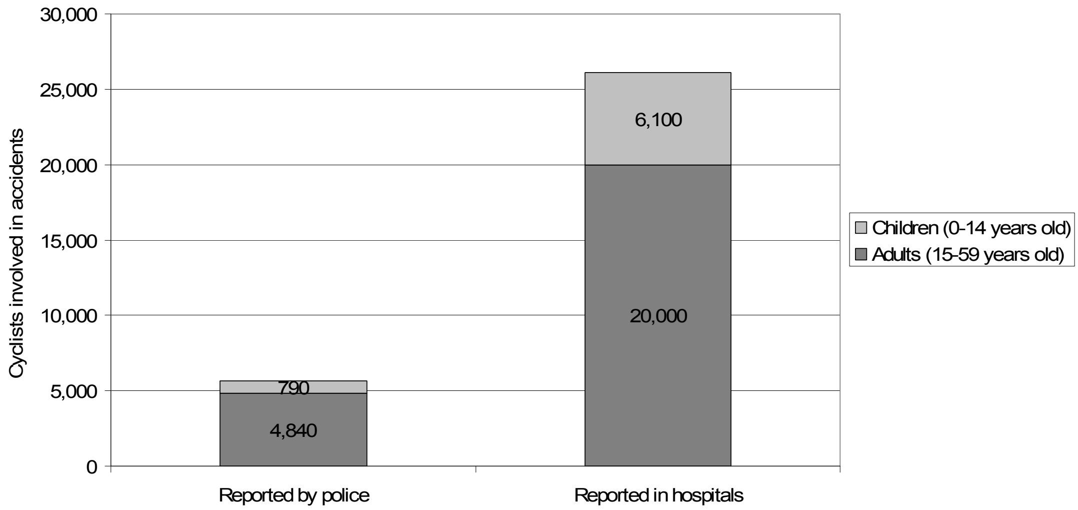


Figure 79: Yearly number of cyclists involved in traffic accidents in Austria, average data from 2002 to 2010. Data source: (BMVIT 2010)

Despite the inaccuracy of data related to traffic causality, different researches have found out that the higher the number of cyclists, the higher the level of safety and less the probability of accident is. For instance, in Germany between 1975 and 1998 cycling increased by 30% and in this period of time the number of accidents with dead cyclists decreased by 66% (Sassen 2009). In Odense, an increase of 24% of cycling between 1999 and 2002 has been linked with a decrease of 20% of the number of accidents involving cyclists (T. Andersen & Edrén n.d.). The correlation pointed by these national researches is confirmed by an international comparison made by the EU-project WALCYNG. As Figure 80 shows, in those countries where citizens cycle more kilometres per day, the risk of accident is lower.

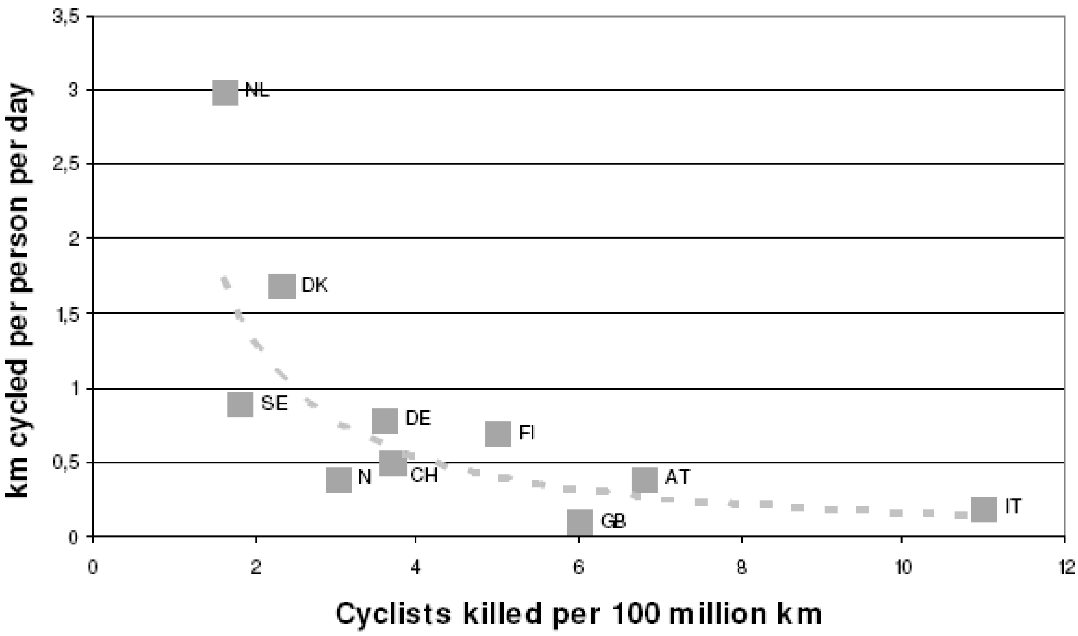


Figure 80: Correlation between accident rates and kilometres cycled per person (ETRA n.d.)

In some cities an increasing number of cyclists have lead to higher levels of accidents in absolute numbers. For example, as Figure 81 shows bicycle use increased in Barcelona, from 2002 to 2007 (year of the launch of the BSS) and as a result a higher number of fatalities was reported. Nevertheless, if we turn absolute values (number of cycle accidents) to relative values (number of cycle accidents per cycle trip), we can see that the effect was actually the opposite. The ratio number of cycle accidents per cycle trip decreased in this period because of the higher use of bicycles and cycling became safer.

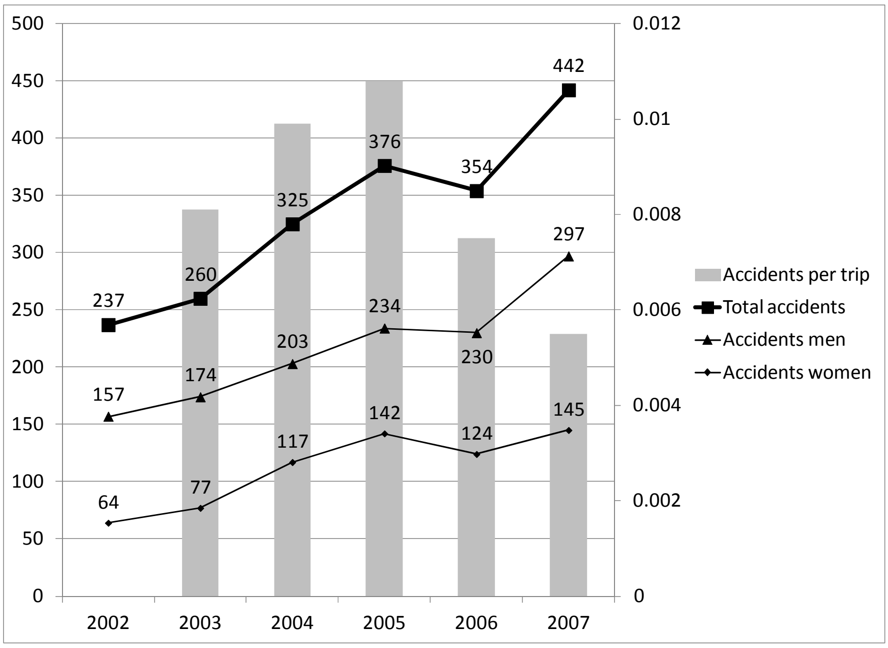


Figure 81: Evolution of the number of cycle accidents and the number of cycle accidents per cycle trip in Barcelona (López 2009)

Due to the lack of available data, it is unfortunately difficult to present accurate figures concerning causality of bike-sharing in traffic safety improvement. As section 6.2.5 has explained, bike-sharing has contributed to increase on average by 8.6% overall cycling just with the inclusion of bike-sharing riders in daily mobility. In particular cases such as Paris, Barcelona and Lyon this increase of cycling modal share has reached 38%, 57% and 92% respectively from the start of the operation of the BSS till 2008. Therefore, it is reasonable to think that the implementation of BSSs has positively influenced to improve cycling conditions and traffic safety in European cities.

This hypothesis can be supported by the example of the city of Paris. Between 2001 and 2006, bicycle modal share increased by 48% while the number of crashes and injuries remains stable (Nadal 2007). In July 2007 Vélib' was implemented and in the first year of operation, 3 customers died and 70 were injured as a result of an accident when riding a bike-sharing bicycle. In this period of time, the number of cycle accidents involving cyclists with both private and bike-sharing bicycles increased by 7% compared to the previous year (Sassen 2009). If we just take in account this figure, bike-sharing could be seen as a cause of accidents. However, it is highly advisable to turn these absolute values to relative ones and take in account an additional data: cycle trips increased by 25% in the same period too (Sassen 2009).

Therefore, although the absolute number of accidents increased after the implementation of the BSS, relative traffic accident figures decreased and from this approach cycling became actually safer in Paris. Figures of later periods such as the balance of year 2008, shows similar results. Despite the number of cyclists injured increased by 25% in 2008 with regard to 2007, the number of cycle trips increased by 50% in the same period (Dargent 2009). It is relevant to remark that many accidents occurred in Paris involved inexperienced riders or careless tourists according to the authorities (Bremner 2008).

Despite these evidences, it is difficult to quantify the precise influence of bike-sharing on the improvement of traffic safety. As section 6.2.5 has exposed, BSSs have been implemented sometime together with other mobility policies and mobility plans. Therefore, BSSs were not the only cause of the lower accident risk in some cities. Complementary instruments such as awareness campaigns could also have influence in this success in reducing traffic accident.

6.5.3 Summary

Figure 82 shows the main indicators and data that may be necessary to evaluate the success of bike-sharing in terms of improvement of traffic safety.

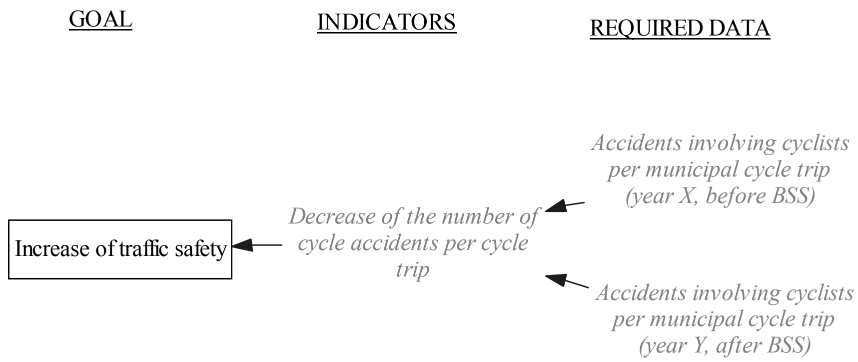


Figure 82: Indicators and data required for evaluating the increase of traffic safety (items highlighted with grey and italic characters means that they are necessary for the evaluation but they were not calculated because of unavailability of data)

Although very few data concerning accidents were available some conclusions can be remarked. Data related to traffic causality can widely differ, but different researches have concluded that the higher the number of cyclists, the higher the level of safety and less the probability of accident. Since bike-sharing has contributed to increase cycling (section 6.2.5) and since this section has shown that a higher number of cyclist leads to higher levels of traffic safety, it can be assumed that the implementation of BSSs has influenced to make cities safer for cycling. For example, although the absolute number of cycle accidents increased after the implementation of the BSSs in Barcelona and Paris, the number of accidents per trip decreased. Precise influence of bike-sharing on improving traffic safety could not be quantified because of lack of data and because BSSs were sometimes implemented together with other mobility actions that could affect this success.

6.6 Economy

6.6.1 Introduction

The implementation of a BSS can be justified by city councils as a way to stimulate the economy of a municipality and their citizens. Four different ways of stimulation of municipal economy have been identified in this dissertation: 1) job creation (section 6.6.2), 2) reduction of household costs (section 6.6.3), 3) promotion of tourism (section 6.6.4) and 4) improvement of city image (section 6.6.5). On the other hand, BSSs can generate externalities. These side costs have to be taken into account to evaluate the contribution of BSSs for municipal economies (section 6.6.6). Although very few data concerning economic impacts of BSSs are currently available, this section shows some hints that explain effects of bike-sharing in these four economic fields.

6.6.2 Job creation

Figure 83 shows the number of employees hired by BSSs in the case studies where data were available. This value varies widely from 1 to 500 as a consequence of the differences of features and sizes of BSSs. On average, one could say that BSSs contribute to create about 37 jobs per municipality.

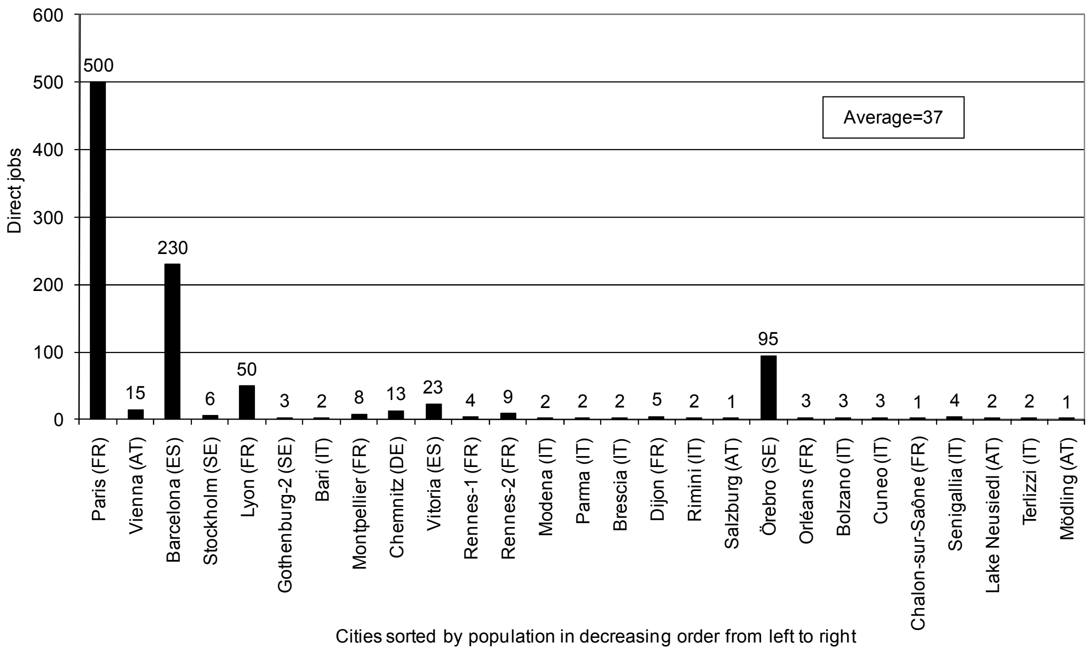


Figure 83: Direct jobs generated by BSSs. Data source: Annex 10.1

The impact of BSSs on the job creation of cities can be estimated by normalizing Figure 83 by city population. As Figure 84 reveals, cities with large-scale BSSs such as Paris, Lyon and Barcelona create between 0.08 and 0.23 employments per 1,000 inhabitants, while the maximum level of employment creation regarding city population corresponds to Örebro (0.7

jobs per 1,000 inhabitants). BSSs generate on average 0.07 jobs per 1.000 inhabitants and the median is 0.03.

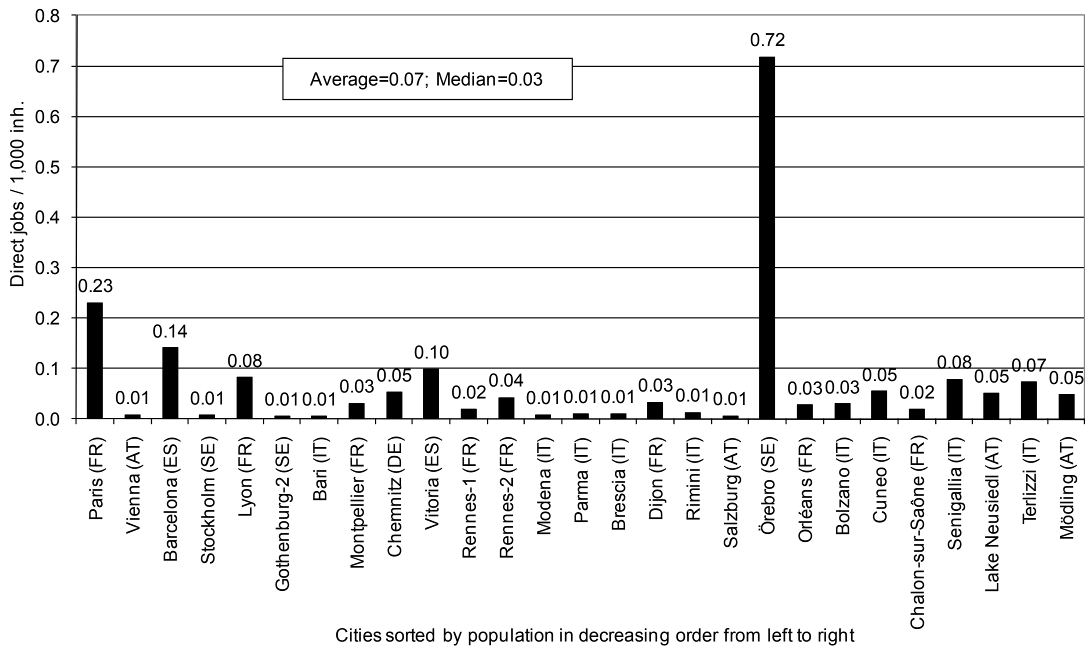


Figure 84: Direct jobs per 1,000 inhabitant generated by BSSs. Data source: Annex 10.1

According to Figure 85, on average European BSSs create 0.04 jobs per bicycle, while the median is 0.02 jobs per bicycle. The BSSs located in Chemnitz and Terlizzi seem to be the most efficient case studies (0.1 jobs per bike-sharing bicycle). It is important to remark that, in terms of economic viability of BSSs, a high number of employees per bicycle is not efficient. However, this section does not analyze the viability of BSSs, but the benefits of BSS for local economies. Therefore, if the goal of a BSS is to create jobs, a high number of jobs generated with a low investment in bicycles can be considered as "efficient".

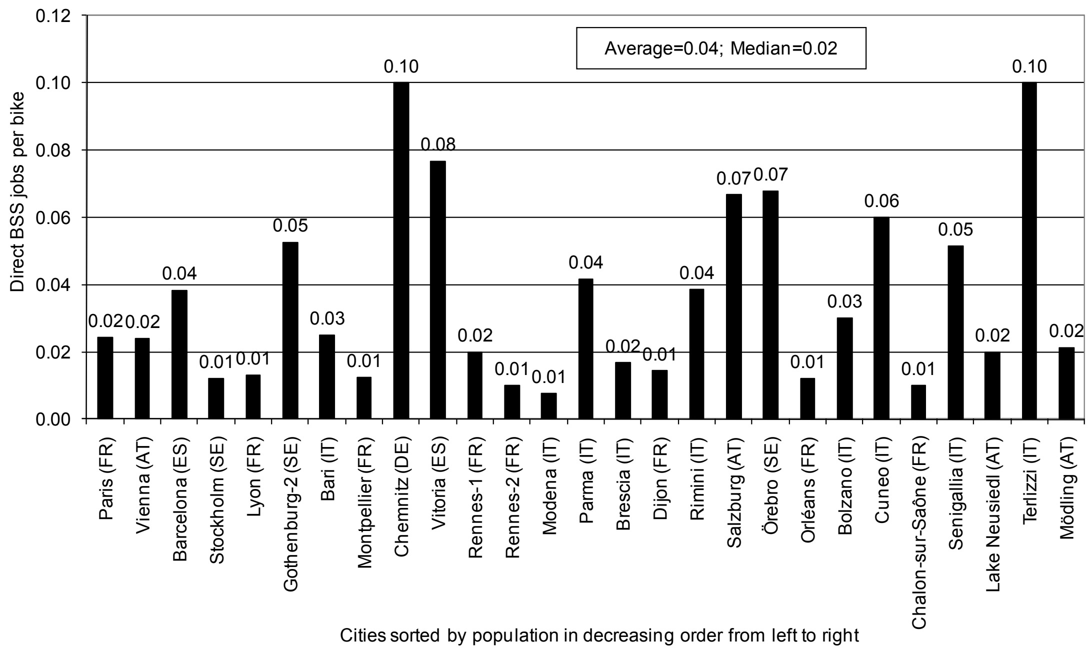


Figure 85: Direct jobs per bicycle generated by BSSs. Data source: Annex 10.1

The BSS of Örebro was launched in 1978 and "unemployed young people recycled old bicycles that were scrapped from residential real state companies and made them available for renting" (Petersen & Robèrt 2009). Therefore, one of the main goals of this BSS was to create employment in the municipality. Also in Chemnitz the social impact of the BSS was one of the priorities. According to the OBIS project, "the bikes used in the system are inexpensive city bikes with custom parts such as fenders or advertisement boards and those parts are made in workshops that qualify people for the first labour market" (Büttner 2010). Other examples of BSSs with social goals out of the list of case studies of this dissertation are the "kommunale Fahrrad" of Bremen and Wedel, which were introduced to provide education and job for unemployed people within the municipality. The bicycles of the City Bikes of Copenhagen were repaired by the Rehabilitation Agency of Copenhagen where around 30 workers receive a 6 months course to learn how to restore bicycles. 80% of these employees find a job after taking part in this course (Sassen 2009).

A short study of the Ministry of Environment of Austria has evaluated the impact of bike-sharing on direct employment creation on the social economy of the country. In the case of Austria, the BSSs Citybike Wien, Freiradl and Nextibke Burgenland produced €1,900,000 of direct added value and 19 direct jobs through the investment on construction of stations and electronic and software for the specific bicycles in 2009 (Thaler & Eder 2009).

Apart from direct employments, bike-sharing generates indirect jobs in economic activities associated to BSSs. In Paris, for instance, sales of bicycles have increased by 15% from the start of Vélib' (Sassen 2009) and sales of related products such as helmets have risen too (NYC Department of City Planning 2009). As a result, economic growth has been stimulated and public authorities have collected additional sale tax revenues (NYC Department of City Planning 2009).

6.6.3 Reduction of transport costs for households

Taking into account the rising price of oil and energy, the consequent increase of travel costs with individual and collective vehicles as well as the low usage fees of BSSs (section 5.6.1), a notable part of customers may travel by bike-sharing because it is more economic than other transport modes. Figure 86 confirms this hypothesis. The figure reveals that from 6% to 20% of bike-sharing subscribers argued that the low price of the service is the main reason for using the system. On average 22% of subscribers have this opinion (16% as median). Furthermore, in Paris 62% of interviewees of a user survey cited Vélib' "as a way to reduce transport costs" (NYC Department of City Planning 2009) and in Vitoria (Spain) 73% customers stated that they use the system "because this is totally for free" (Diario noticias de Álava 2010).

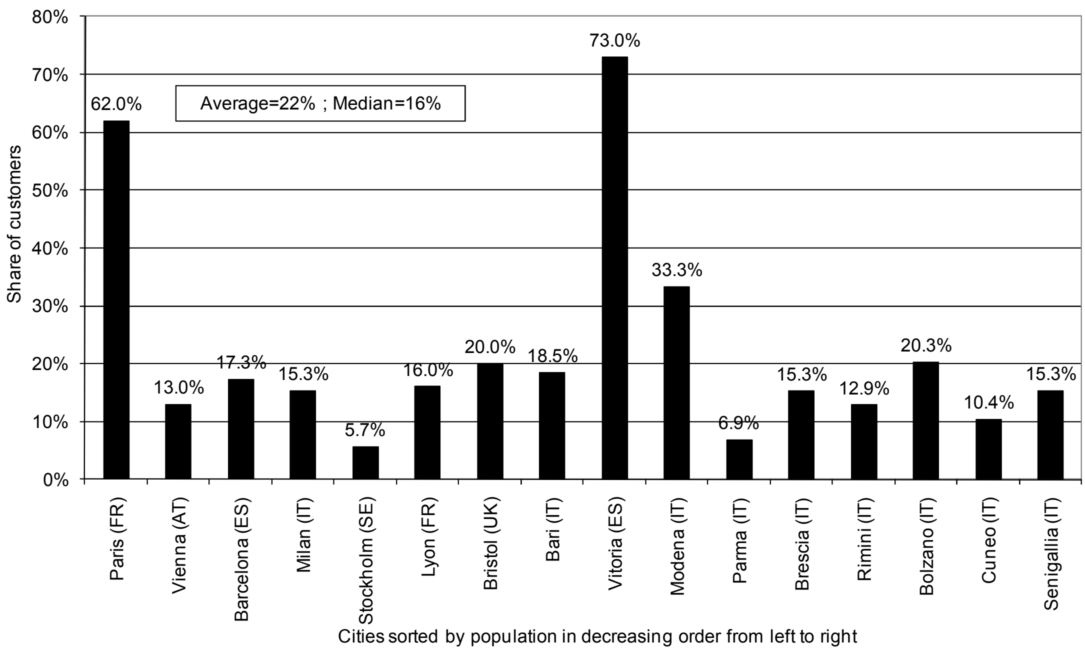


Figure 86: Share of customers that state that the main reason for using the BSS is because it is cheaper than other transport modes. Data source: Annex 10.1

As section 5.6.1 has explained, 24% of analyzed BSSs charge the service from the first minute of rent, while 27% offer unlimited rental time free of charge and 49% offer a delimited period of time, which normally goes from 30 to 60 minutes, without charge. If we analyze this last group, we can observe that the share of trips fitting with the period of time free of charge is similar in all BSSs (Figure 87). On average, 91% of rents do not imply any cost for the customers, which confirm that bike-sharing users rent the bicycles mainly because it is a free service.

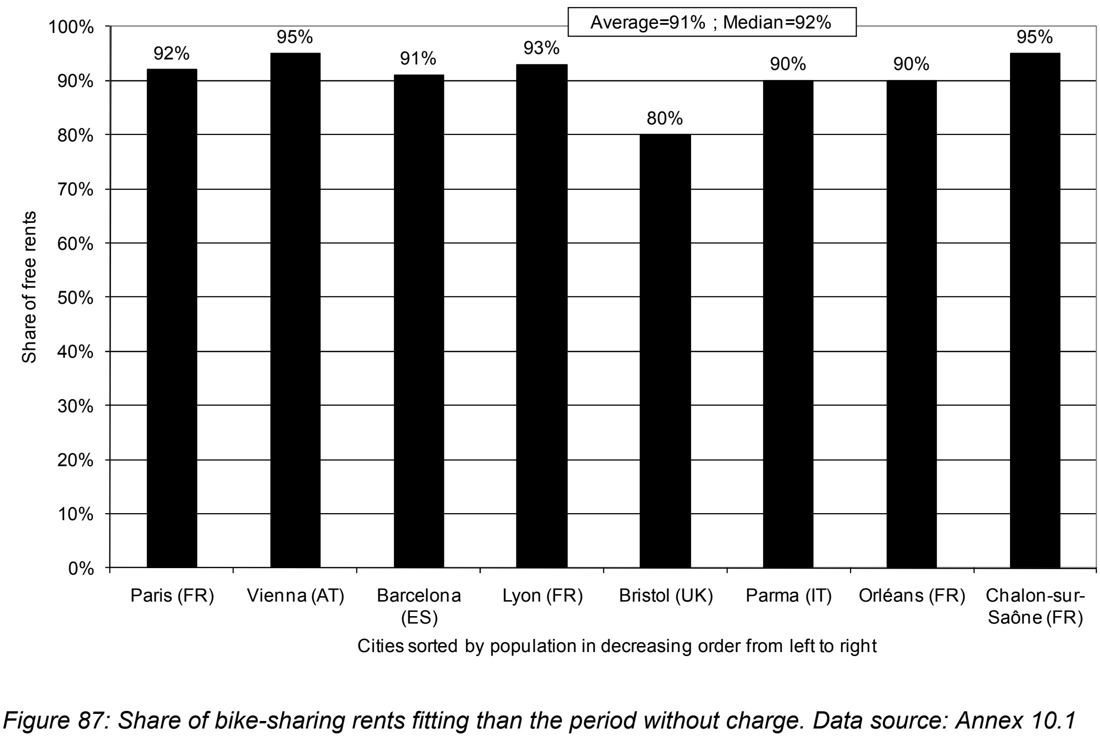


Figure 87: Share of bike-sharing rents fitting than the period without charge. Data source: Annex 10.1

6.6.4 Increase of tourism attractiveness

In Austria, tourism linked to cycling activities represented in 2009 5.65% of the total added value of tourism dedicated to accommodation and catering. Furthermore, cycling produced €317 million of added value in tourism economy what represents 7,616 equivalent full-time jobs and 53% of the whole added value of cycling in all economic sectors (Thaler & Eder 2009).

Therefore, market potential of tourists interested in cycling has a significant relevance in local economies and BSSs can be used as a way to promote this kind of tourism. In particular, bike-sharing may contribute to attract tourism by providing an alternative or complementary way to visit a city.

Unfortunately, no official data concerning the number of tourists using BSSs were found and estimations or indicators of impact of bike-sharing encouraging tourism are not available. However, some conclusions can be extracted from the role and influence of bike-sharing on tourism. For example, as section 5.2.3 has shown, although BSSs rarely define themselves as "tourist oriented", some features can indicate whether tourists are one of their target groups: the availability of short-term subscriptions and flat rates.

- Short-terms subscriptions are memberships that mainly expire in 1 or 7 days. This subscription fee could be more attractive for tourists, because visitors are only temporally established in the city and they do not want to be linked to the BSS when leaving the place. 41% of the BSSs studied offer this kind of subscription (section 5.2.4).
- Flat rate tariffs (including unlimited free systems) encourage long rents of bike-sharing bicycles for a very cheap price. For instance, BSSs operated by nextbike offer one hour of rent for €1 and 24 hours for €5 or €8, depending on the city (Castro 2009; Gröper 2009). This fee is appreciated by tourists that make a one-day excursion for visiting a city or a rural area. 27% of BSSs analyzed in this dissertation are totally free and 65% have flat rates up to the whole day (section 5.6.1).

The influence of tourists is determinant in some cases. For example, in Barclays Cycle Hire in London, opened in 2010, 61% of users subscribed just for one day and 5% for one week, i.e. 66% are short-term subscriptions (Figure 88). If we assume that most short-term subscriptions are signed by tourists, we could conclude that 66% of users of the Barclays Cycle Hire in London are tourist, which demonstrates the high influence of tourism in some BSSs.

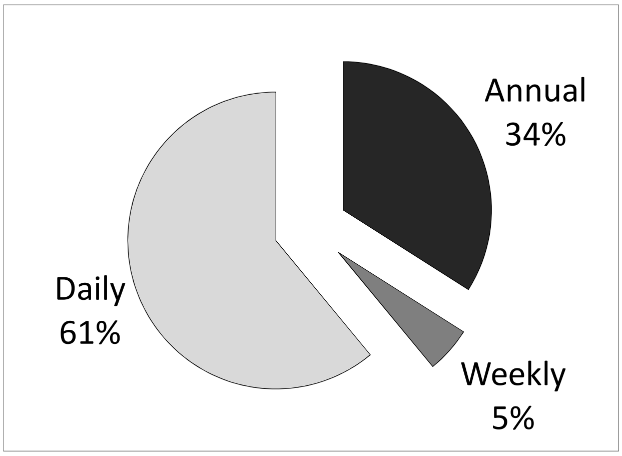


Figure 88: Share of different kinds of subscription in Barclays Cycle Hire in London. Data source: (Georgiou 2010)

This statement is confirmed by the analysis of the case studies of this dissertation. As Figure 89 shows, only four BSSs that offer short-term subscriptions have data available regarding the share of customers that applied for a short subscription. The results are very different from one BSS to another. In Orleans daily and weekly subscriptions in 2008 did not represent more than 4% of the total, while in Paris 99% of people who registered in Vélib' in this year had a subscription for a week or a day.

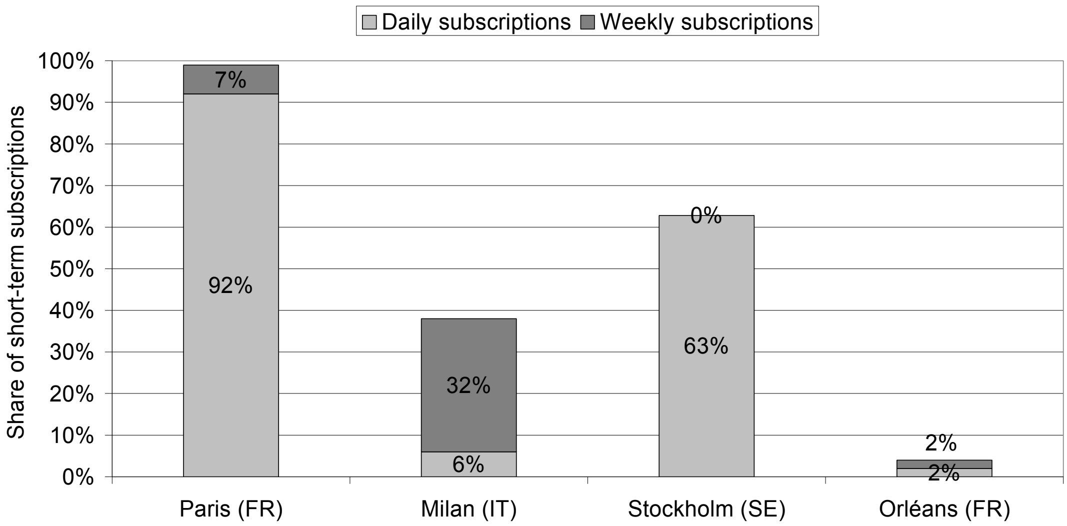


Figure 89: Share of bike-sharing customers with short-term subscriptions. Data source: Annex 10.1

On the other hand, there are factors that can make difficult the use of BSSs for tourists. For instance, those BSSs that do not accept international bank cards but only national bank cards, as it happens in Lyon (Vélo'v 2010), could be a barrier for foreigner visitors. Vélib', in Paris, do not accept American credits cards and some complaints of visitors have been reported (Sassen 2009).

6.6.5 Improvement of city image

Although it is difficult to quantify the effect of BSSs on city image, some examples give us hints about the change experienced. For instance, the goal of the introduction of Vélo'v in Lyon was "to change the balance between different transport modes and to reduce pollution but also to change the image of the city". And according to Jean-Louis Touraine, the mayor of Lyon, it has achieved it because "Vélo'v has changed radically the image of the city and one can see people riding bicycles everywhere" (Anderson 2007). A survey carried out by the agglomeration of Grand Lyon in 2006 confirms this statement. 90% of the members of the BSS think that "Vélo'v was a good initiative" and they confirmed that the BSS improved the "image and the quality of life of the city" (Sassen 2009).

Paris, thanks to the implementation of Vélib' in 2007, "has left behind its previous image of car city to become the world capital of bike-sharing and it is nowadays a pilgrimage point for city majors that are interested to run a similar system" (Sassen 2009). The BSS won in 2007 the British Guild of Tourism Writers' "Best Worldwide Tourism Project" award and it is reasonable to think that such awards have contributed to spread a good image of the project (NYC Department of City Planning 2009).

National and international newspapers, websites and television channels have covered the launch and operation of Bixi, the BSS of Montreal (Canada). The BSS was featured by Times Magazine as one of the 50 best inventions of 2008. Moreover, New York is planning to implement a BSS and the feasibility study has considered the improvement of city image as a benefit of the BSS (NYC Department of City Planning 2009).

The "green" image associated with bike-sharing may contribute to stimulate investments of private sectors in the city or in the BSSs. According to the final report of the EU-project SpiCycles, "the big success of bike sharing created a big image effect. Some cities have established themselves as national frontrunners and showcases for modern cycling policy, as did the operators. Countries with no or very little bike sharing schemes should use these possible image effects to find financial support or a kind of patronage".

6.6.6 Externalities

A research of the Autonomous University of Barcelona (Bea Alonso 2009) reveals that Bicing has side costs associated with the redistribution of bicycles using motor vehicles and with the occupancy of space in Barcelona.

According to this study the negative externalities of the motor trips generated because of redistribution of bicycles cost €2.1 million in 2009 for the city. Some aspects such as accidents, noise, pollution, greenhouse gases or time were considered in the research. The public space occupied by the BSS in Barcelona was also included in the study. Since the BSS does not pay currently anything for this space, an alternative private exploitation such as small shops, bar terraces or even parking lots could provide revenues for the municipality to the value from €3.67 million to €7.35 million.

Therefore, municipalities have to take into account externalities when making the cost-benefit analysis of a BSS. Direct and indirect effects of the system are relevant and they have to be studied before implementing a BSS (section 8.2).

6.6.7 Summary

Four different ways of stimulation of municipal economy have been identified in this dissertation: job creation, reduction of household costs, promotion of tourism and improvement of city image. Figure 90 shows the main indicators and data that were used in this section to evaluate the success of bike-sharing in terms of economy and Table 32 summarizes the main outcomes of the calculations.

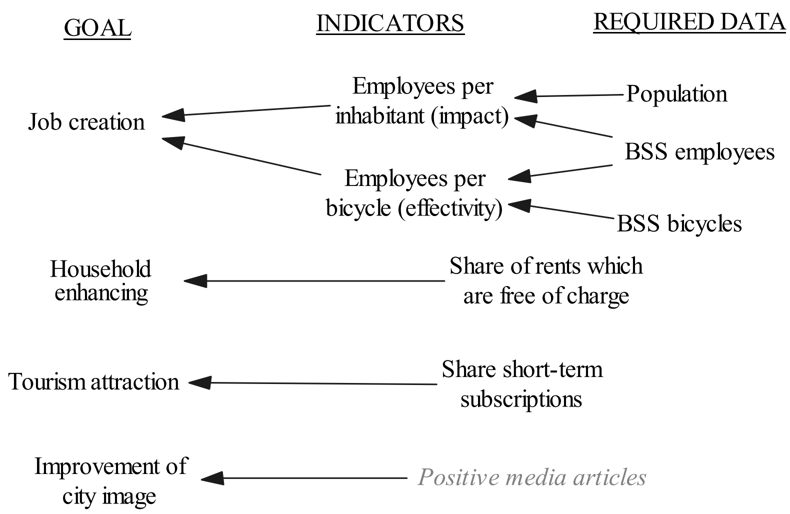


Figure 90: Indicators and data required for evaluating the improvement of municipal economy (discontinuous lines represent links of less accurate but relevant complementary indicators, items highlighted with grey and italic characters might be necessary for the evaluation but they were not calculated because of unavailability of data)

Indicator	Average	Median	Maximal	Unit	N
Job creation					
Jobs created (impact)	0.07	0.03	0.72	jobs/1,000inh	27
Jobs created (efficiency)	0.04	0.02	0.10	jobs/bike	27
Reduction of transport costs for households					
Users that use bike-sharing because is cheaper	22	16	73	%	16
Rents which are free of charge	91	92	95	%	8
Increase of tourism					
Short-term subscriptions	51	50	99	%	4

Table 32: Key values of the bike-sharing success in terms of economy

BSSs dedicated for social goals contribute to create up to 0.7 jobs per 1,000 inhabitants. BSSs create from 0.08 and 0.23 jobs per 1,000 inhabitants in large-scale BSSs such as the ones installed in Paris, Barcelona and Lyon. On average 0.07 jobs per 1,000 per inhabitant and 0.04 jobs per bike-sharing bicycle are created as a result of the implementation of BSSs.

The average share of bike-sharing subscribers that argued that the low price of the service is the main reason for using the system is 22%. On average, 91% trips of BSSs with limited free rental time fit this limit and in this way 91% of trips have no cost for customers. This confirms that bike-sharing users rent the bicycles mainly because it is a free service.

Although BSSs rarely define themselves as “tourist oriented”, there exist some features that can indicate whether tourists are one of the target groups. The existence of short-term subscriptions and flat rate fee are two indicators of tourism oriented BSSs. The influence of tourism is determinant on some BSSs. For example, in Barclays Cycle Hire in London, 66% of subscriptions are short-term and therefore presumably for tourists or leisure mobility and in Paris short-term subscriptions reach 99% of the total memberships.

According to the final report of the EU project SpiCycles, “the big success of bike sharing created a big image effect”. The “green” image associated to bike-sharing can also contribute stimulate investments of private sectors in the city or in the BSSs. Unfortunately, this dissertation could not quantify this likely impact.

In Barcelona, the side costs of externalities associated with the redistribution of bicycles and the occupancy of space reach up to €2.1 million and €7.35 million respectively.

6.7 Economic viability

6.7.1 Introduction

The chapter 5 of this doctoral thesis has shown the impact of bike-sharing so far on improving mobility, environment, health, traffic safety and economy in European cities. However, the success of a BSS has also to be evaluated in terms of economic viability of the project. The economic sustainability is an essential requirement to prolong the mentioned positive effects of bike-sharing as long as possible. For instance, if a BSS is successful reducing car traffic, but it loses money each year so that the monetary deficit causes the close of the BSS, then mobility success will not be durable and consequently the global success will be limited. Well-proportioned balance between costs and incomes is required to guarantee the economic stability and maintain long-term positive effects in the society. Section 6.7.2 will analyze the different costs that BSSs have to face, section 6.7.3 will describe the likely revenues that can fund BSSs and section 6.7.4 will present the balance of both concepts.

6.7.2 Costs

Bike-sharing costs can be divided into two categories:

- implementation costs and
- running costs.

Implementation costs are those that have to be paid only once, while running costs are those costs that have to be paid periodically. As Figure 91 shows, the main items of the implementation costs of Bicing in Barcelona are and installation of bike-sharing stations (70%)

and the purchase of bicycles (17%). The set-up operations, the communication and the administration cost represent the other 13%.

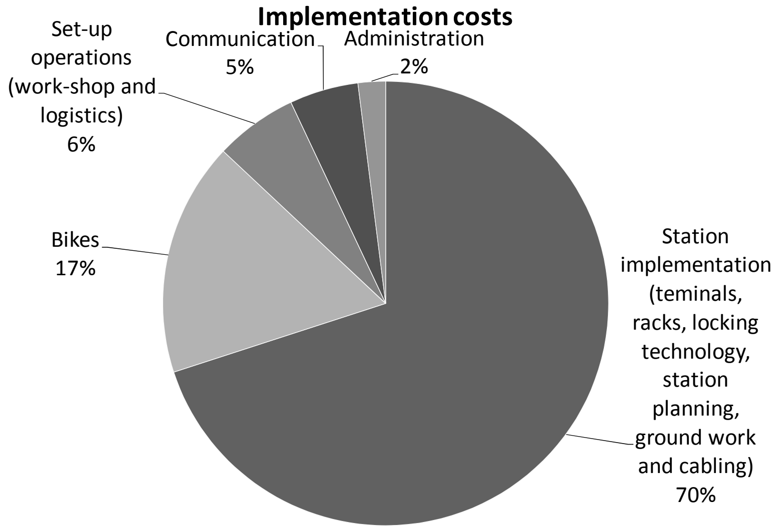


Figure 91: Allocation of implementation costs of Bicing in Barcelona. Data Source: (Büttner et al. 2011)

The cost of a bike-sharing station can vary very widely depending on the model. According to representatives of the different European BSSs interviewed by the project OBIS, the unitary cost of a bike-sharing station ranges from around €600 to €60,000. The average cost of a bike-sharing station is about €12,600, while stations of 50% of models do not exceed €3,800 (Figure 92). In contrast, prices of bicycles seem to be rather more similar between systems. As Figure 93 reveals, one bicycle can cost from €110 to €2,000, while the average price reaches €540.

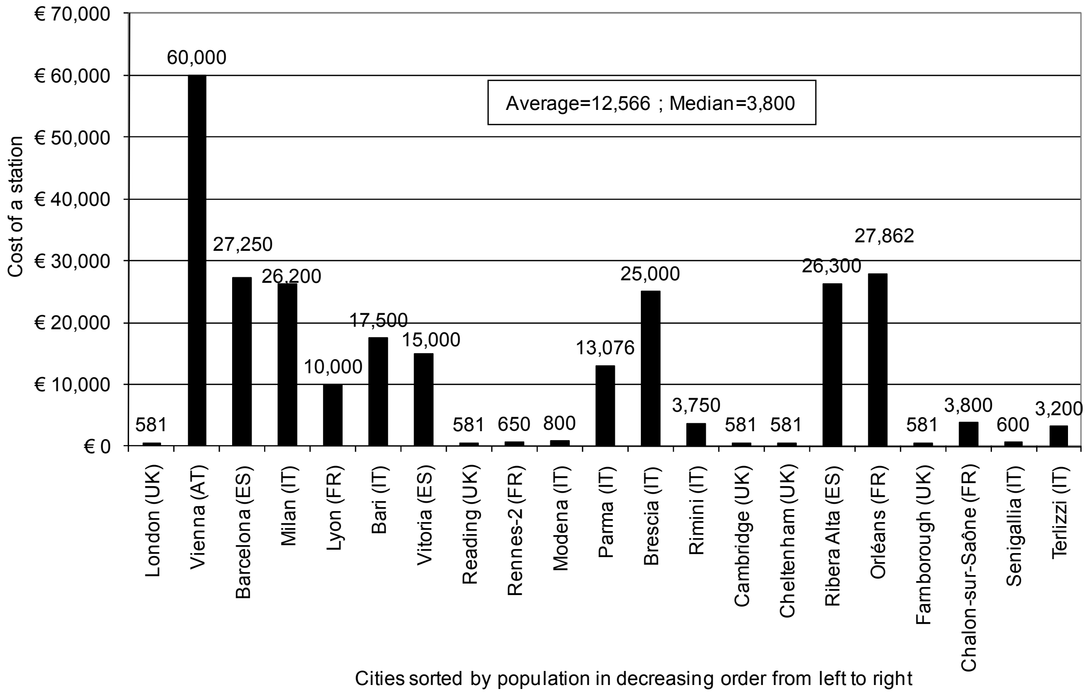


Figure 92: Unitary cost of a bike-sharing station. Data source: Annex 10.1

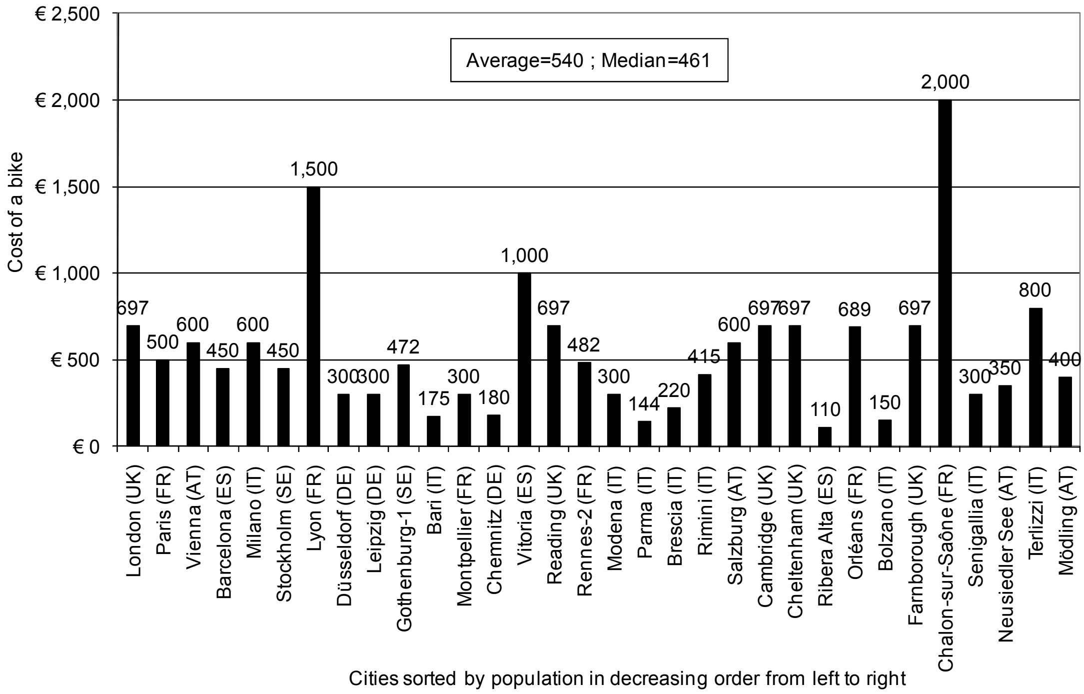


Figure 93: Unitary cost of a bike-sharing bicycle. Data source: Annex 10.1

When representatives of the bike-sharing operators are directly asked to provide an estimation of the total running costs per bicycle and year of their BSSs, the result is the following: annual running costs range from €67 to €1,700 per bicycle, while the average is €730 per bicycle and year and the statistical median €700 (Figure 94). Nevertheless, recent publications point out that total running costs of high technology equipped BSSs might be higher than the values shown in Figure 94 and they might reach from €1,500 to €2,500 per year and bicycle (Sassen 2009). Moreover, depending on the source and on the BSS, both implementation and maintenance costs have been estimated to be €2,000 to €3,000 per bicycle and year (Beroud 2010; Del Jésus 2010) or even between €2,800 to €3,500 per bicycle and year (DeMaio 2009b).

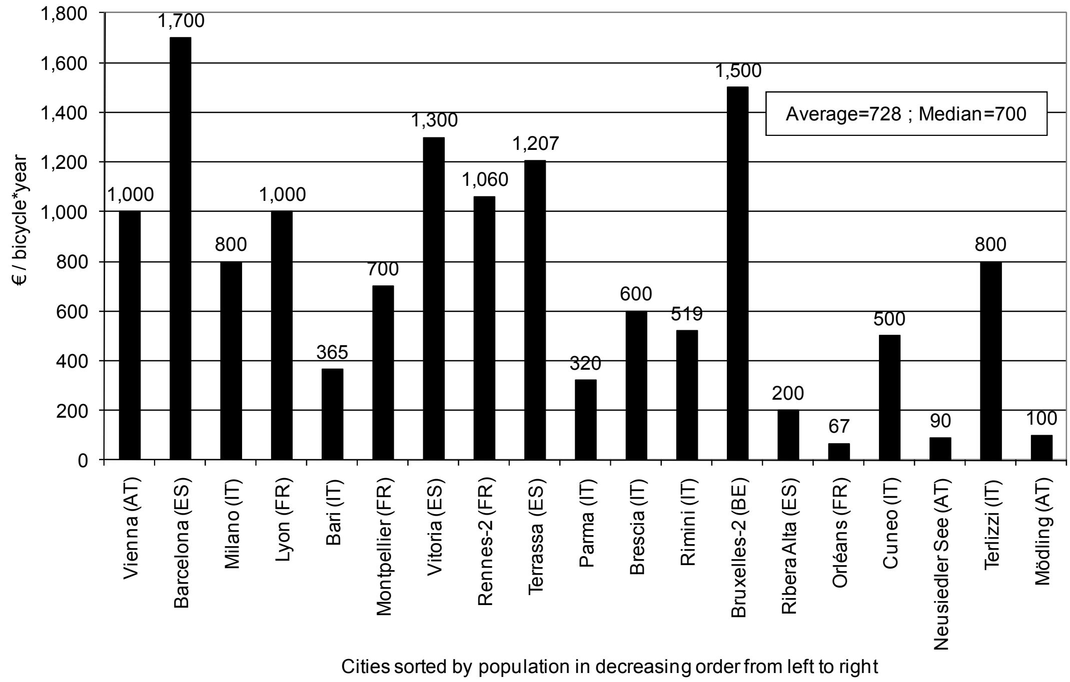


Figure 94: Total running costs per bicycle and year. Data source: Annex 10.1

In Barcelona, 30% of running costs are dedicated to redistribution of bicycles, 22% to maintenance of bicycles and 20% for station maintenance. The back-end system, the administration and the replacement of bicycles and stations represent the other 28% (Figure 95).

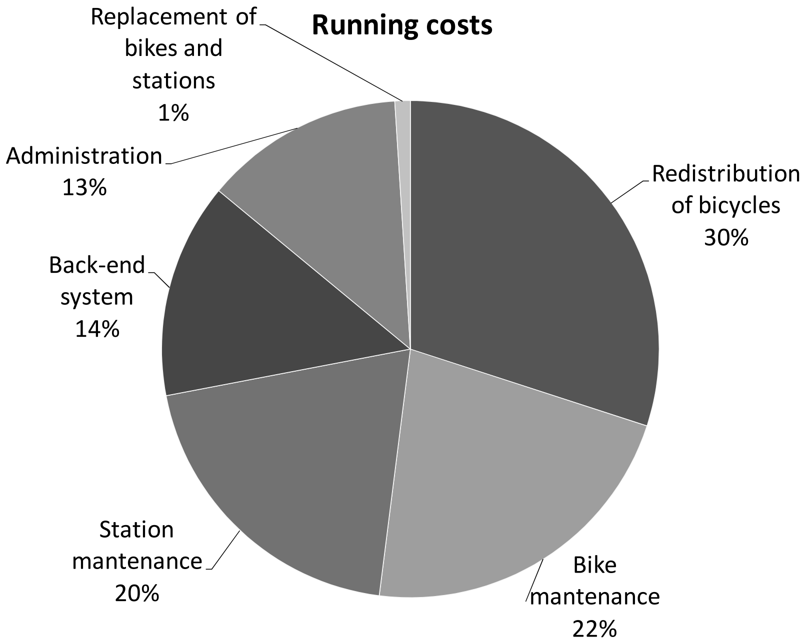


Figure 95: Allocation of running costs of Bicing in Barcelona. Data source: (Büttner et al. 2011)

In all tasks described in Figure 95 staff is need. Therefore, labour costs are one of the most significant factors influencing running costs. According to a study of Frank Beyer (Breyer 2010), salaries can reach up to 60% or 70% of total running costs of BSSs. This share can be reduced through high technology automatic equipment that minimizes the necessity of staff. As Figure 83 has shown in section 6.6.2, BSSs require on average 0.04 employees per bicycle.

Unfortunately, further data concerning allocation of costs of BSSs are not available because bike-sharing operators consider them confidential.

6.7.3 Incomes

BSSs have three ways of self funding:

- Subscription fees
- Usage fees
- Sponsorship of bicycles and stations

Subscription fees as well as usage fees are paid by bike-sharing customers, while sponsorships are funded by private companies that advertise themselves in dedicated space of BSSs. As section 5.2 has explained, length of validity of subscriptions varies depending on the BSS. 39% of BSSs analyzed in this dissertation ask for a subscription fee only once, at the moment of the registration; therefore these fees cannot be considered as a long-term way of funding. In contrast, 61% of BSSs require renewal of memberships and consequently the payment of the subscription is done with a certain periodicity, normally once a year. 27% of these BSSs that require renewal are free of charge, thus they do not represent any revenue either. Only the 46% of BSSs that ask for annual subscription fees that cost between €20 and €30 can be considered as a relevant income. Bicing, in Barcelona, is one of these cases and subscription fees produced about €22 million in the first year of operation (Sassen 2009).

Section 5.6.1 has revealed that 76% of BSSs offer any rental period free of charge and section 6.6.3 has shown that in practice 91% of their rents are for free because the rental duration fits within the period free of charge. Moreover, 24% of BSSs charge the first minute of rent, but even in these cases, fares are very low to be competitive and promote use (section 5.6.1 and 6.6.3). Therefore, the economic contribution of usage fees to the self-funding of BSSs can be considered as residual.

Finally, private companies can fund BSSs though sponsorship of bicycles and stations. This strategy has been chosen by some BSSs such as Citybike in Vienna, nextbike in Germany and Austria, Vélô in Toulouse and Barclays Cycle Hire in London. In Vienna the sponsorship contract is about €100,000 per year, which means around €160 per bicycle. Nextbike in Germany charges from €34 to €48 per bicycle and month, i.e. from about €306 to €432 in a nine moth season (Sassen 2009) and in Austria Leihradl-nextbike ask for €360 per season and bicycle (Pro Umwelt GmbH 2010). In Toulouse, the BSS is financed by user fees, city funds and advertising panels located on bicycles and the HSBC bank logo featured on 1,000 bicycles has generated around €700,000 in revenue in the first year, i.e. about €756 per bicycle (NYC Department of City Planning 2009). Finally, the BSS implemented in London in July 2010, Barclays Cycle Hire, introduced a new development. The name of the sponsor, Barclays Bank, was inserted in the official name of the BSS. Therefore, the amount of money paid by the

Barclays Bank for the five-year sponsorship of the 6,000 planed bicycles reaches a £25 million, around €30.4 million[33], and €1,013 per bicycle and year (London Cycling Campaign 2010).

6.7.4 Balance

Although data concerning costs and incomes of BSSs are very rarely available, results of this section and conclusions of other authors seem to confirm that no BSSs over the world makes profit. In other words, all BSSs lose money and they have to receive direct or indirect economic support to survive (Sassen 2009; DeMaio 2004; Breyer 2010).

In Barcelona, the only way of self-funding of Bicing is the revenue from customers (subscription and usage fee) and it represents only 30% of total annual costs (Sanz & Kisters 2010). A research of Benoit Beroud has revealed the real price of Vélo'v in Lyon, i.e. the fee that customers should actually pay for making the system auto sustainable (Beroud 2007). According to his calculations each customer should pay at least €0.85 per rent or €70 for the annual subscription to cover all costs of operation, while currently 93% of rents are free of charge and annual subscription is €15 in Lyon.

The additional economic support that BSSs require to continue existing can come from two different external sources:

- Public subsidies
- Billboard contracts

Public subsidies have been essential for the creation a development of numerous BSSs in Europe. In fact 43% of the cases studies of this thesis are funded by public authorities (section 5.7). There are two modalities of funding within the group of public subsidized BSSs: 1) short-term subsidies and 2) long-term subsidies.

In Spain the Institute for the Energy Saving and Diversification (IDAE) has subsidized many BSSs along the country to encourage their installation. In total IDAE has invested till 2010 €11,200 million (Sanz & Kisters 2010). In Germany, the Ministry of Transport will fund from 2009 to 2012 the implementation of innovative BSSs that integrate bike-sharing in the public transport network of municipalities with above 100,000 inhabitants with a total budget of €12,700 million (Bus & Bahn 2009; Borcherding et al. 2010). However, public subsidies are single economic supports for punctual periods, e.g. the start of the operation. This short-term subsidies are not a durable way of funding and BSSs subsidized will need additional revenues in the future to survive (Sanz & Kisters 2010).

As section 5.7.1 has shown, public authorities can be investors of BSSs. Here we present some particular examples of BSSs directly or indirectly funded by public authorities through long-term subsidies. In Barcelona, the city does not only fund the system, but also owns it and consequently the municipality is the beneficiary of the user revenues. For the operation of the BSS the city pays a variable amount of money to a bike-sharing provider: Clear Channel.

[33] This amount also includes the sponsorship of the main cycle ways of London, also called Barclays Cycle Superhighways.

The amount of money have changed from the launch due to the expansion of the operating area and other unexpected costs going from initial €5,500,000 per year in 2007 to €16.7 million in 2009 (Sassen 2009; elPeriodico.com 2009). In contrast, in Germany Deutsche Bahn, the national company of railways is the owner, operator and provider of Call a Bike, a BSS that operates in several cities. In Munich, Berlin, Frankfurt and Cologne the BSS is only funded by the public company while in Karlsruhe and Stuttgart the municipality contributes economically to support the operation of the BSS (Borcherding et al. 2010).

When municipalities do not have enough money to fund the BSS, they can opt to integrate the implementation, running and the management costs of a BSS within a billboard contract, which normally entails substantial investments. Billboard advertisement contracts use to include the condition that the signatory private company has to be in charge of the operation of a certain number of stations and bicycles as part of the agreement. Municipalities can in this way externalize the costs of the BSS. For example, in Paris JCDecaux, the operator and provider of Vélib', has licence to exploit 1,628 outdoor displays in compensation of the costs derived of the bike-sharing service. On the other hand, JCDecaux has to pay to the city the space rental of the stations (3.2 million per year). The city receives about €30 million per year from user fees and only if JCDecaux meets all conditions of good operation, the company can receive 12% of these user revenues. Additionally, the city receives €32 million per year from JCDecaux because of the space rental of billboards plus 12% of the incomes generated by advertisement, i.e. from €4 million to €10 million, depending on the source (Sassen 2009; Nadal 2007).

Unfortunately, the content of contracts mixing bike-sharing and billboards are not public and information concerning the terms of the agreement is rarely available (Le Soir 2008; Bea Alonso 2009). In Germany bike-sharing funding models based on billboards contracts have found difficulties because the Antitrust Agency has considered that such BSS as a monopoly that break the competition law. Moreover, advertisement rights are decentralised in this country, i.e. each district owns this right. This circumstance makes more difficult the integrated implementation of a BSS, especially if existing billboard contracts expire in different dates (SpiCycles 2008). In Toulouse the BSS is funded by user fees, city funds and advertising panels located on bicycles. To avoid troubles, the billboard contract and the bike-sharing contract are separated although the bike-sharing operator and the holder of the street furniture are the same company: JCDecaux (NYC Department of City Planning 2009).

6.7.5 Summary

Figure 96 shows the main indicators and data that have been used in this section to evaluate the success of bike-sharing in terms of economic viability and Table 33 summarizes the main quantitative outcomes of this section.

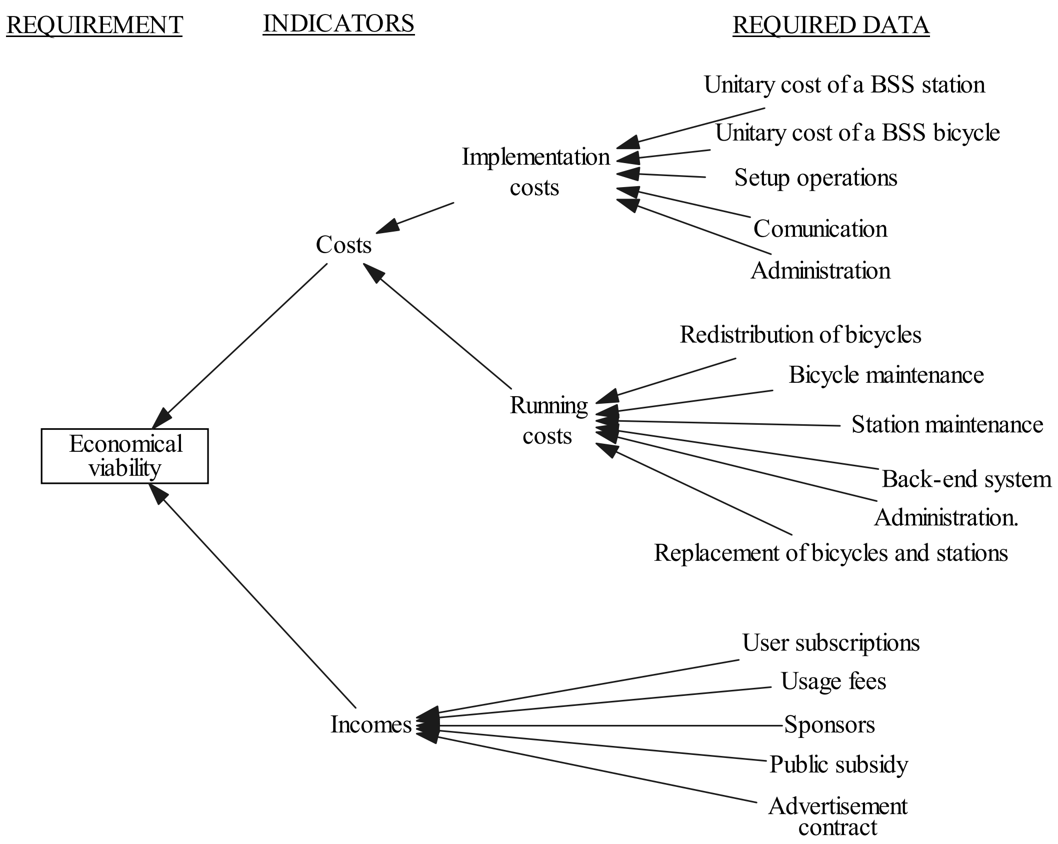


Figure 96: Indicators and data required for evaluating the improvement of economic viability

Indicator	Average	Median	Maximal	Unit	N
Implementing costs					
Cost of a station	12,566	3,800	60,000	€/station	21
Cost of a bicycle	540	461	2,000	€/bicycle	32
Running costs					
Total running costs	728	700	1,700	€/bicycle*year	18

Table 33: Key values of the economic viability of BSSs

Bike-sharing costs can be divided into two categories: 1) implementation costs and 2) running costs. When implementing a BSS the investment in stations and bicycles is unavoidable. Bike-sharing stations cost from around €600 to €60,000 (€12,566 on average), while bicycles cost from €110 to €2,000 (€540 on average). Total running costs are on average €728 per bicycle and year but they can reach up to €3,500 per bicycle and year.

BSSs have three ways of self-funding: 1) subscription fees, 2) usage fees and 3) sponsorship of bikes and stations. Only 28% of BSSs that ask for annual subscription fees that cost between €20 and €30, what could be considered as a relevant income. Incomes coming from the rest of subscriptions and from usage fees can be considered as residual. Sponsorships contribute from €160 to €1,060 per bicycle and year.

Many authors seem to agree that no BSS makes profit, in other words all BSSs lose money and they have to receive direct or indirect economic support to survive. There are two different external sources: 1) public subsidies and 2) billboard contracts. Public subsidies are single economic supports for punctual point of time and additional revenues are required to guarantee the survival of the BSS. On the other hand, billboard contracts are economically substantial but the BSS is integrated in the contract and unfortunately the terms of the agreement between the billboard company and the municipality are normally not transparent enough.

7 FACTORS AFFECTING SUCCESS

7.1 Introduction

Section 6 has estimated the level of success of bike-sharing in terms of sustainability. The aim of this section 7 is to identify the factors that motivate this success (or failure) of BSSs and to evaluate their influence. Two kinds of factors have been identified in this section: 1) driving forces and 2) barriers.

Section 7.2 will analyze in a quantitative way the correlations between driving forces and success and section 7.3 will study in a qualitative way the barriers for success of BSSs providing causes, effects and likely solutions for these barriers.

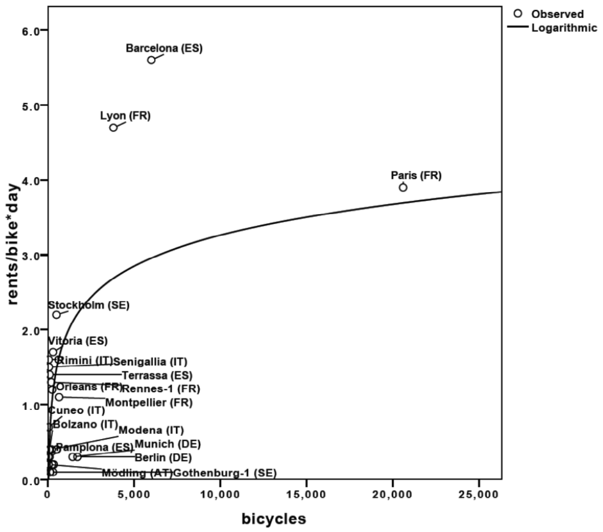
The methodology used in this section has been explained in section 3.2.4.

7.2 Driving forces

7.2.1 Bicycles and stations

The relation between the number of rents per day and the number of bicycles has been assumed as linear (section 3.2.4). In contrast, the relation between the number of rents per day and bike and the number of bicycles must be assumed as logarithmic because the number of rents per day and bike has a limit, i.e. rotation cannot become infinite as the number of bicycles increases. The same principle can be applied for other driving forces affecting rotation. Therefore, the relation between any driving force and the number of rents per day and bike will be a logarithmic curve in this section 7.2.

According to Figure 97, the size of the bike-sharing bicycle fleet increases the level of rents per bicycle, i.e. the higher the number of bicycles, the higher the number of times that they are rented during a day. The Spearman's coefficient is 0.314, which means that there is a low correlation between both variables. Nevertheless, the p-value is 0.104 (higher than 0.1), which reveals that the existing correlation cannot be strictly considered as statistically significant.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.430	19.631	1	26	.000	-2.233	.597

The independent variable is bicycles.

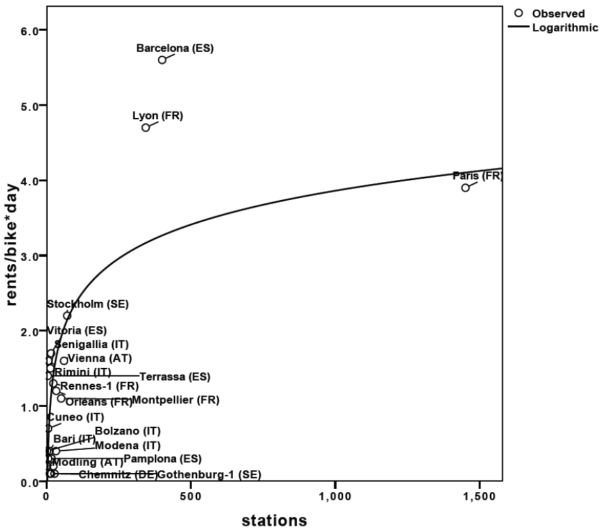
Correlations

rents/bike*day,bicycles		
Spearman's rho	Correlation Coefficient	.314
	Sig. (2-tailed)	.104
	N	28

Figure 97: Model and correlation between the number of bicycles and rotation. Data source: Annex 10.1

As Figure 98 reveals, the number of bike-sharing stations correlates with the level of rotation. The correlation coefficient is 0.499, which means that the correlation can be considered as low. The result of the test is statistically significant because the p-value is 0.015 (lower than 0.1). This correlation means that a number of stations contributes to reach high levels of efficiency, while too low number of stations may lead to low efficiency. An example of this correlation is Brussels. The insufficient number of stations of the BSS Cyclocity, 23, reduced the convenience of the scheme and it caused its close in 2009 (Dector-Vega et al. 2008). To reach higher levels of rents per bicycle Cyclocity was substituted by a large-scale BSS called Villo!, which provided more than 250 stations (Robert 2009a).

The model shows that data fit the following function: Y=-0.623+0.649*Ln(X), where Y means “rotation” in rents per bike and day and X means “number of stations”. The coefficient of determination R^2 value is 0.567. It means that 56.7% of the variation in the dependent variable can be explained by the independent variable.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.567	27.501	1	21	.000	-.623	.649

The independent variable is stations.

Correlations

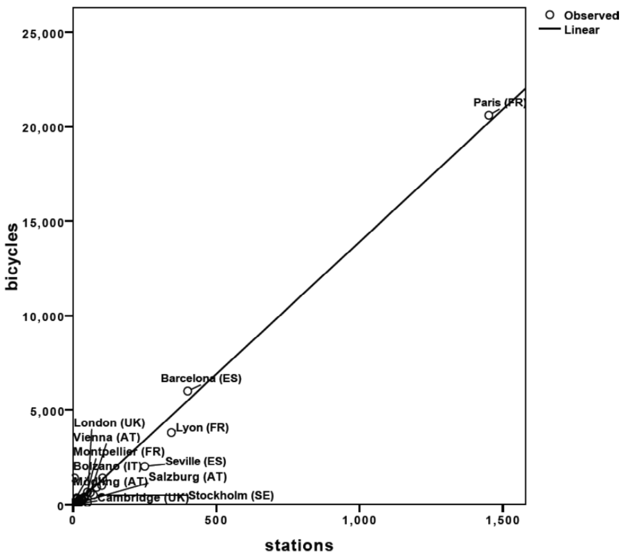
rents/bike*day,stations

Spearman's rho	Correlation Coefficient	.499
	Sig. (2-tailed)	.015
	N	23

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 98: Model and correlation between the number of stations and rotation. Data source: Annex 10.1

The number of bicycles and the number of stations are strongly correlated (Spearman's coefficient 0.822) and this correlation is statistically significant (p-value 0.015) (Figure 99). A high number of stations entails a high number of bicycles according the following linear function Y=-109.271+14.015*X where Y means "number of bicycles" and X "number of stations". Therefore, both the number of bicycles and the number of stations could be considered as only one factor: bike-sharing infrastructure.



Dependent Variable:bicycles

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.986	3113.286	1	43	.000	-109.271	14.015

The independent variable is stations.

Correlations

stations,bicycles

Spearman's rho	Correlation Coefficient	.822
	Sig. (2-tailed)	.000
	N	45

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 99: Model and correlation between the number of stations and bicycles. Data source: Annex 10.1

A likely explanation for the correlation between bike-sharing infrastructure and rotation may be based on the availability of bike-sharing routes. If the number of bike-sharing bicycles and stations is high, the number of the available origin-destination pairs is also high. This availability of routes makes BSSs more accessible and more attractive for customers.

The reader has to be aware that although BSSs with many bicycles and stations seem to report high levels of rotation, it does not mean that an increase bike-sharing infrastructure in a certain BSS leads immediately and necessarily to higher levels of efficiency. The effect of the increase of infrastructure will depend on the balance between supply and demand. Just after increasing the number of bicycles, the daily rents per bicycle decreases due to mathematical reasons. Afterwards, if sufficient demand of new bike-sharing routes exists, the higher supply of bike-sharing infrastructure leads to a higher rotation. The balance of these two opposite short-term and medium-term reactions will determine the final level of rotation. Citybike Wien in Vienna has been analyzed as example of this phenomenon. Figure 100 and Figure 101 show that while the absolute number of rents increased till 2008, the rotation decreased as a result of the growth of the BSS.

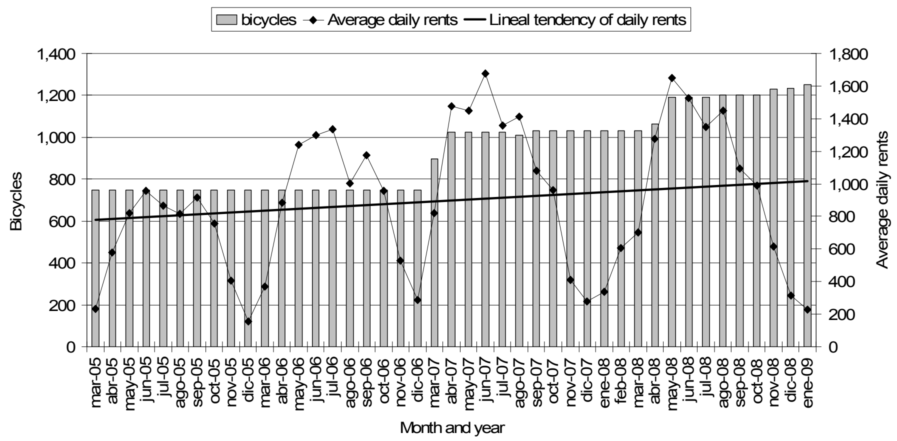


Figure 100: Evolution of the number of bicycles and daily rents in Citybike Wien, Vienna. Data source: (Dechant 2009).

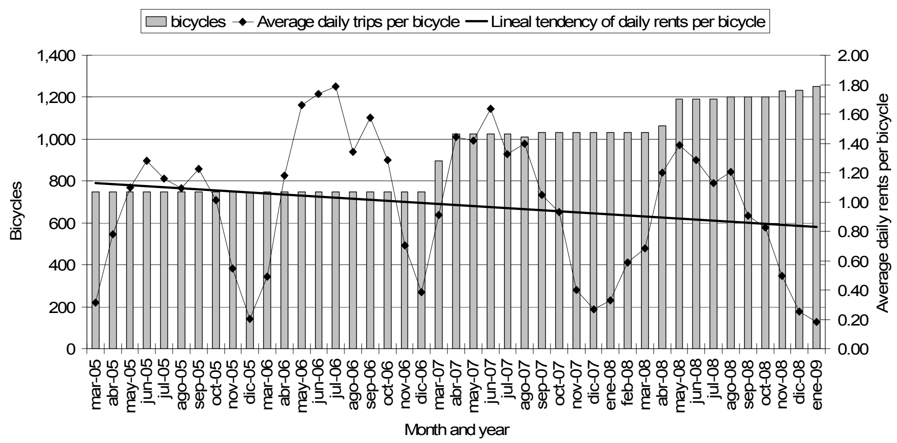
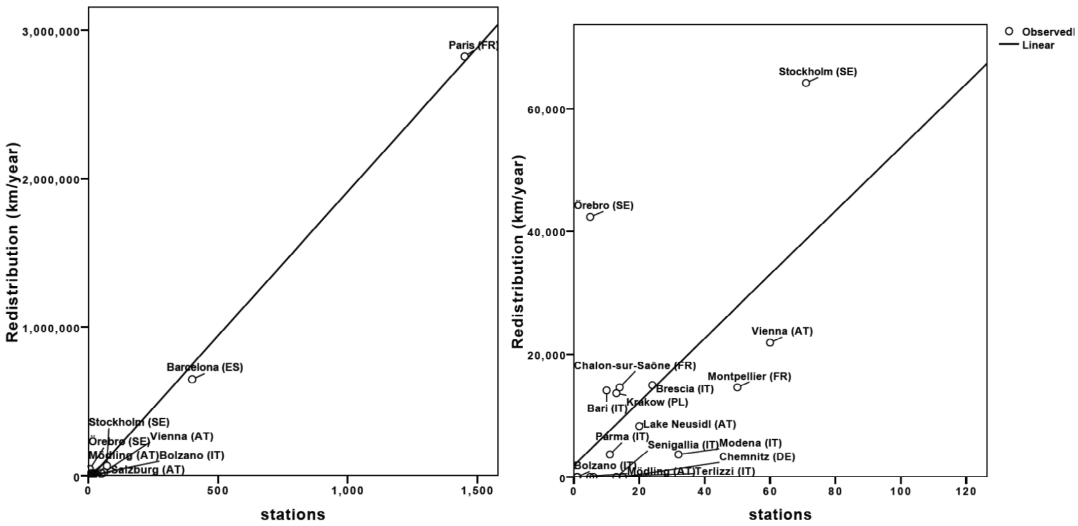


Figure 101: Evolution of the number of bicycles and rotation in Citybike Wien, Vienna. Data source: (Dechant 2009).

Apart from positive effects, a high amount of bike-sharing infrastructure can also lead to negative aspects. As Figure 102 shows, there is a significant correlation between the number of stations implemented and the kilometres required to redistribute the bike-sharing bicycles from full to empty stations. The higher the number of stations, the higher the absolute distance covered by redistribution vans. The correlation between both variables is high (Spearman's coefficient 0.723). The data fit the following linear function Y=-23597.0.37+1942.698*X (R^2=0.996). However, the case study of Paris is very far from the others and it may influence the result. If this case study is removed, the function is Y=1865.704+518.069*X but this function has less accuracy due to the lower value of the coefficient of determination (R^2=0.399).



Dependent Variable:Redistribution (km/year)

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.996	4797.419	1	18	.000	-29597.037	1942.698

The independent variable is stations.

Dependent Variable:Redistribution (km/year)

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.399	10.601	1	16	.005	1865.704	518.069

The independent variable is stations.

Correlations

Redistribution (km/year),stations

Spearman's rho	Correlation Coefficient	.723
	Sig. (2-tailed)	.000
	N	20

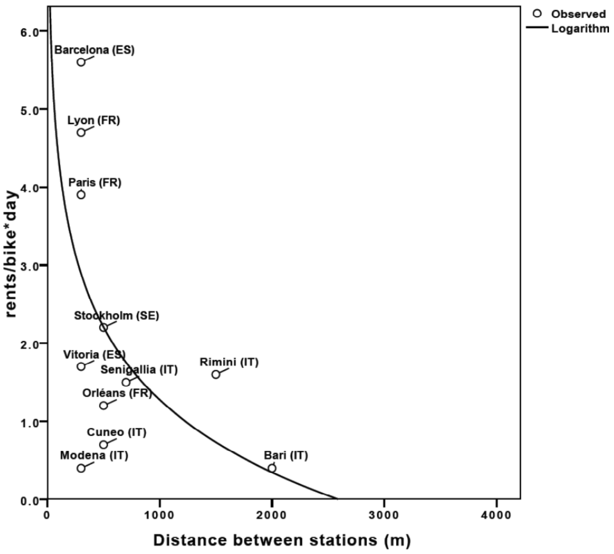
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 102: Model and correlation between the number of bike-sharing stations and the yearly distance covered for redistribution. All case studies on the right and all cases without Paris and Barcelona on the left. Data source: Annex 10.1

There are two parameters that define the way that bike-sharing stations are distributed within a city: the operating area and the station network density.

Unfortunately, very few data concerning the operating area are available. In contrast, the station network density can be measured with two indicators: 1) the average distance between stations and 2) the number of stations per km^2.

The average distance between stations is a usual indicator of the station density in the field of bike-sharing. As Figure 103 shows, dense BSSs report higher values of rotation. The correlation between both variables is moderate (Spearman coefficient -0.521), but this result cannot be considered as statistically significant because the p-value is 0.100 (not strictly lower than 0.1).



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.259	3.148	1	9	.110	10.541	-1.341

The independent variable is Distance between stations (m).

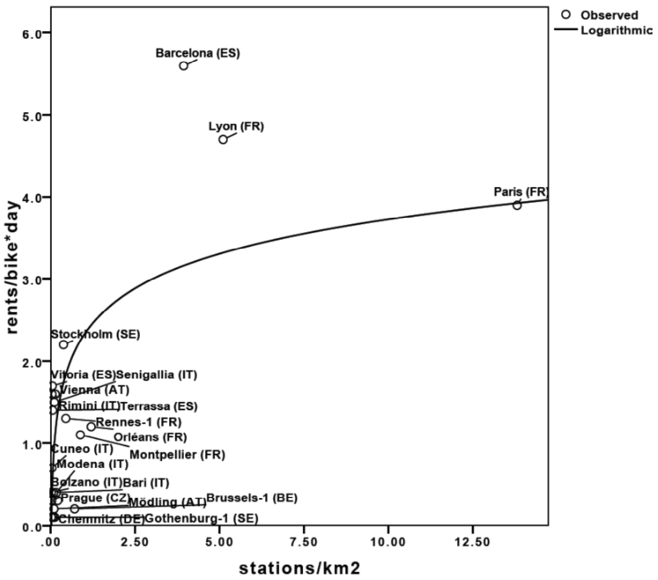
Correlations

rents/bike*day,Distance between stations (m)

Spearman's rho	Correlation Coefficient	-.521
	Sig. (2-tailed)	.100
	N	11

Figure 103: Model and correlation between the distance between bike-sharing stations and rotation. Data source: Annex 10.1

The number of stations in a certain area is another likely indicator of station density. The optimal indicator may be the number station per km^2 of operating area. Nevertheless, the operating area is not a usual available data. An alternative to the operating area is the city area. According to Figure 104, the correlation between rotation and the number of stations per city square kilometre is low (Spearman's coefficient 0.437) but significant (p-value 0.037). The model reveals that the logarithmic function that fit the data is the following: Y=2.327+0.609*Ln(X) with a coefficient of determination equal to 0.532.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.532	23.910	1	21	.000	2.327	.609

The independent variable is stations/km2.

Correlations

rents/bike*day,stations/k...		
Spearman's rho	Correlation Coefficient	.437
	Sig. (2-tailed)	.037
	N	23

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 104: Model and correlation between the density of stations per city km^2 and rotation. Data source: Annex 10.1

A likely reason for this correlation is that denser station networks multiply the possible locations where bicycles can be hired at origin and returned at destination. This fact has two positive effects: 1) it enables shorter walking distances from the trip origin to the bike-sharing station and from the station to the final destination what makes a BSS more convenient and 2) it minimizes dissatisfaction caused by empty or full stations, i.e. by unavailability of bicycles and docking points, what increases the reliability of a BSS. The combination of these two advantages may be the cause of the higher level of rents per bicycle. In Paris, for instance, Vélib' provides more bike-sharing stations than metro stations and this has been pointed as a decisive reason of its popularity (Dargent 2009).

Although there are not enough available data to confirm a correlation, it is reasonable to think that as far as station network density remains equal, an expansion of the operation area increases the rotation too. As a result of the expansion, not only the number of bicycles and stations but also the share of people living close to a bike-sharing station increases and this might motivate the higher bike-sharing use.

Data concerning station network density are average values, but the distribution of bike-sharing stations within an operating area can be irregular. Usually, high-populated areas require more and smaller stations and vice versa. For instance, in Paris the surroundings of the two major metro stations are provided with twelve small stations (about 60 docking points per station), while around the Eiffel Tower and Invalides the stations are fewer and larger (NYC Department of City Planning 2009).

The number of docking points defines the size of bike-sharing stations. According to the transferability fact sheet of the OBIS project (Castro & Emberger 2010), the number of docking points is higher than the number of bicycles. On average, BSSs in cities with more than 100,000 inhabitants provide 1.8 docking points per bicycle, while smaller cities provide 1.2. The higher number of docking points compared to the number of bicycles provides operators with a margin of docking points for bicycles until the saturation of stations. This rate “docking point / bicycle” determines the risk of saturation of stations and the resulting redistribution of bicycles from full stations to empty ones.

Location of bike-sharing stations can also influence the routes to be undertaken by users. As section 3.2.4 has shown, success in terms of reduction of car traffic and increase of public transport attractiveness depends directly on the share of bike-sharing trips shifted from car and public transport. A likely way to affect both shares is by mean of the placement of bike-sharing stations in frequent routes of these transport modes. For instance, if the goal of a BSS is to reduce car traffic, the introduction of the BSS should be preceded by a comprehensive study of car travel demand that finds out the most frequent car routes that could be affordable with a bicycle. The origin and destination of these demanded car trips should be supplied with bike-sharing stations. If the intention of a BSS is to reduce occupancy of public transport vehicles, the initial and final PT stations of the crowded routes should be supplied with bike-sharing stations. If the motivation is to increase intermodality, public transport stops and demanded destinations without public transport supply should be connected with bike-sharing stations. Unfortunately, an estimation of the effectiveness of these instruments was not possible because of unavailability of data, but section 7.2.5 will explain the effects of location of bike-sharing stations close to metro stations.

7.2.2 Technology

According to Figure 105, the level of technology of docking devices at bike-sharing stations determines the availability of service. BSSs that require staff for renting bicycles have to close during nights. In contrast, technology makes BSSs more automatic and staff independent what enables round-the-clock services.

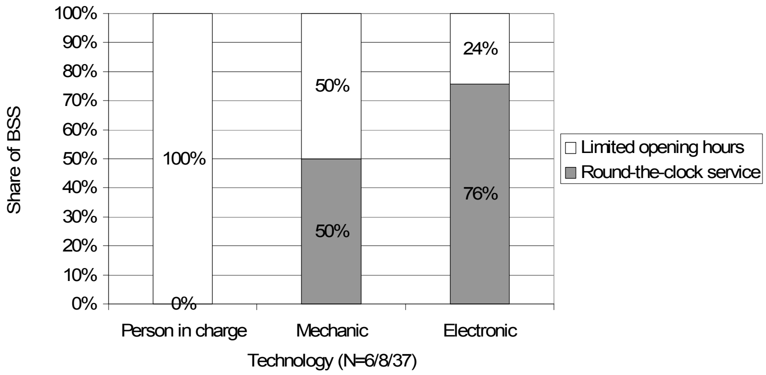
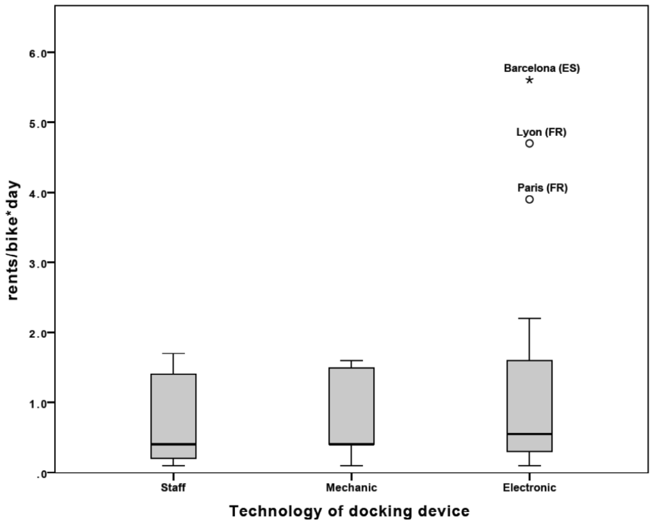


Figure 105: Availability of round-the-clock service in BSSs depending on technology of stations. Data source: Annex 10.1

In contrast, it cannot be demonstrated that as the level of technology at stations increases, the rotation too. Figure 106 shows that the higher values of rotation are reached in higher technology BSSs but correlation between technology and rotation is not significant because the p-value (0.619) is much higher than 0.1.



Correlations

rents/bike*day,Technology of docking device

Spearman's rho	Correlation Coefficient	.098
	Sig. (2-tailed)	.619
	N	28

Figure 106: Correlation between the level of technology of the locking devices at bike-sharing stations and rotation. Data source: Annex 10.1

Regarding the way of identifications, Figure 107 reveals that the level of success in terms of rotation seems to be considerably higher in BSSs that require a smart card (bank card or specific bike-sharing card) compared to BSSs that require a telephone (phone call or SMS). Bike-sharing customers might be more reluctant to rental processes that require a phone call, because of the additional call costs. Unfortunately, the correlation analysis is not possible because the way of identification is a nominal variable, i.e. the valued do not have any order[34].

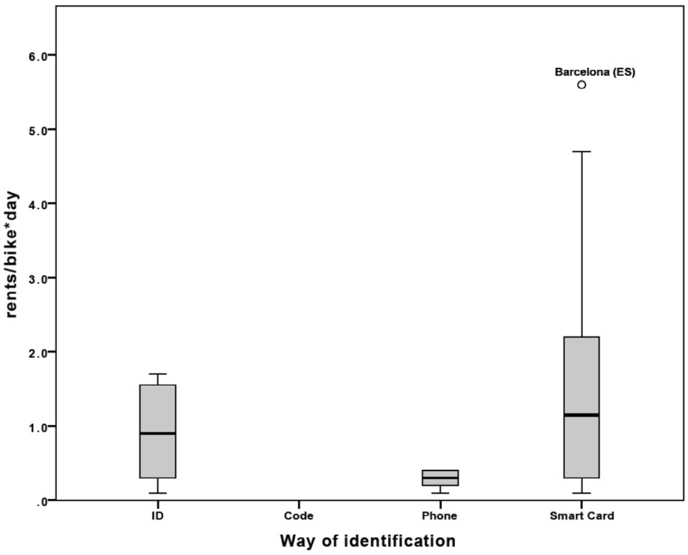


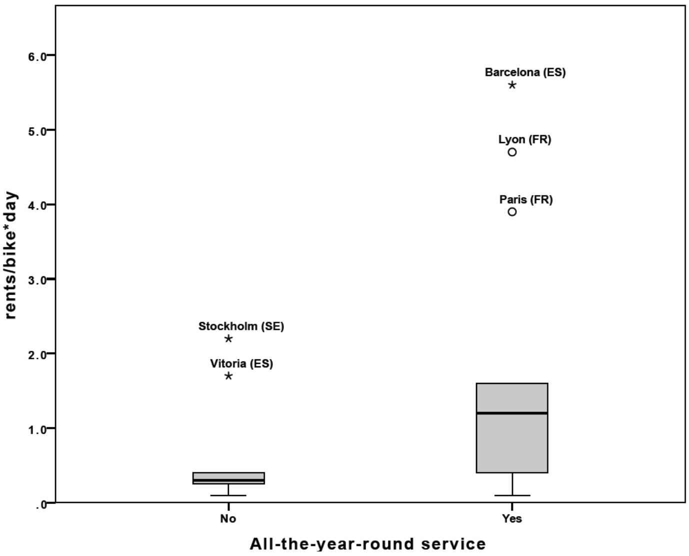
Figure 107: Rotation regarding the way of identification (N=28)[35] . Data source: Annex 10.1

[34] Nominal variables in contrast with metric, ordinal and dichotomous variables cannot be tested by correlation analysis.

[35] No box is represented in the column “code” because only one BSS require a code for identification.

7.2.3 Availability of service

BSSs can operate all the year round or can stop during a certain season. The temporal closing of the service seems to reduce the level of rents of BSSs in terms of efficiency according to Figure 108. The median value of the number of rents per bicycle is higher in BSSs that operate all-the-year-round than in the ones that make seasonal breaks. There is a low correlation between the availability throughout the year and the rotation because the Spearman's coefficient is 0.337 and this correlation is significant since the p-value is 0.08 (less than 0.1).



Correlations

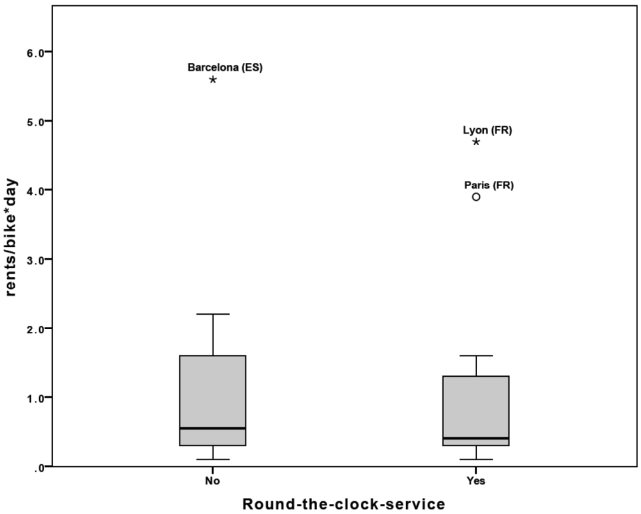
rents/bike*day,All-the-year-round service

Spearman's rho	Correlation Coefficient	.337
	Sig. (2-tailed)	.080
	N	28

Figure 108: Correlation between the availability throughout the year and rotation[36]. Data source: Annex 10.1

Furthermore, bike-sharing operators can choose between offering limited opening hours or round-the-clock service. The wideness of opening hours seems to have no influence in the median number of rents per bicycle, which is similar in both modalities (Figure 109). This conclusion is confirmed by the correlation analysis. The Spearman coefficient is only 0.089, thus there is no correlation between the availability throughout the day of BSSs and rotation. Nevertheless, this result is not statistically significant due to the high p-value (0.653).

[36] No upper whiskers are represented because the largest value of the dataset that is not an outlier is the 3rd quartile.



Correlations

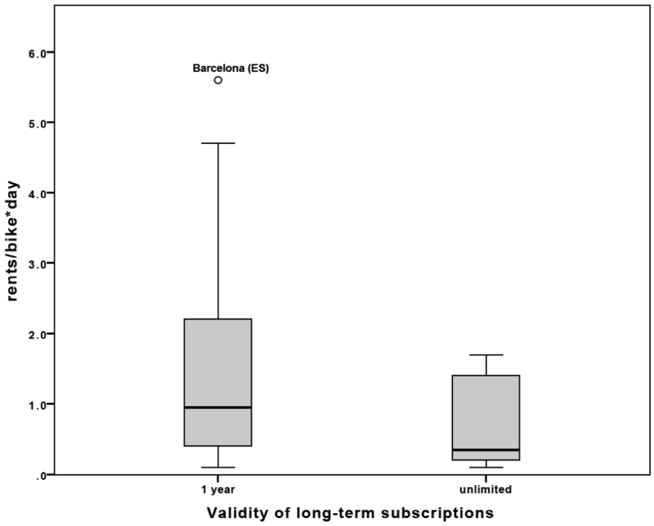
rents/bike*day,Round-the-clock-service

Spearman's rho	Correlation Coefficient	-.089
	Sig. (2-tailed)	.653
	N	28

Figure 109: Correlation between the availability throughout the day and rotation. Data source: Annex 10.1

7.2.4 Subscription and usage fee

Unlimited valid subscriptions are in principal cheaper than annual subscriptions because it has to be paid only once instead of once a year. However, as Figure 110 reveals, the median level of rotation in BSSs that offer one-year subscriptions is higher compared to BSSs with unlimited valid subscriptions. Despite this conclusion based on the box plot diagram, the correlation is not statistically significant because the p-value is higher than 0.1 (0.130)



Correlations

rents/bike*day,Validity of long-term ...

Spearman's rho	Correlation Coefficient	-.293
	Sig. (2-tailed)	.130
	N	28

Figure 110: Correlation between the validity of long-term subscriptions and rotation. Data source: Annex 10.1

As section 5.2.6 has explained, some BSSs ask for a deposit when customers subscribe. If the amount of money is too high, the implementation of such deposit could imply a risk of reduction of customers. For instance, in Paris a deposit of €150 is needed to register. As a result, marginalised citizens who cannot afford the deposit have expressed their disagreement (Petersen 2009).

Usage fees also play a relevant role in the attractiveness of bike-sharing service. The bike-sharing feasibility study of New York City concludes that price elasticity is unknown, but fees must stay below the price of public transport to attract users (NYC Department of City Planning 2009). In fact, section 6.6.3 has revealed that when rental periods free of charge are available, around 91% of users ride as long as the service is for free. This means that bicycles are rarely hired for periods longer than the free time. Hence, the duration of this rental period free of charge is one of the most important indicators of the expensiveness of bike-sharing services. As Figure 111 shows, BSSs that offer 30 minutes of rental free of charge are the most successful ones in terms of rotation. Therefore, free period of time seems to be necessary to encourage the use of a BSS, but 30 minutes seem to be enough to achieve this goal. A correlation analysis is not possible because the function is not monotonic, which is a requirement to perform Spearman correlation tests.

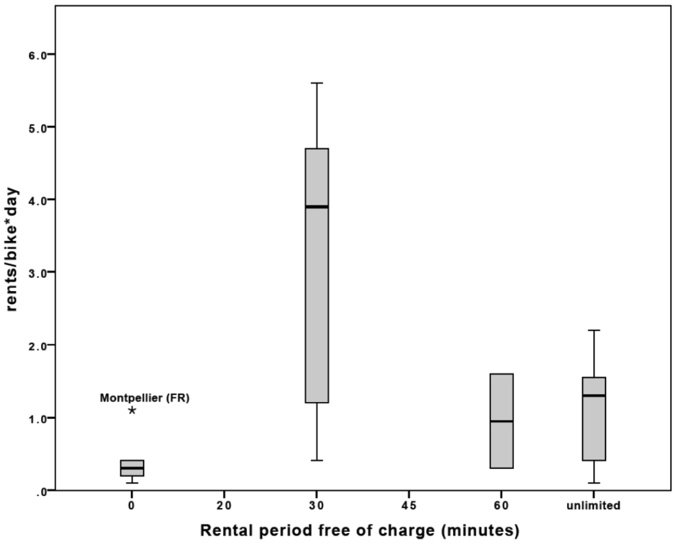


Figure 111: Rotation regarding the duration of the rental period free of charge (N=28)[37] *. Data source: Annex 10.1*

Usage fees have consequences not only in the quantity but also in the duration of rents. As a result, fees can determine the profile of customer that uses the system. BSSs that encourage short-term rents have exponential rising tariffs that make unattractive bike-sharing trips above 2 or 3 hours. The main target group of short-term rents are residents of the city and the main trip purpose, commuting. In contrast, there are other BSSs that encourage long-term rents through flat rates. The target group of long-term rents are tourists and the main trip purpose, leisure. Therefore, the availability of one (or both) of these fares will determine the structure and features of the customer profile of a BSS. Also subscriptions fees can affect users' profile. As section 5.2.2 has explained, there are three main types of subscriptions: short-term, long-term and subscriptions linked to public transport. Short-term subscriptions have validities below one year and they are tourist oriented. Long-term subscriptions can be renewed each

[37] Only usage fees of long-term subscriptions were used for the estimation. The 2 minutes free of charge of the scheme in Prague were considered as 0 minutes. No box is represented in the column "20 minutes" and "45 minutes" because they only have only one case study.

year or valid forever. City residents and usual users require this kind of subscriptions. And finally, economic advantages of subscriptions linked to public transport seasonal cards are especially attractive for commuters. Therefore, depending on the type(s) of subscriptions available in a BSS, the customer profile may vary. Unfortunately, there are no available data to quantify the grade of effectiveness of the availability of a specific usage or subscription fees in catching customers from each wished target group.

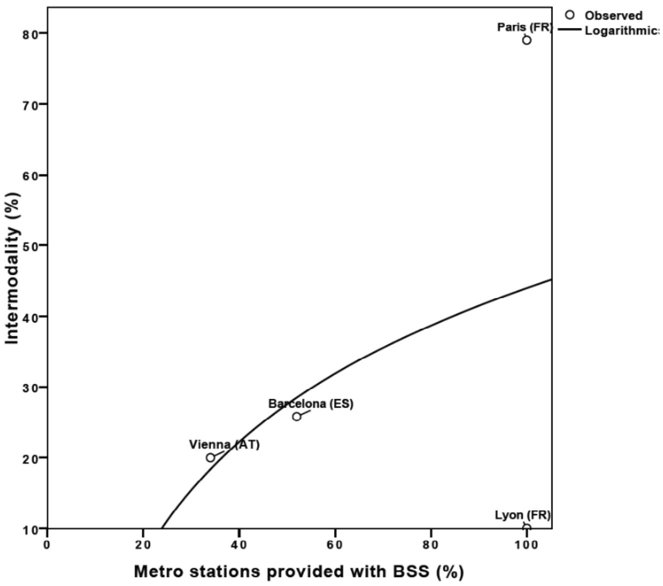
7.2.5 Integration with public transport

Section 6.2.4 has explained that a likely goal of the implementation of a BSS can be the encouragement of intermodality with public transport and to make public transport more attractive. The success increasing intermodality between public transport and bike-sharing depends on the share of bike-sharing trips which are combined with public transport (section 3.2.4). If this rate increases, it means that PT passengers appreciate the possibility of riding a public bicycle as a way to cover the first or the last mile of their trip. There are four main policies for integrating bike-sharing with public transport:

- By placing bike-sharing and public transport stations close to each other
- By offering economical bike-sharing fees to public transport passengers
- By creating a unified ticketing for BSS and PT
- By providing information about how to connect both bike-sharing with public transport stations

The first and the second option only require the decision of the bike-sharing operator, while the third and forth option needs the cooperation with public authorities and public transport companies.

In Paris all train and metro stations in the city are provided with bike-sharing stations, which make easier accessibility and intermodality (NYC Department of City Planning 2009). The placement of bike-sharing stations close to public transport nodes may be an effective instrument to increase intermodality. However, the correlation between the share of metro stations and the level of intermodality cannot be confirmed. As Figure 112 shows, the p-value is very high, probably due to the very few available data. Therefore, the correlation is not statistically significant (p-value 0.895)



Dependent Variable:Intermodality (%)

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.165	.396	1	2	.594	-65.262	23.721

The independent variable is Metro stations provided with BSS (%).

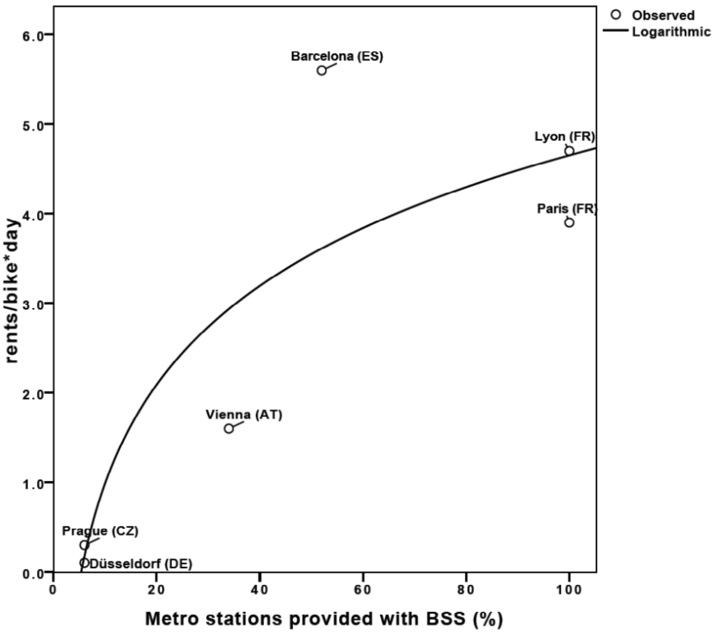
Correlations

Intermodality (%),Metro stations provided with BSS (%)

Spearman's rho	Correlation Coefficient	.105
	Sig. (2-tailed)	.895
	N	4

Figure 112: Model and correlation between the share of bike-sharing trips that are intermodal with public transport and the share of metro stations provided with bike-sharing stations. Data source: Annex 10.1

Closeness between PT and bike-sharing stations may affect not only the grade of intermodality but also bicycle rotation. It is reasonable to think that many PT passengers see bike-sharing terminals adjacent to PT stations. This significant group of potential costumer may increase demand of bike-sharing bicycles and may lead to the success of BSSs in terms of rotation of bicycles. According to Figure 113, this hypothesis may be right and high shares of metro stations provided with bike-sharing stations tend to higher rotation. Although the number of cases with available data is low, only six, correlation between both variables is high (correlation coefficient is 0.794). The correlation is statistically significant because the p-value is 0.059, less than 0.1. The fitted function is the following: Y=-2.676+1.591*Ln(X). The coefficient of determination of this function is 0.771.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.771	13.438	1	4	.021	-2.676	1.591

The independent variable is Metro stations provided with BSS (%).

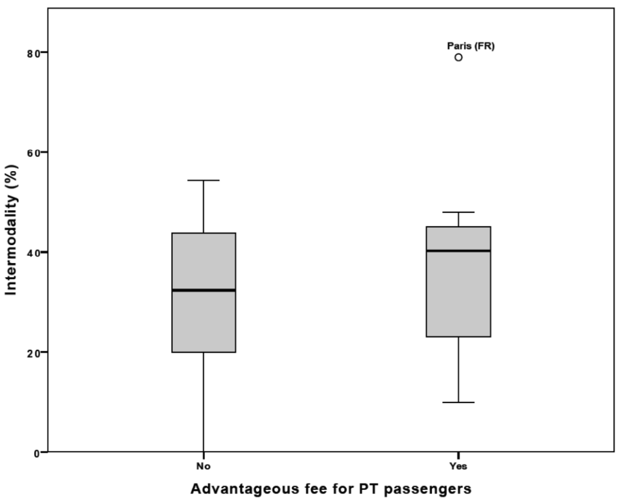
Correlations

rents/bike*day,Metro stations provided with BSS ...

Spearman's rho	Correlation Coefficient	.794
	Sig. (2-tailed)	.059
	N	6

Figure 113: Model and correlation between the share of metro stations provided with bike-sharing stations and rotation. Data source: Annex 10.1

Apart from the allocation of bike-sharing terminals near to public transport stations, bike-sharing operators can offer advantageous fees for holders of seasonal PT cards as a way to integrate both transport modes. In fact, 24% of the studied BSSs do it (section 5.6.1). Economical fees for PT passengers may also contribute to increase the grade of intermodal trips between bike-sharing and public transport according to the tendency shown in the box plot of Figure 114. Nevertheless, no correlation was found between both variables. The p-values is 0.734, far above 0.1, hence the correlation is not statistically significant.



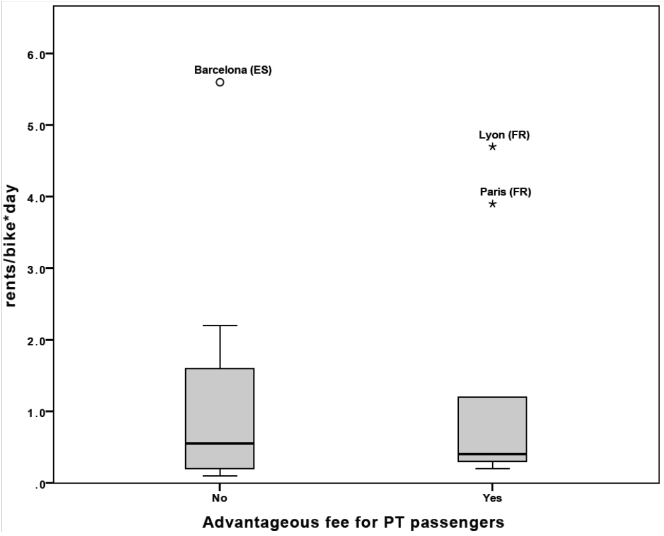
Correlations

Intermodality (%),Advantageous fee for PT passengers

Spearman's rho	Correlation Coefficient	.086
	Sig. (2-tailed)	.734
	N	18

Figure 114: Correlation between the availability of advantageous fees for holders of seasonal PT cards and rotation. Data source: Annex 10.1

The possibility to have access to favourable fees for PT passengers might motivate an increase of the level of rotation. Nevertheless, neither the box plot nor the correlation test can confirm this relation (Figure 115). The p-value is 0.851, much higher than 0.1, which means that the result of the correlation test is not significant.



Correlations

rents/bike*day,Advantageous fee for PT passengers

Spearman's rho	Correlation	.037
	Sig. (2-tailed)	.851
	N	28

Figure 115: Correlation between the advantageous bike-sharing fees for holders of seasonal PT cards and the number of daily rents per bicycle. Data source: Annex 10.1

The unification of customer cards or ticketing of public transport and bike-sharing is other likely instrument to encourage intermodality. In this way, public transport fares would include PT and bike-sharing trip in only one ticket. The cost of the bike-sharing rents could be partially or totally covered by the public transport operator. There are positive examples of cooperation between bike-sharing operators and PT operators in cities such as in Stockholm and Lyon (Büttner et al. 2011).

Finally, information in public transport stops comprising signs and maps that show the most convenient way to reach a bike-sharing station can be utilised as a way to integrate both modes. The city of Barcelona has already implemented this instrument for increasing intermodality between the metro network and Bicing (Figure 116).

Figure 116: Sign (left) and map (right) indicating the closest Bicing terminal in a metro station of Barcelona.

7.2.6 Population

According to the transferability study of the EU-project OBIS, city population might determine several features of BSSs such as bike-sharing technology, opening hours and bicycle fleet size.

The level of technology of the bike-sharing stations seems to be higher in large cities than in small ones. Only 38% of BSSs located in small cities (below 100,000 inhabitants) are provided with electronic devices for unlocking bicycles, while 85% in large cities (above 500,000 inhabitants) are. In contrast, 25% of systems located in small cities and only in 17% of the BSSs of medium cities (between 100,000 and 500,000 inhabitants) need staff. No BSS located in a large city require persons to deliver bike-sharing bicycles (Figure 117). This connection may be based on the fact that large cities usually handle higher budgets for implementing expensive BSSs with high-technology equipment.

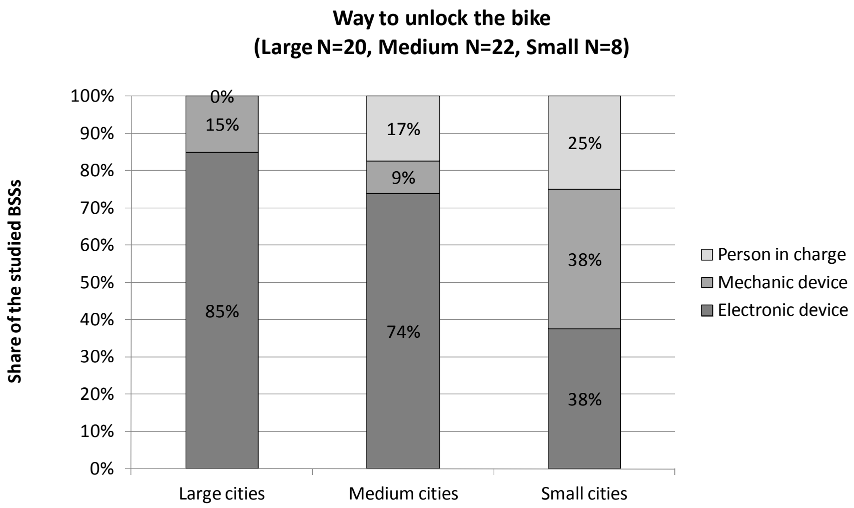


Figure 117: Level of technology of bike-sharing stations regarding the city-size of the location (Castro & Emberger 2010)

Since population affects the level of technology and the level of technology at bike-sharing stations determines the availability of service throughout the day (section 7.2.2) it is reasonable to think that cities with higher population present higher availability of service throughout the day. The study of the OBIS project confirmed this hypothesis. It was found that BSSs that operate non-stop throughout the day are more common in large cities and in small ones. Only 38% of BSSs located in cities below 100,000 inhabitants operate round-the-clock, while 75% of BSSs located in cities above 500,000 do it (Figure 118).

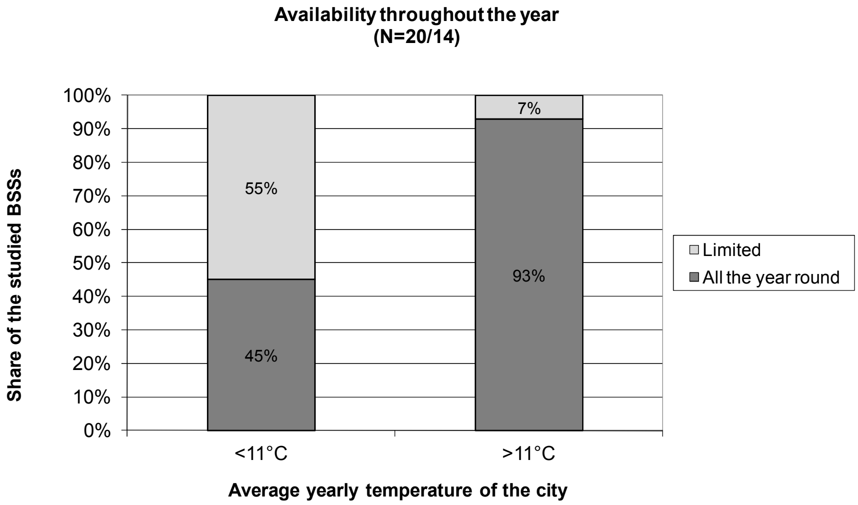


Figure 118: Availability throughout the day regarding the city-size of the location (Castro & Emberger 2010)

As we saw in section 5.6.1, 76% of BSSs offer a limited rental period without charge to encourage the use of the system. The period of time of the free rental differs from one BSS to another, but the most common are 30 minutes, 60 minutes and unlimited free rental. 30 minutes without charge are mainly available by BSSs situated in larger cities, while unlimited free rentals are more available as the city-size decreases (Figure 119).

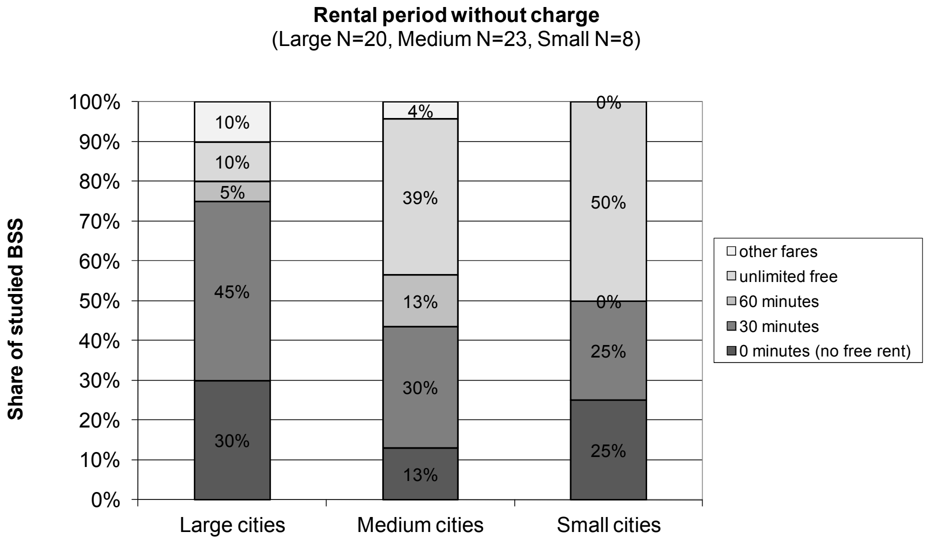


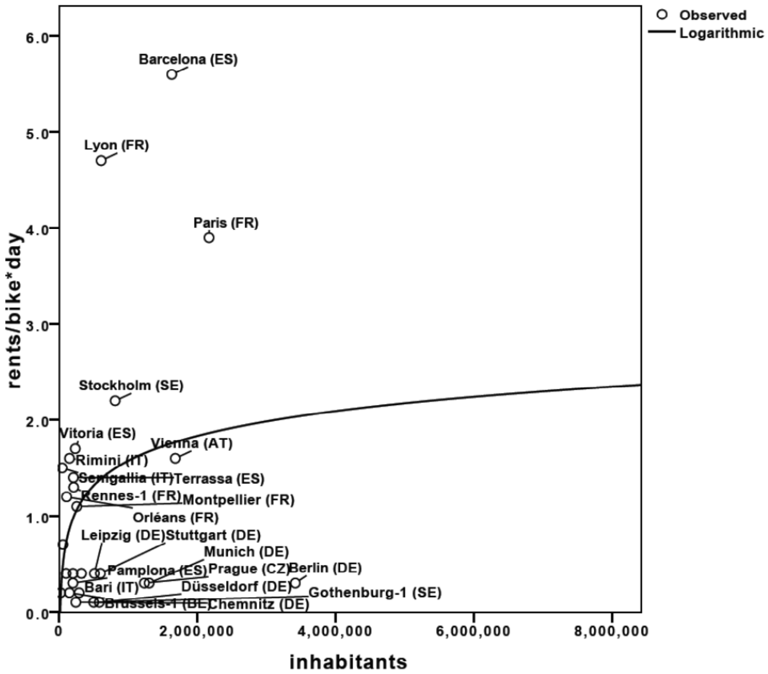
Figure 119: Duration of the rental period free of charge regarding the city-size (Castro & Emberger 2010)

Finally, the number bike-sharing bicycles per capita seems to be similar in all cities independently from their population. Despite a wide range of values of this rate, from 0.1 to more than 100 bicycles per 10,000 inhabitants, the transferability study estimates that on average 14 bicycles per inhabitant are implemented in small cities (below 100,000 inhabitants), 14.4 in medium cities (between 100,000 and 500,000 inhabitants) and 15.6 in large cities (above 500,000 inhabitants). The average number of bike-sharing stations per capita is also similar in the three city-size categories. 1.8 stations per 10,000 inhabitants are constructed in small cities, while 1.3 and 1.5 stations are required in medium and large cities.

	Large cities				Medium cities				Small cities			
	Average	Max	Min	N	Average	Max	Min	N	Average	Max	Min	N
Bicycles per 10,000 inhabitant	**15.6**	95.0	0.1	19	**14.4**	105.8	0.2	20	**14.0**	26.0	1.7	8
Stations per 10,000 inhabitants	**1.5**	6.7	0.1	15	**1.3**	6.7	0.1	22	**1.8**	5.2	0.1	8
Docking points per bicycle	**1.8**	2.3	1.5	6	**1.8**	3.2	1.0	13	**1.2**	1.5	1.0	4

Table 34: Number of bicycles per 10,000 inhabitants, number of stations per 10,000 inhabitants and station size regarding the city-size (Castro & Emberger 2010)

Since the number of bicycles seems to be higher in high-populated cities and since the size of the bicycle fleet increases rotation (section 7.2.1), city population might influence the number of rents per bicycle. The scatter plot of Figure 120 shows a certain tendency but it cannot be demonstrated. The Spearman's coefficient is 0.151 (below the minimum 0.3) and the high p-value is 0.444 (higher than 0.1), which reveals that no correlation is statistically significant.



Dependent Variable:rents/bike*day

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.103	2.991	1	26	.096	-3.569	.372

The independent variable is inhabitants.

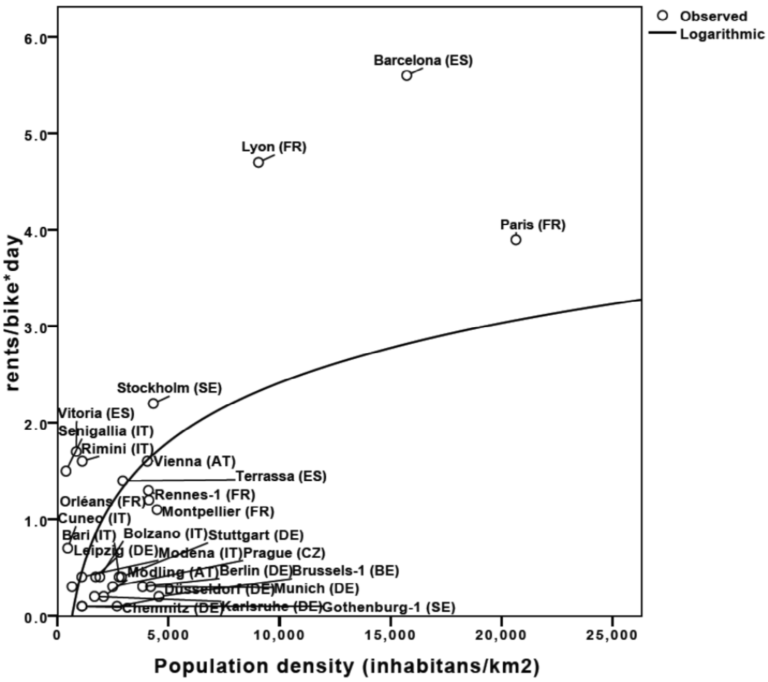
Correlations

rents/bike*day,inhabitants

Spearman's rho	Correlation Coefficient	.151
	Sig. (2-tailed)	.444
	N	28

Figure 120: Model and correlation between population and rotation. Data source: Annex 10.1

In contrast, the influence of population density seems to be relevant influencing the number of rents per bicycle. According to Figure 121 the Spearman's coefficient is 0.351, i.e. there is a correlation that can be considered as low. The correlation is significant since the p-value is 0.067, i.e. less than 0.1.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.355	14.286	1	26	.001	-5.766	.888

The independent variable is Population density (inhabitans/km2).

Correlations

rents/bike*day,Population density (inhabitans/km2)

Spearman's rho	Correlation	.351
	Sig. (2-tailed)	.067
	N	28

Figure 121: Model and correlation between the population density and rotation. Data source: Annex 10.1

7.2.7 Topography

Hilly topography can dissuade potential customers of using BSSs due to the effort necessary to pass slopes. This factor might be especially relevant if we take into account that many bike-sharing customers do not own a private bicycle and consequently they are not fit daily cyclists (section 6.2.5). However, two of the three cities with higher number of rents per bicycle analyzed in this dissertation, Barcelona and Lyon, are located in considerable hilly areas. Therefore, from this approach, topography may not have negative influence on the level of rents. Unfortunately, an analysis of the correlation between topography and rotation has not been possible in this dissertation because of unavailability of data.

A negative effect of hilly topography is the unbalance of bicycles at stations, which causes redistribution. Section 7.3.5 will explains in detail the problems associated to this fact.

7.2.8 Climate

The feasibility study of the OBIS project revealed that availability throughout the year of BSSs is higher in warm cities (Castro & Emberger 2010). 55% of BSSs located in cities below 11ºC of average yearly temperature make a winter pause due to too low demand during this season[38]. In contrast 93% of schemes located in warmer cities do not require any break and operate all the year round (Figure 122).

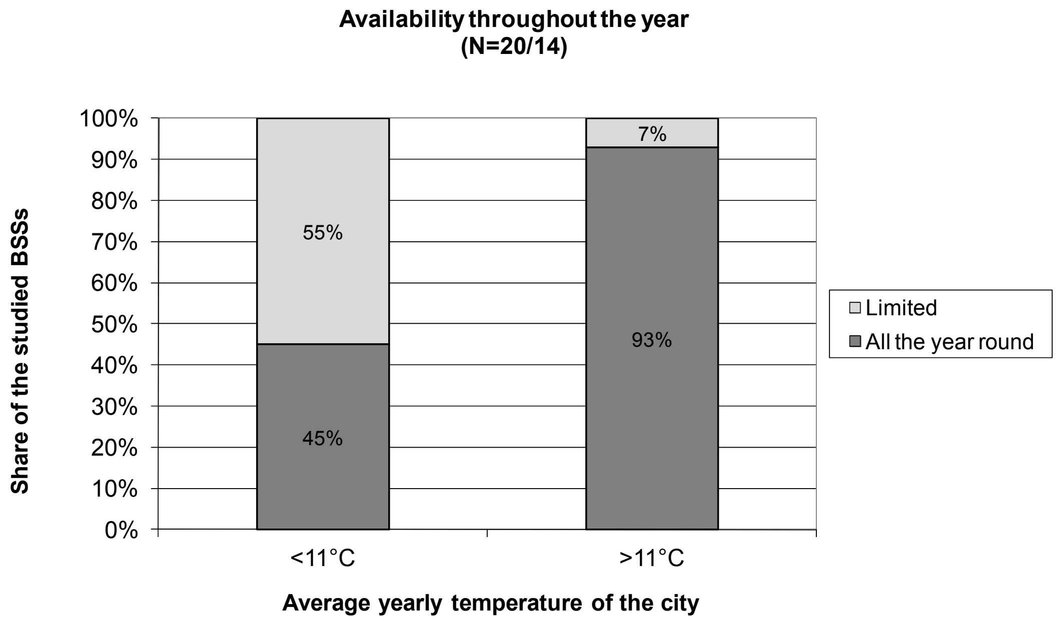
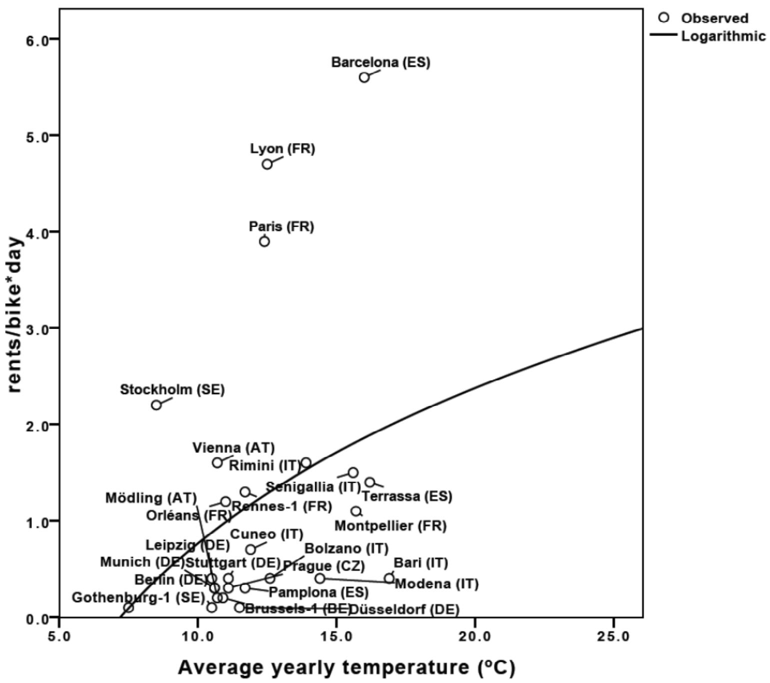


Figure 122: Availability throughout the year regarding the temperature of the city (Castro & Emberger 2010)

The correlation analysis reveals that BSSs located in warm cities manage higher rates of rents per bicycle than BSSs located in cold cities (Figure 123). The Spearman's coefficient is 0.478, which can be considered as low correlation. This result is confirmed by the p-value. It is 0.014, less than 0.1, hence the correlations is significant. According to the model, the logarithmic curve that fits the data is Y=-4.599+2.329*Ln(X). However, the low value of the coefficient of determination (0.098 far from 1) and the high p-value (0.119 higher than 0.1) reveal that the accuracy and significance of the function cannot be confirmed[39].

[38] The limit of 11ºC was chosen to provide a similar number of case studies in both groups according to observed distribution of the data.

[39] Other likely curves were tested but the best adjustment was obtained with the logarithmic function.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.098	2.619	1	24	.119	-4.599	2.329

The independent variable is Average yearly temperature (ºC).

Correlations

rents/bike*day,Average yearly temperature (ºC)

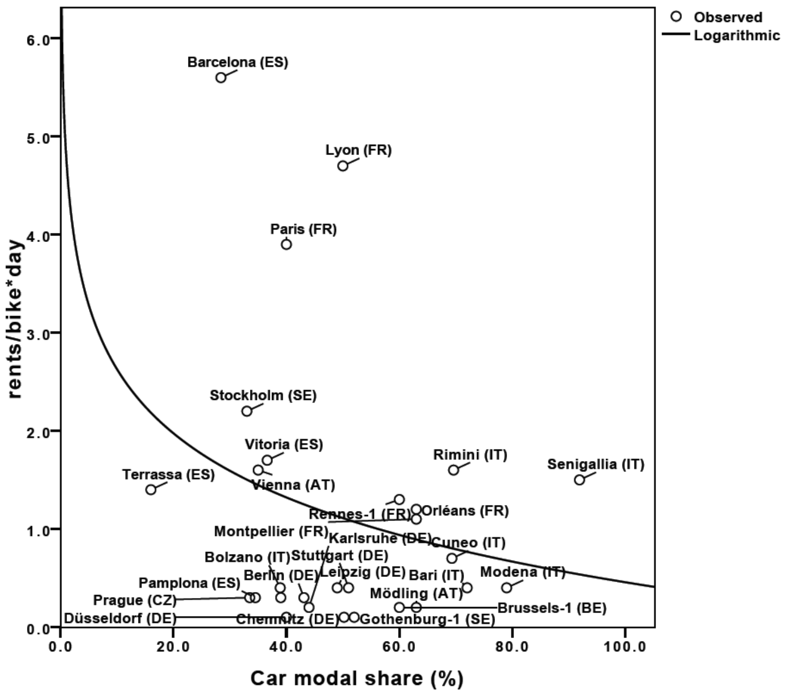
Spearman's rho	Correlation Coefficient	.478
	Sig. (2-tailed)	.014
	N	26

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 123: Model and correlation between the average yearly temperature and rotation. Data source: Annex 10.1

7.2.9 Car use

Rotation of bike-sharing bicycles might be higher in cities with lower car modal share. However, Figure 124 shows that this correlation cannot be confirmed. The high p-value (0.454) reveals that the correlation is not statistically significant.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.060	1.663	1	26	.209	4.800	-.943

The independent variable is Car modal share (%).

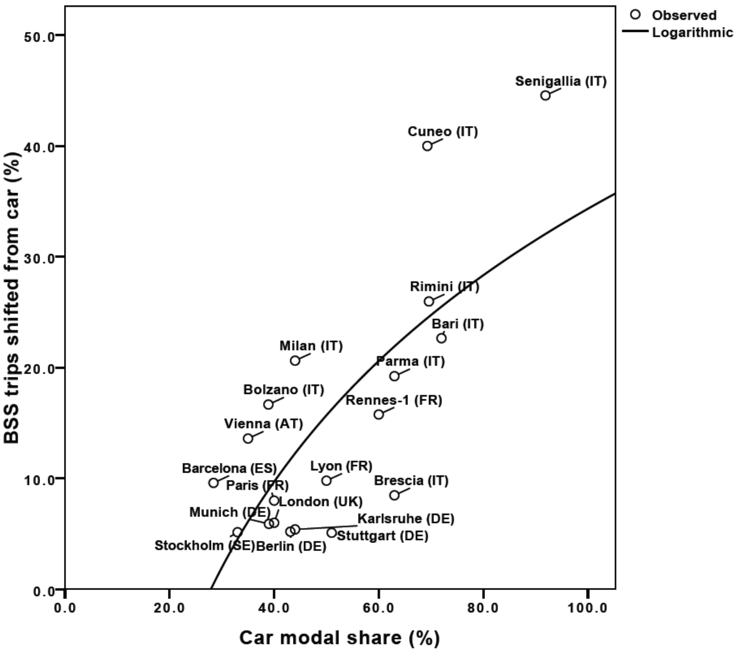
Correlations

rents/bike*day,Car modal share (%)

Spearman's rho	Correlation Coefficient	-.147
	Sig. (2-tailed)	.454
	N	28

Figure 124: Model and correlation between the car modal share and rotation. Data source: Annex 10.1

The car modal share can influence not only the quantity of users but also the characteristics of the bike-sharing users. High car modal shares in cities may lead to high shares of bike-sharing users that are former car drivers or passengers. Figure 125 confirms this theory. The Spearman's coefficient is 0.588. Therefore, the correlation between both variables can be considered as medium. This correlation is statistically significant because the p-value (0.008) is lower than 0.1. According to the model, the data fit the following logarithmic function: Y=-89.472+26.884*Ln(X). This function is statically significant due to the low p-value but the coefficient of determination is 0.521.



Dependent Variable:BSS trips shifted from car (%)

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.521	18.515	1	17	.000	-89.472	26.884

The independent variable is Car modal share (%).

Correlations

BSS trips shifted from car (%),Car modal share (%)

Spearman's rho	Correlation Coefficient	.588
	Sig. (2-tailed)	.008
	N	19

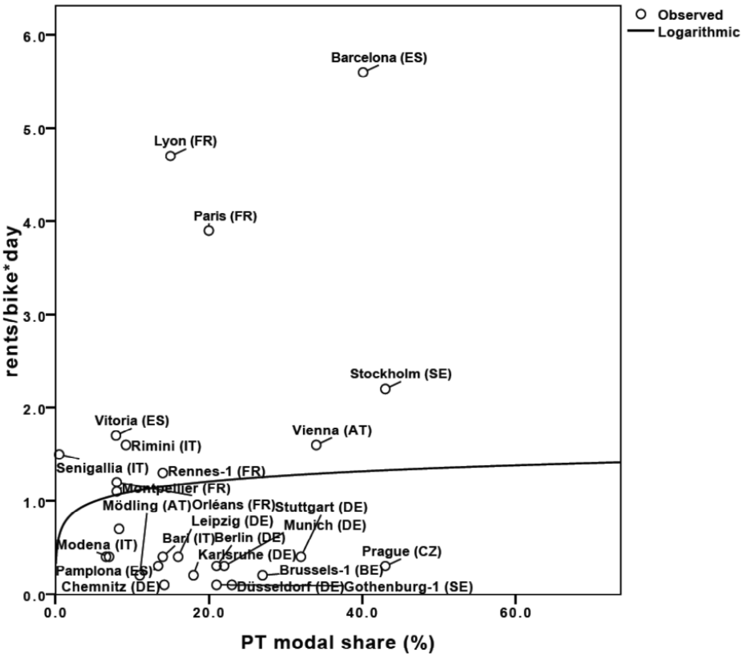
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 125: Model and correlation between the car modal share and the share of bike-sharing trips coming from car. Data source: Annex 10.1

7.2.10 Public transport use

In several sections of this dissertation it has been mentioned that PT passengers are potential users of BSSs. In section 7.2.5, it has been observed that demand of intermodality might increase bike-sharing use and section 6.2.4 revealed that on average 33% of bike sharing customers are former PT passengers. Moreover, section 7.2.7 has shown that population density increase rotation of bicycles. Therefore, since dense populated cities use to have higher public transport modal share (Castro & Emberger 2010), it is reasonable to think that cities with high modal share have higher levels of rotation. Nevertheless, this statement cannot be confirmed according to Figure 126. There is no significant correlation between public transport modal share and bike-sharing rotation, since the p-value is 0.557 (above 0.1)[40].

[40] Although the Spearman's correlation coefficient is negative (-0.112) the slope of the function is positive. This contradictory result may be caused by the low value of both parameters, which are close to 0. Since the values are not significant due to the high p-value, the sign may differ.



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.009	.234	1	25	.633	.736	.158

The independent variable is PT modal share (%).

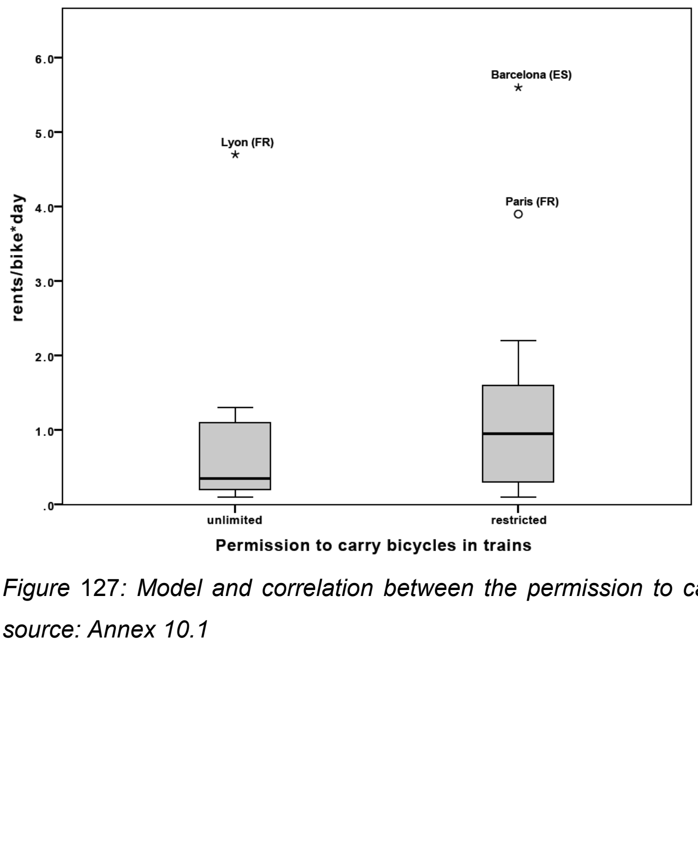
Correlations

rents/bike*day,PT modal share (%)

Spearman's rho	Correlation Coefficient	-.112
	Sig. (2-tailed)	.577
	N	27

Figure 126: Correlation between the public transport modal share and rotation. Data source: Annex 10.1

PT passengers can also own a bicycle and ride to the intial PT station and from the final PT stop to afford the first and last mile of the trip by carrying the bicycle in the PT vehicle. However, this is not always allowed. Some public transport operators do not permit to carry a bicycle in rush hours due to lower space available in vehicles. As section 2.4.5 has explained, bike-sharing can be a potential solution for these circumstances. The box plot of Figure 127 shows that restrictions carrying bicycles in PT vehicles might lead to higher levels of rotation. Nevertheless, no statistically significant correlation was found between them (p-value 0.152).



Correlations

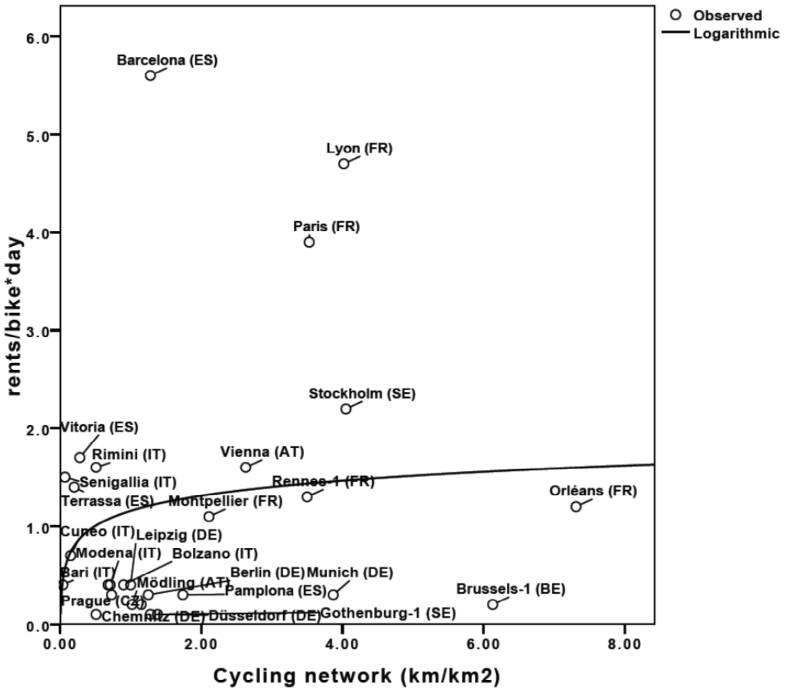
rents/bike*day,Permission to carry bicycles in trains

Spearman's rho	Correlation	.278
	Sig. (2-tailed)	.152
	N	28

Figure 127: Model and correlation between the permission to carry bicycles in trains and rotation. Data source: Annex 10.1

7.2.11 Bicycle use

As we saw in section 6.2.5, bike-sharing has probably motivated the expansion of existing cycling infrastructure. BSSs increase the total number of cyclists circulating and as a result, the demand on cycling infrastructure increases. However, can the existing bicycle infrastructure be a determinant factor of the success in terms of rent rotation? Since bike-sharing users are not expert daily cyclists, they might feel safer when they ride in specific facilities for cycling and this network might increase the attractiveness of BSSs. Figure 128 reveals that there is no significant correlation between dense cycle networks and high levels of bike-sharing rotation. The Spearman's coefficient is 0.074 (below 0.3) and the p-value is 0.714 (above 0.1)



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.041	1.101	1	26	.304	1.158	.221

The independent variable is Cycling network (km/km2).

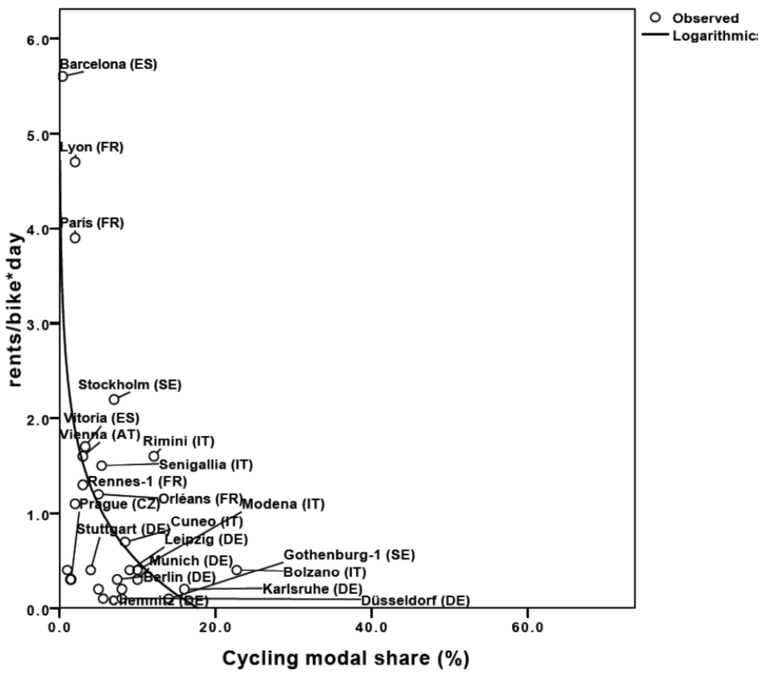
Correlations

rents/bike*day,Cycling network (km/km2)

Spearman's rho	Correlation Coefficient	.073
	Sig. (2-tailed)	.714
	N	28

Figure 128: Correlation between the cycle network density and rotation. Data source: Annex 10.1

In contrast, a high level of use of private bicycle can be a barrier for bike-sharing success in terms of rotation. Figure 129 shows that BSSs situated in cities with high cycling modal shares report less rents per bicycle. The strength of this correlation is low (Spearman's coefficient reaches 0.415) but the result is statistically significant (p-value is 0.031). The logarithmic function that fits the data according to the model is: Y=2.474-0.860*Ln(X).



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.315	11.509	1	25	.002	2.474	-.860

The independent variable is Cycling modal share (%).

Correlations

rents/bike*day,Cycling modal share (%)

Spearman's rho	Correlation Coefficient	-.415
	Sig. (2-tailed)	.031
	N	27

*. Correlation is significant at the 0.05 level (2-tailed).

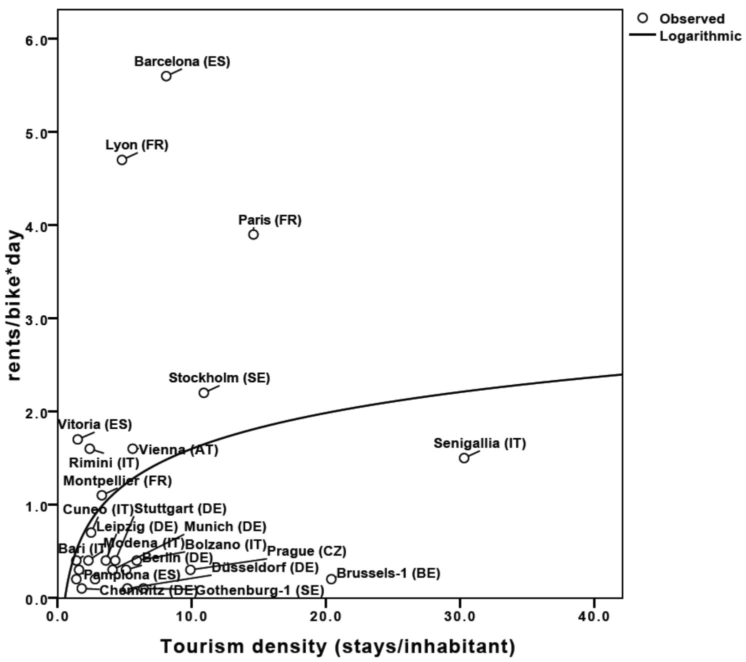
Figure 129: Correlation between the cycle modal share and rotation. Data source: Annex 10.1

Not only bicycle use but also bicycle ownership can constitute an obstacle for bike-sharing success. A research of Freiradl and Leihradl-nextbike in Lower Austria confirms this hypothesis (Castro, Lackner, et al. 2010). Freiradl was a low-tech BSS implemented in Lower Austria from 2003 to 2008. In 2009 the BSS was closed and replaced by a new and higher technology equipped system called Leihradl-nextbike. Several telephone surveys were undertaken in both periods of operation and the result was that 70% of potential Freiradl customers and 61% of potential Leihradl-nextbike customers stated that they did not use the BSSs because they owned a private bicycle.

7.2.12 Tourism

As section 6.6.4 has revealed, 99% of subscriptions of Vélib' in 2008 were short-term subscriptions (one-day and one-week subscriptions), which are the most attractive for tourists. This is not an isolated case. Tourism plays in many BSSs a very relevant role.

Figure 130 shows that the correlation between tourism and rotation of bike-sharing bicycles cannot be confirmed. The Spearman's coefficient is lower than 0.3 (0.187) and this result is not statistically significant according to the p-value, which is higher than 0.1 (0.371).



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.096	2.436	1	23	.132	.322	.555

The independent variable is Tourism density (stays/inhabitant).

Correlations

rents/bike*day,Tourism density (stays/inhabitant)

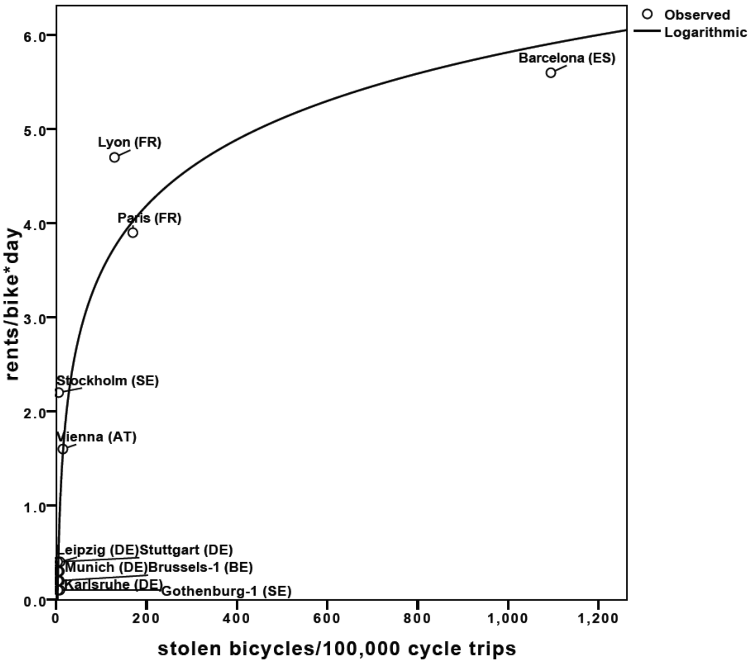
Spearman's rho	Correlation Coefficient	.187
	Sig. (2-tailed)	.371
	N	25

Figure 130: Model and correlation between tourism density and rotation. Data source: Annex 10.1

7.2.13 Vandalism

Although many people have a bicycle at home, not all of them are daily cyclists. Fear of vandalism is one of the main concerns argued by private bicycle owners for not cycling. The advantage of BSSs compared to private bicycles is that customers can ride without exposing their own bicycles to theft or damages (section 2.4.5). This fact may convince reluctant potential cyclists to use bike-sharing bicycles.

Figure 131 confirms this hypothesis, i.e. vandalism encourages potential or even former cyclists to use bike-sharing. A significant medium correlation exists between the municipal vandalism and rotation because the Spearman’s coefficient is 0.641 (higher than 0.5) and the p-value is 0.018 (lower than 0.1). According to the model, a higher the number of stolen bicycles per municipal cycle trip leads to a higher rotation in the following way: Y=-1.179+1.013*Ln(X).



Dependent Variable:rents/bike*day

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.879	79.678	1	11	.000	-1.179	1.013

The independent variable is stolen bicycles/100,000 cycle trips.

Correlations

rents/bike*day,stolen bicycles/100,000 cycle trips

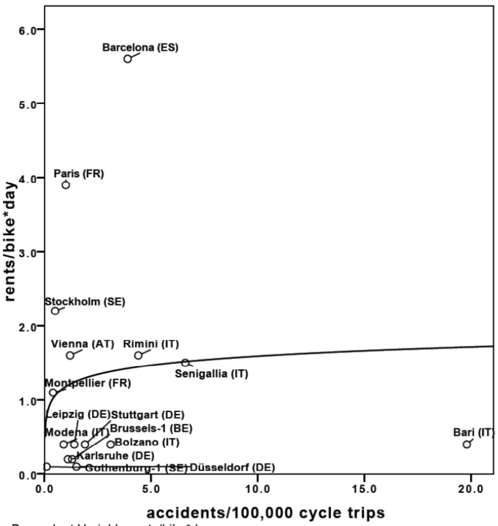
Spearman's rho	Correlation Coefficient	.641
	Sig. (2-tailed)	.018
	N	13

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 131: Model and correlation between municipal bicycle theft per 100,000 inhabitants and rotation. Data source: Annex 10.1

7.2.14 Traffic safety

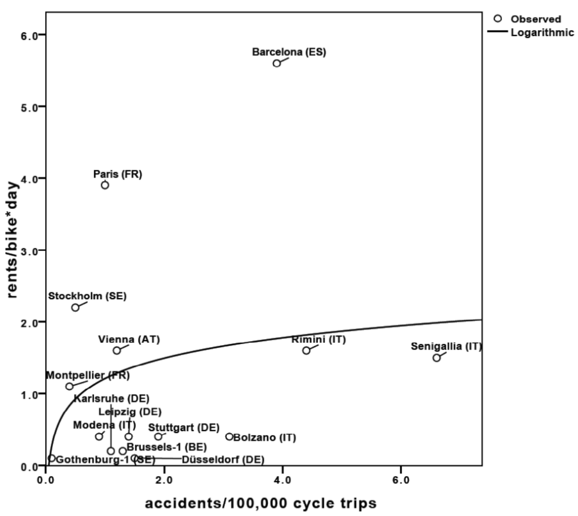
High rates of traffic accident risk in cities might produce fear of circulating by bicycle and consequently it might affect the level of use of bike-sharing. However, according Figure 132, it does not occur. There is no significant correlation between traffic safety and rotation of bike-sharing bicycles. The Spearman’s coefficient is 0.138 (below 0.3) and the p-value is 0.611 (above 0.1). Although the case study of Bari would be removed because, it looks like an outlier, the p-value would remain too high.



Dependent Variable:rents/bike*day

Equation	Model Summary: R Square	F	df1	df2	Sig.	Parameter Estimates: Constant	b1
Logarithmic	.020	.283	1	14	.603	1.181	.178

The independent variable is accidents/100,000 cycle trips.



Dependent Variable:rents/bike*day

Equation	Model Summary: R Square	F	df1	df2	Sig.	Parameter Estimates: Constant	b1
Logarithmic	.074	1.046	1	13	.325	1.210	.411

The independent variable is accidents/100,000 cycle trips.

Correlations

rents/bike*day,accidents/100,000 cycle trips

Spearman's rho	Correlation Coefficient	.138
	Sig. (2-tailed)	.611
	N	16

Figure 132: Model and correlation between the number of cycle accidents per 100,000 municipal cycle trips and rotation. All case studies on the right and all cases except Bari on the right. . Data source: Annex 10.1

7.2.15 Multiple influence

Sections 7.2.1 to 7.2.14 have shown the isolated influence of diverse driving forces on the level of rotation of BSSs, i.e. the influence on each driving force on rotation when the other driving forces remain constant. However, in real life these driving forces do not influence separately but all together and driving forces interact with each other in a complex system.

In this section 7.2.15 a multiple regression analysis has been carried out to consider interactions between driving forces of bike-sharing. In contrast to the above correlation study, independent variables are not defined anymore as “independent”, but as “explanatory”, since it is assumed that the variables are part of a system where they interact.

The single models carried out between the different driving forces and rotation from section 7.2.1 to 7.2.14 fit a logarithmic curve, but the multiple regression model has to be linear. Therefore, the linear multiple regression model has to be adapted with the following equation:

$Y=a_0+a_1X'_1+a_2X'_2+\ldots+a_iX'_j$; where

- Y = rotation in number of daily rents per bicycle,
- X'_1 = Ln(X_1), X'_2,= Ln(X_2),…, X'_i = Ln(X_j) where X_1, X_2,…, X_i are the values of explanatory variables
- a_1, a_2,…,a_i are the coefficients to be estimated

Given the relatively large number of explanatory variables (23) and regarding the maximum number of observations with available data (28) inexactness due to multicollinearity can be expected. To minimize this negative effect in calculations, the number of explanatory variables has been reduced. The criteria for the selection of variables for the multiple regression model are four: 1) correlation between variables have to exist, 2) the correlation has to be significant, 3) the number of observations have to be higher than 20 and 4) the explanatory variables have to be metric (Table 35)[41].

Independent variable	Dependent variable	Correlation level	Significant	N	Type of explanatory variable	Selection multiple regression
Number of bicycles	Rents/bicycle*day	Low	No	28	Metric	No
Number of stations		Low	Yes	23	Metric	**Yes**
Distance between stations		Medium	No	11	Metric	No
Density of stations (station/km2)		Low	Yes	23	Metric	**Yes**
Technology of the docking device		No correlation	No	28	Ordinal	No
Way of identification					Nominal	
All-year-round service		Low	Yes	28	Dichotomous	No
Round-the-clock-service		No correlation	No	28	Dichotomous	No
Validity of long-term subscriptions		No correlation	No	28	Dichotomous	No
Rental period free of charge					Ordinal	
Metro stations provided with BSS		High	Yes	6	Metric	No
Advantageous fee for PT passengers		No correlation	No	28	Dichotomous	No
Population		No correlation	No	28	Metric	No
Population density		Low	Yes	28	Metric	**Yes**
Average yearly temperature		Low	Yes	26	Metric	**Yes**
Car modal share		No correlation	No	28	Metric	No
Cycle network density		No correlation	No	28	Metric	No
Cycling modal share		Low	Yes	27	Metric	**Yes**
PT modal share		No correlation	No	27	Metric	No
Permission to carry bikes in trains		No correlation	No	28	Dichotomous	No
Tourism density		No correlation	No	25	Metric	No
Theft per cycle trip		Medium	Yes	13	Metric	No
Accidents per cycle trip		No correlation	No	16	Metric	No

Table 35: Variables for the multiple regression model

As a result of the selection, only the following five variables have been inserted in the model:

[41] Dichotomous, nominal and ordinal variables may be zero (option “no”). Since the explanatory variables X_i are transformed into an logarithmic function $Ln(X_i)$, if $X_i = 0$ the model will not work.

- Number of stations
- Stations per city km^2
- Population density
- Average yearly temperature
- Cycling modal share

The outcome of the model with these five variables is presented in Table 36.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.824[a]	.679	.572	1.0281

a. Predictors: (Constant), ln.cycling, ln.temperature, ln.population_density, ln.stations, ln.stations_density

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33.547	5	6.709	6.347	.002[a]
	Residual	15.856	15	1.057		
	Total	49.403	20			

a. Predictors: (Constant), ln.cycling, ln.temperature, ln.population_density, ln.stations, ln.stations_density
b. Dependent Variable: rents/bike*day

Coefficients[a]

Model		Unstandardized Coefficients	
		B	Std. Error
1	(Constant)	-4.406	4.883
	ln.stations	.394	.245
	ln.stations_density	.218	.258
	ln.population_density	.184	.369
	ln.temperature	1.371	1.246
	ln.cycling	-.019	.306

Coefficients[a]

Model		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		Beta			Tolerance	VIF
1	(Constant)		-.902	.381		
	ln.stations	.448	1.610	.128	.277	3.615
	ln.stations_density	.254	.845	.412	.236	4.240
	ln.population_density	.123	.498	.626	.349	2.868
	ln.temperature	.176	1.100	.288	.840	1.191
	ln.cycling	-.012	-.061	.952	.574	1.742

a. Dependent Variable: rents/bike*day

Table 36: Linear regression model that determines the value of the rotation regarding five explanatory variables. Data source: Annex 10.1

The first parameter that has to be remarked is the coefficient of determination ("R square"). It is 0.679, which means that 67.9% of the variability observed in rotation can be explained by the assessed values of the explanatory variables. The remaining 33.1% can be explained by variables out of the ones selected for the model or by inherent variability of rotation.

The “adjusted R square” (0.572) shows the value of the coefficient of determination without risk of inflation.

The p-value of the ANOVA test is 0.002; it means that there is only 0.2% of probability of type I (false positive) error. The significance level is 0.1. Therefore the regression model fits significantly well. The null hypothesis is: a_1, a_2,…,a_i = 0 in the linear regression equation $Y=a_0+a_1X'_1+a_2X'_2+\ldots+a_iX'_j$. Since the p-value is lower than the significance level, the null hypothesis can be rejected and at least one of the coefficients is different to zero.

Regarding the coefficients of the equation (“B”), the model predicts the following function:

Y = -4.406+0.394*Ln(stations) + 0.218*Ln(stations/km^2) + 0.184*Ln(inhabitants/km^2) + 1.371*Ln(average yearly temperature in ºC) – 0.019*Ln(cycling share).

Nevertheless, the significance analysis of the T test in every explanatory variable separately shows p-values that range from 0.128 to 0.952. Since they are in all cases higher than 0.1, the association of each variable individually with rotation inside the system is not statistically significant. One likely reason for this deviation is the multicollinearity of the explanatory variables, i.e. several variables may be correlated to each other so that they provide the same information. Although the whole model fits the data well because of the low p-value of the ANOVA test, none of the explanatory variables Xi has a statistical significant impact on predicting Y by itself. To identify multicollineraty, a diagnostic test has been performed. The outcomes are shown in Table 37.

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index
1	1	4.882	1.000
	2	.902	2.327
	3	.167	5.404
	4	.041	10.939
	5	.006	27.482
	6	.001	57.441

Collinearity Diagnostics[a]

Model	Dimension	Variance Proportions					
		(Constant)	ln.stations	ln.stations_density	ln.population_density	ln.temperature	ln.cycling
1	1	.00	.00	.00	.00	.00	.01
	2	.00	.02	.08	.00	.00	.03
	3	.00	.00	.20	.00	.00	.78
	4	.00	.90	.45	.01	.02	.01
	5	.00	.07	.06	.51	.35	.02
	6	1.00	.01	.21	.48	.63	.15

a. Dependent Variable: rents/bike*day

Table 37: Collinearity diagnostic. Data source: Annex 10.1

The highest value of the “condition index” in the model is 57.441, while values above 20 may imply collinearity. Furthermore, the Variance Inflation Factor (“VIF”) shown in Table 37 is another indicator of collinearity. Values higher than 10 are considered as indicating collinearity, but values above 2.5 may represent a collinearity risk in some cases. Three variables of the model exceed the lower limit.

A likely way to reduce multicollinearity and consequently to reduce the p-value of the individual t-tests is to reduce the number of explanatory variables. If the three explanatory variables with higher p-values in the individual t-tests are removed from the model the remaining variables are the following two:

- Number of stations
- Average yearly temperature

When these two remaining variables run the multiple regression model, the result is the one presented in Table 38.

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	ln. temperature, ln.stations	.	Enter

a. All requested variables entered.
b. Dependent Variable: rents/bike*day

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.795[a]	.632	.593	.9782

a. Predictors: (Constant), ln.temperature, ln.stations

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31.226	2	15.613	16.315	.000[a]
	Residual	18.182	19	.957		
	Total	49.408	21			

a. Predictors: (Constant), ln.temperature, ln.stations
b. Dependent Variable: rents/bike*day

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-5.168	2.611		-1.979	.062		
	ln.stations	.645	.120	.749	5.377	.000	.999	1.001
	ln.temperature	1.811	1.035	.244	1.751	.096	.999	1.001

a. Dependent Variable: rents/bike*day

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	ln.stations	ln. temperature
1	1	2.823	1.000	.00	.03	.00
	2	.174	4.033	.01	.97	.01
	3	.003	29.571	.99	.00	.99

a. Dependent Variable: rents/bike*day

Table 38: Linear regression model that determines the value of the rotation regarding two explanatory variables. Data source: Annex 10.1

In this way, R and the adjusted coefficient of determination have similar values to the previous model with five explanatory variables, 0.632 and 0.593 respectively. The p-value of the whole model is now even lower than in the previous model (0.000 instead of 0.002). Therefore, the goodness of the fit is statistically significant. Moreover, in this model with two variables, in contrast with the previous model with five, all p-values of the individual t-tests are lower than 0.1.

They are now 0.000 for the number of station and 0.096 for the average temperature (0.062 for the constant). Therefore, not only the model fits well, but also the variables individually are significant correlated with rotation.

According to this model, the new function is:

Y = -5.168+0.645*Ln(stations) + 1.811*Ln(average yearly temperature in ºC)

This function can be interpreted as follow. Based on only these two variables, for example, if a hypothetical city with 15ºC of average yearly temperature decides to implement a BSS with 20 stations, it can expect around 1.67 rents per bicycles and day. If the city increases the number of stations from 20 to 30 the expected increase of rotation will be 15.6% (from 1.67 to 1.93). If the number increases again from 30 to 40, rotation will be 9.3% higher. And from 40 to 50 stations the increase of rotation will be 5.2%. The decreasing increase of rotation as the number of stations grows is indicative of the original logarithmic function of rotation.

Unfortunately, it is not possible to include more explanatory variables in the model due to multicollinearity. Actually, this combination of explanatory variables is the only one that builds a model with significant results in the individual t-tests (p-values below 0.1). To include more than two explanatory variables in the model avoiding the effects of collinearity, it would be necessary: 1) to search for new variables not included in Table 35, 2) to increase the size of the sample, i.e. more than 28 cases studies with available data and 3) to fill the gaps of not available data in the data matrix.

7.3 Barriers

7.3.1 Overuse

Overuse means that bike-sharing bicycles are rented and ridden more than expected or desired. The level of overuse (and underuse) of a BSS can be determined and foreseen by mean of three likely indicators:

- The number of long-term subscriptions per available bicycle.
- The rotation of bike-sharing bicycles, i.e. the number of times that a bicycle is rented in a day.
- The daily distance covered per bicycle.

Normally, the origin of overuse (and underuse) is an inaccurate estimation of demand and supply of bike-sharing services. An insufficient number of bike-sharing bicycles compared to demand or an excessive demand compared to the number bicycles can cause overuse of BSSs.

Bicing is a representative example of under-estimation of demand. Before the launch of the BSS, the City of Barcelona estimated that 40,000 persons would become members of the BSS. However, 30,000 subscriptions were reported only in the first two months of operation and after one year there were about 100,000 subscribers, more than the double of expected (Bikeoff 2008b; NYC Department of City Planning 2009).

Overuse can be a general problem of a whole BSS, but also a local concern of a certain area or moment. For instance, bike-sharing stations situated close to large public transport nodes are more likely to become saturated, especially in rush hours.

Intensive use of bike-sharing bicycles produces two main negative effects on BSSs:

- Unavailability of service
- Breakdowns of bicycles

Since the bicycles of crowded BSSs are rented many times in a day, stations stay empty of bicycles for long periods of time. Unavailability of bicycles hinders the access to the bike-sharing service and consequently the satisfaction grade of users decreases (section 7.3.9). Not only insufficient bicycles can impair the access to the service, but also insufficient number of stations. For instance, in Paris, over-demand of bike-sharing has caused that customers have even queued in front of terminals of Vélib' to rent a bicycle (Sassen 2009). Implications of the breakdown of the mechanisms of bicycles are explained in section 7.3.4.

There exist several strategies to solve or minimize the negative impacts of overuse. The main instruments are mentioned below.

An increase of the number of bicycles causes an immediate and mathematical reduction of the rate of rotation, which is one of the indicators of under- and overuse. Therefore, the variation of the bike-sharing bicycle fleet can be understood as strategic instrument to restore "reasonable" levels of rotation.

In Barcelona, the increase of the bicycle fleet was not sufficient to mitigate over-use. Initially the increase of bike-sharing stations and bicycles through different expansions contributed to balance supply and demand (Sassen 2009). Nevertheless, demand continued rising and the operator had to implement a complementary solution: the gradual increase of the annual subscription fee (Figure 133). When the BSS was launched, in March 2007, the subscription fee cost €6. Then, a subscription boom took place and the City of Barcelona decided to increase subscription fee up to €24. As a result, the increasing rate moderated. 68% of members declared to be satisfied with those cost of annual subscription (Bikeoff 2008b). However, this first increase was not able to absorb the existing demand and memberships continuous increasing. In 2009 the subscription fee rose up to €30.

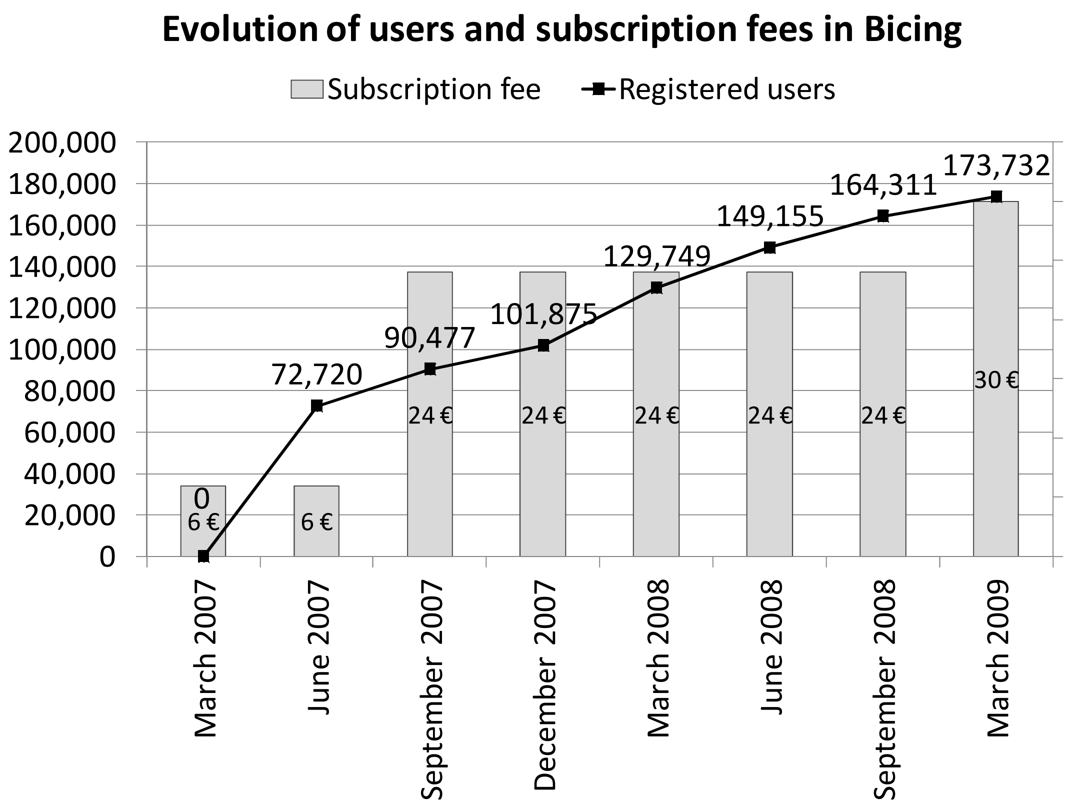


Figure 133: Registration of customers of Bicing regarding rising subscription costs. Data source: (López 2009)

Another instrument to reduce demand is to restrict the access to the BSS to certain target groups. For instance, in Barcelona it was initially allowed for visitors to use Bicing through short-term subscriptions. This option was removed to avoid competition with traditional bike rental business (section 7.2.12) but also to help to control demand by allowing access only to residents (Bikeoff 2008b). In London the operator learned from the experiences of Bicing in Barcelona and the process was the opposite. When Barclay's Cycle Hire was implemented in 2010, the new BSS was available only for users who registered for long-term subscriptions. Short-term subscriptions were allowed after the starting phase (Büttner et al. 2011).

As a last resort, if bike-sharing operators are not able to manage a BSS due to overuse, they could even limit the number of subscriptions and introduce a waiting list. In this way the pressure of demand may be reduced (Bea Alonso 2009; Hayes & Frühauf 2010).

7.3.2 Underuse

Underuse means a lower number of rents than expected or desired. As section 7.3.1 has explained, the level of underuse (and overuse) of a BSS can be determined and foreseen by mean of the number of long-term subscriptions per available bicycle, rotation and the daily distance covered by bicycles.

Contrary to overuse, underuse is caused by an excess of the number of bicycles or by a deficit of demand. Although section 7.2.1 has revealed that a high number of bike-sharing bicycles and stations may lead in principal to increase rotation, it is reasonable to think that this effect is limited. The limiting resource of this chain reaction is the city population (section 7.2.6) and its bike-sharing demand. For instance, if a BSS would implement an extremely high number of bike-sharing bicycles and stations in a small city, it would not necessarily mean that the number of rents would be so high. Bike-sharing infrastructure installed has to fit with real demand. Therefore, an excessive number of bicycles and stations regarding demand may lead to underuse. BSSs with fewer rents than expected can produce two main negative effects:

- Inefficiency
- Economic non-viability

A low efficiency of the bike-sharing infrastructure may compromise the achievement of the goals of the BSS. Moreover, BSSs with a low number of customers cannot aspire to high incomes from users and from sponsorships. Therefore, if goals are not achieved and maintenance costs are unaffordable the operation of BSSs becomes senseless and economically unviable. In this way, underused BSSs can lead to their close and the loss of the money invested.

It is difficult to predict the risk of underuse and this can dissuade investors to fund bike-sharing projects. To avoid the investment loss motivated by underuse, the City Council of Hamburg took out insurance against under-demand. The city has planned to expand the BSS in three phases and the insurance, which has a value of 3 to 5% of the total investment, will cover the removal of stations in case of underuse (Sassen 2009).

The allocation of bike-sharing stations is another crucial factor to avoid underuse and its effects. The inappropriate location of a station when designing a BSS can compromise its level of use and the rotation of its bicycles. BSSs equipped with high technology stations require expensive groundwork such as removal of asphalt, excavation and subterranean energy supply for the docking points and terminals. The possibility to change the location of these terminals is limited. Nevertheless, some BSSs have started offering alternatives in this matter. For instance, Bixi, the BSS implemented in 2008 in Toronto (Canada), introduced a new concept of station that increases the flexibility of locations and reduces costs. The stations of Bixi are supplied with solar energy and they are fixed through metal platforms instead of foundations in soil. In this way, if demand changes or if it is wrongly estimated, the operator can undertake a readjustment of locations and size (number of docking points) of the stations in an easier and cheaper way (DeMaio 2009b). In Berlin a new BSS called StadtRAD has been tested in 2010 and its stations are equipped with innovative concrete docking points that require no groundwork or cabling. The information system and the docking mechanism are integrated in the bicycle lock, which communicates via wireless with the computer of the terminal. This typology of station could also reduce implementation costs and costs of the relocation of the stations (Büttner et al. 2011).

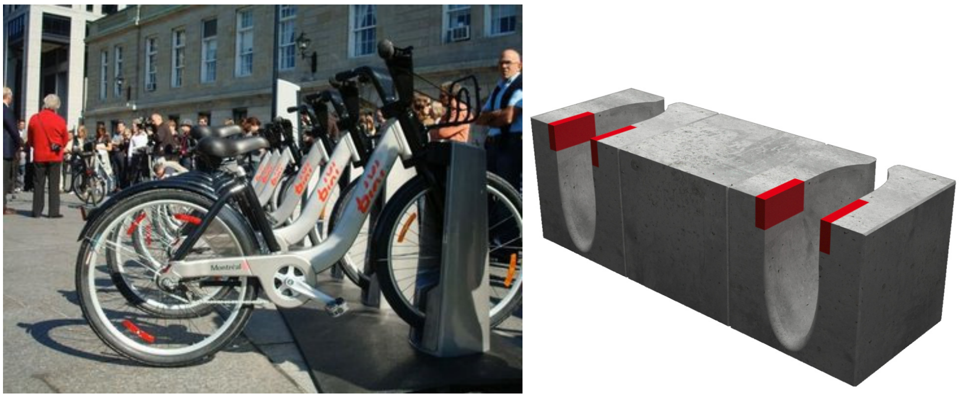


Figure 134: Metal superficial station of Bixi in Montreal (right) (DeMaio 2009b) and concrete station of StadtRAD in Berlin (left) (Büttner et al. 2011)

7.3.3 Theft and damage of bicycles

Although private bicycle theft in cities can be argued as a reason to use bike-sharing (section 7.2.13), vandalism produces also negative effects in BSSs such as theft and damage of bike-sharing bicycles.

Figure 135 shows the average annual number of bicycles stolen of the case studies of this dissertation. It has been calculated by dividing the aggregated number of bicycles stolen from the start of the BSS by the time of life of these BSSs.

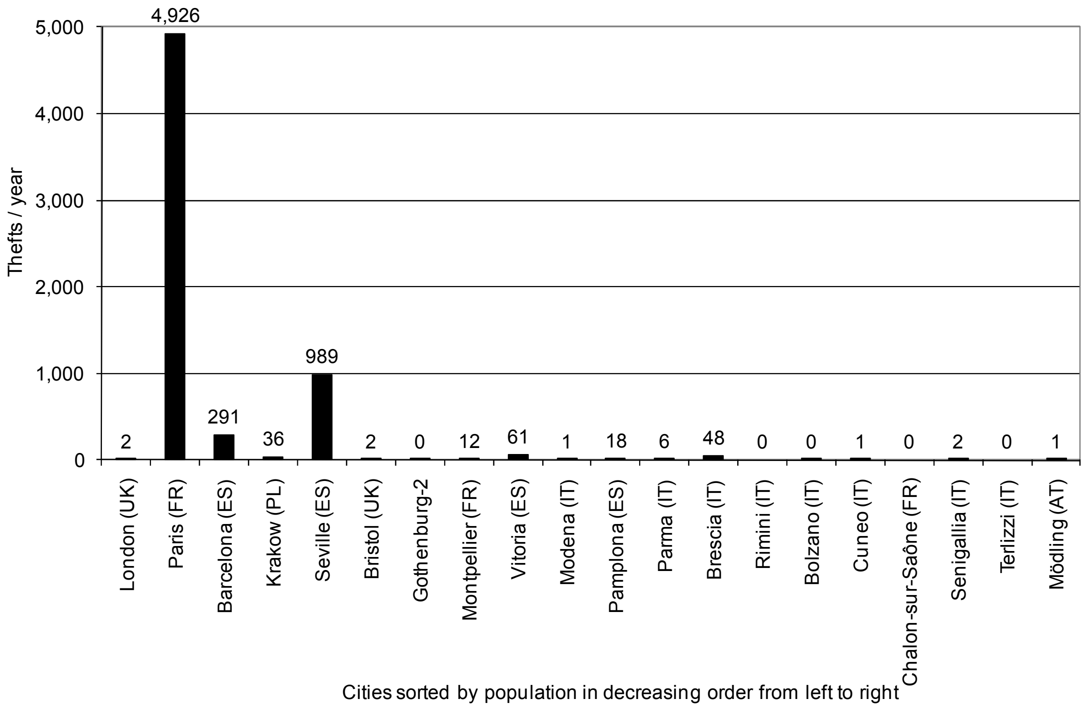


Figure 135: Stolen bicycles per year of operation. Data source: Annex 10.1

If is normalized by the number of bicycles of the bike-sharing fleet, the resulting Figure 136 reveals that in cities such as Seville, Brescia, Krakow and Paris about 50%, 40%, 36% and 24% of the existing bike-sharing fleet is annually stolen. In contrast, in other cities the affection of vandalism seems to be rather moderate. The average ratio of stolen bicycle is 12%, while the statistical median shows that in one half of case studies theft ratio is 4%.

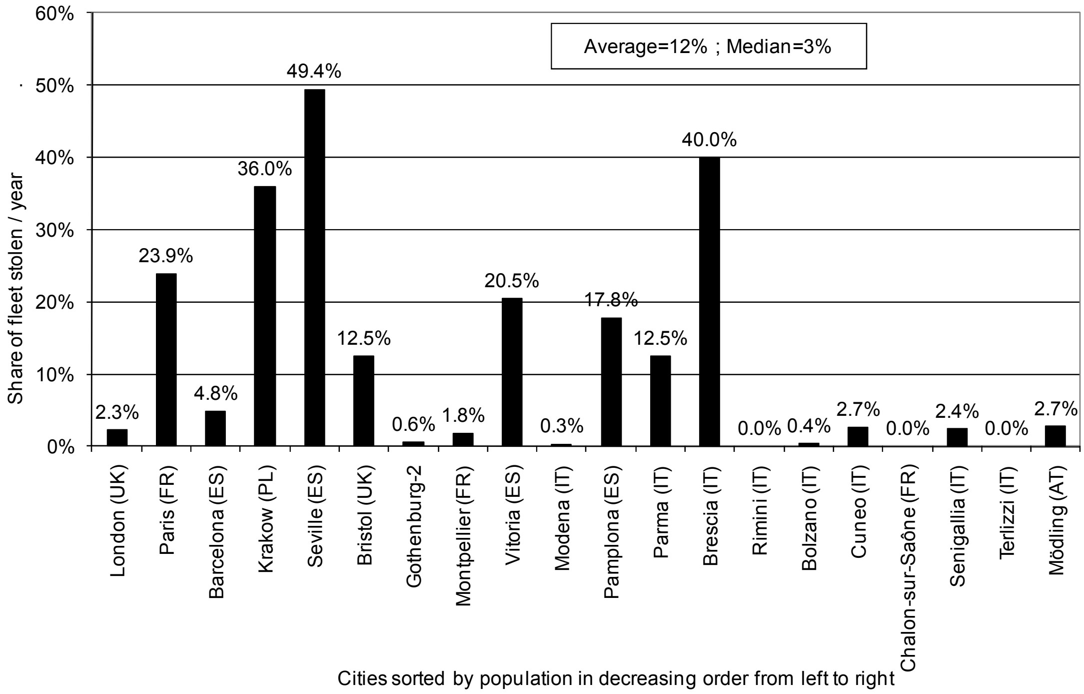


Figure 136: Average share of the bicycle fleet annually stolen. Data source: Annex 10.1

According to the Danish Police, two-thirds of theft of the BSS of Copenhagen, City Bike, are convenient theft, it means the bicycles are stolen just to be used once and then they are abandoned (DeMaio 2001). The same happens in other large-scale BSSs like Bicing in Barcelona. Just from May to December 2009, 3,300 bicycles disappeared temporally but only 400 were actually stolen because 2,900 (88%) were later recovered.

If we assume that Figure 136 shows no-returned bicycles, it is possible to estimate the annual cost due to bicycle theft by multiplying the number of stolen bicycles by the unitary price of bicycles (section 6.7.2)[42]. It the result is normalized with the number available bicycles, we obtain Figure 137. According to this estimation, Sevici, the BSS installed in Seville, spends about €267 per available bicycle and year while the BSS in Vitoria, Krakow and Paris spend €205, €194 and €120 per bicycle and year respectively. In the rest of case studies costs motivated by bicycle theft are below €100 per available bicycle and year. The average annual costs of theft can be established on €57 per bicycle and year, while the statistical median is €15 per bicycle and year.

[42] The average unitary cost of bicycles has been assumed for the case studies without data, e.g. in Krakow, Seville, Bristol, Gothenburg, Pamplona, Cuneo and Senigallia.

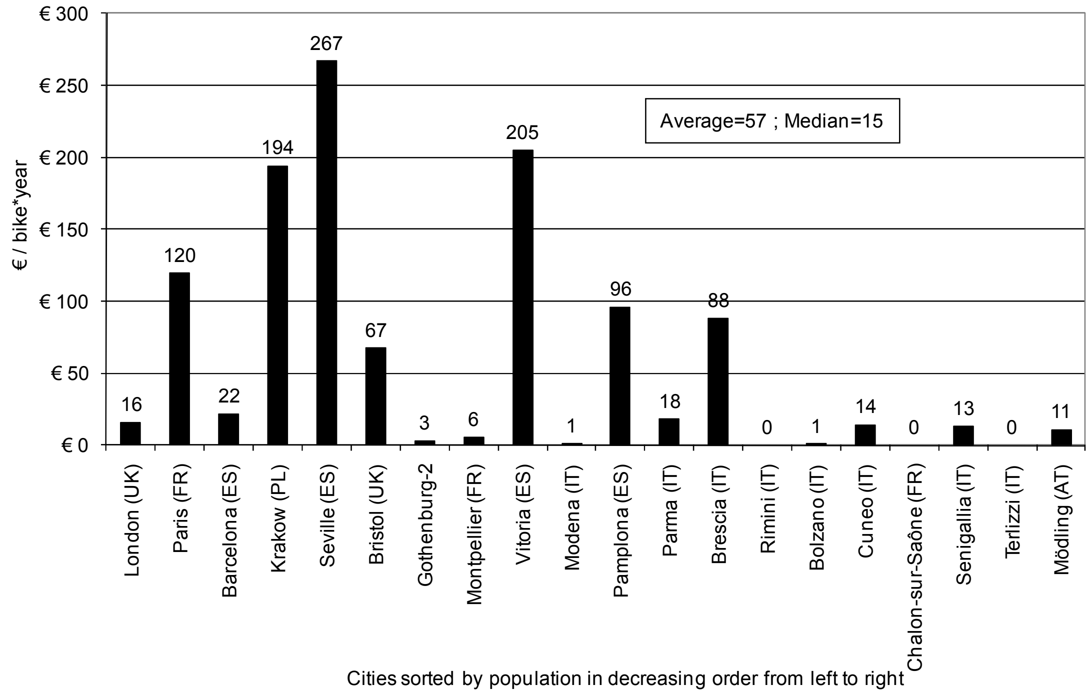


Figure 137: Cost of theft per available bicycle and year. Data source: Annex 10.1

Apart from the substitution of stolen bicycles, vandalism can cause other costs such as repair of damaged bicycles. The proportion of damaged bicycles regarding the stolen ones is in Barcelona 2.4 to 4, i.e. per each 4 bicycles that are purchased because of theft, 2.4 are repaired due to vandalism (Muñoz 2009). The costs of both damaged and stolen bicycles could reach up to €2,000 or €3,000 per bike-sharing bicycle and year (Borcherding et al. 2010). Therefore, vandalism is a considerable concern of bike-sharing operators.

Theft and damage of bike-sharing bicycles imply two negative consequences:

- Maintenance costs increases.
- Quality of service declines, which has effects on satisfaction grade and image.

Bike-sharing operators have implemented several security instruments to reduce vandalism and minimize the effects on the system. For instance, in Berlin, it has been tested that BSSs with fixed stations provide more security than flexible systems without stations. According to the OBIS Handbook, during the laboratory phase of StadtRAD Berlin, 300 test users tried and evaluated the system from March 2010 until November 2010. The system included two technical approaches: flexible stations without docking points and fixed station with docking points. With the help of customer surveys and during frequent discussions with the city administration it was decided that a station with docking points is the preferred option due to potential safety instead of flexible stations that might cause vandalism problems (Büttner et al. 2011).

In Paris and Lyon, the BSS operator, JCDecaux, seems to have identified one the main reasons for the high bicycle theft in both systems: the design of the locking mechanism. This device could motivate that inexperienced users do not return the bike properly and in this way unlocked bicycles are easier stolen and damaged (NYC Department of City Planning 2009). The feasibility study of the BSS of New York City recommends uncomplicated and intuitive locking mechanisms to make the rental process easier and safer, especially for short-term users (NYC Department of City Planning 2009). In Barcelona it is planned to increase the number of stations provided with a light that help to confirm the right parking of bicycles and an audible indication will be introduced to combat a wrong return of bicycles (Bikeoff 2008b). In London, the Barclays Cycle Hire provides information on the handlebars to remind customers how to correctly return the bicycle.

Figure 138: Information in the handlebar of a bicycle of the Barclays Cycle Hire of London

When bicycles are intentionally stolen particular instruments are required. The bicycles of many third generation BSSs are equipped with exclusive components with a different design and shape than commercial ones. In this way, if the bicycles are stolen, they can be easily recognisable and if the components are stolen, they are not usable in commercial bikes. Bicycles can also be personalized with a chip to dissuade theft and to make easier their finding. In Barcelona, for example, bicycles are equipped with a chip that provides them with an electronic identification. The bike-sharing stations read it through radio frequency identification (RFID) tags (Bremner 2008). Stations inform a centralized computer in real-time about when the bikes are hired and returned and it confirms the unique ID of the bike. These data are also used to manage the system and to make statistics (NYC Department of City Planning 2009; Bikeoff 2008b). GPS could help BSSs to locate and collect the stolen bikes and to provide more accurate data about the true distance covered by each trip (DeMaio 2009b). Bicing initially planed to equip the fleet of bicycles with GPS devices but the project was finally refused because of the high costs of implementation (Bikeoff 2008b).

One of the main and most usual instruments to avoid damages in bicycles is to protect the components and to integrate them in internal parts. For instance, to hide breaks, light and gears cables in tubes of the bicycle structure (Sassen 2009; NYC Department of City Planning 2009).

As section 5.5.5 has explained, some BSSs ask for fines to their members in case of inappropriate usage or theft, but also municipal fines could be asked to reinforce the punishment. A report of the Bikeoff project, which studied the main weakness and most common incidents of the security of Bicing in Barcelona, has suggested this solution. Despite the particular design of the fleet of Bicing, a considerable number of bicycles has been stolen and some of them appear abandoned in the city of Barcelona, in the metropolitan area or even in far cities such as Bilbao, where the cycles cannot be recognised. The chips with the electronic identification have been sometimes removed, docking points have been manipulated to avoid the right return of bicycles and enable theft, locks have been cut, bike seat have been slit and chains, gears and lights damaged. To combat the high rate of vandalism, the City Council of Barcelona plans to implement a municipal fine of €750 based on breach of the civil laws (Muñoz 2009).

7.3.4 Breakdowns

During their operative life, bicycles can break down. The types of damages in bike-sharing bicycles are diverse. A user survey carried out in 2006 in London revealed the most frequent defects of bicycles of the BSS OYbike were the following (Noland & Ishaque 2006): 30% of customers stated that “gears did not work well” while 26% assured that “locking device did not work or was difficult to use”. Other problems found were that “pedals were broken” (17%), “brakes did not work well” (15%), “seat adjustment was incorrect” (11%), “tyre pressure was too low” (9%) and “lights and reflector was missing or damaged” (9%)[43]. Only 28% of customers affirmed that used bike-sharing bicycles had no faults.

Similar figures can be found in other BSSs. The City Council of Barcelona considers “normal” that 8% of the bicycle fleet of Bicing has to be daily repaired because of intensive usage. According to a study of the city of Barcelona, 12% of bicycles available at bike-sharing stations have heavy functional defects that avoid the normal usage and 55% of bicycles have light defects such as broken bells and lights. These light defects are compatible with the usage of the bicycle but illegal according to the municipal traffic rules (Muñoz 2009).

Breakdowns in bicycles can be caused by three reasons: 1) by climate conditions that boost deterioration of bike-sharing bicycles situated outdoors and exposed to meteorological agents, 2) by vandalism and 3) by intensive usage. Breakdowns generate unavailability of bicycles and lower capacity of the service. Altogether motivates bad image of BSSs and dissatisfaction of customers. Additionally, transport of staff and bicycles is required for minor and major repairs. Therefore, breakdowns of bicycles can also increase maintenance costs and CO_2 emissions. High rates of damaged bicycles and the consequent lower level of service might cause other indirect over-costs. For instance, the municipality of Paris may charge JCDecaux for not maintaining the fleet in a good state (NYC Department of City Planning 2009).

Operators have implemented several instruments to reduce breakdowns. Bicycles are especially designed to be robust. For instance, bicycles of Citybike Wien in Vienna are equipped with tyres filled of gum instead of air filled inner tubes to avoid flats. Bicycles without gears are also more durable and they report fewer breakdowns (Castro 2009).

[43] Multiple responses were allowed in the questionnaire

In Leipzig, the operator of nextbike stated that the company does not buy the entire bicycles. The company buy the bicycle components and they make the montage themselves. In this way they can guarantee the optimal initial quality of the bicycles (Sassen 2009).

When breakdowns are not evitable, operators focus their efforts on identifying them as soon as possible to minimize inconveniences for users. For instance, the bicycles of Vélib' in Paris are equipped with a microchip that informs the operator about the status of the cycle mechanism. If the bicycle is broken or does not work properly, the microchip sends the information to the terminal (Sassen 2009). Users of the Barclays Cycle Hire in London can report bicycle breakdowns just pushing a button (Georgiou 2010).

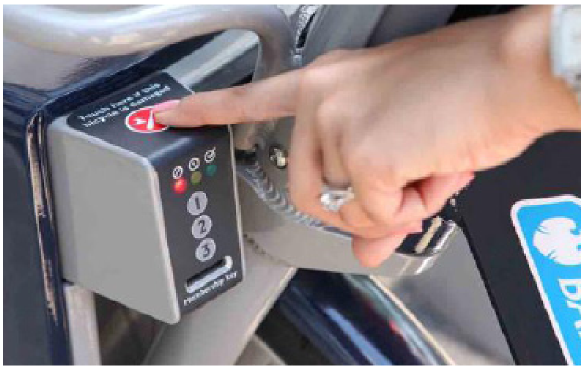


Figure 139: Device in the docking point used by customers to report damaged bicycles in the Barclays Cycle Hire of London (Georgiou 2010).

In Paris, to reduce the environmental impact of transport due to breakdowns, 80% of breakdowns are repaired in situ at the stations and the workers go to the stations by private bicycle. The other 20% of damages require transport to the repair depot and “green vehicles” such as natural gas and electrical propelled vehicles are used (Dargent 2009).

7.3.5 Redistribution

When bike-sharing stations are empty, there are no bicycles available and customers cannot access the service. On the other hand when bike-sharing stations are full, bicycles occupy all docking points and customers cannot return the rented bike. In these two cases bicycles have to be redistributed from full stations to empty stations to recover the balance of occupancy and the level of service. Redistribution can be carried out by bike-sharing customers or by operators. In Lyon 60% of total bicycle movements between stations occurs naturally by mean of voluntary user trips and 40% are mandatory due to full stations. A half of the mandatory trips are made by users that ride to the next station with available docking points and the other half of trips are made by the operator through vehicles. Therefore, redistribution of bicycles represents 20% of all bike-sharing bicycles movements (Snead & Dector-Vega 2008).

Redistribution is one of the most important concerns of current BSSs because it produces significant negative impacts. Congestion of stations and unavailability of bicycles can affect satisfaction grade of customers. “Mandatory redistribution” carried out by users also worse the image of the system. Mechanical redistribution carried out by the operator is costly as well as polluting because dedicated staff is to be hired and bike-sharing vans emit CO_2 when transporting bicycles.

Unequal occupancy of stations can be caused by three factors:

- Topography
- Extensive operating area
- Irregular temporal demand

Bike-sharing customers seem to be reluctant to ride uphill. Bike-sharing bicycles located in elevated areas are normally rented only for ridding down and they are very rarely ridden up. As a result of this unbalanced bicycle flow, stations of elevated areas become quickly empty, while BSSs situated in the downer part become full of bicycles from upper part. Barcelona is one of the most representative examples of the impact of topography in bicycle distribution. Figure 140 shows the city map of Barcelona and the location of the bike-sharing stations. The hilliest districts of the city are in the upper half part of the map, while the flat area of the Mediterranean coast is in the downer part. Red circles represent full stations and blue cycles empty ones. The diameter is the time during a day in this status. Thus, as we can observe stations situated on elevated areas are most of time empty, while the stations of the coast are mainly full.

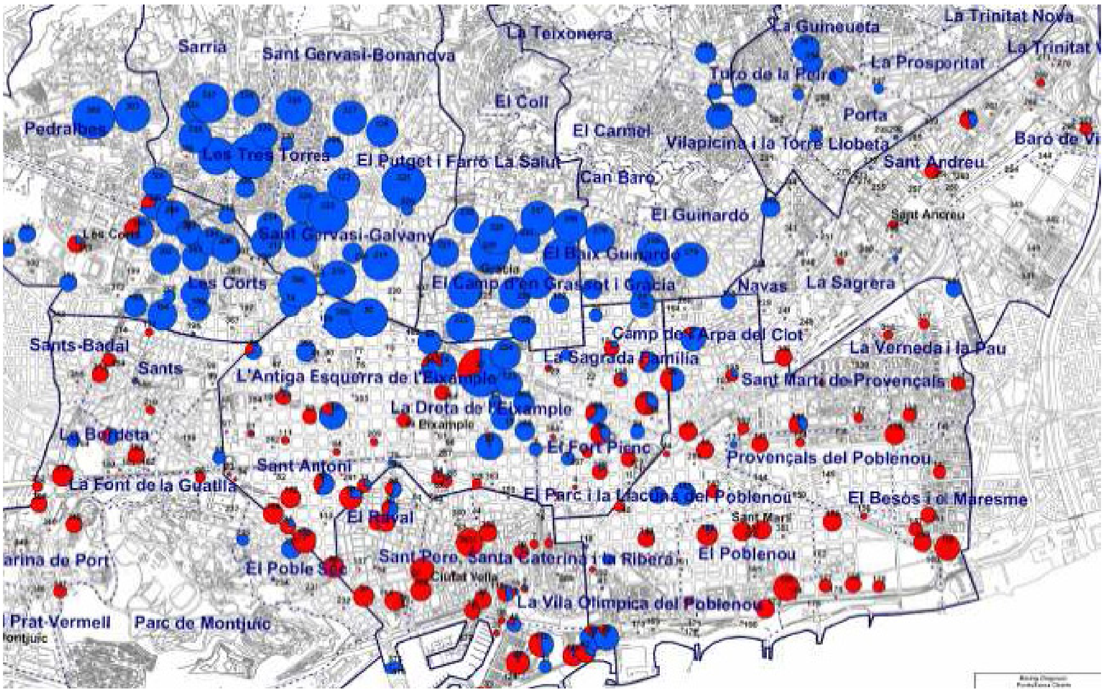


Figure 140: Unequal distribution of bicycles at BSS stations in Barcelona (López 2009).

According to section 7.2.1, operation area of BSSs also determines the level of redistribution. BSSs with extensive operating areas seem to require longer distances to redistribute the existing bike-sharing bicycles, since distance between station pairs become longer.

Irregular demand throughout the day can also motivate redistribution of bike-sharing bicycles and as section 7.2.5 explains, public transport plays a very relevant role in this phenomenon. In the morning commuters arrive at the city by public transport and they require bike-sharing services to cover the last mile of the trip. Thus, bike-sharing stations located in railway stations or other important public transport nodes manage a very intense demand and become quickly empty. The destination of many commuters is the downtown, thus, as a consequence, bike-sharing stations situated in the city centre become full. In the evening the migration process is opposite. Commuters return home and take bicycles from the centre emptying bike-sharing stations. As a consequence, bike-sharing stations located close to public transport nodes become saturated.

Operators have implemented and still implement numerous instruments to avoid redistribution or at least to minimize the impact.

To reduce distribution of bicycles due to topographical reasons, the OBIS project recommended avoiding the placement of BSS stations in elevated areas (Castro & Emberger 2010).

If it is unavoidable to locate stations in elevated areas, electrically pedal assisted bicycles, also called pedelecs, can help to make easier the return to uphill stations. There are several experiences of BSSs implementing pedelecs in the bicycle fleet. For instance, Velopass, the BSS installed in Fribourg (Switzerland), provides 20 standard bicycles and 12 pedelecs to ride across the city (Fribourg City 2011). In Segovia, Spain, 50% of the 195 bicycles of the BSS, Segovia de BICIo, are electrically pedal assisted (Aalto 2010). It is expected that the integration of pedelecs in BSSs will continue growing. As co-winner of a national competition of the German government, the city of Stuttgart received €2,700,000 in federal funding for extending its existing BSS (Call a bike) including pedelecs in the bicycle fleet. Call a bike provided in 2008 400 bikes at 65 stations across the city, while the new pedelec system will provide 1,000 pedelecs and standard Call a bike bicycles at 120 rental stations (ExtraEnergy 2009).

In Paris, where the city has received complains that redistribution efforts of Vélib' are not enough, the BSS has introduced a pseudo-economic incentive to encourage customers to return the bicycles uphill. Bike-sharing users that return the rented bicycle at elevated stations (called V+) receive 15 minutes free of charge in a following rent. In 2008 314,443 returns in V+ stations, upper parts of the city were reported, which represents 1.1% of the annual rents (DeMaio 2009b; Robert 2009a).

To minimize redistribution caused by irregular demand, the bike-sharing feasibility study of the implementation of Barclays Cycle Hire in London recommended in 2008 to avoid the placement of bike-sharing stations in main public transport nodes (Dector-Vega et al. 2008). However, the Barclays Cycle Hire finally provided PT stations with bike-sharing terminals, probably because this instrument may reduce intermodality between bike-sharing and public transport and may reduce the market potential of the BSS. The elaboration of a comprehensive study of demand at public transport nodes to provide the sufficient number of bicycles and docking points at bike-sharing stations and to avoid saturation and consequent redistribution is anyway advisable.

When despite the instruments against redistribution, unbalance of bicycles at bike-sharing stations still exist; operators focus their efforts on minimizing the environmental impact and minimizing the unavailability of bicycles. Concerning the environmental impact of unavoidable redistribution, some BSSs have introduced clean vehicles to reduce emission of pollution. For instance, Barclays Cycle Hire in London and Velomagg' in Montpellier redistributes bicycles with electric vehicles that do not emit pollution (Büttner et al. 2011; Georgiou 2010). In Paris, redistribution and maintenance fleet comprises 130 electric bicycles, 20 natural gas and electric vans (NYC Department of City Planning 2009). Moreover, "CO_2 emissions of these vehicles are offset by a contract with Climat Mundi, cycle racks are powered with renewable energy and bicycles are cleaned with collected rainwater without detergent" (Dargent 2009).

Figure 141: Electric vehicle for redistribution in Barclays Cycle Hire, London. Source (Georgiou 2010)

Concerning the unavailability of bicycles, several different instruments have been introduced. If a bike-sharing customer arrives at a bike-sharing station to hire a bicycle and the station is empty or he/she wants to return a bicycle and the station full, in both cases the customer has to look for another station, what causes his/her dissatisfaction. Most of BSSs show maps of the bike-sharing station network at terminals to facilitate this search. However, if live information about the occupancy of stations is offered in advance either by Internet or mobile phone, customers can go directly to the available station and without inconveniences. On-line live information is currently rather common in BSSs, while mobile phone information platforms have started to be implemented. For instance, Bicing provides a mobile phone platform called I-Bicing, which provides information of the current location of customer, the closest station and the availability of bicycles and parking places in stations (Romero 2010).

When the arrival of customers to an empty or full station is unavoidable, BSSs have some tools to minimize the dissatisfaction of users. Certain BSSs such as Citybike Wien in Vienna encourage "mandatory redistribution" by offering about 15 minutes of additional rental time if the station is full. Users just have to report this situation at the bike-sharing station and they receive the extra-time (Citybike Wien 2010). In Barcelona and Stockholm if a station is empty, customers can make a phone call to report the unavailability of bicycles and the operator, Clear Channel in both cases, transports bikes with a van and supply immediately the station with bicycles (Dector-Vega et al. 2008).

7.3.6 Traffic accidents

As section 6.4.4 has explained, BSSs may contribute all around Europe to reduce the number of accidents per cycle trip as a result of the effect of the critical mass. Bike-sharing users increase the total number of bicycles on the streets and the "critical mass" makes cyclists more visible and respected. Despite this positive phenomenon, it is right that absolute number of cycle accidents have increased in cities where BSSs were implemented.

Traffic accidents involving bike-sharing customers could spread fear of cycling and ridding bike-sharing bicycles. To avoid a negative image of bike-sharing and to preserve municipal traffic safety, some instruments have been implemented in European cities. For instance, in Paris, since a considerable share of the bike-sharing customers do not cycle regularly, leaflets with basic information about traffic rules and cycling skills were distributed (Dector-Vega et al. 2008). Additionally, the City of Paris together with the operator of the system, JCDecaux, have launched an overall awareness campaign in September 2008 to prevent traffic causalities and to encourage all road users to regard traffic rules (Sassen 2009). London launched a safety campaign due to the start of Barclays Cycle Hire. The aim of the campaign was to remind bike-sharing users the necessity of respect traffic rules concerning attitude towards pedestrians, traffic signs, lighting in the night and appropriate usage of bicycles to prevent accidents (Georgiou 2010) (Figure 142). Furthermore, the information provided on the handlebars of the bicycles warns customers about the risk motor vehicles turning (Figure 138).

Figure 142: Traffic safety campaign in London (Georgiou 2010)

Helmet use might minimize the effects of accidents with bike-sharing users involved. Two likely ways to foster helmet use in BSSs might be providing free helmets for annual memberships or helmets automatically provided at the stations by the bike-sharing user card. Nevertheless, helmet obligation may reduce the number of bike-sharing trips because it may disseminate a dangerous image of cycling and fear of cycling may be a barrier for new cyclists.

If accidents cannot be minimized insurance could help to limit the liability of bike-sharing customers. As section 5.2 has revealed, subscriptions of at least 26% of the 51 BSSs studied in this dissertation include an insurance to cover likely accident risks of customers, third involved parties or both.

7.3.7 Public space conflicts

When planning the introduction of a BSS in a city, the placement of bike-sharing stations can become a challenge because of unavailability of free public space. Public space in cities is currently divided by dedicated infrastructure such as sidewalks, cycle ways, roads or public transport lanes and it is occupied by municipal equipment such as light posting, trees, benches, billboards and other types of street furniture. As a result of the level of occupancy of public space, BSSs deal with troubles such as protests from social groups, incompatibility of existing laws and costs of opportunity.

Bike-sharing stations are mainly located in former sidewalks or car parking places. In Paris, around 3,000 car-parking slots were converted to bike-sharing stations (Büttner et al. 2011). In contrast, in Barcelona very few stations of Bicing are located on road space (Bikeoff 2008b). In both cities, Paris and Barcelona, when the stations are placed on roads, the limited bike-sharing area is marked and protected with coloured bollards to avoid incidents and accidents with car traffic (NYC Department of City Planning 2009). Stations situated in sidewalks may limit the pedestrian flow and can motivate complaints of pedestrian lobbies and neighbours associations, while car parking spaces shifted to bike-sharing can cause complaints of car lobbies. Even cycling associations might feel aggrieved due the occupancy of public space for bike-sharing stations. For instance, in Hamburg the German Cycling Club (ADFC) has demanded for a long time the installation of cycling racks for private bicycles and finally available space has been occupied by a BSS, what has motivated a public complain of the association (Sassen 2009). Public complains from pedestrians, cars and cyclist might worse the image of BSSs and reduce the popularity and willingness to use of potential customers.

Moreover, according to the OBIS project “difficulties in terms of physical integration do mostly occur when stations shall be erected on property around PT stations. Space is often hardly available especially in crowded inner cities. Additionally PT operators struggle with the implementation of bike stands for private bikes. Thus the process of authorisation by the PT operator can take a considerable time span” (Büttner et al. 2011).

The introduction of bike-sharing stations can also entail problems related to the design and the integration in the urban landscape. For instance, the City of Paris prioritizes sightlines and has strict rules regarding historical urban landscape. Hence, bike-sharing stations cannot be found in historic boulevards but inside secondary streets or city parks. Location and design of bicycles, stations and billboards annexes has been closely controlled to guarantee sightlines and pedestrian access as well as to minimize visual impact in historical urban areas. The placement and design of bike-sharing infrastructure has been guided by three organisations: the Studio of City Planning of Paris (Atelier Parisien d’Urbanisme), the French Architectural Association (Architectes de Batiments de France) and the Transportation Department (Sections Territoriales de Voire) (NYC Department of City Planning 2009).

Finally, not only the direct costs of construction of bike-sharing stations but also indirect costs, such as costs of opportunity of the space occupancy, have to be taken into account. As section 6.6.6 explains, the City of Barcelona could earn from €3,670,000 to €7,350,000 as a result of an alternative exploitation of the public space occupied by the BSS.

To avoid such problems, the EU-project OBIS recommends elaborating a comprehensive space availability study before implementing any BSS (Castro & Emberger 2010). Afterwards, it is advisable to conduct round tables with all stakeholders affected by the occupancy of space (social groups and competent departments) and to agree the final location of stations.

BSSs should be as most space-efficient as possible to enable their implementation but some considerations concerning station placement should be taken into account. According to the feasibility study of New York City (NYC Department of City Planning 2009):

- "Bike-sharing stations should be placed primarily on roadbeds because this location does not impact on pedestrians and do not require costly modifications to existing networks of public services such as sewer".
- "If the station has to be installed on sidewalks, narrow sidewalks have to be avoided and the bike-sharing infrastructures should be place in line with street furniture and trees to facilitate the pedestrian flow. Frontages of open-air municipal parking lots, peripheries of parks and recycling of underutilized places such as under viaducts are also especially advisable".

Additionally, the OBIS project points that "the placement of the stations should be safe without disturbing other road and pavement users. It must not interfere with other users of the public space, like cleaning vehicles, snow clearing, disabled people, etc. And special consideration should be made for the visibility to and from the bicycles and stations" (Petersen 2009).

Finally, bike-sharing station models based on concrete or metal modules without subterranean foundation could also facilitate the introduction or even the reallocation of conflictive stations in cities with limited space available (section 7.3.2).

7.3.8 Competition with bike rental shops

Rental shops have been for a long time the only way to rent a bicycle in cities and tourists have been their quasi-exclusive target group. When bike-sharing started to be implemented in European cities, BSSs introduced two main advantages compared to rental shops: unidirectional trips instead of bidirectional ones and cheaper usage fees. In fact, as section 5.6.1 and 5.2 have revealed the usage of 27% of BSSs studied in this dissertation is totally free of charge, while 27% of one yearly subscription and 40% of unlimited subscriptions fees are free of charge.

Figure 143 shows five examples of pricing competition between bike-sharing and rental shops, if bike-sharing registration or usage is charged. If a tourist would arrive to Stockholm, Barcelona, Paris, Berlin or Leipzig and he/she would like to rent a bicycle, in all cities he/she could opt for a BSS or a traditional bike rental[44]. Which option would be more economical for him/her? Considering the shortest available subscriptions which are rather tourists oriented and summing together subscription and usage fees, the diagram shows that the BSSs of Stockholm and Berlin are more economical than the bike rental shops of these cities for periods of rent between 2 and 3 hours, while the BSS of Paris is more convenient the first hour and a half. In contrast the BSS in Leipzig is in any case cheaper than bike rental shops. Only Barcelona operates a BSS unattractive for tourist compared to traditional companies and it is the only one of the five examples that would totally avoid any conflict with traditional bike rental.

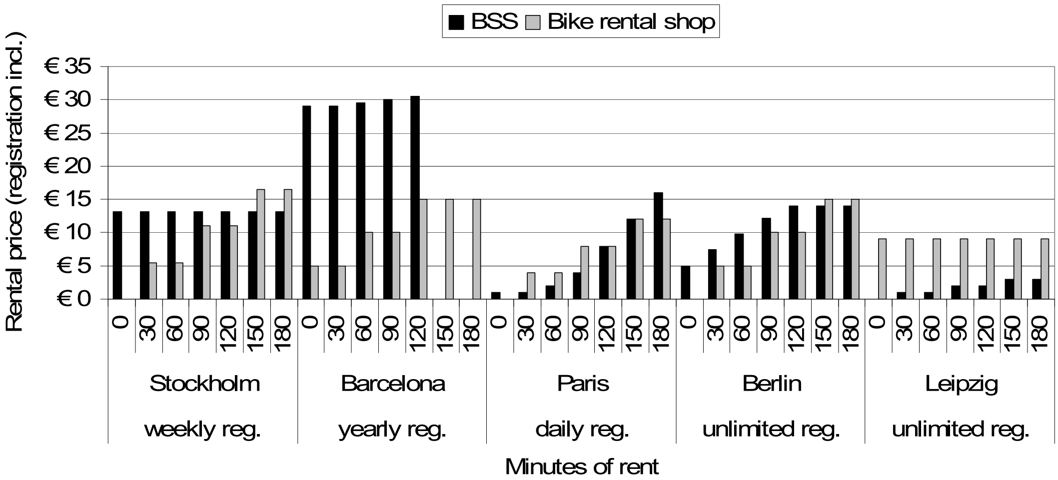


Figure 143: Rental price up to 3 hours of usage in BSSs and bike rental shops of different cities. Data source: (Petersen 2009; Frühauf & Hayes 2009; Robert 2009b; Robert 2009a; Vélib' 2009b; Gröper 2009).

Figure 144 shows the same five examples for a longer rental period: 24 hours. The maximal rental duration permitted in Stockholm is 3 hours and in Barcelona is 2 hours, while the rental of a bike-sharing bicycle in Paris is extremely more expensive than a normal bike rental. Thus, they both would avoid conflicts with traditional shops. On the contrary, long rents in Berlin and Leipzig are more convenient with the BSSs than with rental shops because of the flat rates offered. BSSs with flat rates, normally for the whole day, have as a main goal to attract tourists and leisure mobility. As a result, they may enter directly in conflict with rental shops.

[44] The traditional bike rental shop was randomly chosen.

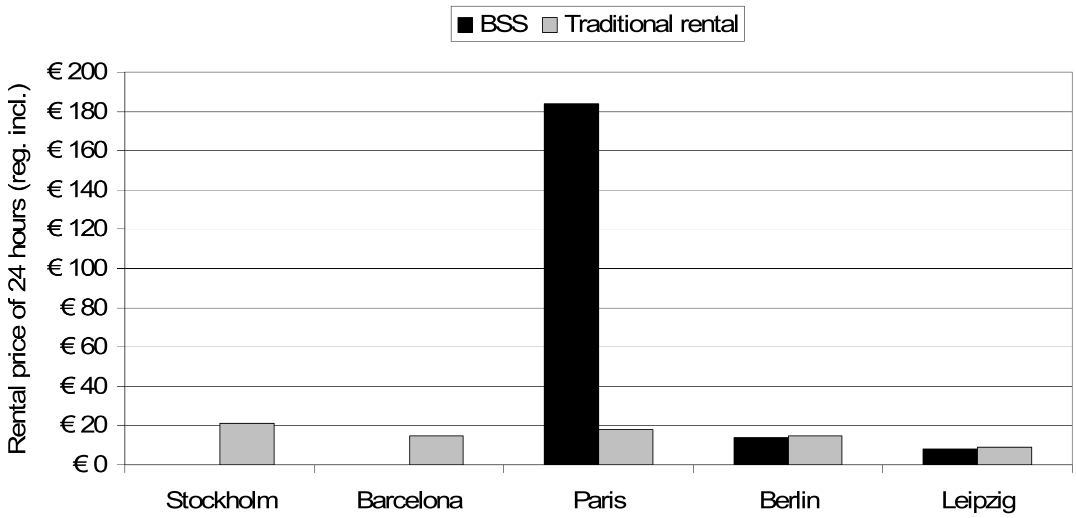


Figure 144: Rental price up of 24 hours of usage in BSS and bike rental shops of different cities. Data source: (Petersen 2009; Frühauf & Hayes 2009; Robert 2009b; Robert 2009a; Vélib' 2009b; Gröper 2009).

Although the BSSs located in Paris, Barcelona and Lyon reach high levels of use, existing shops might reduce the market share of BSSs due to competition. Moreover, bike rental shops could also undertake public complains because of unfair-competition and endanger the exterior image of BSSs. In Stockholm even "lawsuits have been brought against the city by private cycle hire firms" (Petersen 2009).

Two likely strategies to pacify the conflicts between BSSs and traditional bicycle rental shops are the following: rental shops can offer complementary services to avoid the overlap of the market and BSSs can avoid short-term subscriptions mainly used by tourists.

In Vienna, as a result of the implementation of Viennabike (the predecessor of Citybike Wien) traditional bike rental shops lost 20% of turnover. The reduction of customers was also appreciable in certain rental shops in Burgenland (Austria) after the launch of nextbike-Burgenland in several towns of the region. Shopkeepers complained in both cases and the solution was similar. Shops oriented the business towards other market sector and focused on services that cannot be provided by BSSs, such as guide tours and rents for groups that normally required big amount of bicycles (Castro 2009).

In contrast, in Barcelona shops do not change their commercial strategy but the BSS. Initially Bicing planed to offer weekly subscriptions, together with daily subscriptions, which are specially oriented for tourists. However, accusations of unfair competition made by bicycle renting companies lead to the removal of the short-term subscription. Currently Bicing only offers yearly subscriptions and thus residents have become the exclusive target group of the BSS (Sassen 2009). Additionally, the website of Bicing explains that it is not a tourist bicycle rental but a BSS oriented for daily trips and it shows the addresses of local rental companies (Bicing 2010).

7.3.9 Dissatisfaction and bad image

The satisfaction grade of bike-sharing customers seems to be acceptable across different BSSs. In Rennes, before the close of the system, 92% of users of Vélo á la carte stated that they were “satisfied” or “very satisfied” with the service (Sassen 2009). In Paris, a survey carried out in 2009 showed that 75% of members of Vélib’ affirmed that they were “quite satisfied” and 19% were “very satisfied” (Vélib’ 2009a). 90% of users of Vélo’v in Lyon would recommend the system (Cyclocity 2008). The satisfaction rate of users reaches 7.7/10 in Lyon (Cyclocity 2008), while in Barcelona this score is 6.3/10 (López 2009). However, information about former bike-sharing customers that stop using the system because of dissatisfaction or about external image of BSSs is rarely available.

A comprehensive user survey of the City Council of Barcelona, carried out in 2009 revealed how this satisfaction rate is built in the mind of users and which factors are more relevant for them (López 2009). The result is shown in Figure 145. According to the opinion of users of Bicing, the three most relevant items for a satisfactory service are the availability of docking points at the destination, the availability of bicycles at the origin of the trip and the favourable location of stations. Precisely, users of Bicing mainly propose to improve availability of docking points and bicycles in the BSS. On the other side are the less relevant items. Subscription fee is the 4th less relevant item, while the usage fee after the free rental period is the less relevant factor according to the members of Bicing.

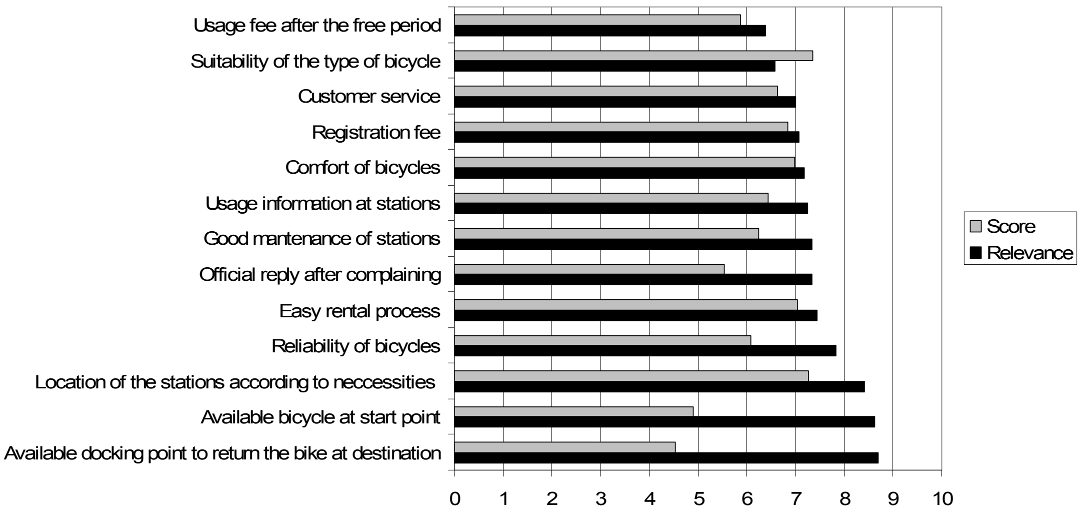


Figure 145: Score and relevance of aspects of Bicing according to the opinion of users. Data source: (López 2009)

It is important to differentiate between two terms: satisfaction grade and image.

Satisfaction grade makes reference to previous experiences of customers that have ever used a BSS. If this indicator is high, it means users are likely to repeat the experience and will hire bicycles again or even more frequently. On the contrary, dissatisfaction can cause unreliability, infrequent rents and even drop out of members.

Image is the general opinion regarding a BSS. This factor affects especially to potential customers. Those people are not bike-sharing members but are willing to subscribe under certain conditions. They could join or not the BSS depending on image.

Dissatisfaction grade and bad image arise as a result of one or more than one of the problems described in sections 7.3.1 to 7.3.8. Satisfaction grade and image can change existing willingness to use a BSS, i.e. bike-sharing demand. In other words, BSSs with high satisfaction grade and good image are more likely to convince customers and potential customers to hire a bicycle of the system and vice versa. Therefore, although it could not be quantified, we could state that both satisfaction and image contribute to increase the rotation of bicycles and consequently the efficiency of the system.

Nevertheless, it should be taken into account that the effect of a positive or negative satisfaction grade and image are not immediate, they need some time to be effective. For instance, in Barcelona, as Figure 146 shows, the number of rents decreased in 2010 despite the appreciable improvement of the quality of service. However, this reduction of rents in 2009-2010 may actually responds to a decrease of the quality of services in previous period, since the quality of service worse in 2009 compared to 2008. Therefore, changes of users and non-user opinions could require up to one year to be effective in the number of rents.

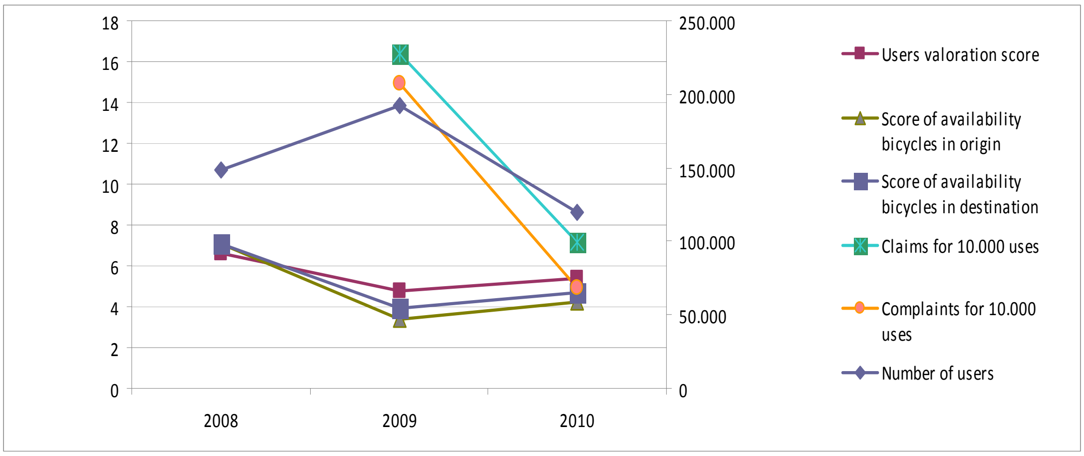


Figure 146: Evolution of the satisfaction grade, the availability of bicycles, claims, complains and rents in Bicing in 2008, 2009 and 2010 (Hayes & Frühauf 2010)

7.4 Summary

Table 39 shows an overview of the quantified correlations between driving forces with indicators of bike-sharing success (especially rotation) studied in this section.

- The highest correlations are found between the number of stations and the distance covered by vans for redistributions of bike-sharing bicycles as well as between the share of metro stations provided with bike-sharing and rotation (number of rents per bicycle).
- There is medium correlation between city vandalism and rotation and between the municipal car modal share and the share of bike-sharing rents coming from car.

- The number of stations, the number of stations per city km2, the availability of all-the-year-round service, the population density, the average yearly temperature and the cycling modal share have significant low influence on the number of rents per bicycle. The influence of car modal share on the share of bike-sharing trips coming from cars can be considered as low too.

Bike-sharing factors							
Category	**Driving force**	**Success indicator**	**Spearman's correlation coefficient**	**Correlation level**	**p-value**	**Significant**	**N**
Bicycles & stations	Number of bicycles	Rents/bicycle*day	0.314	Low	0.104	No	28
	Number of stations	Rents/bicycle*day	0.499	Low	0.015	Yes	23
		Redistribution (km/year)	0.723	High	0.000	Yes	20
	Distance between stations	Rents/bicycle*day	-0.521	Medium	0.100	No	11
	Stations per city km^2	Rents/bicycle*day	0.473	Low	0.037	Yes	23
Technology	Technology of the docking device	Rents/bicycle*day	0.098	No correlation	0.619	No	28
	Way of identification	Rents/bicycle*day	(Nominal variable)				
Availability of service	All-year-round service	Rents/bicycle*day	0.337	Low	0.080	Yes	28
	Round-the-clock-service	Rents/bicycle*day	-0.089	No correlation	0.653	No	28
Subscription & usage fee	Validity of long-term subscriptions	Rents/bicycle*day	-0.293	No correlation	0.130	No	28
	Rental period free of charge	Rents/bicycle*day	(Nominal variable)				
Integration with PT	Metro stations provided with BSS	Intermodality (%)	0.105	No correlation	0.895	No	4
		Rents/bicycle*day	0.794	High	0.059	Yes	6
	Advantageous fee for PT passengers	Intermodality (%)	0.086	No correlation	0.734	No	18
		Rents/bicycle*day	0.037	No correlation	0.851	No	28
City factors							
Category	**Driving force**	**Success indicator**	**Spearman's correlation coefficient**	**Correlation level**	**p-value**	**Significant**	**N**
Population	Population	Rents/bicycle*day	0.151	No correlation	0.444	No	28
	Population density	Rents/bicycle*day	0.351	Low	0.067	Yes	28
Topography	(qualitative description)						
Climate	Average yearly temperature	Rents/bicycle*day	0.478	Low	0.014	Yes	26
Car use	Car modal share	Rents/bicycle*day	-0.147	No correlation	0.454	No	28
	Car modal share	BSS shift to car (%)	0.558	Medium	0.024	Yes	21
Bicycle use	Cycle network density	Rents/bicycle*day	0.073	No correlation	0.714	No	28
	Cycling modal share	Rents/bicycle*day	-0.415	Low	0.031	Yes	27
Public transport use	PT modal share	Rents/bicycle*day	-0.112	No correlation	0.577	No	27
	Permission to carry bikes in trains	Rents/bicycle*day	0.278	No correlation	0.152	No	28
Tourism	Tourism density	Rents/bicycle*day	0.187	No correlation	0.371	No	25
Vandalism	Theft per cycle trip	Rents/bicycle*day	0.641	Medium	0.018	Yes	13
Traffic safety	Accidents per cycle trip	Rents/bicycle*day	0.138	No correlation	0.611	No	16

Table 39: Outcome of the correlation and the multiple regression analysis

The following function might predict rotation on base of the five driving forces with higher correlation with rotation.

Rotation (rents/bike*day) = -4.406+0.394*Ln(stations) + 0.218*Ln(stations/km^2) + 0.184*Ln(inhabitants/km^2) + 1.371*Ln(average yearly temperature in ºC) – 0.019*Ln(cycling share).

Although the whole model fit significantly well, the p-value of the individual t-tests resulted too high because of multicollinearity. This might have a negative effect on the reliability of the equation. To minimize the effect of multicollinearity the number of variables has been reduced. Thus, rotation could be predicted in a significant way on base of two variables that interact according to the following multiple regression model:

Rotation (rents/bike*day) = -5.168+0.645*Ln(stations) + 1.811*Ln(average yearly temperature in ºC)

Overuse, underuse, theft, breakdowns, redistribution, vandalism, traffic safety and space unavailability and competition with traditional rental shops have been identified as the main barriers that hinder the development of BSSs. Table 40 recapitulates causes, consequences and likely solutions for these barriers when implementing and operating a BSS.

Barriers	Reasons	Effects	Solutions
Overuse	Bicycle&station shortage	Unavailability of bicycles / dissatisfaction	Increase bicycles & stations
			Increasing fees
	High demand	Breakdowns	Restricting target users
			Limiting members
Underuse	Bicycle&station excess	Unefficiency	Insurance for reallocation of stations
	Low demand	Economic non-viability	Flexible stations without subterranean foundation
Theft and damage of bicycles	City vandalism	Unavailability of bicycles / dissatisfaction	Easy mechanisms for returning bicycles
			Light or audio signals to confirm the right return
			Exclusive design of bicycle and components
	Wrong return of bicycles	Repair and substitution costs	GPS chips in bicycles for easier finding
			Protect bicycle components in internal parts
			Municipal fines
Breakdowns	Overuse	Unavailability of bicycles / dissatisfaction	High quality and durable design of bicycles
	Vandalism	Repair and transport costs	Automatic or manual devices to report defects
		Pollution	"Green vehicles" for repairs
Redistribution	Topography	Transport costs	Avoid elevated areas
			Electric bicycles
		Unavailability of bicycles / dissatisfaction	Economic incentives
	Irregular demand		Comprenhensive study of demand at PT stations
			Clean vehicles for redistribution
		Pollution	Live information by Internet or mobile phone
	Extensive operating area		Additional time to return the bicycle
			Redistribution ordered by customer at the station
Traffic accidents	Missregarding of traffic rules	Fear of cycling	Safety campaigns
			Insurance included in the BSS subscription
Space conflicts	Lack of space	Protests of road users	Comprenhensive study of availability of space
			Round tables with stakeholders
		Incompatibility with laws	Space efficient desing
			Placement of station on road space
		Costs of opportunity	Recycling of underutilized places
			Flexible stations without subterranean foundation
Competition with bike rental shops	Tourist cities	Reduction of market share	Rental shops offer complementary services
		Official complaints	BSS avoid short-term subscriptions

Table 40: Causes, consequences and solutions of likely barriers of BSS

8 CONCLUSION

8.1 Discussion

Bike-sharing trips represent on average around 0.1% of all urban journeys generated in European cities where BSSs are operating (section 6.2.2). At most this share reaches circa 0.9%. Therefore, bike-sharing is still a very small part of European mobility. On the other hand, it is also remarkable that the BSSs have achieved these results in very short time. For example, the most used BSSs, located in Paris, Barcelona started their operation in 2007 and Lyon in 2005. Since the calculations of this doctoral thesis are based on a cross section analysis mostly with data from 2008, it means that these BSSs obtained the presented impacts in just one and three years, what is remarkable. Moreover, future (and present) expansions and optimisations of bike-sharing systems might contribute to increase the number of bike-sharing trips and their role in urban mobility.

Some municipalities may have implemented or may plan to implement a BSS to reduce car traffic. However, as it has been stated by other authors “while reduced traffic congestion is a noble goal, bike-sharing is likely to contribute minimally to this goal” (DeMaio 2004). This dissertation has numerically confirmed this assumption and it has demonstrated that the impact of BSSs on car mobility can be currently considered as very low (section 6.2.3). On average only 0.04% of daily car traffic has been removed thanks to BSSs in European cities and the maximal reported car trip shift reaches around 0.2%. Hence, taking into account the ambitious goals of some municipalities concerning car traffic reduction, these figures might be disappointing. Two reasons might explain the poor success obtained by BSSs reducing car traffic: the limited role of bike-sharing in the whole urban mobility and the reluctance of car-users to shift to other transport modes. Firstly, as long as bike-sharing bicycles only represents up to 0.9% of urban daily trips, we should assume that BSSs will be able to affect only minimally absolute figures of mobility. Secondly, on average only 15% bike-sharing trips were made previously by car. This share is even lower than 10% in the BSSs of Paris, Barcelona and Lyon despite they are the most influent BBSs on mobility due to their high number of rents.

The influence of bike-sharing reducing public transport vehicles occupancy seems to be more significant that car trip shift but it is also limited (section 6.2.4). On average, only 0.45% of public transport trips were transferred to bike-sharing bicycles as a result of the implementation of BSSs in European cities. Nevertheless, a significant contribution of BSSs to increase the synergy with public transport through intermodality has been observed. On average, 40% of bike-sharing users still hold a public transport seasonal card, which means that they are frequent public transport passengers and they may combine their trips with bike-sharing. Actually, although only 0.37% of PT trips are connected with BSSs, 34% of bike-sharing trips are connected with public transport. These and other outcomes of this dissertation confirm the hypothesis of Paul DeMaio: “Residents living downtown who want to bike will likely have their own bicycle and prefer its use. However, commuters will either drive or take transit downtown. Those arriving by car will likely not use a bike-sharing bicycle as a segment of their trip due to the directness car travel provides. On the other hand, commuters who take transit and must transfer or walk as part of their trip may choose to use a bike-sharing bicycle to save time instead of transferring or walking. Thus, of those trips made for commuting purposes, bike-sharing bicycles will likely be most useful for the last leg of a trip to work or the first leg of the return home." Therefore, intermodality between bike-sharing and public transport is one the main potentials of BSSs to improve urban mobility.

Only the direct increase of bicycles on streets due to bike-sharing operation could be estimated in this dissertation (section 6.2.5). On average, the introduction of bike-sharing bicycles in urban mobility meant an increase of 8.5% regarding the initial number of trips made by bicycle, but increases of up to 91.5% have been reported. Although indirect increase of bike-sharing due to critical mass effects could not be quantified, they may be relevant. Some municipalities and bike-sharing operators have attributed to bike-sharing the whole responsibility of reported increases of cycling. Nevertheless, such conclusions might be tricky. As this dissertation has demonstrated, BSSs have been implemented together with other cycling policies (e.g. expansion of the cycleway network) and they also might impact on the existing increases of the cycling modal share in European cities.

According to the calculations carried out in this research, the net contribution of BSSs to reduce CO_2 has been very low (section 6.3). Two reasons explain this fact: the modest gross reduction of CO_2 reached by BSSs and the CO_2 emission caused as a result of the bike-sharing operation. Even in successful cases in terms of absolute values like Vélo'v, the CO_2 saving only represents 0.04% of the total yearly mobility CO_2 emissions of the city of Lyon. Gross CO_2 reduction due to BSSs is minimized by CO_2 emissions produced as a result of redistribution of bike-sharing bicycles. On average BSSs save more CO_2 than they emit: 80 CO_2 kilograms per 1.000 inhabitants and year are saved and 23 CO_2 kilograms per 1.000 inhabitants and year are emitted. Although the CO_2 balance might be in principal positive in all bike-sharing, final net CO_2 could be very modest and it makes questionable the success of BSSs in terms of environment.

BSSs can contribute to improve health of citizen twofold: reducing harmful pollutants and increasing fitness of users. However, in practice only the second way seem to be really effective (section 6.4). Since this dissertation has demonstrated that BSSs have affected minimally to reduce car traffic, their contribution reducing CO_2 and other pollutants such as PM, CO and NOx can be assessed as modest. In contrast, the 36 minutes that users ride on bike-sharing bicycles (if we assume they make round trips of the average rental duration, 18 minutes) may contribute to improve their fitness and therefore their health. In this case, the likely positive effects on muscles and joints, immune system and heart functions associated to cycling bike-sharing bicycles during more than 30 minutes would be relevant. The only pitfall of the bike-sharing success increasing fitness of citizens is the share of people benefited, which is still very limited. Positive health effects of cycling only happen if customers ride frequently and only 0.9% of the population are bike-sharing members that ride everyday bike-sharing bicycles.

It was demonstrated in other publications that the higher the number of cycling modal share in a city, the lower the accident rate of cyclists is (section 6.5). This dissertation has found a significant increase of bicycle use in cities where BSSs were implemented. Therefore, it is reasonable to state that bike-sharing may increase traffic safety by increasing the number of cyclists. Unfortunately, the accurate reduction of accidents could not be quantified. The qualitative analysis of the several single cases studied has shown that although the absolute number of accidents with cyclists involved increased after the introduction of BSSs, the relative rate, i.e. the number of accidents normalised by the total number of trips by bicycle, actually decreased. That would mean that bike-sharing contribute in a relevant way to increase traffic safety of cyclists in European cities.

The economic implications of BSSs were also analyzed in this dissertation (section 6.6). Some small and manual BSSs that set as a priority to contribute to improve employment opportunities were successful. For instance, the BSS in Örebro obtains the highest impact creating jobs with 0.7 jobs per 1,000 inhabitants and the BSS in Chemnitz is creates 0.1 jobs per bike-sharing bicycle. Although these values are modest, they are far away from other cases studies analyzed (even from large-scale BSSs). Therefore, we could state that only manual BSSs that do aim create jobs might reach a significant influence on employment market. However, most of existing BSSs are automatic or are planning to upgrade to an automatic system. This minimizes the benefits of BSSs in job creation. In contrast, the success of bike-sharing reducing household's travel costs seems to be more relevant. On average, 22% of customers use bike-sharing because it is cheaper than other transport modes and the 91% of rents are free of charge (when limited free rental time is offered). These two indicators confirm that citizens that want to save transport costs ride bike-sharing bicycles and BSSs seem to be successful. Unfortunately, the success of bike-sharing increasing tourism could not be demonstrated. What the dissertation revealed is the great influence of tourist in some BSSs. In Paris, for example, 99% of subscriptions are short-term subscriptions (one-day or one-week validity), which is the most convenient subscription type for city visitors. Contributions of bike-sharing to city image could not be proved either. Although some favourable hints could be observed, the impact of the green image could not be quantified.

Finally, this dissertation has shown that BSSs are loss making and not economically self-sustainable, because costs are in every case higher than incomes (Section 6.7). BSSs do require compensating the losses either through economic support of public authorities or integrating bike-sharing costs in a billboard contract. A handicap of BSSs integrated in billboard contracts is that BSSs become completely owned and operated by private companies and excluded from the integrated transport planning of the city. Moreover, municipal governments and private companies have different interests. According to the EU-project SpiCycles, private operators have normally interest only in making profit (SpiCycles 2008) and according to the bike-sharing feasibility study of New York, locations of bike-sharing stations that are lucrative for the company might not be such convenient for the public needs (NYC Department of City Planning 2009). Furthermore, when billboard contract finish the future of BSSs is uncertain.

Although it did not happen yet, it might happen that if a contract expires, bike-sharing services would stop being offered and the BSS could even be abandoned. In contrast, municipal BSSs might enable better integration with all transport modes and better coordination with city development plans. Nevertheless, the survival of BSSs should not depend on short-term subsidies that compromise the future of the system. The economic support of public authorities, when existing, should be durable.

This creates a dilemma: since BSSs are all loss making, why should public authorities fund them? In opinion of the author of this dissertation, costs generated by BSSs, if they are affordable, should be internalised by municipalities in the same way that they do it with public transport. Public transport is normally loss making. Passengers do not pay the real full price of the tickets. Public authorities subsidize the service because it contributes to avoid traffic jams and consequent undesired effects (pollution, time-spending…). If the real goal of a municipality is e.g. to reduce car traffic, it should be assumed that some investments will be required. BSSs should be seen as a tool to achieve a goal that imply monetary costs but that will bring future benefits if the BSS is successful. Public transport companies could internalizes bike-sharing costs as Deutsche Bahn does in Germany. Call a Bike is not conceived as a direct income generating but a as way to offer a complementary service to their customers that will make the travel by train more attractive and what will bring future incomes. Concerning the efficiency of BSSs there is still an open discussion (Bea Alonso 2009). It has been questioned whether achievements of BSSs are enough to justify their internal and external costs. For instance, if a municipality aims to increase cycling, would it not be cheaper and more effective to build more dedicated cycling infrastructure instead of implementing a BSS? Lack of data regarding whole costs of BSSs makes very difficult to answer such questions. According to the figures presented in this dissertation, bike-sharing success seems to be very limited in comparison with the money invested. Nevertheless, it is out of the capacity of this research to determine which kind of instruments could be more cost-effective than BSSs achieving the sustainability goals.

In sum, the main strengths of BSSs seem to be the following: 1) making intermodal trips with public transport more attractive, 2) increasing bicycle use and 3) increasing traffic safety. These three facts actually interact with each other as the “loop of increasing bike-sharing use” of Figure 147 explains. If intermodality between transport mode and bike-sharing is favoured, a relevant sector of potential customers may be willing to rent bicycles. Moreover, one of the advantages of bike-sharing bicycles compared with private ones is that customers do not have to worry about bicycle theft. Mainly, these two factors might generate the first wave of bike-sharing customers renting bicycles. According to section 6.5, the presence of bike-sharing bicycles helps to increase visibility of cyclists in cities and to increase respect of car drivers toward cyclists. As a result, not only objective, but also subjective perception of traffic safety increases. Therefore, potential cyclists initially reluctant to ride because of traffic dangers start riding their own bicycles. Again the number of bicycles on the street increases and traffic safety too. This fact convinces new customers to become members of the BSS. And in this way the loop closes and re-starts. The limiting factor of this reaction is the size of the BSS.

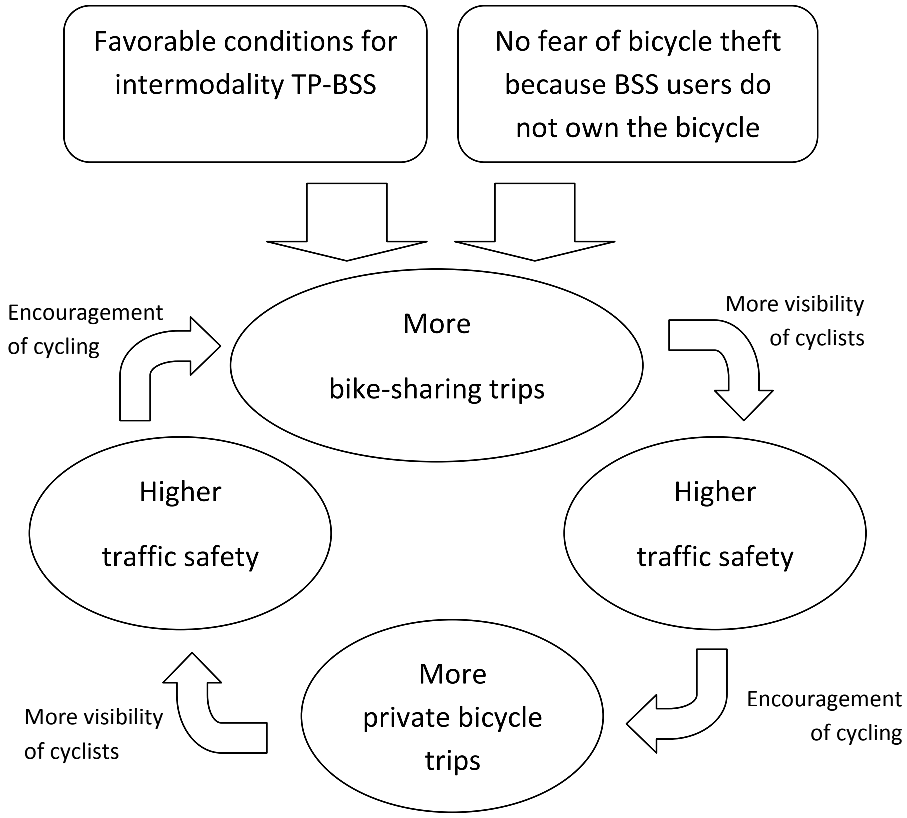


Figure 147: Loop of increasing bike-sharing use

Current cycling and public transport policies may act as opportunities for the expansion and optimisation of European BSSs. For instance, the level of cycling is increasing in most of European cities and more and more people decide to ride a bicycle to undertake their daily or leisure trips. Either due to a fashionable trend or due to the critical mass effect, BSSs could take benefit of this momentum and take the “green wave” to convince most reluctant potential users to ride bike-sharing bicycles and increase their market potential. The end of the existing gap in the co-operation between public transport operators and bike-sharing operators could accelerate the application of BSSs to intermodality. The general interest for combined use of both transport modes through integrated fees, closeness of stations and information is increasing.

On the other hand, there are two main weaknesses of BSSs: 1) their contribution reducing car traffic and pollution (lower than expected) and 2) their unsustainable funding. Some threats might compromise the future and survival of bike-sharing. Some small and not successful BSSs have been subsided during their whole lifetime. However, as a result of the current European economic crisis, municipalities with limited budget might stop funding BSSs. Since BSSs are loss making, these schemes might have to close. Large-scale schemes require high investments and private companies usually fund them. Nevertheless, separating development of BSSs from municipal integrated transport strategies might cause only private commercial revenues and not real public benefits. In addition, redistribution of bicycles from full to empty stations is one of the main concerns of BSSs still unsolved. Redistribution generates numerous negative implications that might affect the viability of BSSs. It increases operations costs, it reduces environmental achievements, it causes unavailability of service and it may affect satisfaction grade of users, which might reduce level of rents.

8.2 General recommendations for BSSs

If we consider bike-sharing as a tool to achieve public benefits, then municipalities, which are the main stakeholders watching over welfare of citizens, should regulate the introduction of BSSs. Based on the outcomes of this dissertation, the following general recommendations should be taken into account when introducing or optimizing a BSS:

1. Consider the option of not implementing a BSS: After the popularity of some large-scale BSSs, numerous cities have implemented or have planed to introduce a BSS. In some cases bike-sharing has become “chic” and have been considered as a “must have” (Büttner et al. 2011). Nevertheless, as not all cities have to provide metro network because a minimum density of demand is required, not all cities have to provide bike-sharing services. Depending on the specific necessities and characteristics of the city, bike-sharing may be (or not) a positive option.
2. Define the goal of the BSS: The goals of the bike-sharing should be clear, basically because without goals there is not success. Success means achievement of goals and cities can only evaluate the success of a BSS if the goals are enough defined in advance. The following likely goals could justify the introduction of a BSS: reducing car traffic, increasing cycling, increasing public transport attractiveness, reducing CO_2, increasing health, increasing traffic safety or enhancing municipal economy (section 6).
3. Set quantitative evaluating indicators: Once the goal of the BSS is clear, the next question to be answered should be “how will we evaluate the success achieving this goal?” Indicators provide a unit of measure. The number of rents is a very widely used and a representative indicator of every likely goal. Nevertheless, it is not the only one. Other variables can determine the final success of a BSS. For instance, if the intention of a BSS is to reduce car traffic and pollution, not only the number of rents should be high but also the share of bike-sharing trips coming from motor vehicles (section 7.1).
4. Define the characteristics of the BSS according to the goal and the city: There are numerous and very different models of BSSs and success will depend significantly on the selected bike-sharing configuration (section 5). Bike-sharing characteristics should be specific for the set goal and all variables affecting this type of success. For instance, if the goal of a BSS is to reduce car traffic and pollution, its features should enable not only a high level of rents in general but also a high level of specific rents coming from motor vehicles (section 7.2.15)
5. Set realistic objectives within a period according to the city and the BSS characteristics: Objectives represent the value to be achieved in selected indicators.

City factors and bike-sharing factors can contribute to achieve (or hinder) success (section 7.2).

6. Ensure durable funding: If the BSS is successful achieving the goal, but lack of funding causes its close, the project will be a failure (section 6.7).
7. Collect data for the evaluating indicators: Data will be very important to evaluate the success of the BSS. Data collection may require automatic devices for operational information (e.g., number of rents, date and location of the rent and return, etc.) and surveys to know the opinion of user and non-users.
8. Evaluate regularly the success of the BSS in terms of impact and efficiency: If the values of the indicators reach the wished quantitative objective for this date, it means that the BSS was successful so far.
9. Identify external and internal barriers that (may) affect negatively the success of the BSS and provide strategies to minimize them: Unexpected problems can arise when operating the BSS (section 7.3). Innovative solutions as well as good practices of other BSSs can help to minimize negative impacts.

8.3 Creating new bike-sharing concepts

So far existing BSSs have focused their efforts on reaching high number of rents by providing as many stations and bicycles as possible. It is right that the quantity of bike-sharing infrastructure affects positively the number of rents (section 7.2.1) but this strategy may have two main failures:

- As mentioned in section 8.2, current focus on reaching high number of rents underestimates the relevance of the other variables. Although the number of rents is a significant variable for achieving all kinds of success, it is not the only one. For instance, if the goal of a BSS is reduce car traffic, for having success not only the number of rents should be high but also the share of car trips shifted to bike-sharing. Specific goals might require selective actions within the corresponding target group.
- Large-scale bike-sharing infrastructure requires high investments and maintenance costs and they may cause negative consequences such as bicycle redistribution from full to empty station (section 7.3.5). A high number of stations provide a big variety of likely bike-sharing routes, which makes the service more attractive for customers, but on the other hand a high number of places for returning for bicycles multiply the possibilities of unbalance (section 7.2.1).

Based on the outcomes of this dissertation, the author suggests a different approach: creating small-scale BSSs that solve specific problems instead of implementing expensive large-scale BSSs with low impact in ambitious goals. It has been demonstrated that the impact of BSSs decreasing car traffic and pollution is very limited even in large-scale BSSs (section 6.2.3 and 6.3). And although large-scale BSSs play a relevant role promoting safe traffic and cycling habits, extended bike-sharing infrastructure causes the above-mentioned problems of high costs and redistribution. In contrast, bike-sharing services applied to public transport intermodality do not necessarily require extensive operating areas and have significant potential increasing public transport attractiveness. Three new likely bike-sharing concepts are suggested in this dissertation to interact with public transport keeping costs and undesired side effects such as redistribution and costs as low as possible:

- Linear concept: Some destinations with irregular but defined passenger demand are not supplied by public transport because the routes would be cost inefficient. For instance, factories and office buildings in suburbs are sometimes not provided with public transport due to their irregular demand. Many people commute to work in the morning and go home in the evening but meanwhile very few passengers would use public transport. If the existing public transport network does not provide any door-to-door service, people prefer to use cars to reach their destinations. Linear concepts of bike-sharing might provide a specific solution for this specific necessity when commuting. A bike-sharing station could be installed at the closest PT stop and a second bike-sharing station at the working place. Both stations would have the same capacity because hypothetically the same people that would rent a bike-sharing bicycle in the morning at the PT stop would use it for returning.

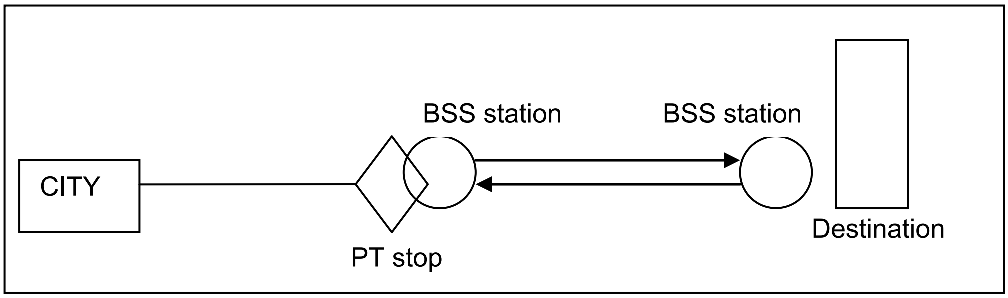


Figure 148: Linear concept of bike-sharing

- “Open-closed hand” concept: It could also happen that near to a public transport stop there is not one but several potential demanded destinations, e.g. in a university campus there are several faculty buildings. A BSS may provide a cheap and environmental way to connect public transport and destination dissuading people to use cars and reducing travel time of existing public transport passengers. In the case of the university campus, one bigger bike-sharing station should be installed at the public transport stop and each faculty building should be provided with a secondary bike-sharing station. In this way, bicycles would be taken in the morning at the PT stop and returned in the evening in a movement similar to an opening and closing hand. The model is viable if demand between secondary bike-sharing stations can be considered residual. If significant demand between secondary bike-sharing stations or if hours in-between exist, these routes could be restricted to ensure the balance of bicycles and avoid redistribution. This concept can be implemented at university campus, industrial areas or residential suburbs, where there are several likely destinations without trip demand between them and where these destinations are located around a PT station used for commuting.

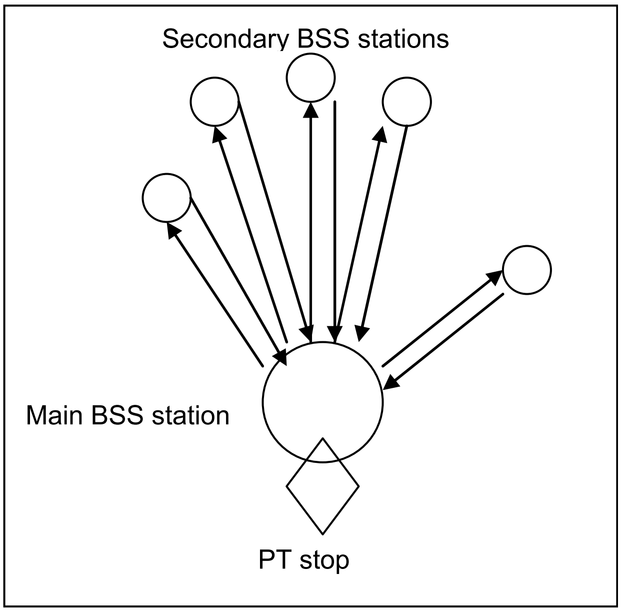


Figure 149: "Open-closed hand" concept of bike-sharing

- "Multiple open-close hand" concept: The "open-closed hand" concept could be implemented at the same time in several places in a city but exchange of bicycles between different "hands" should be restricted to avoid unbalance and redistribution.

The three concepts of bike-sharing presented above have as a main advantage that costs and environmental impacts of redistribution of bicycles are minimized. The systems work within a closed cycle where the fleet of bicycles is naturally compensated and distributed by users commuting. Moreover, these concepts meet the interest of public authorities and private companies. Public authorities that manage public transport systems may be interested on improving the quality of service by connecting end stations with further destinations by mean of a BSS. On the other hand, private companies may be interested on implementing sustainable mobility plans for workers that would reduce environment impacts and improve the image of the company. Since private companies and public authorities may have interest in this kind of models, the running and implementation costs of the BSS may be shared by the two stakeholders.

8.4 Scientific contribution and open research issues

Bike-sharing is a recent mobility concept. It has been always considered as a positive element of urban transport. However, very few scientific researches had studied the effects of the BSSs before this dissertation. This dissertation has contributed to elevate scientific knowledge about BSSs as follow:

- The quantification of sustainability of bike-sharing in terms of mobility, environment, health, safety, and economy with a comprehensive sample of case studies has revealed that the most relevant positive effects of BSSs are the increase of intermodality with public transport, the increase of cycling and traffic safety. On average, 34% of bike-sharing trips are connected with public transport and 40% of bike-sharing users hold a public transport seasonal card. Furthermore, the direct increase of cycling due to bike-sharing trips is on average 8.5%, while the maximal value reaches 91.5%. Although indirect effects of bike-sharing on cycling as a result of the critical mass could not be quantified, they may be relevant. Both direct and indirect effects increase traffic safety through a higher visibility of cyclists. In contrast, quantified impacts of BSSs on car traffic and environment are still limited. On average only 15% of bike-sharing users come from cars and 0.04% of the total daily car trips have been shifted to BSSs. The maximal value of car shift reaches around 0.2%.

- The calculation of the level of correlation between several key factors and the success of BSSs through statistical methods has showed that the highest influence on a increased number of rents per bicycle and day are found in the following factors: the share of metro stations provided with bike-sharing, city vandalism, the number of stations, the number of stations per city km2, the availability of all-the-year-round service, the population density, the average yearly temperature and cycling.
- Equations that describe the single and multiple influences of these factors on the level of use of BSSs using single and multiple regression analyses conclude that the following function might predict rotation on base of the five driving forces with higher correlation with rotation. Rotation (rents/bike*day) = -4.406+0.394*Ln(stations) + 0.218*Ln(stations/km^2) + 0.184*Ln(inhabitants/km^2) + 1.371*Ln(average yearly temperature in ºC) – 0.019*Ln(cycling share). This rotation could be predicted in a statistical significant way on base of two variables that interact according to the following multiple regression model: Rotation (rents/bike*day) = -5.168+0.645*Ln(stations) + 1.811*Ln(average yearly temperature in ºC)

On the other hand, some issues could not be studied in this dissertation because of lack of data or capacity. Five open issues that can be analyzed in future researches are the following:

- Influence of BSSs on indirect increase of cycling: The number of cyclists that were convinced to ride their own bicycles as a result of the bike-sharing operation and the critical mass effect is a key factor to determine the total increase of cycling motivated by BSSs. However, it is based on subjective perceptions and very specific surveys will be needed to study this relevant influence of bike-sharing. Lack of data also hindered the quantification of bike-sharing success in terms of traffic safety, municipal economy and economic viability.

- Effectiveness on different target groups: With more specific data it would be interesting to identify problems and to quantify the grade of effectiveness of the bike-sharing policies (e.g. especial usage or subscription fees, location of stations, etc.) in catching customers from a specific target group.
- Financing form: Due to the confidentiality of data regarding financing of BSSs, this dissertation could not make a comprehensive analysis of the economic viability of bike-sharing. Conclusions of future researches focused on this matter may entail ideas for new ways of funding and new strategies for reduction of costs.
- Convenience of bike-sharing compared with other instruments: If it is taken into consideration the impact and efficiency of BSSs achieving a goal, certain instruments might be more effective. For example, if the goal of a municipality is to increase cycling, the introduction of a BSS might be questioned as best strategy compared to other cycling policies such as dedicated infrastructure for private bicycles. It would be interesting to contrast impact and efficiency of BSSs compared with different complementary instruments
- Interactions between factors: Higher availability of data may enable more reliable multiple regression analysis to find up interconnections between different affecting factors. This network of influences might even make possible the creation of a model that predicts the success of a BSS depending on the existing and modifiable circumstances.
- Suitability of cities for BSS: Not all cities have to implement a BSS. There can be cities where BSSs are not the best tool to achieve the sustainability goals. The finding of a methodology that determines whether a city is suitable or not for a BSS may be appreciated. Furthermore, if the decision is to implement a BSS, a methodology that defines the most favourable characteristics of the BSS for the given city may represent a valuable tool.

9 ABBREVIATIONS

AT: Austria
BE: Belgium
BSS: Bike-Sharing Scheme
CZ: Czech Republic
DE: Germany
ES: Spain
EU: European Union
FR: France
GDP: Gross Domestic Product
ID: Identity card
IT: Italy
Kg: kilograms
LT: Long-term
max: maximum
min: minimum
N: Number of cases
NA: Not available
NS: No sense
PL: Poland
PT: Public transport
OBIS: Optimising Bike Sharing in European Cities
SE: Sweden
ST: Short-term
SWOT: Strengths, Weaknesses, Opportunities and Threats
UK: United Kingdom
USA: United States of America
WHO: World Health Organisation

10 ANNEXES

10.1 Database

Table 41 shows the database that fundament the calculations of this dissertation. The case studies are ordered, as in section 6, by city population. The data sources of the case studies are following:

- London: (Williamson 2009b; Williamson 2009a; Noland & Ishaque 2006; Oybike 2010)
- Berlin: (Gröper 2009; Büttner 2009; Sassen 2009; City council of Berlin 2010)
- Rome: (Menichetti 2009; Vecchiotti & Menichetti 2009; Atac Bikesharing 2010)
- Paris: (Robert 2009b; Robert 2009a; Vélib' 2009b; Sassen 2009; Vélib' 2007; Nadal 2007; Vélib' 2008; Vélib' 2009a; Dargent 2009; Bea Alonso 2009; DeMaio 2009b; City of Paris 2004; NYC Department of City Planning 2009)
- Vienna: (Castro 2009; Castro & Emberger 2009; Dechant 2009; Schneeweiss 2007; Stadt Wien 2010; Citybike Wien 2010)
- Barcelona: (Frühauf 2009; Frühauf & Hayes 2009; Bicing 2010; Bea Alonso 2009; elPeriodico.com 2009; Sassen 2009; NYC Department of City Planning 2009; Dector-Vega et al. 2008; Bikeoff 2008b; Bicing 2009; Cazorla 2009; City council of Barcelona 2008; Romero 2008)
- Munich: (Gröper 2009; Büttner 2009)
- Milan: (Menichetti 2009; Vecchiotti & Menichetti 2009; Bikemi 2010)
- Prague: (Martinek 2009b; Martinek 2009a; Carbusters n.d.; Beroud 2007; Homeport n.d.)
- Stockholm: (Petersen 2009; Petersen & Robèrt 2009; Stockholm City Bikes 2010; Sassen 2009; Wikipedia 2010d; ManagEnergy 2010; City of Stockholm 2010)
- Krakow: (Dworak 2009; Kowalewska & Ejsmont 2009; Bikeone 2010)
- Seville: (Frühauf 2009; Frühauf & Hayes 2009; Sevici 2010; Gonzalo et al. 2008; García Jaén n.d.)
- Saragossa:(Frühauf 2009; Frühauf & Hayes 2009; Bizi 2010)
- Lyon: (Robert 2009b; Robert & Richard 2009; Vélo'v 2010; Vélo'v 2009; Sassen 2009; Grand Lyon 2009b; Snead & Dector-Vega 2008; Beroud 2007; Pignon sur Rue 2010; Grand Lyon 2006; NYC Department of City Planning 2009)
- Stuttgart: (Gröper 2009; Büttner 2009; Wikipedia 2010d)
- Düsseldorf: (Gröper 2009; Büttner 2009; nextbike 2010; Sassen 2009)
- Bristol: (Williamson 2009b; Williamson 2009a)

- Leipzig: (Gröper 2009; Büttner 2009; nextbike 2010)
- Gothenburg-1: (Petersen 2009; Petersen & Robèrt 2009; Wikipedia 2010d)
- Gothenburg-2: (Petersen 2009; Petersen & Robèrt 2009; Wikipedia 2010d)
- Bari: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; Bicincittà 2010)
- Karlsruhe: (Gröper 2009; Büttner 2009; DB Bahn 2009; City of Karlsruhe 2007)
- Montpellier: (Robert 2009b; Robert & Richard 2009; Vélomagg' 2008; maville.com 2009)
- Chemnitz: (Gröper 2009; Büttner 2009; Gemnitzer Gewölbegänge e.V. 2009)
- Vitoria: (Frühauf 2009; Frühauf & Hayes 2009; Gonzalo et al. 2008; City council of Vitoria 2009b; Diario noticias de Álava 2010; City council of Vitoria n.d.; City council of Vitoria 2009a; Escudero n.d.)
- Reading: (Williamson 2009b; Williamson 2009a; Oybike 2010)
- Rennes-1: (Robert 2009b; Robert & Richard 2009; Sassen 2009; Clear Channel 2010)
- Rennes-2: (Robert 2009b; Robert & Richard 2009; le vélo star 2009)
- Terrassa: (Frühauf 2009; Frühauf & Hayes 2009; Gonzalo et al. 2008; Ajuntament Terrassa 2009; AEMET 2010)
- Modena: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; PROMT 2003)
- Pamplona: (Frühauf 2009; Frühauf & Hayes 2009; Europa Press 2010; City council of Pamplona 2007b; AEMET 2010; City council of Pamplona 2007a)
- Parma: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; Bicincittà 2010; PuntoBici 2010)
- Brescia: (Menichetti 2009; Vecchiotti & Menichetti 2009; Bicimia 2009)
- Dijon: (Robert 2009b; Robert & Richard 2009; Velodi n.d.)
- Rimini: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; City of Rimini 2008; Tu Tiempo 2010)
- Salzburg: (Castro 2009; Castro & Emberger 2009)
- Brussels-1: (Robert 2009b; Robert 2009a; Le Soir 2008; Cyclocity 2008; Statistics Belgium 2008)
- Brussels-2: (Robert 2009b; Robert & Richard 2009; Villo! 2010; Statistics Belgium 2008)
- Örebro: (Petersen 2009; Petersen & Robèrt 2009)
- Cambridge: (Williamson 2009b; Williamson 2009a; Oybike 2010)
- Cheltenham: (Williamson 2009b; Williamson 2009a; Oybike 2010)
- Ribera Alta: (Frühauf 2009; Frühauf & Hayes 2009; Talavera 2009; Ambici 2009)
- Orléans: (Robert 2009b; Robert & Richard 2009; Véló+ 2009)

- Bolzano: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; City council of Bolzano 2010; ViaNova n.d.)
- Farnborough: (Williamson 2009b; Williamson 2009a; Oybike 2010)
- Cuneo: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; City of Cuneo 2005)
- Chalon-sur-Saône: (Robert 2009b; Robert & Richard 2009)
- Senigallia: (Vecchiotti 2009; Vecchiotti & Menichetti 2009; City of Senigallia 2008)
- Lake Neusiedl: (Castro 2009; Castro & Emberger 2009)
- Terlizzi: (Vecchiotti 2009; Vecchiotti & Menichetti 2009)
- Mödling: (Castro 2009; Castro & Emberger 2009)

BSS DATA			London (UK)	Berlin (DE)	Rome (IT)	Paris (FR)	Vienna (AT)	Barcelona (ES)	Munich (DE)	Milan (IT)	Prague (CZ)	Stockholm (SE)
Users shifted from another transport mode	%	x1	77%	97%	NA	100%	96%	100%	97%	71%	NA	100%
Share of shifted users that traveled by car	%	x2	7.8%	5.4%	NA	8.0%	14.1%	9.6%	6.1%	29.0%	NA	5.2%
Share of shifted users that traveled by PT	%	x3	44.2%	38.5%	NA	65.0%	69.4%	51.3%	35.4%	48.4%	NA	58.1%
Share of shifted users that traveled by bike	%	x4	7.8%	13.0%	NA	NA	16.4%	NA	12.5%	12.9%	NA	9.7%
Share of shifted users that w alked	%	x5	27.3%	31.9%	NA	20.0%	NS	26.1%	31.2%	9.7%	NA	26.6%
Trip purpose: Working and education	%	x6	11.0%	41.2%	NA	61.0%	20.0%	66.8%	35.1%	57.9%	NA	48.5%
Yearly rents	rents/year	x7	NA	171,148	NA	29,245,984	363,428	12,307,828	126,472	NA	3,020	239,852
Year			NA	2008	NA	2008	2008	2008	2008	NA	2008	2008
Yearly operative days	days/year	x8	365	306	365	365	365	365	306	365	365	214
Bicycles	bikes	x9	108	1,715	120	20,600	626	6,000	1,436	1,400	30	500
Year			2009	2009	2009	2009	2009	2009	2009	2009	2007	2009
Share of BSS trips that are intemodal	%	x10	39%	51%	NA	79%	24%	30%	44%	67%	NA	36%
Share of BSS intermodal trips connecting w ith PT	%	x11	100%	94%	NA	100%	83%	86%	91%	75%	NA	NA
Users holding a seasonal PT card	%	x12	NA	39%	NA	NA	44%	NA	42%	NA	NA	54%
Share of users that do not ow n a bicycle	%	x13	48%	10%	NA	NA	37%	NA	10%	47%	NA	NA
Distance covered from the start	km	x14	NA	NA	NA	7,000,000	NA	NA	NA	NA	NA	NA
till this date	date		NA	NA	NA	31/06/07	NA	NA	NA	NA	NA	NA
Rents from start	rents	x15	NA	556,949	NA	4,000,000	NA	8,700,000	528,454	NA	6,936	NA
till this date	date		31/12/2008	31/12/2008	NA	31/08/2007	NA	01/06/2008	31/12/2008	NA	24/03/2009	NA
Distance covered in 2008	km/year	x16	NA	NA	NA	NA	1,141,630	33,200,000	NA	NA	NA	NA
Number of redistribution vans	vans	x17	NA	NA	NA	200	2	46	NA	NA	NA	3
Daily distance covered by all redistribution vans	km/day	x18	NA	NA	NA	NA	60	NA	NA	NA	NA	300
Unitary CO2 emission of redistribution vans	kg/km	x19	NA	NA	NA	NA	0.19	NA	NA	NA	NA	0.155
Fossil fuel for redistribution vans		x20	NA	NA	NA	NA	Yes	Yes	NA	NA	NA	Yes
Average duration of rents	min	x21	NA	58	NA	18	23	14	44	NA	10	38
Subscriptions	persons	x22	NA	49,189	NA	198,913	161,475	175,000	42,206	16,456	NA	30,000
till this date	dd/mm/yyyy		NA	31/12/2008	NA	15/07/2008	31/01/2009	01/03/2009	31/12/2008	01/07/2009	NA	31/12/2008
Share of users that use the BSS daily	%	x23	NA	0.7%	NA	NA	3.0%	NA	0.4%	68.4%	NA	14.3%
Direct jobs created	job	x24	NA	NA	NA	500	15	230	NA	NA	NA	6
Share of customers that state that the main reason for using the BSS is because it is cheaper	%	x25	NA	NA	NA	62.0%	13.0%	17.3%	NA	15.3%	NA	5.7%
Share of rents free of charge	%	x26	NA	NA	NA	92%	95%	91%	NA	NA	0%	NA
Share of daily memberships in 2008	%	x27	NA	NA	NA	92%	NA	NA	NA	6%	NA	63%
Share of w eekly memberships in 2008	%	x28	NA	NA	NA	7%	NA	NA	NA	32%	NA	NA
Unitary cost of a station	€/station	x29	581	NS	NA	NA	60,000	27,250	NS	26,200	NA	NA
Unitary cost of a bicycle	€/bike	x30	697	NA	NA	500	600	450	NA	600	NA	450
Total maintenance cost	€/bike*year	x31	NA	NA	NA	NA	1,000	1,700	NA	800	NA	NA
Theft from the start of the BSS	bikes	x32	11	NA	NA	7,800	NA	800	NA	NA	NA	NA
months of operation till data	months		54	NA	NA	19	NA	33	NA	NA	NA	NA
Minimum age	years	x35	No min. Age	16	NA	14	12	16	16	16	No min. Age	18
Use allow ed for everyone		x36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Validity of short-term subscription	days	x37	1&7	Not offered	Not offered	1&7	Not offered	Not offered	Not offered	1&7	Not offered	3
Validity of long-term subscriptions		x38	unlimited	unlimited	unlimited	1 year	unlimited	1 year	unlimited	1 year	1 year	1 year
Specific PT subscription		x39	No	Yes	No	Yes	No	No	Yes	No	No	No
Short-term subscription fee	€	x40	5.65	Not offered	Not offered	1.00&5.00	Not offered	Not offered	Not offered	2.50&6.00	Not offered	13.11
Long-term subscription fee	€	x41	11.62	5.00	5.00	29.00	1.00	30.00	5.00	36.00	0.00	26.22
Desposit (long-term)	€	x42	0	0	30	150	0	0	0	0	20	0
Insurance		x43	No	Third-party	NA	No	No	All risk	Third-party	Third-party	NA	No
Bicycles w ith gears		x44	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Both brakes on handlebar		x45	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Bicycles w ith tyres filled w ith air		x46	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Fixed stations		x47	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Protection of bikes		x48	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door
All-the-year-round service		x49	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Round-the-clock service		x50	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
Way of identification		x51	Phone	Phone	Smart Card	Smart Card	Smart Card	Smart Card	Phone	Smart Card	Smart Card	Smart Card
Operating area	cities	x52	1	1	1	1	1	1	1	1	1	1
Limit of use	hours	x53	24	No limit	24	24	120	2	No limit	7	72	3
Fine	€	x54	NA	NS	NA	150.00	600.00	150.00	NS	150.00	7.26	0.00
Rental time free of charge (long-term tariff)	minutes	x55	30	0	0	30	60	30	0	30	0	unlimited
Fare unit (long-term tariff)		x56	€/30&60min	€/minute	€/30min	€/30min	€/hour	€/30&60min	€/minute	€/30&60min	€/minute	unlimited
Flat rate		x57	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes
Bank transfer payment		x58	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes
Bank card payment		x59	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Pre-paid card payment		x60	No	No	Yes	Yes	No	No	No	No	Yes	No
Cash payment		x61	No	No	No	No	No	No	No	No	Yes	Yes
Investor		x62	Private company	Private company	Public authority	Private company	Private company	Public authority	Private company	Private company	Other	Private company
Operator		x63	Private company	Private company	Public authority	Private company	Private company	Private company	Private company	Private company	Other	Private company
Provider		x64	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Other	Other
Provider companies		x65	Veolia	Call a bike	Bicincittà	JCDecaux	JCDecaux	Clear Channel	Call a bike	Clear Channel	Veolia	Clear Channel
Number of stations	stations	x66	50	0	19	1,451	60	400	0	103	17	71
Year			2009	2009	2009	2009	2009	2009	2009	2009	2007	2009
Distance betw een stations	m	x67	NA	NS	NA	300	NA	300	NS	NA	NA	500
Technology of the locking device		x68	Electronic	Electronic	Electronic	Electronic	Electronic	Electronic	Electronic	Electronic	Electronic	Electronic
Metro stations provided w ith BSS	metro stations	x69	NA	NS	NA	298	31	78	NS	NA	3	2NS
CITY DATA												
Daily municipal trips	trips/day	y1	23,800,000	12,500,000	NA	10,500,000	4,536,718	7,851,000	4,000,000	NA	NA	2,693,745
Car modal share	%	y2	40.0%	43.1%	53.0%	40.0%	35.0%	28.4%	39.0%	44.0%	33.5%	33.0%
PT modal share	%	y3	28.0%	21.0%	29.0%	20.0%	34.0%	40.1%	22.0%	39.0%	43.0%	43.0%
Cycling modal share	%	y4	2.0%	7.4%	2.0%	2.0%	3.0%	0.4%	10.0%	4.0%	1.5%	7.0%
Walking modal share	%	y5	29.0%	28.0%	15.0%	38.0%	28.0%	31.6%	29.0%	13.0%	22.0%	15.0%
Cycling modal share before the BSS	%	y6	NA	7.4%	NA	2.0%	3.0%	0.8%	13.0%	NA	NA	7.0%
Population	inhabitants	y7	7,556,900	3,416,255	2,724,347	2,168,000	1,680,266	1,629,537	1,302,376	1,295,705	1,233,211	810,120
EU standard CO2 emission of cars	CO2 kg/km	y8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EU standard CO emission of diesel cars	CO g/km	y9	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
EU standard PM emission of diesel cars	PM g/km	y10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
EU standard NOx emission of diesel cars	NOx kg/km	y11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Average duration of private bicycle trips	minutes	y12	25	NA	NA	NA	22	NA	NA	NA	NA	19
Number of metro stations	metro stations	y14	270	303	NA	298	90	150	94	78	54	100
Avergage yearly temperature	°C	y15	12.8	10.6	NA	12.4	10.7	16.0	10.6	NA	11.1	8.5
Cycle netw ork	km	y16	NA	1,115	NA	371	1,090	130	1,200	NA	360	760
Area of the city	km2	y17	1,596.00	891.67	1,285.30	105.00	414.88	101.40	310.40	182.00	496.00	187.74
Permission for carrying bikes in PT trains		y18	restricted	unlimited	restricted	restricted	restricted	restricted	restricted	restricted	unlimited	restricted
Yearly overnight stays in tourist accomodations	stays/year	y19	95,846,000	17,285,837	NA	31,569,100	9,356,045	13,198,982	5,281,265	15,840,000	12,174,591	8,853,000
Yearly municipal bicycle theft	cases/year	y20	NA	23,645	NA	130,080	7,415	125,474	6,080	NA	638	3,789
Yearly cycle accidents	accidents/year	y21	NA	NA	NA	770	617	442	NA	NA	120	370
Population density	inhab/km2	y22	4,761.00	3,831.30	2,119.62	20,648.00	4,046.00	15,730.87	4,195.80	2,825.47	2,486.20	4,315.12

BSS DATA			Krakow (PL)	Seville (ES)	Saragossa (ES)	Lyon (FR)	Stuttgart (DE)	Düsseldorf (DE)	Bristol (UK)	Leipzig (DE)	Gothenburg-1 (SE)	Gothenburg - 2 (SE)
Users shifted from another transport mode	%	x1	NA	NA	NA	98%	84%	NA	100%	NA	NA	100%
Share of shifted users that traveled by car	%	x2	NA	NA	NA	10.0%	6.0%	NA	NA	NA	NA	NA
Share of shifted users that traveled by PT	%	x3	NA	NA	NA	46.0%	34.1%	NA	NA	NA	NA	NA
Share of shifted users that traveled by bike	%	x4	NA	NA	NA	6.0%	8.0%	NA	NA	NA	NA	NA
Share of shifted users that w alked	%	x5	NA	NA	NA	38.0%	43.6%	NA	NA	NA	NA	NA
Trip purpose: Working and education	%	x6	NA	25.2%	NA	80.0%	37.6%	NA	50.0%	NA	NA	NA
Yearly rents	rents/year	x7	NA	NA	NA	6,467,825	59,520	8,000	NA	50,000	2,877	NA
Year			NA	NA	NA	2008	2008	2008	NA	2008	2008	NA
Yearly operative days	days/year	x8	273	365	365	365	306	244	365	275	365	365
Bicycles	bikes	x9	100	2,000	400	3,800	525	300	16	500	125	57
Year			2009	2009	2009	2009	2009	2008	2009	2009	2009	2009
Share of BSS trips that are intemodal	%	x10	NA	NA	NA	40%	44%	NA	NA	NA	NA	NA
Share of BSS intermodal trips connecting w ith PT	%	x11	NA	NA	NA	25%	91%	NA	50%	NA	NA	NA
Users holding a seasonal PT card	%	x12	NA	NA	NA	50%	46%	NA	NA	NA	NA	NA
Share of users that do not ow n a bicycle	%	x13	NA	NA	NA	NA	22%	NA	NA	NA	NA	NA
Distance covered from the start	km	x14	NA	NA	NA	38,750,000	NA	NA	NA	NA	NA	NA
till this date	date		NA	NA	NA	01/01/2009	NA	NA	NA	NA	NA	NA
Rents from start	rents	x15	8,700	NA	NA	18,080,887	79,171	NA	1,035	NA	NA	NA
till this date	date		22/12/2008	NA	NA	01/01/2009	31/12/2008	NA	01.04.09	NA	NA	NA
Distance covered in 2008	km/year	x16	NA	NA	NA	15,800,000	NA	NA	NA	NA	NA	NA
Number of redistribution vans	vans	x17	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
Daily distance covered by all redistribution vans	km/day	x18	50	NA	NA	NA	NA	NA	NA	NA	NA	0
Unitary CO2 emission of redistribution vans	kg/km	x19	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
Fossil fuel for redistribution vans		x20	Yes	NA	NA	NA	NA	NA	NA	NA	NA	No van
Average duration of rents	min	x21	28	NA	NA	17	25	300	18	300	NA	NA
Subscriptions	persons	x22	605	92,024	NA	60,000	4,211	3,000	350	30,000	NA	800
till this date	dd/mm/yyyy		22/12/2008	05/11/2008	NA	01/05/2007	31/12/2008	31/12/2008	01/04/2009	31/12/2008	NA	10/05/2009
Share of users that use the BSS daily	%	x23	NA	NA	NA	NA	1.2%	NA	55.0%	NA	NA	NA
Direct jobs created	job	x24	NA	NA	NA	50	NA	NA	NA	NA	NA	3
Share of customers that state that the main reason for using the BSS is because it is cheaper	%	x25	NA	NA	NA	16.0%	NA	NA	20.0%	NA	NA	NA
Share of rents free of charge	%	x26	NA	NA	NA	93%	NA	0%	80%	0%	100%	0%
Share of daily memberships in 2008	%	x27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Share of w eekly memberships in 2008	%	x28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unitary cost of a station	€/station	x29	NA	NA	NA	10,000	NS	NA	NA	NA	NA	NA
Unitary cost of a bicycle	€/bike	x30	NA	NA	NA	1,500	NA	300	NA	300	472	NA
Total maintenance cost	€/bike*year	x31	NA	NA	NA	1,000	NA	NA	NA	NA	NA	NA
Theft from the start of the BSS	bikes	x32	3	1,236	NA	NA	NA	NA	1	NA	NA	1
months of operation till data	months		1	15	NA	NA	NA	NA	6	NA	NA	36
Minimum age	years	x35	18	14	16	14	16	16	12	16	18	No min. Age
Use allow ed for everyone		x36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Validity of short-term subscription	days	x37	7,30&90	7	3	1&7	Not offered	Not offered	Not offered	Not offered	Not offered	Not offered
Validity of long-term subscriptions		x38	1 year	1 year	1 year	1 year	unlimited	unlimited	unlimited	unlimited	1 year	unlimited
Specific PT subscription		x39	No	No	No	Yes	Yes	No	No	No	No	No
Short-term subscription fee	€	x40	2.56&5.34	5.00	5.00	1.00&3.00	Not offered	Not offered	Not offered	Not offered	Not offered	Not offered
Long-term subscription fee	€	x41	21.37	10.00	20.00	15.00	5.00	1.00	11.62	1.00	20.98	1.05
Desposit (long-term)	€	x42	26	150	200	150	0	0	0	0	0	0
Insurance		x43	No	No	User insured	No	Third-party	Third-party	Third-party	Third-party	No	No
Bicycles w ith gears		x44	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NA
Both brakes on handlebar		x45	No	Yes	No	Yes	Yes	No	Yes	No	No	NA
Bicycles w ith tyres filled w ith air		x46	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed stations		x47	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
Protection of bikes		x48	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door
All-the-year-round service		x49	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes
Round-the-clock service		x50	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Way of identification		x51	Code	Smart Card	Smart Card	Smart Card	Phone	Phone	Smart Card	Phone	Smart Card	Phone
Operating area	cities	x52	1	1	1	2	1	1	1	1	1	3
Limit of use	hours	x53	12	24	24	24	No limit	No limit	48	No limit	4	10
Fine	€	x54	10.85	NA	150.00	150.00	NS	NS	232.32	NS	0.00	0.00
Rental time free of charge (long-term tariff)	minutes	x55	20	30	30	30	30	0	30	0	unlimited	0
Fare unit (long-term tariff)		x56	€/30min	€/30&60min	€/30min	€/30min	€/minute	€/hour	€/30&60min	€/hour	unlimited	€/rent
Flat rate		x57	No	No	No	No	Yes	Yes	NA	Yes	Yes	Yes
Bank transfer payment		x58	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Bank card payment		x59	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
Pre-paid card payment		x60	No	No	No	Yes	No	No	Yes	No	No	No
Cash payment		x61	No	No	No	No	No	No	No	No	Yes	No
Investor		x62	Other	Public authority	Public authority	Public authority	Private company	Private company	Private company	Private company	Private company	Other
Operator		x63	Other	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Other
Provider		x64	Other	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Other	Other
Provider companies		x65	Other	JCDecaux	Clear Channel	JCDecaux	Call a bike	Nextbike	Vipre	Nextbike	Clear Channel	Other
Number of stations	stations	x66	13	250	40	343	0	27	8	0	11	0
Year			2009	2009	2009	2009	2009	2009	2009	2009	2009	2009
Distance betw een stations	m	x67	2,000	NA	NA	300	NS	NA	NA	NA	NA	NA
Technology of the locking device		x68	Electronic	Electronic	Electronic	Electronic	Electronic	Mechanic	Electronic	Mechanic	Electronic	Mechanic
Metro stations provided w ith BSS	metro stations	x69	NS	11	NS	43	26	6	NS	NS	NS	NA
CITY DATA												
Daily municipal trips	trips/day	y1	NA	NA	NA	1,936,000	1,731,810	1,667,820	NA	1,633,638	1,464,899	1,464,899
Car modal share	%	y2	37.0%	NA	NA	50.0%	51.0%	40.0%	NA	49.0%	52.0%	52.0%
PT modal share	%	y3	62.0%	NA	NA	15.0%	32.0%	23.0%	NA	16.0%	21.0%	21.0%
Cycling modal share	%	y4	NA	NA	NA	2.0%	4.0%	8.0%	NA	9.0%	14.0%	14.0%
Walking modal share	%	y5	NA	NA	NA	32.0%	13.0%	28.0%	NA	26.0%	12.0%	12.0%
Cycling modal share before the BSS	%	y6	NA	NA	NA	1.0%	4.0%	8.0%	NA	9.0%	14.0%	14.0%
Population	inhabitants	y7	756,267	699,145	682,283	608,000	597,176	581,122	551,066	510,512	500,197	500,197
EU standard CO2 emission of cars	CO2 kg/km	y8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EU standard CO emission of diesel cars	CO g/km	y9	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
EU standard PM emission of diesel cars	PM g/km	y10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
EU standard NOx emission of diesel cars	NOx kg/km	y11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Average duration of private bicycle trips	minutes	y12	NA	NA	NA	NA	NA	NA	NA	NA	20	20
Number of metro stations	metro stations	y14	0	NA	NA	43	NA	99	NA	0	0	0
Avergage yearly temperature	°C	y15	8.4	18.6	15.5	12.5	11.1	11.5	NA	10.5	10.5	9.7
Cycle netw ork	km	y16	70	84	NA	270	140	300	NA	296	590	590
Area of the city	km2	y17	326.86	140.80	973.78	67.16	207.36	217.02	110.00	297.36	462.42	462.42
Permission for carrying bikes in PT trains		y18	restricted	restricted	restricted	unlimited	unlimited	unlimited	restricted	unlimited	restricted	restricted
Yearly overnight stays in tourist accomodations	stays/year	y19	NA	NA	NA	2,929,000	2,586,640	3,045,609	NA	1,838,512	3,212,000	3,212,000
Yearly municipal bicycle theft	cases/year	y20	NA	NA	NA	18,240	810	3,925	NA	4,560	3,100	3,100
Yearly cycle accidents	accidents/year	y21	118	NA	NA	NA	477	721	NA	764	46	46
Population density	inhab/km2	y22	2,313.00	4,965.52	688.82	9,053.01	2,880.00	2,677.70	394.20	1,717.00	1,109.82	1,109.82

BSS DATA			Bari (IT)	Karlsruhe (DE)	Montpellier (FR)	Chemnitz (DE)	Vitoria (ES)	Reading (UK)	Rennes-1 (FR)	Rennes-2 (FR)	Terrassa (ES)	Modena (IT)
Users shifted from another transport mode	%	x1	81%	96%	NA	NA	NA	NA	83%	NA	NA	NA
Share of shifted users that traveled by car	%	x2	28.0%	5.6%	NA	NA	NA	NA	19.0%	NA	NA	NA
Share of shifted users that traveled by PT	%	x3	27.3%	37.3%	NA	NA	NA	NA	46.0%	NA	NA	NA
Share of shifted users that traveled by bike	%	x4	22.0%	13.2%	NA	NA	NA	NA	2.0%	NA	NA	NA
Share of shifted users that walked	%	x5	22.7%	35.0%	NA	NA	NA	NA	33.0%	NA	NA	NA
Trip purpose: Working and education	%	x6	35.2%	49.0%	NA	NA	NA	NA	39.0%	NA	25.2%	64.2%
Yearly rents	rents/year	x7	10,571	19,803	266,000	4,523	95,637	NA	96,683	NA	50,473	36,500
Year			2008	2008	2008	2008	2008	NA	2007	NA	2007	2008
Yearly operative days	days/year	x8	365	306	365	337	183	365	365	365	365	365
Bicycles	bikes	x9	80	343	650	130	300	13	200	900	100	224
Year			2009	2009	2008	2008	2009	2009	2009	2009	2007	2009
Share of BSS trips that are intemodal	%	x10	58%	46%	NA	NA	NA	NA	NA	NA	NA	66%
Share of BSS intermodal trips connecting with PT	%	x11	63%	93%	NA	NA	NA	NA	NA	NA	NA	20%
Users holding a seasonal PT card	%	x12	41%	39%	NA	NA	NA	NA	NA	NA	NA	NA
Share of users that do not own a bicycle	%	x13	71%	12%	NA	NA	32%	NA	NA	NA	NA	18%
Distance covered from the start	km	x14	NA	NA	NA	NA	NA	NA	NA	NA	NA	54,750
till this date	date		NA	NA	NA	NA	NA	NA	NA	NA	NA	31/12/2008
Rents from start	rents	x15	15,327	26,303	318,000	NA	NA	NS	494,311	NA	NA	67,500
till this date	date		30/11/2008	31/12/2008	01/04/2009	NA	NA	NS	31/12/2007	NA	NA	31/12/2008
Distance covered in 2008	km/year	x16	NA	NA	NA	NA	NA	NA	NA	NA	NA	27,750
Number of redistribution vans	vans	x17	1	NA	3	0	NA	NA	NA	NA	NA	1
Daily distance covered by all redistribution vans	km/day	x18	NA	NA	40	0	NA	NA	NA	NA	NA	10
Unitary CO2 emission of redistribution vans	kg/km	x19	NA	NA	NA	0	NA	NA	NA	NA	NA	0.3
Fossil fuel for redistribution vans		x20	NA	NA	Yes	No van	NA	NA	Yes	NA	NA	Yes
Average duration of rents	min	x21	25	33	270	NA	NA	NA	44	NA	NA	120
Subscriptions	persons	x22	530	1,881	9,000	NS	41,207	NA	4,839	NA	4,721	2,000
till this date	dd/mm/yyyy		30/11/2008	31/12/2008	01/04/2009	NS	31/12/2008	NA	31/12/2007	NA	01/05/2009	31/12/2008
Share of users that use the BSS daily	%	x23	21.7%	1.1%	NA	NA	NA	NA	NA	NA	NA	44.0%
Direct jobs created	job	x24	2	NA	8	13	23	NA	4	9	NA	2
Share of customers that state that the main reason for using the BSS is because it is cheaper	%	x25	18.5%	NA	NA	NA	73.0%	NA	NA	NA	NA	33.3%
Share of rents free of charge	%	x26	100%	NA	NA	100%	100%	NA	100%	NA	100%	100%
Share of daily memberships in 2008	%	x27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Share of weekly memberships in 2008	%	x28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unitary cost of a station	€/station	x29	17,500	NS	NA	NA	15,000	581	NA	650	NA	800
Unitary cost of a bicycle	€/bike	x30	175	NA	300	180	1,000	697	NA	482	NA	300
Total maintenance cost	€/bike*year	x31	365	NA	700	NA	1,300	NA	NA	1,060	1,207	NA
Theft from the start of the BSS	bikes	x32	NA	NA	22	NA	87	NA	NA	NA	NA	3
months of operation till data	months		NA	NA	22	NA	17	NA	NA	NA	NA	48
Minimum age	years	x35	18	16	No min. Age	No min. Age	No min. Age	No min. Age	No min. Age	14	16	18
Use allowed for everyone		x36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Validity of short-term subscription	days	x37	Not offered	Not offered	1	1&30	Not offered	1&7	1	1&7	Not offered	Not offered
Validity of long-term subscriptions		x38	1 year	unlimited	unlimited	unlimited	unlimited	unlimited	1 year	1 year	unlimited	1 year
Specific PT subscription		x39	Yes	Yes	Yes	No	No	No	No	Yes	No	No
Short-term subscription fee	€	x40	Not offered	Not offered	2.00	0.00	Not offered	5.65	0.00	1.00&5.00	Not offered	Not offered
Long-term subscription fee	€	x41	10.00	5.00	0.00	0.00	0.00	11.62	0.00	22.50	0.00	0.00
Desposit (long-term)	€	x42	0	0	150	0	0	0	23	150	0	20
Insurance		x43	No	Third-party	NA	No	NA	No	No	No	No	No
Bicycles with gears		x44	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Both brakes on handlebar		x45	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Bicycles with tyres filled with air		x46	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Fixed stations		x47	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protection of bikes		x48	Out-door covered	Out-door	Depot	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door
All-the-year-round service		x49	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Round-the-clock service		x50	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No
Way of identification		x51	Smart Card	Phone	Smart Card	ID	ID	Phone	Smart Card	Smart Card	ID	ID
Operating area	cities	x52	1	1	7	1	1	1	1	1	1	1
Limit of use	hours	x53	15	No limit	12	24	4	24	2	24	2	No limit
Fine	€	x54	NS	NS	NA	NS	NS	NA	0.00	150.00	100.00	NS
Rental time free of charge (long-term tariff)	minutes	x55	unlimited	0	0	0	unlimited	30	unlimited	30	unlimited	unlimited
Fare unit (long-term tariff)		x56	unlimited	€/minute	€/hour	€/rent	unlimited	€/30&60min	unlimited	€/30min	unlimited	unlimited
Flat rate		x57	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Bank transfer payment		x58	NS	Yes	Yes	No	NS	No	Yes	Yes	NS	NS
Bank card payment		x59	NS	Yes	Yes	No	NS	Yes	No	Yes	NS	NS
Pre-paid card payment		x60	NS	No	No	No	NS	No	No	No	NS	NS
Cash payment		x61	NS	No	Yes	Yes	NS	No	No	No	NS	NS
Investor		x62	Private company	Private company	Public authority	Public authority	Public authority	Private company	Private company	Private company	Public authority	Public authority
Operator		x63	Public authority	Private company	Public authority	Association	Public authority	Private company	Private company	Private company	Public authority	Association
Provider		x64	Private company	Private company	Private company	Other	Public authority	Private company	Other	Private company	NA	Private company
Provider companies		x65	Bicincittà	Call a bike	Other	Other	Other	Veolia	Clear Channel	EFFIA	Other	C'entro in bici
Number of stations	stations	x66	10	0	50	15	15	4	23	82	4	32
Year			2009	2009	2008	2009	2009	2009	2009	2009	2007	2009
Distance between stations	m	x67	2,000	NS	NA	NA	300	NA	NA	NA	NA	300
Technology of the locking device		x68	Electronic	Electronic	Electronic	Staff	Staff	Electronic	Electronic	Electronic	Staff	Mechanic
Metro stations provided with BSS	metro stations	x69	NS	NS	2NS	NS	NS	NS	NS	NS	NS	NS
CITY DATA												
Daily municipal trips	trips/day	y1	138,448	837,859	946,050	700,362	564,011	NA	1,264,830	1,264,830	NA	750,000
Car modal share	%	y2	72.0%	44.0%	63.0%	50.2%	36.6%	NA	60.0%	60.0%	NA	79.0%
PT modal share	%	y3	14.0%	18.0%	8.0%	14.2%	7.9%	NA	14.0%	14.0%	NA	7.0%
Cycling modal share	%	y4	1.0%	16.0%	2.0%	5.6%	3.3%	NA	3.0%	3.0%	NA	10.0%
Walking modal share	%	y5	13.0%	22.0%	27.0%	30.0%	49.9%	NA	23.0%	23.0%	NA	4.0%
Cycling modal share before the BSS	%	y6	NA	16.0%	2.0%	5.6%	1.4%	NA	3.0%	3.0%	NA	9.1%
Population	inhabitants	y7	322,511	288,917	255,000	241,504	233,399	232,662	209,900	209,900	206,245	200,007
EU standard CO2 emission of cars	CO2 kg/km	y8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EU standard CO emission of diesel cars	CO g/km	y9	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
EU standard PM emission of diesel cars	PM g/km	y10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
EU standard NOx emission of diesel cars	NOx kg/km	y11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Average duration of private bicycle trips	minutes	y12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Number of metro stations	metro stations	y14	9	NA	0	0	NA	NA	15	15	NA	0
Avergage yearly temperature	°C	y15	16.9	NA	15.7	7.5	NA	NA	11.7	11.7	16.2	14.4
Cycle network	km	y16	5	200	120	113	78	NA	180	180	14	130
Area of the city	km2	y17	116.20	173.46	56.88	220.85	276.80	NA	51.50	51.50	70.20	183.23
Permission for carrying bikes in PT trains		y18	restricted	restricted	unlimited	unlimited	restricted	restricted	unlimited	unlimited	restricted	restricted
Yearly overnight stays in tourist accomodations	stays/year	y19	439,488	817,286	850,000	432,386	348,537	NA	NA	NA	NA	454,128
Yearly municipal bicycle theft	cases/year	y20	NA	1,932	NA	530	NA	NA	NA	NA	NA	NA
Yearly cycle accidents	accidents/year	y21	100	557	25	267	NA	NA	NA	52	NA	239
Population density	inhab/km2	y22	2,775.00	1,666.00	4,482.70	1,093.00	843.20	420.30	4,093.00	4,093.00	2,939.60	1,091.56

BSS DATA			Pamplona (ES)	Parma (IT)	Brescia (IT)	Dijon (FR)	Rimini (IT)	Salzburg (AT)	Brussels-1 (BE)	Brussels-2 (BE)	Örebro (SE)	Cambridge (UK)
Users shifted from another transport mode	%	x1	NA	92%	68%	NA	71%	NA	NA	NA	NA	NA
Share of shifted users that traveled by car	%	x2	NA	20.8%	12.5%	NA	36.4%	NA	NA	NA	NA	NA
Share of shifted users that traveled by PT	%	x3	NA	33.3%	50.0%	NA	15.2%	NA	NA	NA	NA	NA
Share of shifted users that traveled by bike	%	x4	NA	4.2%	20.8%	NA	15.2%	NA	NA	NA	NA	NA
Share of shifted users that w alked	%	x5	NA	41.7%	16.7%	NA	33.3%	NA	NA	NA	NA	NA
Trip purpose: Working and education	%	x6	NA	50.0%	71.4%	NA	65.5%	NA	NA	NA	NA	NA
Yearly rents	rents/year	x7	5,307	NA	NA	NA	29,785	NA	19,455	NA	NA	NA
Year			2008	NA	NA	NA	2008	NA	2008	NA	NA	NA
Yearly operative days	days/year	x8	183	365	365	365	365	365	365	365	365	365
Bicycles	bikes	x9	101	48	120	350	52	15	250	1,000	1,400	3
Year			2009	2008	2009	2009	2009	2009	2009	2009	2009	2009
Share of BSS trips that are intemodal	%	x10	NA	100%	81%	NA	76%	NA	NA	NA	NA	NA
Share of BSS intermodal trips connecting w ith PT	%	x11	NA	23%	67%	NA	58%	NA	NA	NA	NA	NA
Users holding a seasonal PT card	%	x12	NA	23%	NA	NA	34%	NA	NA	NA	NA	NA
Share of users that do not ow n a bicycle	%	x13	NA	36%	36%	NA	41%	NA	NA	NA	NA	NA
Distance covered from the start	km	x14	8,740	NA	49,000	NA	NA	NS	NA	NA	NA	NA
till this date	date		31/10/2007	NA	28/02/2009	NA	NA	NS	NA	NA	NA	NA
Rents from start	rents	x15	4,370	19,384	45,547	NA	29,785	NA	NA	NA	NA	NA
till this date	date		31/10/2007	31/12/2008	28/02/2009	NA	13/12/2008	NA	NA	NA	NA	NA
Distance covered in 2008	km/year	x16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Number of redistribution vans	vans	x17	NA	NA	NA	NA	0	0	NA	NA	3	NA
Daily distance covered by all redistribution vans	km/day	x18	NA	10	41	NA	0	0	NA	NA	NA	NA
Unitary CO2 emission of redistribution vans	kg/km	x19	NA	NA	NA	NA	0	0	NA	NA	NA	NA
Fossil fuel for redistribution vans		x20	NA	Yes	Yes	NA	No van	No van	NA	NA	NA	NA
Average duration of rents	min	x21	23	30	12	NA	480	83	56	NA	NA	NA
Subscriptions	persons	x22	1,956	696	1,518	15,000	180	NA	NA	NA	NA	NA
till this date	dd/mm/yyyy		17/06/2008	31/12/2008	28/02/2009	27/03/2009	13/12/2008	NA	NA	NA	NA	NA
Share of users that use the BSS daily	%	x23	NA	0.0%	85.7%	NA	32.1%	NA	NA	NA	NA	NA
Direct jobs created	job	x24	NA	2	2	5	2	1	NA	NA	95	NA
Share of customers that state that the main reason for using the BSS is because it is cheaper	%	x25	NA	6.9%	15.3%	NA	12.9%	NA	NA	NA	NA	NA
Share of rents free of charge	%	x26	NS	90%	100%	NA	100%	NA	NS	0%	100%	NS
Share of daily memberships in 2008	%	x27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Share of w eekly memberships in 2008	%	x28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unitary cost of a station	€/station	x29	NA	13,076	25,000	NA	3,750	NS	NA	NA	NA	581
Unitary cost of a bicycle	€/bike	x30	NA	144	220	NA	415	600	NA	NA	NA	697
Total maintenance cost	€/bike*year	x31	NA	320	600	NA	519	NA	NA	1,500	NA	NA
Theft from the start of the BSS	bikes	x32	6	15	40	NA	0	NA	NA	NA	NA	NA
months of operation till data	months		4	30	10	NA	3	NA	NA	NA	NA	NA
Minimum age	years	x35	12	18	14	14	18	12	14	No min. Age	No min. Age	No min. Age
Use allow ed for everyone		x36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Validity of short-term subscription	days	x37	Not offered	Not offered	Not offered	7&180	Not offered	Not offered	7	1	Not offered	1&7
Validity of long-term subscriptions		x38	unlimited	1 year	1 year	1 year	1 year	unlimited	1 year	1 year	unlimited	unlimited
Specific PT subscription		x39	No	No	No	No	No	No	No	NA	No	No
Short-term subscription fee	€	x40	Not offered	Not offered	Not offered	1.00&14.00	Not offered	Not offered	1.50	1.50&7.00	Not offered	5.65
Long-term subscription fee	€	x41	0.00	25.00	0.00	24.00	0.00	1.00	10.00	1.50	0.00	11.62
Desposit (long-term)	€	x42	150	10	25	150	10	0	0	NA	0	0
Insurance		x43	No	Third-party	No	No	User insured	No	No	No	Third-party	No
Bicycles w ith gears		x44	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Both brakes on handlebar		x45	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Bicycles w ith tyres filled w ith air		x46	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Fixed stations		x47	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protection of bikes		x48	Out-door	Out-door covered	Out-door	Out-door	Out-door	Out-door covered	Out-door	Out-door	Depot	Out-door
All-the-year-round service		x49	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Round-the-clock service		x50	No	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes
Way of identification		x51	Smart Card	Smart Card	Smart Card	Smart Card	ID	Smart Card	Smart Card	Smart Card	ID	Phone
Operating area	cities	x52	1	1	1	1	1	1	1	NA	1	1
Limit of use	hours	x53	4	No limit	8	24	17	120	24	NA	24	24
Fine	€	x54	150.00	NS	NA	282.90	NS	600.00	50.00	NA	0.00	NA
Rental time free of charge (long-term tariff)	minutes	x55	60	60	45	30	unlimited	60	0	30	unlimited	30
Fare unit (long-term tariff)		x56	€/hour	€/hour	€/hour	€/30min	unlimited	€/hour	€/30&60min	€/30min	unlimited	€/30&60min
Flat rate		x57	No	NA	Yes	No	Yes	No	No	No	Yes	Yes
Bank transfer payment		x58	Yes	No	No	Yes	NS	No	No	Yes	No	No
Bank card payment		x59	No	Yes	Yes	No	NS	Yes	Yes	Yes	Yes	Yes
Pre-paid card payment		x60	No	Yes	Yes	No	NS	Yes	No	No	No	No
Cash payment		x61	No	Yes	Yes	No	NS	No	No	No	Yes	No
Investor		x62	Public authority	Private company	Public authority	Public authority	Public authority	Private company	Private company	Private company	Public authority	Private company
Operator		x63	Private company	Private company	Public authority	Private company	Association	Private company	Private company	Private company	Public authority	Private company
Provider		x64	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Private company	Public authority	Private company
Provider companies		x65	CEMUSA	Bicincittà	Bicincittà	Clear Channel	C'entro in bici	JCDecaux	JCDecaux	JCDecaux	Other	Veolia
Number of stations	stations	x66	5	11	24	39	6	1	23	100	5	2
Year			2008	2009	2009	2009	2009	2009	2009	2009	2009	2009
Distance betw een stations	m	x67	NA	800	300	300	1,500	NS	NA	NA	4,000	NA
Technology of the locking device		x68	Electronic	Electronic	Electronic	Electronic	Mechanic	Electronic	Electronic	Electronic	Staff	Electronic
Metro stations provided w ith BSS	metro stations	x69	NS	NS	NS	NS	NS	NS	NA	NA	NS	NS
CITY DATA												
Daily municipal trips	trips/day	y1	638,746	78,672	NA	760,000	61,937	490,000	701,261	701,261	403,639	NA
Car modal share	%	y2	34.5%	63.0%	63.0%	49.0%	69.6%	46.0%	60.0%	60.0%	47.0%	NA
PT modal share	%	y3	13.4%	10.4%	15.0%	16.0%	9.2%	16.0%	27.0%	27.0%	4.7%	NA
Cycling modal share	%	y4	1.4%	13.3%	NA	3.0%	12.1%	16.0%	5.0%	5.0%	16.8%	NA
Walking modal share	%	y5	50.7%	13.3%	NA	31.0%	8.7%	22.0%	NA	NA	31.0%	NA
Cycling modal share before the BSS	%	y6	1.4%	NA	NA	NA	12.1%	NA	5.0%	5.0%	NA	NA
Population	inhabitants	y7	199,608	196,864	190,089	151,504	149,747	149,201	148,873	148,873	132,277	131,465
EU standard CO2 emission of cars	CO2 kg/km	y8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EU standard CO emission of diesel cars	CO g/km	y9	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
EU standard PM emission of diesel cars	PM g/km	y10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
EU standard NOx emission of diesel cars	NOx kg/km	y11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Average duration of private bicycle trips	minutes	y12	15	NA	NA	NA	NA	NA	NA	NA	15	NA
Number of metro stations	metro stations	y14	NA	0	0	0	0	0	60	60	0	NA
Avergage yearly temperature	°C	y15	11.7	14.4	24.6	NA	13.9	10.0	10.9	10.9	7.5	NA
Cycle netw ork	km	y16	41	83	NA	50	68	171	200	200	305	NA
Area of the city	km2	y17	23.55	260.77	2,068.40	40.41	134.49	65.65	32.60	32.60	380.10	115.65
Permission for carrying bikes in PT trains		y18	restricted	restricted	restricted	restricted	restricted	restricted	unlimited	unlimited	restricted	restricted
Yearly overnight stays in tourist accomodations	stays/year	y19	328,048	492,612	720,000	NA	354,805	2,152,945	3,041,623	3,041,623	377,440	NA
Yearly municipal bicycle theft	cases/year	y20	NA	NA	NA	NA	NA	1,318	880	880	2,264	NA
Yearly cycle accidents	accidents/year	y21	NA	81	NA	NA	120	NA	166	166	9	NA
Population density	inhab/km2	y22	653.31	754.93	2,110.00	3,750.10	1,113.44	2,270.00	4,566.00	4,566.00	348.01	364.40

BSS DATA			Cheltenham (UK)	Ribera Alta (ES)	Orléans (FR)	Bolzano (IT)	Farnborough (UK)	Cuneo (IT)	Chalon-sur-Saône (FR)	Senigallia (IT)	Lake Neusidl (AT)	Terlizzi (IT)	Mödling (AT)
Users shifted from another transport mode	%	x1	NA	NA	NA	70%	NA	90%	NA	56%	NA	NA	NA
Share of shifted users that traveled by car	%	x2	NA	NA	NA	23.8%	NA	44.4%	NA	79.2%	NA	NA	NA
Share of shifted users that traveled by PT	%	x3	NA	NA	NA	35.7%	NA	16.7%	NA	0.0%	NA	NA	NA
Share of shifted users that traveled by bike	%	x4	NA	NA	NA	4.7%	NA	11.1%	NA	4.1%	NA	NA	NA
Share of shifted users that w alked	%	x5	NA	NA	NA	35.7%	NA	27.8%	NA	16.6%	NA	NA	NA
Trip purpose: Working and education	%	x6	NA	71.0%	NA	35.7%	NA	49.1%	NA	23.3%	NA	NA	NA
Yearly rents	rents/year	x7	NA	NA	114,000	8,750	NA	13,000	NA	36,000	NA	NA	2,947
Year			NA	NA	2008	2008	NA	2008	NA	2008	NA	NA	2008
Yearly operative days	days/year	x8	365	365	365	214	365	365	365	365	214	365	365
Bicycles	bikes	x9	26	350	250	100	10	50	100	68	100	20	47
Year			2009	2009	2009	2009	2009	2009	2009	2009	2007	2008	2009
Share of BSS trips that are intemodal	%	x10	NA	NA	NA	50%	NA	71%	NA	63%	NA	NA	NA
Share of BSS intermodal trips connecting w ith PT	%	x11	NA	NA	NA	20%	NA	58%	NA	0%	NA	NA	NA
Users holding a seasonal PT card	%	x12	NA	NA	NA	44%	NA	56%	NA	9%	NA	NA	NA
Share of users that do not ow n a bicycle	%	x13	NA	NA	NA	72%	NA	100%	NA	94%	NA	NA	NA
Distance covered from the start	km	x14	NA	NA	NA	NA	NA	150,000	NA	NA	NA	NA	NA
till this date	date		NA	NA	NA	NA	NA	31/12/2008	NA	NA	NA	NA	NA
Rents from start	rents	x15	NA	NA	150,245	25,297	NA	60,000	5,000	98,000	NA	1,063	10,995
till this date	date		NA	NA	31/01/2009	31/12/2008	NA	31/12/2008	27/03/2009	01/02/2009	NA	20/05/2008	31/12/2008
Distance covered in 2008	km/year	x16	NA	NA	NA	NA	NA	30,000	NA	NA	NA	NA	NA
Number of redistribution vans	vans	x17	NA	NA	NA	0	NA	NA	1	0	1	0	0
Daily distance covered by all redistribution vans	km/day	x18	NA	NA	NA	0	NA	NA	40	0	NA	0	0
Unitary CO2 emission of redistribution vans	kg/km	x19	NA	NA	NA	0	NA	NA	NA	0	NA	0	0
Fossil fuel for redistribution vans		x20	NA	NA	NA	No van	NA	NA	Yes	No van	NA	No van	No van
Average duration of rents	min	x21	NA	NA	NA	NA	NA	90	15	480	300	NA	7,200
Subscriptions	persons	x22	NA	900	1,687	150	NA	1,100	250	846	NA	NA	686
till this date	dd/mm/yyyy		NA	11/11/2009	31/01/2009	31/12/2008	NA	31/12/2008	27/03/2009	01/02/2009	NA	NA	31/12/2008
Share of users that use the BSS daily	%	x23	NA	NA	NA	25.0%	NA	25.0%	NA	20.0%	NA	NA	20.0%
Direct jobs created	job	x24	NA	NA	3	3	NA	3	1	4	2	2	1
Share of customers that state that the main reason for using the BSS is because it is cheaper	%	x25	NA	NA	NA	20.3%	NA	10.4%	NA	15.3%	NA	NA	NA
Share of rents free of charge	%	x26	NS	100%	90%	0%	NA	100%	95%	100%	0%	100%	100%
Share of daily memberships in 2008	%	x27	NA	NA	2%	NA	NA	NA	NA	NA	NA	NA	NA
Share of w eekly memberships in 2008	%	x28	NA	NA	2%	NA	NA	NA	NA	NA	NA	NA	NA
Unitary cost of a station	€/station	x29	581	26,300	27,862	NA	581	NA	3,800	600	NA	3,200	NA
Unitary cost of a bicycle	€/bike	x30	697	110	689	150	697	NA	2,000	300	350	800	400
Total maintenance cost	€/bike*year	x31	NA	200	67	NA	NA	500	NA	NA	90	800	100
Theft from the start of the BSS	bikes	x32	NA	NA	NA	2	NA	6	0	3	NA	0	6
months of operation till data	months		NA	NA	NA	68	NA	54	15	22	NA	2	56
Minimum age	years	x35	No min. Age	15	14	No min. Age	No min. Age	18	16	No min. Age	16	18	14
Use allow ed for everyone		x36	Yes	Only residents	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Validity of short-term subscription	days	x37	1&7	Not offered	1&7	Not offered	1&7	Not offered	1&30	Not offered	Not offered	Not offered	Not offered
Validity of long-term subscriptions		x38	unlimited	1 year	1 year	1 year	unlimited	1 year	1 year	unlimited	unlimited	1 year	unlimited
Specific PT subscription		x39	No	No	Yes	Yes	No	No	Yes	No	No	No	No
Short-term subscription fee	€	x40	5.65	Not offered	1.00&3.00	Not offered	5.65	Not offered	1.00&2.00	Not offered	Not offered	Not offered	Not offered
Long-term subscription fee	€	x41	11.62	6.00	10.00	0.00	11.62	0.00	15.00	0.00	1.00	0.00	0.00
Desposit (long-term)	€	x42	0	0	150	10	0	10	0	10	0	10	0
Insurance		x43	No	No	No	No	No	No	No	No	No	No	No
Bicycles w ith gears		x44	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Both brakes on handlebar		x45	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Bicycles w ith tyres filled w ith air		x46	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Fixed stations		x47	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protection of bikes		x48	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Out-door	Depot
All-the-year-round service		x49	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Round-the-clock service		x50	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No
Way of identification		x51	Phone	Smart Card	Smart Card	ID	Phone	Smart Card	Phone	ID	Phone	ID	ID
Operating area	cities	x52	1	5	3	1	1	1	1	1	9	1	65
Limit of use	hours	x53	24	3	24	No limit	24	No limit	12	14	No limit	No limit	168
Fine	€	x54	NA	150.00	150.00	NS	NA	NS	150.00	NS	NS	NS	10.00
Rental time free of charge (long-term tariff)	minutes	x55	30	unlimited	30	0	30	unlimited	30	unlimited	0	unlimited	unlimited
Fare unit (long-term tariff)		x56	€/30&60min	unlimited	€/30min	€/rent	€/30&60min	unlimited	€/30min	unlimited	€/hour	unlimited	unlimited
Flat rate		x57	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Bank transfer payment		x58	No	Yes	No	No	No	NS	No	NS	Yes	No	NS
Bank card payment		x59	Yes	Yes	Yes	No	Yes	NS	Yes	NS	Yes	No	NS
Pre-paid card payment		x60	No	Yes	Yes	No	No	NS	No	NS	Yes	No	NS
Cash payment		x61	No	No	No	Yes	No	NS	No	NS	No	NS	NS
Investor		x62	Private company	Public authority	Public authority	Public authority	Private company	Public authority	Public authority	Other	Private company	Public authority	Public authority
Operator		x63	Private company	Other	Private company	Association	Private company	Private company	Private company	NA	Private company	Public authority	Public authority
Provider		x64	Private company	Private company	Private company	Public authority	Private company	Private company	Private company	Private company	Public authority	Private company	Association
Provider companies		x65	Veolia	Other	EFFIA	Other	Veolia	Bicincittà	Call a bike	C'entro in bici	Nextbike	C'entro in bici	Other
Number of stations	stations	x66	11	13	33	1	2	5	14	13	20	5	1
Year			2009	2009	2009	2009	2009	2009	2009	2009	2008	2008	2009
Distance betw een stations	m	x67	NA	350	500	NA	NA	500	400	700	NA	NA	NS
Technology of the locking device		x68	Electronic	Electronic	Electronic	Staff	Electronic	Electronic	Electronic	Mechanic	Mechanic	Mechanic	Staff
Metro stations provided w ith BSS	metro stations	x69	NS	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
CITY DATA													
Daily municipal trips	trips/day	y1	NA	NA	292,249	77,000	NA	NA	NA	280,000	103,829	NA	157,000
Car modal share	%	y2	NA	49.0%	63.0%	38.9%	NA	69.3%	NA	91.9%	62.0%	NA	63.0%
PT modal share	%	y3	NA	4.0%	8.0%	6.6%	NA	8.3%	NA	0.5%	11.0%	NA	11.0%
Cycling modal share	%	y4	NA	3.0%	5.0%	22.7%	NA	8.4%	2.9%	5.4%	5.0%	NA	8.0%
Walking modal share	%	y5	NA	44.0%	21.0%	31.6%	NA	13.6%	NA	2.2%	22.0%	NA	18.0%
Cycling modal share before the BSS	%	y6	NA	NA	5.0%	17.5%	NA	NA	NA	5.4%	NA	NA	8.0%
Population	inhabitants	y7	110,320	109,335	107,841	99,751	57,147	54,970	50,000	44,377	38,455	27,425	20,682
EU standard CO2 emission of cars	CO2 kg/km	y8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EU standard CO emission of diesel cars	CO g/km	y9	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
EU standard PM emission of diesel cars	PM g/km	y10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
EU standard NOx emission of diesel cars	NOx kg/km	y11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Average duration of private bicycle trips	minutes	y12	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA
Number of metro stations	metro stations	y14	NA	NA	0	0	NA	0	0	0	0	0	0
Avergage yearly temperature	°C	y15	NA	16.0	11.0	12.6	NA	11.9	NA	15.6	11.7	20.0	10.7
Cycle netw ork	km	y16	NA	10	201	48	NA	17	50	8	527	5	10
Area of the city	km2	y17	46.41	269.20	27.48	53.24	19.49	119.87	15.22	115.77	484.69	68.30	9.95
Permission for carrying bikes in PT trains		y18	restricted	restricted	restricted	restricted	restricted	restricted	restricted	restricted	restricted	restricted	restricted
Yearly overnight stays in tourist accomodations	stays/year	y19	NA	NA	NA	591,242	NA	139,518	NA	1,346,583	NA	NA	28,356
Yearly municipal bicycle theft	cases/year	y20	NA	NA	NA	NA	NA	NA	NA	NA	223	NA	NA
Yearly cycle accidents	accidents/year	y21	NA	NA	NA	195	NA	NA	NA	362	NA	NA	NA
Population density	inhab/km2	y22	406.80	341.75	4,117.00	1,906.00	293.20	458.58	3,292.00	381.00	79.34	400.00	2,079.00

Table 41: Database of case studies

10.2 Calculations based on the database

The following assumptions and additional explanations about the calculation and the database are to be considered:

- It was assumed that the share of users that declared to shift from a transport mode to bike-sharing is the same as the share of trips.
- The data of Vienna concerning the travel shift from another transport mode to bike-sharing was extracted from the results of an Internet survey. It was exactly asked "How often would you drive a car if Citybike is out of service?" The share of shifted trips corresponds to the share of the people who stated that they would use "very often" a certain transport mode. "Walking" was not a likely answer of the survey.
- The data concerning the purpose of bike-sharing rents in German case studies were taken from multi-answer surveys.
- The data of yearly bike-sharing rents correspond to the year 2008, except data from Rennes-1 and Terrassa that correspond to 2007.
- The data of the total municipal trips are in some cases previous to the introduction of the BSSs and therefore they do not include the bike-sharing trips. Nevertheless, the number of bike-sharing trips is so low compared to the total municipal trips that the influence of this fact can be considered as residual in the final result of the bike-sharing modal share.
- Daily municipal trips of Vienna, Stuttgart, Düsseldorf, Leipzig, Karlsruhe, Montpellier, Chemnitz, Pamplona and Orleans were obtained by mean of population and average daily trips per person.
- It was assumed that each bike-sharing rent comprises only one trip.
- Bicycle trips made before the implementation of a BSS have been considered residual for the calculation of the increase of cycling due to bike-sharing.
- The "share of bike-sharing intermodal trips connecting with PT" corresponds to the sum of shares of all kind of public transport modes that are taken before connecting with bike-sharing. Public transport modes used after bike-sharing are minority.
- The distance covered by bike-sharing trip was calculated by dividing total distance from the launch of the BSSs by total rents since this date. As exception, the distance per trip in Vienna and Barcelona, was calculated by dividing annual distance by annual trips in 2008 because aggregate data were not available in these two cities. Since very few case studies have available data concerning distance of trips, to continuous the calculation with a significant number of case studies, it has been assumed that bike-sharing trips in Berlin, Munich, Stockholm, Stuttgart, Karlsruhe, Rennes, Rimini, Bolzano and Senigallia are 2 kilometres long (the average value).

- No variation of CO_2 emission of redistribution vehicles depending on load has been considered.
- Very few case studies provide information about the distance covered by redistribution vans. To continue the calculation with a significant number of case studies, it has been assumed that the redistribution distance of cases without data is the average BSSs with available data (Vienna, Stockholm, Montpellier, Modena and Chalon-sur-Saône), i.e. 39 km.
- After checking the correspondence between time and distance of the BSSs of Modena and Cuneo, these two case studies have been removed from the estimation of pedalling time. Their rental time is much longer than reasonable for the reported distance, what indicates time without pedalling.
- The average unitary cost of bicycles has been assumed for case studies without data.
- Bike-sharing rents data corresponds mostly to 2008, while bike-sharing bicycle data corresponds to 2009. The number of bicycles in 2008 may be lower than in 2009. Therefore, the reader must be aware this fact might affect some results of section 6 and 7.

			London (UK)	Berlin (DE)	Rome (IT)	Paris (FR)	Vienna (AT)	Barcelona (ES)	Munich (DE)	Milan (IT)	Prague (CZ)	Stockholm (SE)
Users substituting car by BSS	%	z1=x1*x2	6.0%	5.2%	NA	8.0%	13.6%	9.6%	5.9%	20.6%	NA	5.2%
Users substituting PT by BSS	%	z2=x1*x3	34.0%	37.3%	NA	65.0%	66.7%	51.3%	34.3%	34.4%	NA	58.1%
Users substituting bicycle by BSS	%	z3=x1*x4	6.0%	12.6%	NA	NA	15.8%	NA	12.1%	9.2%	NA	9.7%
Users substituting walking by BSS	%	z4=x1*x5	21.0%	30.9%	NA	20.0%	NA	26.1%	30.2%	6.9%	NA	26.6%
Daily rents	rents/day	z5=x7/x8	NA	559	NA	80,126	996	33,720	413	NA	8	1,121
BSS Modal share	%	z6=z5/y1	NA	0.00%	NA	0.76%	0.02%	0.43%	0.01%	NA	NA	0.04%
Daily municipal car trips	trips/day	z7=y1*y2	9,520,000	5,381,250	NA	4,200,000	1,587,851	2,227,329	1,560,000	NA	NA	888,936
Daily car trips shifted to BSS	trips/day	z8=z1*z5	NA	29	NA	6,410	135	3,237	24	NA	NA	58
Share of car trips shifted to BSS	%	z9=z7/z8	NA	0.00%	NA	0.15%	0.01%	0.15%	0.00%	NA	NA	0.01%
Car trips shifted per bicycle	trips/bike*day	z10=z8/x9	NA	0.02	NA	0.31	0.22	0.54	0.02	NA	NA	0.12
Daily PT trips shifted to BSS	trips/day	z11=z2/x5	NA	209	NA	52,082	664	17,298	142	NA	NA	651
Daily municipal PT trips	trisp/day	z12=y1*y3	6,664,000	2,627,500	NA	2,100,000	1,542,484	3,145,896	880,000	NA	NA	1,158,311
Share of PT trips shifted to BSS	%	z13=z11/z12	NA	0.0%	NA	2.5%	0.0%	0.5%	0.0%	NA	NA	0.1%
PT trips shifted per bicycle	trips/bike*day	z14=z11/x9	NA	0.1	NA	2.5	1.1	2.9	0.1	NA	NA	1.3
Share of bike-sharing trips connected with PT	%	z15=x10*x11	39%	48%	NA	79%	20%	26%	40%	50%	NA	NA
Daily intermodal trips BSS - PT	trips/year	z16=z15*z5	NA	268	NA	63,300	199	8,685	165	NA	NA	NA
Share of PT trips connected with BSS	%	z17=z16/z12	NA	0.01%	NA	3.01%	0.01%	0.28%	0.02%	NA	NA	NA
Daily PT trips connected with BSS per bicycle	trips/bike*day	z18=z16/x9	NA	0.16	NA	3.07	0.32	1.45	0.12	NA	NA	NA
Daily cycling trips before the start of the BSS	trips/day	z19=y1*y6	NA	921,250	NA	210,000	136,102	58,883	520,000	NA	NA	188,562
Direct increase of cycling	%	z20=z5/z19	NA	0.1%	NA	38.2%	0.7%	57.3%	0.1%	NA	NA	0.6%
Direct cycle trips per bicycle	trips/bike*day	z21=z5/x9	NA	0.33	NA	3.89	1.59	5.62	0.29	NA	0.28	2.24
Distance per BSS trip	km/trip	z22=x14/x15 or =x16/x7	NA	NA	NA	1.8	3.1	2.7	NA	NA	NA	NA
Distance per BSS trip (&average for unknown values)	km/trip	z23=z22 & average	2.0	2.0	2.0	1.8	3.1	2.7	2.0	2.0	2.0	2.0
Yearly car trips shifted to BSS	trips/year	z24=z8*x8	NA	8,907	NA	2,339,679	49,314	1,181,551	7,456	NA	NA	12,357
Yearly former car distance	km/year	z25=z24*z23	NA	17,889	NA	4,094,438	154,908	3,187,200	14,976	NA	NA	24,819
Yearly saved CO2 emissions	t/year	z26=z25*y8/1000	NA	3	NA	655	25	510	2	NA	NA	4
Yearly CO2 saving per 1,000 inhabitant	kg/1000inh*year	z27=z26/y7*10^6	NA	1	NA	302	15	313	2	NA	NA	5
Yearly CO2 saving per bicycle	kg/bike*year	z28=z27/x9*1000	NA	2	NA	32	40	85	2	NA	NA	8
Daily distance per redistribution van	km/van*day	z29=x18/19	NA	NA	NA	NA	30	NA	NA	NA	NA	100
Daily redistribution distance per van (&average for unknown values)	km/van*day	z30=z29 & average	39	39	39	39	30	39	39	39	39	100
Total daily redistribution distance (&average unitary distance for unknown values)		z31=x18 & z30*x17	NA	NA	NA	7,733	60	1,779	NA	NA	NA	300
Yearly distance covered for redistribution	km/year	z32=z31*x8	NA	NA	NA	2,822,667	21,900	649,213	NA	NA	NA	64,200
Unitary CO2 emission of redistribution vans (&average for unknown values with fossil fuel)	kg/km	z33=x19 & average	NA	NA	NA	NA	0.19	0.215	NA	NA	NA	0.155
Yearly CO2 emission due to redistribution	t/year	z34=x33*z32/1000	NA	NA	NA	NA	4	140	NA	NA	NA	10
Yearly CO2 emission per 1,000 inh	kg/1000inh*year	z35=z34/y7*10^6	NA	NA	NA	NA	2	86	NA	NA	NA	12
Yearly CO2 emission per bicycle	kg/bike*year	z36=z34/x9*1000	NA	NA	NA	NA	7	23	NA	NA	NA	20
Yearly net car distance saved	km/year	z37=z25-z32	NA	NA	NA	NA	133,008	2,537,987	NA	NA	NA	-39,381
Yearly net CO2 saved	t/year	z38=z26-z34	NA	NA	NA	NA	21	370	NA	NA	NA	-6
Yearly net PM saving	g/year	z39=z37*y9	NA	NA	NA	NA	665	12,690	NA	NA	NA	-197
Yearly net CO saving	g/year	z40=z37*y10	NA	NA	NA	NA	66,504	1,268,993	NA	NA	NA	-19,691
Yearly net NOx saving	g/year	z41=z37*y11	NA	NA	NA	NA	23,941	456,838	NA	NA	NA	-7,089
Yearly PM saved per 1,000 inh	g/1000inh*year	z42=z39/y7*1000	NA	NA	NA	NA	0.4	7.8	NA	NA	NA	-0.2
Yearly CO saved per 1,000 inh	g/1000inh*year	z43=z40/y7*1000	NA	NA	NA	NA	39.6	778.7	NA	NA	NA	-24.3
Yearly NOx saved per 1,000 inh	g/1000inh*year	z44=z41/y7*1000	NA	NA	NA	NA	14.2	280.3	NA	NA	NA	-8.8
Yearly PM saved per bicycle	g/bike*year	z45=z39/x9	NA	NA	NA	NA	1.1	2.1	NA	NA	NA	-0.4
Yearly CO saved per bicycle	g/bike*year	z46=z40/x9	NA	NA	NA	NA	106.3	211.5	NA	NA	NA	-39.4
Yearly NOx saved per bicycle	g/bike*year	z47=z41/x9	NA	NA	NA	NA	38.3	76.1	NA	NA	NA	-14.2
Pedalling time per rent (contrastable and reasonable rent time)	min	z48=x21	NA	NA	NA	18.0	22.5	14.1	NA	NA	NA	NA
Speed of BSS trips	km/h	z49=z48/x21*60	NA	NA	NA	5.8	8.4	11.5	NA	NA	NA	NA
Share of population registered in the BSS	%	z50=x22/y7	NA	1.4%	NA	9.2%	9.6%	10.7%	3.2%	1.3%	NA	3.7%
Direct jobs per 1,000 inh	jobs/1000inh	z51=x24/y7*1000	NA	NA	NA	0.23	0.01	0.14	NA	NA	NA	0.01
Direct jobs per bicycle	jobs/1000inh	z52=x24/x9	NA	NA	NA	0.02	0.02	0.04	NA	NA	NA	0.01
Bike-sharing bicycles stolen per year	bicycles/year	z53=x32/x33*12	2	NA	NA	4,926	NA	291	NA	NA	NA	NA
Share of bicycle fleet annually stolen	%	z54=z53/x9	2.3%	NA	NA	23.9%	NA	4.8%	NA	NA	NA	NA
Unitary cost of bicycles (&average)	€/bike	z55=x30 (&average)	697	540	540	500	600	450	540	600	540	450
Yearly cost of theft	€/year	z56=z53*z55	1,704	NA	NA	2,463,158	NA	130,909	NA	NA	NA	NA
Yearly cost of theft by bicycle	€/bike*year	z57=z56/x9	16	NA	NA	120	NA	22	NA	NA	NA	NA
Daily rents per bicycle	rents/bike*year	z62=z5/x9	NA	0.3	NA	3.9	1.6	5.6	0.3	NA	0.3	2.2
Share of metro stations provided with BSS	%	z63=x69/y14	NA	NA	NA	100%	34%	52%	NA	NA	6%	NA
Density of cycle network	km/km2	z64=y16/y17	NA	1.3	NA	3.5	2.6	1.3	3.9	NA	0.7	4.0
Overnight stays per inhabitants	stays/inhabitant *year	z65=y19/y7	12.7	5.1	NA	14.6	5.6	8.1	4.1	12.2	9.9	10.9
Yearly bicycle trips	trips/year	z66=y1*y4*365	173,740,000	336,256,250	NA	76,650,000	49,677,064	11,462,460	146,000,000	NA	NA	68,825,194
Yearly theft per 100,000 cycle trips	cases/100000 trips *year	z67=y20/z66 *100000	NA	7.0	NA	169.7	14.9	1,094.7	4.2	NA	NA	5.5
Yearly accidents per 100,000 cycle trips	accidents/ 100000 trips *year	z68=y21/z66 *100000	NA	NA	NA	1.0	1.2	3.9	NA	NA	NA	0.5
Station density	stations/km²	z69=x66/y17	0.03	NA	0.01	13.82	0.14	3.94	NA	0.57	0.03	0.38

			Krakow (PL)	Seville (ES)	Saragossa (ES)	Lyon (FR)	Stuttgart (DE)	Düsseldorf (DE)	Bristol (UK)	Leipzig (DE)	Gothenburg-1 (SE)	Gothenburg-2 (SE)
Users substituting car by BSS	%	z1=x1*x2	NA	NA	NA	9.8%	5.1%	NA	NA	NA	NA	NA
Users substituting PT by BSS	%	z2=x1*x3	NA	NA	NA	45.1%	28.8%	NA	NA	NA	NA	NA
Users substituting bicycle by BSS	%	z3=x1*x4	NA	NA	NA	5.9%	6.8%	NA	NA	NA	NA	NA
Users substituting w alking by BSS	%	z4=x1*x5	NA	NA	NA	37.2%	36.8%	NA	NA	NA	NA	NA
Daily rents	rents/day	z5=x7/x8	NA	NA	NA	17,720	195	33	NA	182	8	NA
BSS Modal share	%	z6=z5/y1	NA	NA	NA	0.92%	0.01%	0.00%	NA	0.01%	0.00%	NA
Daily municipal car trips	trips/day	z7=y1*y2	NA	NA	NA	968,000	883,223	667,128	NA	800,483	761,748	761,748
Daily car trips shifted to BSS	trips/day	z8=z1*z5	NA	NA	NA	1,737	10	NA	NA	NA	NA	NA
Share of car trips shifted to BSS	%	z9=z7/z8	NA	NA	NA	0.18%	0.00%	NA	NA	NA	NA	NA
Car trips shifted per bicycle	trips/bike*day	z10=z8/x9	NA	NA	NA	0.46	0.02	NA	NA	NA	NA	NA
Daily PT trips shifted to BSS	trips/day	z11=z2/x5	NA	NA	NA	7,988	56	NA	NA	NA	NA	NA
Daily municipal PT trips	trisp/day	z12=y1*y3	NA	NA	NA	290,400	554,179	383,599	NA	261,382	307,629	307,629
Share of PT trips shifted to BSS	%	z13=z11/z12	NA	NA	NA	2.8%	0.0%	NA	NA	NA	NA	NA
PT trips shifted per bicycle	trips/bike*day	z14=z11/x9	NA	NA	NA	2.1	0.1	NA	NA	NA	NA	NA
Share of bike-sharing trips connected w ith PT	%	z15=x10*x11	NA	NA	NA	10%	40%	NA	NA	NA	NA	NA
Daily intermodal trips BSS - PT	trips/year	z16=z15*z5	NA	NA	NA	1,772	79	NA	NA	NA	NA	NA
Share of PT trips connected w ith BSS	%	z17=z16/z12	NA	NA	NA	0.61%	0.01%	NA	NA	NA	NA	NA
Daily PT trips connected w ith BSS per bicycle	trips/bike*day	z18=z16/x9	NA	NA	NA	0.47	0.15	NA	NA	NA	NA	NA
Daily cycling trips before the start of the BSS	trips/day	z19=y1*y6	NA	NA	NA	19,360	69,272	133,426	NA	147,027	205,086	205,086
Direct increase of cycling	%	z20=z5/z19	NA	NA	NA	91.5%	0.3%	0.0%	NA	0.1%	0.0%	NA
Direct cycle trips per bicycle	trips/bike*day	z21=z5/x9	NA	NA	NA	4.66	0.37	0.11	NA	0.36	0.06	NA
Distance per BSS trip	km/trip	z22=x14/x15 or =x16/x7	NA	NA	NA	2.1	NA	NA	NA	NA	NA	NA
Distance per BSS trip (&average for unknow n values)	km/trip	z23=z22 & average	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Yearly car trips shifted to BSS	trips/year	z24=z8*x8	NA	NA	NA	633,847	3,024	NA	NA	NA	NA	NA
Yearly former car distance	km/year	z25=z24*z23	NA	NA	NA	1,358,427	6,074	NA	NA	NA	NA	NA
Yearly saved CO2 emissions	t/year	z26=z25*y8/1000	NA	NA	NA	217	1	NA	NA	NA	NA	NA
Yearly CO2 saving per 1,000 inhabitant	kg/1000inh*year	z27=z26/y7*10^6	NA	NA	NA	357	2	NA	NA	NA	NA	NA
Yearly CO2 saving per bicycle	kg/bike*year	z28=z27/x9*1000	NA	NA	NA	57	2	NA	NA	NA	NA	NA
Daily distance per redistribution van	km/van*day	z29=x18/19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Daily redistribution distance per van (&average for unknow n values)	km/van*day	z30=z29 & average	39	39	39	39	39	39	39	39	39	39
Total daily redistribution distance (&average unitary distance for unknow n values)		z31=x18 & z30*x17	50	NA	NA	NA	NA	NA	NA	NA	NA	0
Yearly distance covered for redistribution	km/year	z32=z31*x8	13,650	NA	NA	NA	NA	NA	NA	NA	NA	0
Unitary CO2 emission of redistribution vans (&average for unknow n values w ith fossil fuel)	kg/km	z33=x19 & average	0.215	NA	NA	NA	NA	NA	NA	NA	NA	0
Yearly CO2 emission due to redistribution	t/year	z34=x33*z32/1000	3	NA	NA	NA	NA	NA	NA	NA	NA	0
Yearly CO2 emission per 1,000 inh	kg/1000inh*year	z35=z34/y7*10^6	4	NA	NA	NA	NA	NA	NA	NA	NA	0
Yearly CO2 emission per bicycle	kg/bike*year	z36=z34/x9*1000	29	NA	NA	NA	NA	NA	NA	NA	NA	0
Yearly net car distance saved	km/year	z37=z25-z32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net CO2 saved	t/year	z38=z26-z34	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net PM saving	g/year	z39=z37*y9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net CO saving	g/year	z40=z37*y10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net NOx saving	g/year	z41=z37*y11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly PM saved per 1,000 inh	g/1000inh*year	z42=z39/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly CO saved per 1,000 inh	g/1000inh*year	z43=z40/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly NOx saved per 1,000 inh	g/1000inh*year	z44=z41/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly PM saved per bicycle	g/bike*year	z45=z39/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly CO saved per bicycle	g/bike*year	z46=z40/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly NOx saved per bicycle	g/bike*year	z47=z41/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pedalling time per rent (contrastable and reasonable rent time)	min	z48=x21	NA	NA	NA	17.0	NA	NA	NA	NA	NA	NA
Speed of BSS trips	km/h	z49=z48/x21*60	NA	NA	NA	7.6	NA	NA	NA	NA	NA	NA
Share of population registered in the BSS	%	z50=x22/y7	0.1%	13.2%	NA	9.9%	0.7%	0.5%	0.1%	5.9%	NA	0.2%
Direct jobs per 1,000 inh	jobs/1000inh	z51=x24/y7*1000	NA	NA	NA	0.08	NA	NA	NA	NA	NA	0.01
Direct jobs per bicycle	jobs/1000inh	z52=x24/x9	NA	NA	NA	0.01	NA	NA	NA	NA	NA	0.05
Bike-sharing bicycles stolen per year	bicycles/year	z53=x32/x33*12	36	989	NA	NA	NA	NA	2	NA	NA	0
Share of bicycle fleet annually stolen	%	z54=z53/x9	36.0%	49.4%	NA	NA	NA	NA	12.5%	NA	NA	0.6%
Unitary cost of bicycles (&average)	€/bike	z55=x30 (&average)	540	540	540	1,500	540	300	540	300	472	540
Yearly cost of theft	€/year	z56=z53*z55	19,431	533,699	NA	NA	NA	NA	1,079	NA	NA	180
Yearly cost of theft by bicycle	€/bike*year	z57=z56/x9	194	267	NA	NA	NA	NA	67	NA	NA	3
Daily rents per bicycle	rents/bike*year	z62=z5/x9	NA	NA	NA	4.7	0.4	0.1	NA	0.4	0.1	NA
Share of metro stations provided w ith BSS	%	z63=x69/y14	NA	NA	NA	100%	NA	6%	NA	NA	NA	NA
Density of cycle netw ork	km/km2	z64=y16/y17	0.2	0.6	NA	4.0	0.7	1.4	NA	1.0	1.3	1.3
Overnight stays per inhabitants	stays/inhabitant *year	z65=y19/y7	NA	NA	NA	4.8	4.3	5.2	NA	3.6	6.4	6.4
Yearly bicycle trips	trips/year	z66=y1*y4*365	NA	NA	NA	14,132,800	25,284,432	48,700,348	NA	53,665,021	74,856,355	74,856,355
Yearly theft per 100,000 cycle trips	cases/100000 trips *year	z67=y20/z66 *100000	NA	NA	NA	129.1	3.2	8.1	NA	8.5	4.1	4.1
Yearly accidents per 100,000 cycle trips	accidents/ 100000 trips *year	z68=y21/z66 *100000	NA	NA	NA	NA	1.9	1.5	NA	1.4	0.1	0.1
Station density	stations/km²	z69=x66/y17	0.04	1.78	0.04	5.11	NA	0.12	0.07	NA	0.02	NA

			Bari (IT)	Karlsruhe (DE)	Montpellier (FR)	Chemnitz (DE)	Vitoria (ES)	Reading (UK)	Rennes-1 (FR)	Rennes-2 (FR)	Terrassa (ES)	Modena (IT)
Users substituting car by BSS	%	z1=x1*x2	22.6%	5.4%	NA	NA	NA	NA	15.8%	NA	NA	NA
Users substituting PT by BSS	%	z2=x1*x3	22.0%	35.9%	NA	NA	NA	NA	38.2%	NA	NA	NA
Users substituting bicycle by BSS	%	z3=x1*x4	17.8%	12.7%	NA	NA	NA	NA	1.7%	NA	NA	NA
Users substituting w alking by BSS	%	z4=x1*x5	18.3%	33.7%	NA	NA	NA	NA	27.4%	NA	NA	NA
Daily rents	rents/day	z5=x7/x8	29	65	729	13	523	NA	265	NA	138	100
BSS Modal share	%	z6=z5/y1	0.02%	0.01%	0.08%	0.00%	0.09%	NA	0.02%	NA	NA	0.01%
Daily municipal car trips	trips/day	z7=y1*y2	99,683	368,658	596,012	351,582	206,428	NA	758,898	758,898	NA	592,500
Daily car trips shifted to BSS	trips/day	z8=z1*z5	7	3	NA	NA	NA	NA	42	NA	NA	NA
Share of car trips shifted to BSS	%	z9=z7/z8	0.01%	0.00%	NA	NA	NA	NA	0.01%	NA	NA	NA
Car trips shifted per bicycle	trips/bike*day	z10=z8/x9	0.08	0.01	NA	NA	NA	NA	0.21	NA	NA	NA
Daily PT trips shifted to BSS	trips/day	z11=z2/x5	6	23	NA	NA	NA	NA	101	NA	NA	NA
Daily municipal PT trips	trisp/day	z12=y1*y3	19,383	150,815	75,684	99,451	44,557	NA	177,076	177,076	NA	52,500
Share of PT trips shifted to BSS	%	z13=z11/z12	0.0%	0.0%	NA	NA	NA	NA	0.1%	NA	NA	NA
PT trips shifted per bicycle	trips/bike*day	z14=z11/x9	0.1	0.1	NA	NA	NA	NA	0.5	NA	NA	NA
Share of bike-sharing trips connected w ith PT	%	z15=x10*x11	36%	42%	NA	NA	NA	NA	NA	NA	NA	13%
Daily intermodal trips BSS - PT	trips/year	z16=z15*z5	10	27	NA	NA	NA	NA	NA	NA	NA	13
Share of PT trips connected w ith BSS	%	z17=z16/z12	0.05%	0.02%	NA	NA	NA	NA	NA	NA	NA	0.03%
Daily PT trips connected w ith BSS per bicycle	trips/bike*day	z18=z16/x9	0.13	0.08	NA	NA	NA	NA	NA	NA	NA	0.06
Daily cycling trips before the start of the BSS	trips/day	z19=y1*y6	NA	134,057	18,921	39,220	7,727	NA	37,945	37,945	NA	68,250
Direct increase of cycling	%	z20=z5/z19	NA	0.0%	3.9%	0.0%	6.8%	NA	0.7%	NA	NA	0.1%
Direct cycle trips per bicycle	trips/bike*day	z21=z5/x9	0.36	0.19	1.12	0.10	1.74	NA	1.32	NA	1.38	0.45
Distance per BSS trip	km/trip	z22=x14/x15 or =x16/x7	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.8
Distance per BSS trip (&average for unknow n values)	km/trip	z23=z22 & average	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.8
Yearly car trips shifted to BSS	trips/year	z24=z8*x8	2,394	1,063	NA	NA	NA	NA	15,247	NA	NA	NA
Yearly former car distance	km/year	z25=z24*z23	4,808	2,135	NA	NA	NA	NA	30,623	NA	NA	NA
Yearly saved CO2 emissions	t/year	z26=z25*y8/1000	1	0	NA	NA	NA	NA	5	NA	NA	NA
Yearly CO2 saving per 1,000 inhabitant	kg/1000inh*year	z27=z26/y7*10^6	2	1	NA	NA	NA	NA	23	NA	NA	NA
Yearly CO2 saving per bicycle	kg/bike*year	z28=z27/x9*1000	10	1	NA	NA	NA	NA	24	NA	NA	NA
Daily distance per redistribution van	km/van*day	z29=x18/19	NA	NA	13	NA	NA	NA	NA	NA	NA	10
Daily redistribution distance per van (&average for unknow n values)	km/van*day	z30=z29 & average	39	39	13	39	39	39	39	39	39	10
Total daily redistribution distance (&average unitary distance for unknow n values)		z31=x18 & z30*x17	39	NA	40	0	NA	NA	NA	NA	NA	10
Yearly distance covered for redistribution	km/year	z32=z31*x8	14,113	NA	14,600	0	NA	NA	NA	NA	NA	3,650
Unitary CO2 emission of redistribution vans (&average for unknow n values w ith fossil fuel)	kg/km	z33=x19 & average	NA	NA	0.215	0	NA	NA	0.215	NA	NA	0.3
Yearly CO2 emission due to redistribution	t/year	z34=x33*z32/1000	NA	NA	3	0	NA	NA	NA	NA	NA	1
Yearly CO2 emission per 1,000 inh	kg/1000inh*year	z35=z34/y7*10^6	NA	NA	12	0	NA	NA	NA	NA	NA	5
Yearly CO2 emission per bicycle	kg/bike*year	z36=z34/x9*1000	NA	NA	5	0	NA	NA	NA	NA	NA	5
Yearly net car distance saved	km/year	z37=z25-z32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net CO2 saved	t/year	z38=z26-z34	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net PM saving	g/year	z39=z37*y9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net CO saving	g/year	z40=z37*y10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly net NOx saving	g/year	z41=z37*y11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly PM saved per 1,000 inh	g/1000inh*year	z42=z39/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly CO saved per 1,000 inh	g/1000inh*year	z43=z40/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly NOx saved per 1,000 inh	g/1000inh*year	z44=z41/y7*1000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly PM saved per bicycle	g/bike*year	z45=z39/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly CO saved per bicycle	g/bike*year	z46=z40/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yearly NOx saved per bicycle	g/bike*year	z47=z41/x9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pedalling time per rent (contrastable and reasonable rent time)	min	z48=x21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Speed of BSS trips	km/h	z49=z48/x21*60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Share of population registered in the BSS	%	z50=x22/y7	0.2%	0.7%	3.5%	NA	17.7%	NA	2.3%	NA	2.3%	1.0%
Direct jobs per 1,000 inh	jobs/1000inh	z51=x24/y7*1000	0.01	NA	0.03	0.05	0.10	NA	0.02	0.04	NA	0.01
Direct jobs per bicycle	jobs/1000inh	z52=x24/x9	0.03	NA	0.01	0.10	0.08	NA	0.02	0.01	NA	0.01
Bike-sharing bicycles stolen per year	bicycles/year	z53=x32/x33*12	NA	NA	12	NA	61	NA	NA	NA	NA	1
Share of bicycle fleet annually stolen	%	z54=z53/x9	NA	NA	1.8%	NA	20.5%	NA	NA	NA	NA	0.3%
Unitary cost of bicycles (&average)	€/bike	z55=x30 (&average)	175	540	300	180	1,000	697	540	482	540	300
Yearly cost of theft	€/year	z56=z53*z55	NA	NA	3,600	NA	61,412	NA	NA	NA	NA	225
Yearly cost of theft by bicycle	€/bike*year	z57=z56/x9	NA	NA	6	NA	205	NA	NA	NA	NA	1
Daily rents per bicycle	rents/bike*year	z62=z5/x9	0.4	0.2	1.1	0.1	1.7	NA	1.3	NA	1.4	0.4
Share of metro stations provided w ith BSS	%	z63=x69/y14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Density of cycle netw ork	km/km2	z64=y16/y17	0.0	1.2	2.1	0.5	0.3	NA	3.5	3.5	0.2	0.7
Overnight stays per inhabitants	stays/inhabitant *year	z65=y19/y7	1.4	2.8	3.3	1.8	1.5	NA	NA	NA	NA	2.3
Yearly bicycle trips	trips/year	z66=y1*y4*365	505,335	48,930,983	6,906,165	NA	6,793,512	NA	13,849,889	NA	NA	27,375,000
Yearly theft per 100,000 cycle trips	cases/100000 trips *year	z67=y20/z66 *100000	NA	3.9	NA	NA	NA	NA	NA	NA	NA	NA
Yearly accidents per 100,000 cycle trips	accidents/ 100000 trips *year	z68=y21/z66 *100000	19.8	1.1	0.4	NA	NA	NA	NA	NA	NA	0.9
Station density	stations/km²	z69=x66/y17	0.09	NA	0.88	0.07	0.05	NA	0.45	1.59	0.06	0.17

			Pamplona (ES)	Parma (IT)	Brescia (IT)	Dijon (FR)	Rimini (IT)	Salzburg (AT)	Brussels-1 (BE)	Brussels-2 (BE)	Örebro (SE)	Cambridge (UK)
Users substituting car by BSS	%	z1=x1*x2	NA	19.2%	8.5%	NA	26.0%	NA	NA	NA	NA	NA
Users substituting PT by BSS	%	z2=x1*x3	NA	30.8%	33.9%	NA	10.8%	NA	NA	NA	NA	NA
Users substituting bicycle by BSS	%	z3=x1*x4	NA	3.8%	14.1%	NA	10.8%	NA	NA	NA	NA	NA
Users substituting w alking by BSS	%	z4=x1*x5	NA	38.5%	11.3%	NA	23.8%	NA	NA	NA	NA	NA
Daily rents	rents/day	z5=x7/x8	29	NA	NA	NA	82	NA	53	NA	NA	NA
BSS Modal share	%	z6=z5/y1	0.00%	NA	NA	NA	0.13%	NA	0.01%	NA	NA	NA
Daily municipal car trips	trips/day	z7=y1*y2	220,367	49,571	NA	372,400	43,134	225,400	420,757	420,757	189,812	NA
Daily car trips shifted to BSS	trips/day	z8=z1*z5	NA	NA	NA	NA	21	NA	NA	NA	NA	NA
Share of car trips shifted to BSS	%	z9=z7/z8	NA	NA	NA	NA	0.05%	NA	NA	NA	NA	NA
Car trips shifted per bicycle	trips/bike*day	z10=z8/x9	NA	NA	NA	NA	0.41	NA	NA	NA	NA	NA
Daily PT trips shifted to BSS	trips/day	z11=z2/x5	NA	NA	NA	NA	9	NA	NA	NA	NA	NA
Daily municipal PT trips	trisp/day	z12=y1*y3	85,592	8,143	NA	121,600	5,725	78,400	189,340	189,340	18,970	NA
Share of PT trips shifted to BSS	%	z13=z11/z12	NA	NA	NA	NA	0.2%	NA	NA	NA	NA	NA
PT trips shifted per bicycle	trips/bike*day	z14=z11/x9	NA	NA	NA	NA	0.2	NA	NA	NA	NA	NA
Share of bike-sharing trips connected w ith PT	%	z15=x10*x11	NA	23%	54%	NA	44%	NA	NA	NA	NA	NA
Daily intermodal trips BSS - PT	trips/year	z16=z15*z5	NA	NA	NA	NA	36	NA	NA	NA	NA	NA
Share of PT trips connected w ith BSS	%	z17=z16/z12	NA	NA	NA	NA	0.62%	NA	NA	NA	NA	NA
Daily PT trips connected w ith BSS per bicycle	trips/bike*day	z18=z16/x9	NA	NA	NA	NA	0.69	NA	NA	NA	NA	NA
Daily cycling trips before the start of the BSS	trips/day	z19=y1*y6	8,942	NA	NA	NA	7,470	NA	35,063	35,063	NA	NA
Direct increase of cycling	%	z20=z5/z19	0.3%	NA	NA	NA	1.1%	NA	0.2%	NA	NA	NA
Direct cycle trips per bicycle	trips/bike*day	z21=z5/x9	0.29	NA	NA	NA	1.57	NA	0.21	NA	NA	NA
Distance per BSS trip	km/trip	z22=x14/x15 or =x16/x7	2.0	NA	1.1	NA	NA	NA	NA	NA	NA	NA
Distance per BSS trip (&average for unknow n values)	km/trip	z23=z22 & average	2.0	2.0	1.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Yearly car trips shifted to BSS	trips/year	z24=z8*x8	NA	NA	NA	NA	7,736	NA	NA	NA	NA	NA
Yearly former car distance	km/year	z25=z24*z23	NA	NA	NA	NA	15,538	NA	NA	NA	NA	NA
Yearly saved CO2 emissions	t/year	z26=z25*y8/1000	NA	NA	NA	NA	2	NA	NA	NA	NA	NA
Yearly CO2 saving per 1,000 inhabitant	kg/1000inh*year	z27=z26/y7*10^6	NA	NA	NA	NA	17	NA	NA	NA	NA	NA
Yearly CO2 saving per bicycle	kg/bike*year	z28=z27/x9*1000	NA	NA	NA	NA	48	NA	NA	NA	NA	NA
Daily distance per redistribution van	km/van*day	z29=x18/19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Daily redistribution distance per van (&average for unknow n values)	km/van*day	z30=z29 & average	39	39	39	39	39	39	39	39	39	39
Total daily redistribution distance (&average unitary distance for unknow n values)		z31=x18 & z30*x17	NA	10	41	NA	0	0	NA	NA	116	NA
Yearly distance covered for redistribution	km/year	z32=z31*x8	NA	3,650	14,965	NA	0	0	NA	NA	42,340	NA
Unitary CO2 emission of redistribution vans (&average for unknow n values w ith fossil fuel)	kg/km	z33=x19 & average	NA	0.215	0.215	NA	0	0	NA	NA	NA	NA
Yearly CO2 emission due to redistribution	t/year	z34=x33*z32/1000	NA	1	3	NA	0	0	NA	NA	NA	NA
Yearly CO2 emission per 1,000 inh	kg/1000inh*year	z35=z34/y7*10^6	NA	4	17	NA	0	0	NA	NA	NA	NA
Yearly CO2 emission per bicycle	kg/bike*year	z36=z34/x9*1000	NA	16	27	NA	0	0	NA	NA	NA	NA
Yearly net car distance saved	km/year	z37=z25-z32	NA	NA	NA	NA	15,538	NA	NA	NA	NA	NA
Yearly net CO2 saved	t/year	z38=z26-z34	NA	NA	NA	NA	2	NA	NA	NA	NA	NA
Yearly net PM saving	g/year	z39=z37*y9	NA	NA	NA	NA	78	NA	NA	NA	NA	NA
Yearly net CO saving	g/year	z40=z37*y10	NA	NA	NA	NA	7,769	NA	NA	NA	NA	NA
Yearly net NOx saving	g/year	z41=z37*y11	NA	NA	NA	NA	2,797	NA	NA	NA	NA	NA
Yearly PM saved per 1,000 inh	g/1000inh*year	z42=z39/y7*1000	NA	NA	NA	NA	0.5	NA	NA	NA	NA	NA
Yearly CO saved per 1,000 inh	g/1000inh*year	z43=z40/y7*1000	NA	NA	NA	NA	51.9	NA	NA	NA	NA	NA
Yearly NOx saved per 1,000 inh	g/1000inh*year	z44=z41/y7*1000	NA	NA	NA	NA	18.7	NA	NA	NA	NA	NA
Yearly PM saved per bicycle	g/bike*year	z45=z39/x9	NA	NA	NA	NA	1.5	NA	NA	NA	NA	NA
Yearly CO saved per bicycle	g/bike*year	z46=z40/x9	NA	NA	NA	NA	149.4	NA	NA	NA	NA	NA
Yearly NOx saved per bicycle	g/bike*year	z47=z41/x9	NA	NA	NA	NA	53.8	NA	NA	NA	NA	NA
Pedalling time per rent (contrastable and reasonable rent time)	min	z48=x21	23.0	NA	12.0	NA	NA	NA	NA	NA	NA	NA
Speed of BSS trips	km/h	z49=z48/x21*60	5.2	NA	5.4	NA	NA	NA	NA	NA	NA	NA
Share of population registered in the BSS	%	z50=x22/y7	1.0%	0.4%	0.8%	9.9%	0.1%	NA	NA	NA	NA	NA
Direct jobs per 1,000 inh	jobs/1000inh	z51=x24/y7*1000	NA	0.01	0.01	0.03	0.01	0.01	NA	NA	0.72	NA
Direct jobs per bicycle	jobs/1000inh	z52=x24/x9	NA	0.04	0.02	0.01	0.04	0.07	NA	NA	0.07	NA
Bike-sharing bicycles stolen per year	bicycles/year	z53=x32/x33*12	18	6	48	NA	0	NA	NA	NA	NA	NA
Share of bicycle fleet annually stolen	%	z54=z53/x9	17.8%	12.5%	40.0%	NA	0.0%	NA	NA	NA	NA	NA
Unitary cost of bicycles (&average)	€/bike	z55=x30 (&average)	540	144	220	540	415	600	540	540	540	697
Yearly cost of theft	€/year	z56=z53*z55	9,715	864	10,560	NA	0	NA	NA	NA	NA	NA
Yearly cost of theft by bicycle	€/bike*year	z57=z56/x9	96	18	88	NA	0	NA	NA	NA	NA	NA
Daily rents per bicycle	rents/bike*year	z62=z5/x9	0.3	NA	NA	NA	1.6	NA	0.2	NA	NA	NA
Share of metro stations provided w ith BSS	%	z63=x69/y14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Density of cycle netw ork	km/km2	z64=y16/y17	1.7	0.3	NA	1.2	0.5	2.6	6.1	6.1	0.8	NA
Overnight stays per inhabitants	stays/inhabitant *year	z65=y19/y7	1.6	2.5	3.8	NA	2.4	14.4	20.4	20.4	2.9	NA
Yearly bicycle trips	trips/year	z66=y1*y4*365	3,263,990	3,824,875	NA	8,322,000	2,726,714	28,616,000	12,798,013	12,798,013	24,705,739	NA
Yearly theft per 100,000 cycle trips	cases/100000 trips *year	z67=y20/z66 *100000	NA	NA	NA	NA	NA	4.6	6.9	6.9	9.2	NA
Yearly accidents per 100,000 cycle trips	accidents/ 100000 trips *year	z68=y21/z66 *100000	NA	2.1	NA	NA	4.4	NA	1.3	1.3	0.0	NA
Station density	stations/km²	z69=x66/y17	0.21	0.04	0.01	0.97	0.04	0.02	0.71	3.07	0.01	0.02

			Cheltenham (UK)	Ribera Alta (ES)	Orléans (FR)	Bolzano (IT)	Farnborough (UK)	Cuneo (IT)	Chalon-sur-Saône (FR)	Senigallia (IT)	Lake Neusiedl (AT)	Terlizzi (IT)	Mödling (AT)
Users substituting car by BSS	%	z1=x1*x2	NA	NA	NA	16.7%	NA	40.0%	NA	44.6%	NA	NA	NA
Users substituting PT by BSS	%	z2=x1*x3	NA	NA	NA	25.0%	NA	15.0%	NA	0.0%	NA	NA	NA
Users substituting bicycle by BSS	%	z3=x1*x4	NA	NA	NA	3.3%	NA	10.0%	NA	2.3%	NA	NA	NA
Users substituting w alking by BSS	%	z4=x1*x5	NA	NA	NA	25.0%	NA	25.0%	NA	9.4%	NA	NA	NA
Daily rents	rents/day	z5=x7/x8	NA	NA	312	41	NA	36	NA	99	NA	NA	8
BSS Modal share	%	z6=z5/y1	NA	NA	0.11%	0.05%	NA	NA	NA	0.04%	NA	NA	0.01%
Daily municipal car trips	trips/day	z7=y1*y2	NA	NA	184,117	29,953	NA	NA	NA	257,404	64,374	NA	98,910
Daily car trips shifted to BSS	trips/day	z8=z1*z5	NA	NA	NA	7	NA	14	NA	44	NA	NA	NA
Share of car trips shifted to BSS	%	z9=z7/z8	NA	NA	NA	0.02%	NA	NA	NA	0.02%	NA	NA	NA
Car trips shifted per bicycle	trips/bike*day	z10=z8/x9	NA	NA	NA	0.07	NA	0.28	NA	0.65	NA	NA	NA
Daily PT trips shifted to BSS	trips/day	z11=z2/x5	NA	NA	NA	10	NA	5	NA	0	NA	NA	NA
Daily municipal PT trips	trisp/day	z12=y1*y3	NA	NA	23,380	5,082	NA	NA	NA	1,400	11,421	NA	17,270
Share of PT trips shifted to BSS	%	z13=z11/z12	NA	NA	NA	0.2%	NA	NA	NA	0.0%	NA	NA	NA
PT trips shifted per bicycle	trips/bike*day	z14=z11/x9	NA	NA	NA	0.1	NA	0.1	NA	0.0	NA	NA	NA
Share of bike-sharing trips connected w ith PT	%	z15=x10*x11	NA	NA	NA	10%	NA	41%	NA	0%	NA	NA	NA
Daily intermodal trips BSS - PT	trips/year	z16=z15*z5	NA	NA	NA	4	NA	15	NA	0	NA	NA	NA
Share of PT trips connected w ith BSS	%	z17=z16/z12	NA	NA	NA	0.08%	NA	NA	NA	0.00%	NA	NA	NA
Daily PT trips connected w ith BSS per bicycle	trips/bike*day	z18=z16/x9	NA	NA	NA	0.04	NA	0.29	NA	0.00	NA	NA	NA
Daily cycling trips before the start of the BSS	trips/day	z19=y1*y6	NA	NA	14,612	13,475	NA	NA	NA	15,008	NA	NA	12,560
Direct increase of cycling	%	z20=z5/z19	NA	NA	2.1%	0.3%	NA	NA	NA	0.7%	NA	NA	0.1%
Direct cycle trips per bicycle	trips/bike*day	z21=z5/x9	NA	NA	1.25	0.41	NA	0.71	NA	1.45	NA	NA	0.17
Distance per BSS trip	km/trip	z22=x14/x15 or =x16/x7	NA	NA	NA	NA	NA	2.5	NA	NA	NA	NA	NA
Distance per BSS trip (&average for unknow n values)	km/trip	z23=z22 & average	2.0	2.0	2.0	2.0	2.0	2.5	2.0	2.0	2.0	2.0	2.0
Yearly car trips shifted to BSS	trips/year	z24=z8*x8	NA	NA	NA	1,459	NA	5,200	NA	16,043	NA	NA	NA
Yearly former car distance	km/year	z25=z24*z23	NA	NA	NA	2,930	NA	13,000	NA	32,222	NA	NA	NA
Yearly saved CO2 emissions	t/year	z26=z25*y8/1000	NA	NA	NA	0	NA	2	NA	5	NA	NA	NA
Yearly CO2 saving per 1,000 inhabitant	kg/1000inh*year	z27=z26/y7*10^6	NA	NA	NA	5	NA	38	NA	116	NA	NA	NA
Yearly CO2 saving per bicycle	kg/bike*year	z28=z27/x9*1000	NA	NA	NA	5	NA	42	NA	76	NA	NA	NA
Daily distance per redistribution van	km/van*day	z29=x18/19	NA	NA	NA	NA	NA	NA	40	NA	NA	NA	NA
Daily redistribution distance per van (&average for unknow n values)	km/van*day	z30=z29 & average	39	39	39	39	39	39	40	39	39	39	39
Total daily redistribution distance (&average unitary distance for unknow n values)		z31=x18 & z30*x17	NA	NA	NA	0	NA	NA	40	0	39	0	0
Yearly distance covered for redistribution	km/year	z32=z31*x8	NA	NA	NA	0	NA	NA	14,600	0	8,275	0	0
Unitary CO2 emission of redistribution vans (&average for unknow n values w ith fossil fuel)	kg/km	z33=x19 & average	NA	NA	NA	0	NA	NA	0.215	0	NA	0	0
Yearly CO2 emission due to redistribution	t/year	z34=x33*z32/1000	NA	NA	NA	0	NA	NA	3	0	NA	0	0
Yearly CO2 emission per 1,000 inh	kg/1000inh*year	z35=z34/y7*10^6	NA	NA	NA	0	NA	NA	63	0	NA	0	0
Yearly CO2 emission per bicycle	kg/bike*year	z36=z34/x9*1000	NA	NA	NA	0	NA	NA	31	0	NA	0	0
Yearly net car distance saved	km/year	z37=z25-z32	NA	NA	NA	2,930	NA	NA	NA	32,222	NA	NA	NA
Yearly net CO2 saved	t/year	z38=z26-z34	NA	NA	NA	0	NA	NA	NA	5	NA	NA	NA
Yearly net PM saving	g/year	z39=z37*y9	NA	NA	NA	15	NA	NA	NA	161	NA	NA	NA
Yearly net CO saving	g/year	z40=z37*y10	NA	NA	NA	1,465	NA	NA	NA	16,111	NA	NA	NA
Yearly net NOx saving	g/year	z41=z37*y11	NA	NA	NA	527	NA	NA	NA	5,800	NA	NA	NA
Yearly PM saved per 1,000 inh	g/1000inh*year	z42=z39/y7*1000	NA	NA	NA	0.1	NA	NA	NA	3.6	NA	NA	NA
Yearly CO saved per 1,000 inh	g/1000inh*year	z43=z40/y7*1000	NA	NA	NA	14.7	NA	NA	NA	363.0	NA	NA	NA
Yearly NOx saved per 1,000 inh	g/1000inh*year	z44=z41/y7*1000	NA	NA	NA	5.3	NA	NA	NA	130.7	NA	NA	NA
Yearly PM saved per bicycle	g/bike*year	z45=z39/x9	NA	NA	NA	0.1	NA	NA	NA	2.4	NA	NA	NA
Yearly CO saved per bicycle	g/bike*year	z46=z40/x9	NA	NA	NA	14.6	NA	NA	NA	236.9	NA	NA	NA
Yearly NOx saved per bicycle	g/bike*year	z47=z41/x9	NA	NA	NA	5.3	NA	NA	NA	85.3	NA	NA	NA
Pedalling time per rent (contrastable and reasonable rent time)	min	z48=x21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Speed of BSS trips	km/h	z49=z48/x21*60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Share of population registered in the BSS	%	z50=x22/y7	NA	0.8%	1.6%	0.2%	NA	2.0%	0.5%	1.9%	NA	NA	3.3%
Direct jobs per 1,000 inh	jobs/1000inh	z51=x24/y7*1000	NA	NA	0.03	0.03	NA	0.05	0.02	0.08	0.05	0.07	0.05
Direct jobs per bicycle	jobs/1000inh	z52=x24/x9	NA	NA	0.01	0.03	NA	0.06	0.01	0.05	0.02	0.10	0.02
Bike-sharing bicycles stolen per year	bicycles/year	z53=x32/x33*12	NA	NA	NA	0	NA	1	0	2	NA	0	1
Share of bicycle fleet annually stolen	%	z54=z53/x9	NA	NA	NA	0.4%	NA	2.7%	0.0%	2.4%	NA	0.0%	2.7%
Unitary cost of bicycles (&average)	€/bike	z55=x30 (&average)	697	110	689	150	697	540	2,000	300	350	800	400
Yearly cost of theft	€/year	z56=z53*z55	NA	NA	NA	53	NA	720	0	491	NA	0	514
Yearly cost of theft by bicycle	€/bike*year	z57=z56/x9	NA	NA	NA	1	NA	14	0	7	NA	0	11
Daily rents per bicycle	rents/bike*year	z62=z5/x9	NA	NA	1.2	0.4	NA	0.7	NA	1.5	NA	NA	0.2
Share of metro stations provided w ith BSS	%	z63=x69/y14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Density of cycle netw ork	km/km2	z64=y16/y17	NA	0.0	7.3	0.9	NA	0.1	3.3	0.1	1.1	0.1	1.0
Overnight stays per inhabitants	stays/inhabitant *year	z65=y19/y7	NA	NA	NA	5.9	NA	2.5	NA	30.3	NA	NA	1.4
Yearly bicycle trips	trips/year	z66=y1*y4*365	NA	NA	5,333,546	6,379,835	NA	NA	NA	5,477,920	1,894,870	NA	4,584,400
Yearly theft per 100,000 cycle trips	cases/100000 trips *year	z67=y20/z66 *100000	NA	NA	NA	NA	NA	NA	NA	NA	11.8	NA	NA
Yearly accidents per 100,000 cycle trips	accidents/ 100000 trips *year	z68=y21/z66 *100000	NA	NA	NA	3.1	NA	NA	NA	6.6	NA	NA	NA
Station density	stations/km²	z69=x66/y17	0.24	0.05	1.20	0.02	0.10	0.04	0.92	0.11	0.04	0.07	0.10

Table 42: Calculations

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