SOCIO-SPATIAL ASPECTS OF FUNCTIONING OF BIKE-SHARING SYSTEM “BICING”IN BARCELONA, SPAIN

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FEBRUARY, 2015

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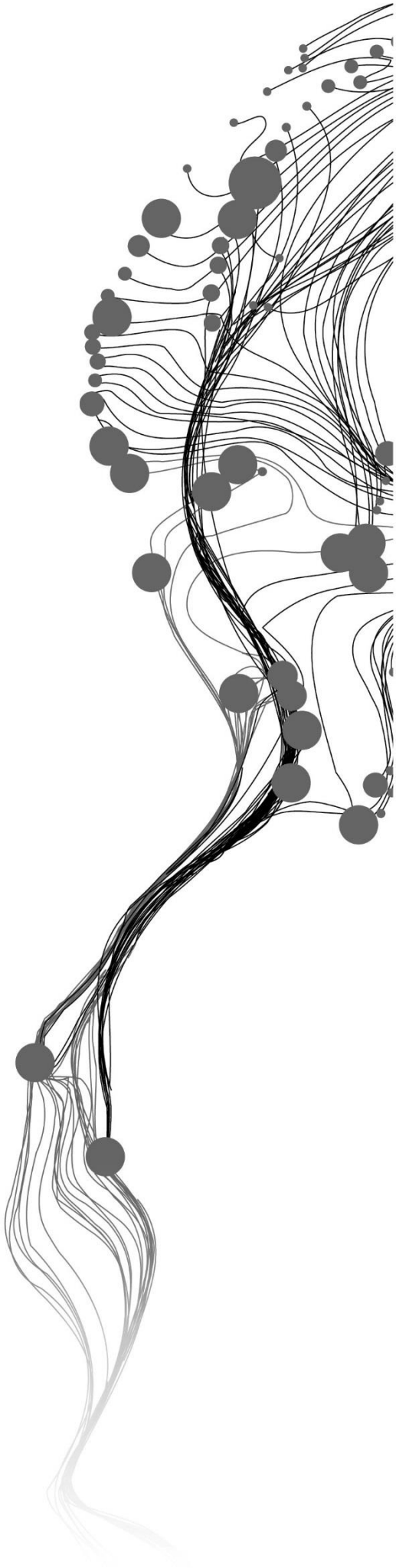

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Enschede, The Netherlands, February, 2015

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban planning and management

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ABSTRACT

Bike-sharing systems in last decades became spread worldwide and very popular mode of transport in all cities where were they installed. Many studies focused on bike-sharing systems, their functioning and effect on everyday life of their users. These studies treated bike-sharing systems both in general, but also on specific parts, locations or aspects of their functioning. This research is focused on Barcelona and its bike-sharing system called Bicing, installed in 2007. Bicing until today was analysed according to economic aspects of functioning and on a city level. This research brought novelty to Bicing analysis in a way that its functioning is examined in spatial and social aspect, i.e. the effect of city's neighbourhoods' spatial and social characteristics on Bicing users and their will to use this bike-sharing system more or less often. Besides that, it was analysed how urban and social characteristics of different parts of Barcelona affect Bicing users, and which obstacles are users dealing with according to the features of the location where Bicing is used. The results of the research showed that Bicing users' and trip's characteristics vary on a part of the city and its properties, but also that bike-sharing systems cannot be analysed on a city level, but it is necessary to dig deeper into the neighbourhood level in order to obtain detailed view of any system's functioning. The research ended up with recommendations and directions for an eventual improvement of Bicing, but also other bike-sharing systems that face similar issues.

ACKNOWLEDGEMENTS

Firstly I would like to say thanks to my parents, sister and friends who turned into a family for supporting me during the whole period of studying in the Netherlands and making it pleasant and enjoyable.
In addition, I would like to thank European Union and Erasmus Mundus programme for giving me the opportunity to study at ITC, University of Twente.

Special thanks go to my supervisors who led me through the thesis process and helped me to carry out this project successfully. Also big thanks to ITC and its staff for supporting and helping me during the complete study period.

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1. INTRODUCTION

The city of Barcelona as the second largest city in Spain has undergone a radical transformation in the last decades: its economic base, social structure, the population's habits and its urban structure (Marshall, 2004). The urban changes that took place in Barcelona had reflection on transport and traffic in general, in a way that existing infrastructure was reconstructed and expanded, but also new modes of transport were introduced. These transport novelties can be seen in new metro, tram and bus lines all over the Barcelona metropolitan region, but the most recent new mode of transport is bike-sharing system Bicing (Marshall, 2004).

1.1. BIKE-SHARING SYSTEM AND BIKING IN BARCELONA

The bike-sharing system called Bicing, placed in Barcelona, was introduced in 2007. Bicing started with 14 stations and 200 bicycles, developing every year, and resulting in 400 stations, 6.000 bicycles and 190.000 users today (Mut, 2010). This system is not for tourist use, since the local authorities did not want to create competition with companies who rent bicycles for visitors of the city. In Barcelona there are 30 million bike trips annually, from which 40% are made using Bicing (Mut, 2010).

The functionality of the Bicing system is based on a short-term bike usage and it is mainly focused on covering small and medium distances within the Barcelona city area. In order to use Bicing, users need to register to the Bicing system by paying the amount annually which will provide them a card for unlimited usage during the year, where the first half hour of usage is free of charge and every next half an hour is charged at 30 cents up to maximum of 2 hours. Exceeding this period is penalized with 3 euros per hour. If a user needs to use a bicycle, he or she must take one from a station with occupied slots, ride to his destination station, and leave it on a free slot. The system registers every time a user takes or parks a bike in a slot (Kaltenbrunner, Meza, Grivolla, Codina, and Banchs, 2010).

Usage of Bicing bike-sharing system varies depending on different areas of the city. This system in Barcelona so far has been analysed only on economic aspects and only on Barcelona's metropolitan area level, without getting deeper into the problem and defining it according to different urban forms of Barcelona and their characteristics. The novelty of the current research relies on the analysis of the Bicing according to spatial, physical and social characteristics of three typical urban forms of the city (definition of the three urban forms is in appendixes). These typical urban areas are different between each other according to their spatial characteristics (size of bike lanes if present, location and distribution of stations of the public transport), social features (trip purposes, density and fluctuation of people and bikers, social structure of the users) and physical properties (location and distribution of Bicing stations, amount and capacity of the stations).

The problems with the functioning of the Bicing bike-sharing system are reflected firstly in the economic aspect, which clearly shows that the Bicing system is not working properly, i.e. not providing planned profit. The system requires 9.673 million euros per year for its operation, while the profit from users directly is 2.24 million, which makes coverage of 23.14%. The rest of the money needed for system functioning is funded from the City council and municipalities (Mut, 2010). There are no additional sources of funding, while additional costs exist. Other expenses for institutions related to Bicing functionality are bicycle reparation that causes 12% of the fleet to be annually out of service, from which 62.5% are made by vandal attacks and theft that cost 240.000 euros for Barcelona council (Ajuntament de Barcelona, Barcelona de Serveis Municipals, S.A., 2014).

Another aspect of the system's non-functionality has a social, physical and spatial character. Related to economic aspects, the biggest issue in Bicing's functioning is its price rise (from 6€/year in 2007 to 30€/year today) which led to a decrease in number of users, mostly social groups with low incomes. Unpractical time of usage is one of the disadvantages of the system (e.g., system is out of function after midnight during working days). Besides that, a lack of organization and proper bike disposal is still leading to occurrence of stations that have no free bikes to take or, in destination stations, no free slots for parking (Ajuntament de Barcelona, Barcelona de Serveis Municipals, S.A., 2014). Due to the spatial and morphological structure of the city, bicycle paths in certain parts are not adequate for bike use (caused by hilly terrain or no bike roads at all). On the other hand, many bike roads are mixed with vehicle usage or they are lacking bike-sharing stations. The fact that Bicing has reached its limit and cannot expand anymore makes it unsustainable. One of the reasons mentioned is the impossibility for trucks to replace and dispose used bicycles (Mut, 2010).

2. RESEARCH PROBLEM, OBJECTIVES AND QUESTIONS

2.1. RESEARCH PROBLEM

The bike-sharing system in Barcelona, Bicing, operated with success until 2010 when problems in the system's functionality start to occur. From then until now, annually the number of users declined and at the same time, financial debts were increasing which is considered as **disfunctionality**. The Bicing system concept was taken from Lyon's bike-sharing system which, in Lyon, works very good (Mut, 2010). If it is taken into account that the same company manages both bike-sharing systems, it is very intriguing why it does not function properly in the Catalan capital.

So far, there are several explanations related to an economic disfunctionality of the system, but none related to social and spatial aspects and their eventual combination.

The aim of this research therefore is to explore as much as possible the social, spatial and urban factors that influence Bicing's (dis)functionality. At the same time, its goal is to put obtained results into an urban form context and investigate whether urban form related factors could explain some of the problems, according to Barcelona's typical urban areas.

In the end, the research should end up with recommendations and possible solutions not only for Bicing but also for bike-sharing networks worldwide.

2.2. RESEARCH OBJECTIVES

2.2.1. GENERAL OBJECTIVE

1. To identify social, spatial and physical factors that can explain the functioning of Bicing

2.2.2. SPECIFIC OBJECTIVES

1. To create a ranking of the factors by their influence related to the system's functioning
2. To define the factors and users characteristics
3. To develop recommendations for system improvement

2.3. RESEARCH QUESTIONS

2.3.1. GENERAL OBJECTIVE

- Which are the factors that influence the functionality of Bicing?
- Which factors have the biggest effect on Bicing and where?
- Which parts of the system are 'critical'?

2.3.2. SPECIFIC OBJECTIVES

- **Objective 1**
  - Which factors and aspects are most related to Bicing's functionality?
  - Which factors are chosen for further research?
- **Objective 2**
  - What are the spatial factors' characteristics?
  - What are social characteristics of the users of Bicing?
- **Objective 3**
  - What are possible recommendations for improvement of the functionality of Bicing?

2.4. CONCEPTUAL FRAMEWORK

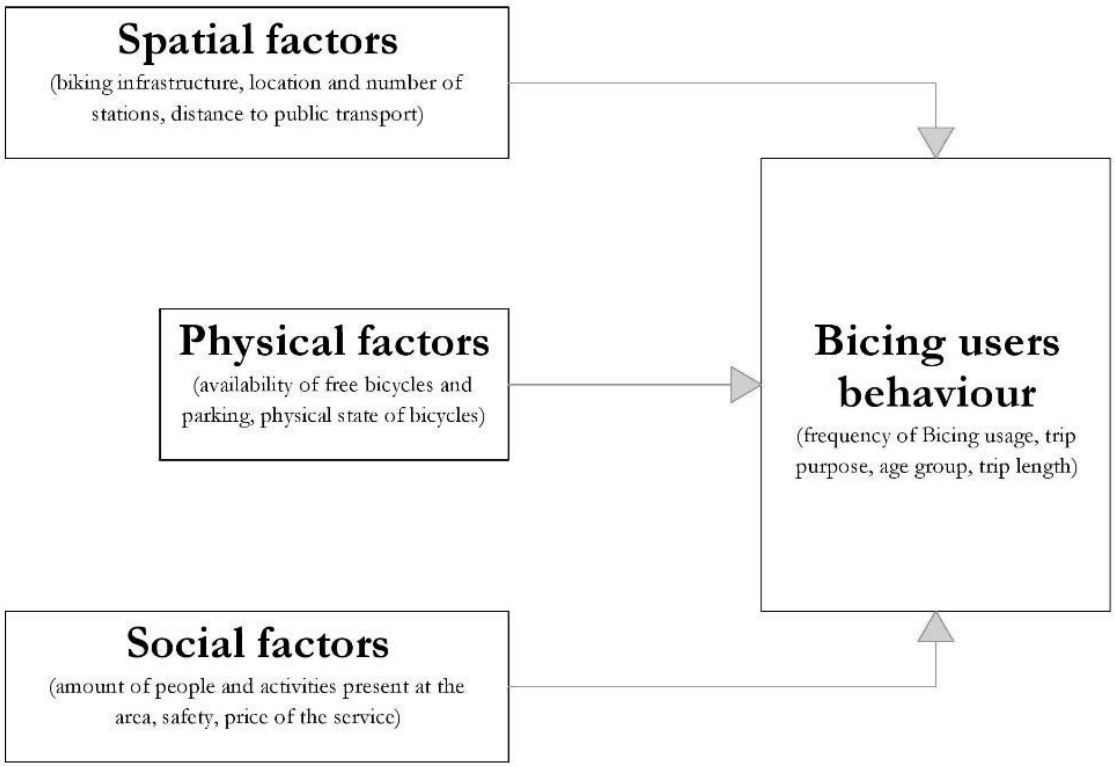


Figure 1. Conceptual framework

The conceptual framework of the research relies on a deep analysis and combination of spatial, social and physical aspects that have influence on behaviour of current users of the Bicing bike-sharing system and their will to use this system more or less often. These mentioned aspects, as shown in Figure 1 have enormous effect on Bicing users and their mutual influence cannot be left out during analysis of Bicing. In this research it will be shown how characteristics of spatial, social and physical aspects in different parts of Barcelona affect Bicing users and define characteristics of their trip made using this bike-sharing system.

3. LITERATURE REVIEW

In many studies there are defined large groups of factors affecting bicycle and bike-sharing use. These factors range from the built environment characteristics (urban form, infrastructure, facilities) to factors related to the natural environment (topography, seasons, climate and weather), social and psychological factors (attitudes and social norms, ecological beliefs, habits), and other factors related to cost, travel time, effort and safety (García-Palomares, Gutiérrez, and Latorre, 2012).

3.1. SPATIAL AND URBAN ASPECTS OF FUNCTIONING OF BIKE-SHARING SYSTEMS AND BARCELONA

For successful functioning of any bike-sharing system it is crucial to define appropriate locations of system's stations, especially in relation public transport network which can be integrated physically and operationally with bike-sharing system (Midgley, 2011). In this case, bike-sharing system becomes a complementary mode within public transport system because it extends the radius of influence of the stations, both public transport and bike-sharing system's (Martens, 2007). According to that, bike-sharing stations should not be located more than 500 m from important traffic origins and destinations, but also number of stations and their capacity should be considered during their allocation (Romero, Ibeas, Moura, Benavente, and Alonso, 2012).

The allocation of bike-sharing system stations should consider also other points of interest of its users, besides public transport. According to this, analysis of a certain location for its future bike stations position should involve population density of station's supposed coverage, since higher density ensures higher usage of stations (Faghih-Imani, Eluru, El-Geneidy, Rabbat, and Haq, 2014).

The neighbourhood characteristics like street type, density, "cycle friendliness" and accessibility of shopping facilities also influence the number of trips made and their length (Schepel and Zuidgeest, 2009). According to that, Faghih-Imani et al. (2014) state that increased number of restaurants (and similar facilities) at certain area results in an increased usage of shared bicycles, especially in the afternoon and evening.

Land use pattern, urban structure and bike-sharing are co-dependent and mutually influence each other in a complex and dynamic way. Meng, et al. (2014) state that higher density of commercial activities and work facilities at some location encourage cycling at that area. One of the urban structures that are very suitable for bike-sharing systems is polycentric pattern, which can be found in Barcelona. This type of urban form has the advantage of integrating different functions and activities at one location, so local population (in this case bicycle users) do not have to travel a long way to reach their daily or weekly needs, like shopping, work or recreation (Meng, Koh, Wong, and Zhong, 2014). According to that, users of bike-sharing systems are influenced by built environment and urban structure in that way that bikers are more encouraged to bike as the amount of available destinations increases within available time and space (Marquet and Miralles-Guasch, 2014). Retail and service density, and urban location all relate to the average separation between residences and potential destinations, suggesting that distance plays an

important role in explaining transportation bicycle use. Longer distances to selected destinations, as determined by land use patterns, discourage transportation-oriented bicyclists (Handy, Xing, and Buehler, 2010).

Midgley (2011) in his studies emphasizes the importance of bicycle infrastructure that enables bike-sharing users to cycle safely and continuously throughout the area covered by the bike-sharing system. At the same time, biking infrastructure not only provide safe and continuous bicycle usage, but also it encourages people to use bike-sharing system in their town (Faghih-Imani, Eluru, El-Geneidy, Rabbat, and Haq, 2014). For example, people living within a half-mile from bicycle paths will at least 20% more likely to use bicycle at least once a week, compared to people living further from the bike lanes. Stated preference studies almost uniformly found that both cyclists and non-cyclists preferred having bike lanes to riding in mixed traffic (Pucher, Dill, and Handy, 2010). Not only biking infrastructure, but also better street connectivity, retail density and land use are associated with increased usage of shared bicycle and bicycles in general (Frank, Bradley, Kavage, Chapman, and Lawton, 2007). Pucher, et al. (2010) considered reducing maximum speed limits for motor vehicles increase bike-sharing usage in two ways: by increasing the speed of bicycling, and by increasing the safety of bicycling. Most studies show increased bicycling with lower automobile speed limits.

After general information about bike-sharing conditions, it is important to give a general and brief overview of the city of Barcelona, which has a compact urban environment, characterised by high densities. Mixed land uses are also an important characteristic, especially with a commercial structure marked by small retail businesses. On average, every square kilometre contains up to five educational institutions, as community facilities and public provisions cover 10% of the total surface area (Marquet and Miralles-Guasch, 2014).

The Barcelona urban region is structured in a large, diverse and compact centre (the municipality of Barcelona), a very dense first metropolitan ring (32 municipalities), an extensive second metropolitan ring (124 municipalities), and, finally, 7 sub-centres (municipalities between 50 000 and 200 000 inhabitants) which may be defined as poly-centric in terms of employment and service (Catalán, Saurí, and Serra, 2008). Barcelona's morphological characteristics are defined by mixed land uses, homogeneous high density developments, and a planning tradition focused on well-distributed services and facilities (Marquet and Miralles-Guasch, 2014a).

3.2. SOCIAL ASPECTS OF FUNCTIONING OF BIKE-SHARING SYSTEMS

As well as spatial and urban factors, social factors have an important effect on the usage of bike-sharing systems. Marquet and Miralles-Guasch (2014) highlight the importance of the locations of bike-sharing systems in social aspect. According to them, the use and importance of proximity increases with age. As people grow older, so does the complexity of their personal schedules and they need to either find closer destinations or travel faster to reach desired destinations. Also, social groups with tighter schedules and space–time prisms, tend to rely more on the local scale if possible, especially for the personal trips. In contrast, younger people (16–29 years of age) make fewer personal trips (44.5%) and even fewer of those trips are within the proximity scale (29%); all of which accounts for short walking trips representing only 20% for younger mobility, compared with 25% for older people. According to that, the fact that the urban environment provides the potentially proximity trips, it does not mean that every social group uses this local scale with the same frequency. Understanding which social factors foster this specific kind of travel behaviour is a key stage in order to encourage cycling and, in this, usage of bike-sharing systems (Marquet and Miralles-Guasch, 2014).

Bicycle infrastructure also has a different effect on certain social groups. Several studies stress the need to consider characteristics of the users of bike-sharing system. Many studies found differences in cycling preferences between men and women, with women generally more attracted to infrastructure with less or no motor vehicle traffic. Social factors can determine the quality of cycling conditions and can enable and encourage the use of bikes, or simply discourage it. From the perspective of travel behaviour, bicycle infrastructure affects the usage of bicycling, affecting travel time, safety, comfort, enjoyment, and other qualities of the bicycling experience that may be important to an individual when deciding whether or not to bicycle (Handy, Xing, and Buehler, 2010).

Pucher, et al. (2010) consider that only infrastructure and location of bike-sharing stations have an effect on the users, but also culture, custom, and habit can foster bicycling in cities with high levels of cycling culture, but also discourage bicycling in cities with lower levels of bicycle usage.

3.3. CONDITIONS FOR PLANNING AND FUNCTIONING OF BIKE-SHARING SYSTEMS

The appropriate planning is one of the crucial steps during introducing any bike-sharing system. It has to include the evaluation of the travel costs of users, the facility costs of bike stations, the setup costs of bicycle lanes, as well as the service level, which is measured by the coverage range of both the origins and destinations and the availability rate of pick-up bike requests at stations (Lin and Yang, 2011). The planning decisions need to make a balance or find an appropriate balance between the overall cost and the service levels. According to that, during planning, an optimal position of bike-sharing stations can increase the number of people who are encouraged to switch to public bicycle. The main issues in this case are the long-term decisions on facility investments for bike stations, the setup cost for the construction of bicycle lanes, the bike inventory costs, and the path travel costs for bike users (Romero, Ibeas, Moura, Benavente, and Alonso, 2012).

For the success of the bike-sharing system, it is important that the system guarantees the availability of a free bicycle and parking slot. Each station should contain enough bicycles to increase the possibility that each user can find a bicycle when needed. Hence, measures of service quality in the system include both the availability rate and the coverage level of the stations. A trip is considered covered only in case if both its origin and destination are covered. Lower number of rental stations results in lower overall bike inventory costs, but also lower decreased coverage of demand. On the other hand, a bike-sharing system with more stations also allows shorter trips between origins/destinations and stations, in that way potentially decreasing total travel costs. However, additional costs of constructing and operating the stations will be present due to the higher number of stations (Romero, Ibeas, Moura, Benavente, and Alonso, 2012).

The ability to deal with its demand is a crucial factor for the success of bike-sharing systems. Actually, the main complaints by bike-sharing system users relate to the unavailability of free bicycles at their desired station and unavailability of parking slots at their destinations, which is solved by repositioning of bicycles. There are two repositioning models. Static repositioning is performed during the night, when the system is idle, while dynamic repositioning takes place during the day in order to deal with bike shortages at certain stations (Raviv and Kolka, 2013).

Several different authorities can lead organization and management of bike-sharing systems. In an advertising-company-initiated model, the company offers to develop and manage a bike-sharing system in a certain location in exchange for the rights to use public space to display advertisements on billboards, bus shelters or kiosks. For example, advertising companies most typically provide bike-sharing systems in larger cities, which is the case with Barcelona, because these cities have greater amount of advertising space and larger population and therefore provide greater potential for generating advertising and product revenue (Nakamura and Abe, 2014).

One of the possible future improvements are potential "fourth generation" bike-sharing systems that are already under development and include movable stations, solar-powered stations, electric bicycles and mobile phone applications. Of these innovations, the introduction of electric bicycles is likely to be the most significant in terms of attractiveness, especially in cities with slopes like Barcelona (Midgley, 2011).

According to the literature and studies so far made, it is obvious that spatial and urban aspects that affect bike-sharing systems and users behaviour the most are the locations of stations, their number and proximity to public transport stations. Besides that, land use patterns, facilities and activities present are factors that have high influence on encouraging people to use public bicycles, as well as biking infrastructure and its quality, which related to perception of safety by users.

On the other hand, availability of free bikes and parking slots at the stations are crucial aspects during evaluation of satisfaction with bike-sharing system by its users. Hence, these mentioned aspects (bicycle infrastructure, location and number of stations, distance from public transport stations, activities and amount of people present, safety, availability of free bicycles and parking slots, as well as, physical state of bicycles) are considered for further research and fieldwork process.

4. RESEARCH DESIGN AND METHODOLOGY

Research related to bike-sharing systems that combine spatial and social factors of its functioning, and at the same time, putting them into a specific urban context has not been done so far. As described before, this research is a novelty by itself, which means that a specific research methodology had to be developed. The methodology explains how the data were collected, analysed, connected (merged) and represented as a result.

4.1. STUDY AREA

The research takes place in Barcelona, capital of Autonomous Community of Catalonia and second largest city in the Kingdom of Spain.

As the Barcelona's bike-sharing system Bicing has been analysed so far only on city level, this research will focus on neighbourhood levels of the city. This means that (three) different parts of the city will be put in focus, or more precisely, aspects of functioning and usage of Bicing will be analysed according to spatial and social characteristics of the mentioned areas of Barcelona.

The first area represents the old urban form of the city (neighbourhood **GRÀCIA**) whose characteristics are presented in appendix 1. Gràcia's spatial characteristics are that it has organic urban form, narrow streets and roads whose usage is mixed between vehicles, bicycles and pedestrians. The majority of the functions include collective housing and partly business areas. A circulation of people is high and its social structure is diverse, since the population density is high. Bicing stations are not densely distributed.

The area called **PLAÇA DE CATALUNYA** is located in the centre of the city, it represents the main traffic point surrounded by educational, business, cultural and touristic values. Population density and people and traffic fluctuation is high. On this area bike lanes partly exist. Bicing stations are relatively densely distributed.

MAGÒRIA is the part that represents the suburbs of the city where fluctuation of people and vehicles are low, as well as population density. Magòria mostly consists of housing and green areas. Bike lanes are only partly present, and Bicing's stations are sparsely distributed in the area (more details in appendix 1).

4.2. OPERATIONAL PLAN

Answers to research questions were obtained firstly from literature and secondly from official sources related to Barcelona's specific case. Since some research questions needed to be answered and/or complemented by additional data, extra information was obtained from the fieldwork. The answer to all research questions were gotten by merging and connecting literature and fieldwork data. However, certain research questions were answered exclusively by fieldwork data collection.

Questions that requested both literature and fieldwork data (e.g. social factors related questions) were answered by firstly, setting assumptions or drawing temporary conclusions obtained from literature information. Secondly, mentioned assumptions were accepted, rejected or modified using fieldwork data resulting in final answers.

Merged pre- and fieldwork data were used to continue with the research that resulted with answered research objectives and questions. Finally, the research also presents recommendations and directions for Barcelona's bike-sharing system, but for other systems worldwide as well. In Table 1 it is shown for which objectives were used which methods and data.

Table 1. Objectives, their methods and purpose

OBJECTIVE	METHOD	METHOD PURPOSE	REQUIRED DATA
Identification of social, spatial and physical factors	Literature review, later complemented by additional data from fieldwork	To define factors that influence functioning and usage of Bicing bike-sharing system	Literature data related to factors that influence usage and function of bike-sharing systems worldwide, especially in Barcelona
List, ranking and choice of factors	Firstly literature was used to rank and choose preliminary factors which were assessed by survey respondents for final choice and ranking	To identify relevant factors that have the strongest influence on usage and functioning of Bicing bike-sharing system	Information about relevance and effect of factors on bike-sharing systems. Rating of factors by Bicing users.
Characteristics of factors and users	Combination of literature data and fieldwork data collection and/or exclusively literature or fieldwork data. GIS analysis.	To define characteristics of factors that were chosen for further research. To analyse social structure of users of the Bicing.	Qualitative and quantitative data related to factors' features and characteristics of users and their usage of Bicing. Base maps of city locations.
Recommendations for system improvement	Analysis of Bicing bike-sharing system and its features.	To point on weak points of the system and present ideas that can lead to improvement of the system and increased number of users.	Results of this research.

4.3. DATA COLLECTION AND DATA PROCESSING

The spine of the research is definitely literature. In this particular case, crucial information and data were obtained from literature related to: bike-sharing and biking in general, basic and advanced conditions for their successful functionality, experiences from other bike-sharing systems, and of course specifications to Barcelona's biking characteristics, Bicing and urban and spatial features of the city. Among found information and data, a filtering has been done in order to select relevant information for the research data for bike-sharing systems and Barcelona case. Three typical urban forms of Barcelona are chosen according to their different characteristics: spatial (spatial, physical and urban features) and social (social structure, population density, circulation of people). In the appendix 1 examples of these three typical and relevant urban forms of Barcelona's metropolitan area are attached.

Besides literature, data collection also includes fieldwork data collection (Figure 2). Data collection on the field (in situ) is explained in the next chapter.

Data sources were official and relevant scientific sites, books and articles related to biking, bike-sharing and Barcelona. Besides that, many data were obtained from Barcelona official sources like City council (Ajuntament de Barcelona), Cartographic and geologic institute of Catalonia (Institut cartogràfic i geològic de Catalunya) and Bicing's official website.

Necessary data also included maps and graphical presentations of city locations, their characteristics and infrastructure level and quality. Some of the data related to previous studies that is not available to public, were obtained from Urban department of City council (Ajuntament de la Ciutat de Barcelona) and Autonomous community of Catalonia (Generalitat de Catalunya). Graphical information is supplement to complete research and its parts, but also it provides better understanding of much information stated in the thesis.

An important part of spatial analysis of the Bicing system was made using GIS tools. In ArcMap software spatial relation between Bicing stations and public transport stations was analysed and presented graphically. According to maximum walking distance of 500 m between public transport stations and other points of interest (in this case Bicing stations), **buffer** tool was used to show the coverage of the areas by public transport stations, i.e. to show if Bicing stations were located appropriately according the location of public transport stations. For a stations density, analysis tool **point density** was used, with stations radius of 250 m. The purpose of this analysis was to show how stations are distributed across all three areas, as one the important element for functioning of any bike-sharing system.

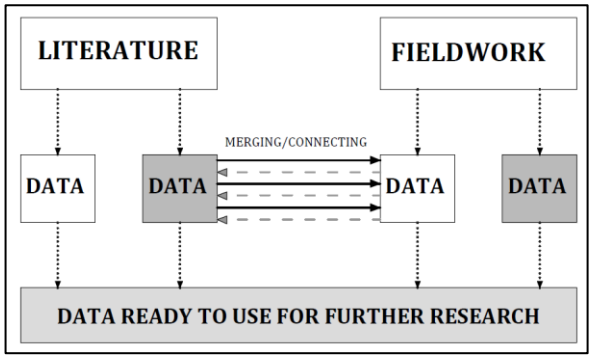


Figure 2. Concept of data collection and processing

4.4. FIELDWORK DATA COLLECTION

4.4.1. PURPOSE OF THE SURVEY

The main purpose of the survey was to get an insight into Bicing's functioning quality and to obtain information on what are the biggest obstacles for users of this bike-sharing system, as well as suggestions for improvement of the system. Besides that, the survey shows the basic characteristics of the surveyed users and the main features of the trip made.

Also the results of the conducted survey show which elements have the biggest negative effect on users depending on the location in the city and their social, spatial and urban characteristics. Besides those mentioned social structure of the surveyed users and trip characteristics are presented, as well as their relation to location and its features.

The second part of the fieldwork consisted out of an observation. According to this, bicycle infrastructure, its characteristics and physical state of Bicing parts (bicycles and stations) have been analysed and evaluated. This part is closely related to performance of the bike-sharing system and users' will to use it more or less often.

4.4.2. CHARACTERISTICS AND CONDUCTION OF THE SURVEY

The survey consisted of three parts: evaluation of presented socio-spatial elements by users, suggestions on what should be improved and a third part which involved characteristics of a user and a trip.

An evaluation of the factors was made by users where is given them an opportunity to mark each of the factors on a scale from 1 to 5. In this case, grade 1 means that an element has no negative effect on Bicing users, while 5 is considered as very negative, or simply said, as an obstacle for this particular user.

The second question was an open one and the respondent was asked to give an example of what could be improved and make them use this bike-sharing system more often.

The final part analysed the respondent as a user of Bicing and the characteristics of the trip made by Bicing. Example of one made survey is in appendix 2.

Some questions were different depending on the location in the city and its characteristics. Questions will be described in detail in further text.

The survey was conducted in Catalan and Spanish (Castilian), as official languages in Autonomous community of Catalonia.

4.4.3. QUESTIONS IN THE SURVEY

The first part in the survey consisted of grading the factors by Bicing user. The exact question was: **Which elements limit you from using Bicing more often in this area?**

The aspects presented were:

Spatial aspects: Presence of bike lanes
Location of the stations at the area
Number of stations at the area
Distance/connection from public transport stations

Social aspects: Price of Bicing service
Functions and activities present at the area
Amount of people present and passing by and through this area
Safety of cyclists

Physical aspects: Availability of free bikes
Availability of free parking slots
Physical state of bicycles

The second question was an open one and it was asked: **What elements would encourage you to use Bicing more often at this area?**

The third part consisted of characteristics of user and trip. A user was asked to provide the information about their **age, trip purpose, trip length, frequency of usage per week and sex**.

The observation section consisted of six parts which are:

- **Capacity of the stations**
- **Presence of bike lanes (present, partly present or not present)**
- **Approximate average width of bike lanes**
- **Physical state of bicycles (no defects, minor defects, major defects or not rideable)**
- **Physical state of stations (no problem, minor or major problems during taking and dropping off the bicycle)**
- **Distance from public transport stations (less than 100 m, 100-500 m, or more than 500 m)**

4.4.4. APPROACHING AND CONDUCTING THE SURVEYS

The surveys, as mentioned before, were conducted in Catalan and Spanish. The respondents were interviewed at the Bicing stations. During taking or dropping off the bike they were asked to give their opinion about this bike-sharing system according to the questions presented in survey. Besides that, due to the insufficient number of surveys that were thus obtained, people on the street were stopped, asked if they are users of Bicing and if they are, they were asked to answer the survey related to specific area of Barcelona, selected in advance in a pre-fieldwork process.
On average, surveys took 2-4 minutes depending on the user.

All respondents understood all the questions and had no problem with answering them. A very small number of respondents needed an explanation of some parts, which in the end were answered without difficulties.

4.4.5. LOCATIONS AND AREA OF SURVEYS CONDUCTION

The bike-sharing system Bicing situated in Barcelona was evaluated through surveys at three different locations in the city. The locations were chosen by their different characteristics (spatial and social) like infrastructure quality, amount and fluctuation of people in the area, activities and contents present, traffic and transport quality and connection to it, location within the city and urban form. Besides that, the social structure of people that use Bicing is different since there are different trip purposes and functions in each area which encourage (or discourage) people to use more or less this bike-sharing system.

The locations where surveys were conducted are: **Plaça de Catalunya, Gràcia** and **Magòria**. The locations of these areas within the city are presented in Figure 3.

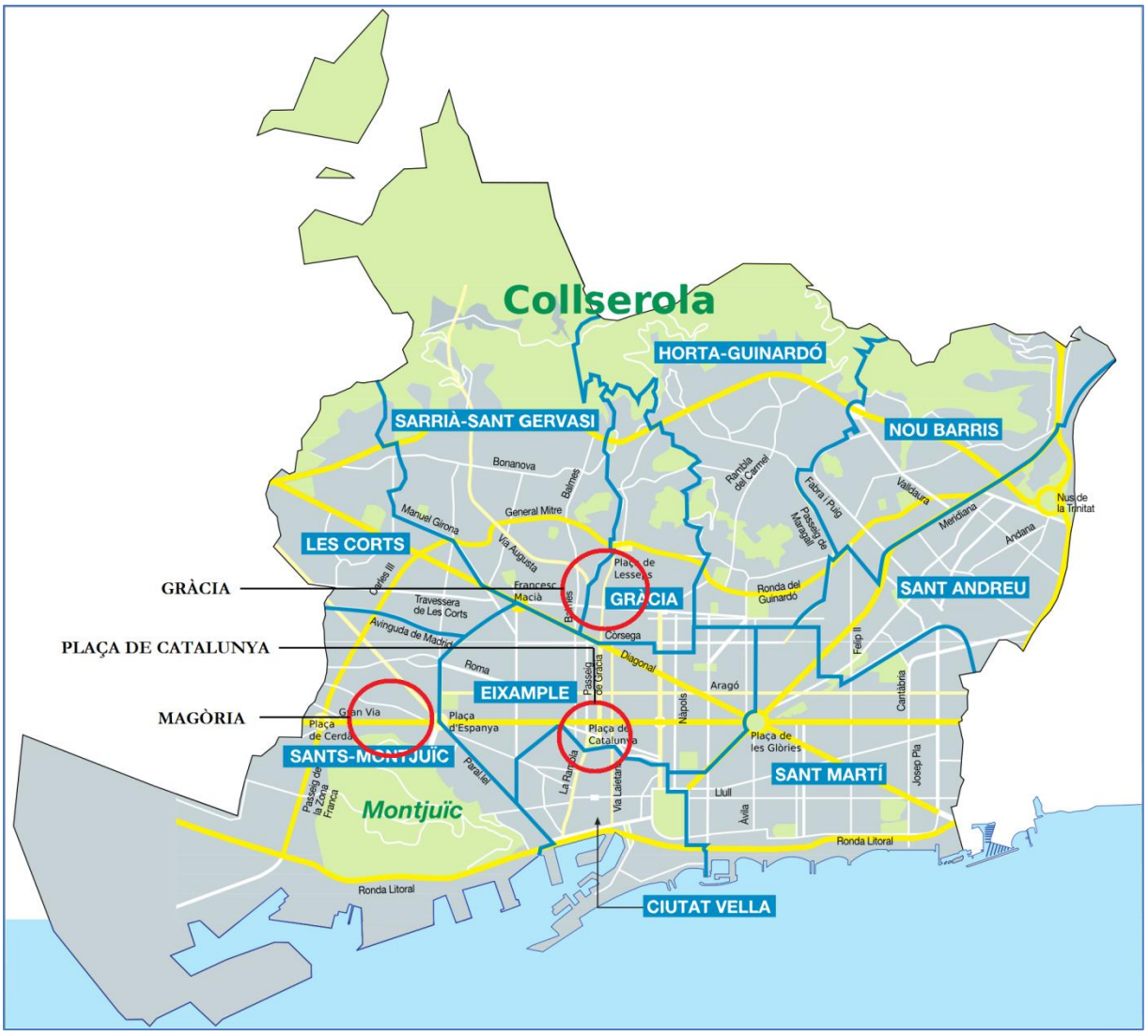


Figure 3. Districts of Barcelona metropolitan area and study areas (source: www.bcn.cat)

5. CHARACTERISTICS OF BARCELONA'S URBAN FORMS

5.1. GENERAL INFORMATION AND FOUNDATION OF TODAY'S URBAN FORM

The Barcelona region is consisted of 162 municipalities, in an area of approximately 3 200 km^2 and a radius of 55 km (Garcia-López and Muñiz, 2012). The city is characterised by compact urban structure, with high densities present in the region. Land uses, as an important factor, are mixed and marked by small retail businesses and commercial activities. On average, every square kilometre consists up to five educational institutions, at the same time, public spaces and facilities cover around 10% of the city territory (Marquet and Miralles-Guasch, 2014).
Urban surface of Barcelona exceeds the administrative city border, and with a population of approximately 4.5 million, Barcelona is the sixth most populous metropolitan region in the European Union. It is the the biggest city on the Mediterranean Sea, situated on the coast between two rivers, Llobregat and Besòs, surrounded on the west by mountain Serra de Collserola, whose tallest point is 512 metres. The city itself covers the area of 101 km^2. 120 kilometres divides Barcelona from Pyrenees and the Spanish border with Republic of France (INE, 2012).

Mega events stimulated urban transformation of Barcelona. Hence, it started in 1888 when the city was a host of Universal Exposition. The motto of the event was "Paris of the South" and the goal was to present the city in a new image. However, the most radical transformation of Barcelona's urban structure was during the preparation of the city for the Olympic Games in 1992. The city council of Barcelona stated that the Olympic Games had huge impact on regeneration and transformation of the city and its surroundings. According to history overview, Barcelona changed from typical industrial city into a flexible city i.e. a city able to cope with modern and fast changes, in this case related to urban phenomena. The most important Olympic reconstruction included actions like opening the city to the sea side, reconstructing the historical objects in the neighbourhood of Gòtic, but also building road infrastructure around the metropolitan region of Barcelona (Brunet, 1995).
The structure of metropolitan area of Barcelona is quite different from the model of the central city, which is compact, diverse, and dense (Duarte, 2007).

In general, many of the mediterranean urban regions are facing a change towards more dispersed and horizontal rather than vertical growth at the expense of forested, and natural environments. This urban region is structured in a large, diverse and compact centre (the municipality of Barcelona), a very dense first metropolitan ring (32 municipalities), a second metropolitan ring (124 municipalities), and, in the end, 7 sub-centres (municipalities between 50,000 and 200,000 inhabitants) which can be considered as self-sufficient cities in terms of employment and service (Catalán, Saurí, and Serra, 2008).

Weather conditions are known to have important effect cycling. It has been confirmed that warm and dry weather conditions encourage biking, but especially recreational bicycle trips (Corcoran, Li, Rohde, Charles-Edwards, and Mateo-Babiano, 2014).

The topography of Barcelona is diverse and consists out of plane areas near the coast and hilly parts increasing from the coast in direction of the north. The central business district of the city occupies the plane part, while the hilly parts mainly consist of collective housing and individual housing in the northeast (El web de la ciutat de Barcelona, 2014). The importance of topography and slope percentages for biking will be explained in the further text.

5.1.1. GENERAL INFORMATION ABOUT POPULATION AND ECONOMY CHARACTERISTICS

According to Barcelona's City Council, Barcelona's population in 2013 was 1 620 943 people (city centre), while the metropolitan region had a population of 5 375 774 (Ajuntament de Barcelona, 2013). The highest density of population (15.99/km^2), activities and traffic are concentrated in the city centre, which is characteristic of the majority of European cities. The most populated neighbourhood in Barcelona is Eixample where Plaça de Catalunya is located.

The age structure of population in Barcelona is:

- 0 – 24 (12.5%)
- 15 – 24 (8.7%)
- 25 – 64 (57.6%)
- 64 and older (21.2%) (Ajuntament de Barcelona, 2013).

The sex structure of Barcelona area is:

- Female – 52.58%
- Male – 47.42%.

The main sectors that contribute to the growing economy of Barcelona are tourism, fashion, power resources, media and food. Tourism is an important industry in Barcelona as the city is considered as one of the top tourist attractions in the world, leaving behind only cities like London and Paris. Barcelona has a highly diverse economic structure. One of the major economic features of Barcelona is its strong industrial base, which greatly exceeds the average of other European regions. Barcelona's industry is based on its importance as one of Europe's biggest seaports. Madrid is the institutional and financial centre of Spain, but Barcelona is considered as its most culturally and industrially vibrant city. Barcelona's main industrial sectors are the automotive, consumer electronics, chemical and pharmaceutical, food and energy industries (Invest in Barcelona, 2014).

5.1.2. TOURISTS AND TOURISM AND ITS AFFECT ON CYCLISTS IN BARCELONA

Tourism is one the most important economic activities in the city as a part of tertiary economic activities. In 2013 Barcelona has been visited by more than 7.5 million tourists making more than 16 million overnight stays (Ajuntament de Barcelona, 2013).

Tourism and tourists have a huge positive impact on the city's economy as a main economy branch of the city. At the same time, it has an enormous effect on the quality of life of the local population. In other words, since there is a high number of visitors on a relatively compact and small city centre (where all touristic attractions are located) often there is a conflict between interests of citizens, tourists and authorities. Tourists and places for their entertainment flooded usually quiet and peaceful neighbourhoods. It is not rare to find posters on buildings, which say about dissatisfaction of residents, like "We want to sleep", "Don't make noise" or "Tourists, go home" (Figure 4).

Figure 4. Residents' message to tourists "We want a decent neighbourhood" (source: own photo)

Figure 5. Crowded pedestrian area La Rambla (source: own photo)

Besides quality of living, tourism effects also traffic and transport features. In the central areas of the city there are many tourists' points of interest, so very often areas designated for pedestrians or cyclists are filled with tourists making it unable to use for its purpose (Figure 5). In this case, local population usually avoid these locations, in many cases making them frustrated.

As stated in the previous text, the large number of tourists throughout the whole year in Barcelona has a negative effect on traffic performance in the city and all transport modes, in a way of not being able to use areas designated for certain transport mode (pedestrian areas, bike lanes and vehicle roads).

5.2. CHARACTERISTICS OF PLAÇA DE CATALUNYA

5.2.1. URBAN CHARACTERISTICS OF PLAÇA DE CATALUNYA

The central business district in the city of Barcelona is located at this area: Plaça de Catalunya. It is a main crossing point of all transport and traffic directions, as well as a meeting point of citizens and, especially, tourists.

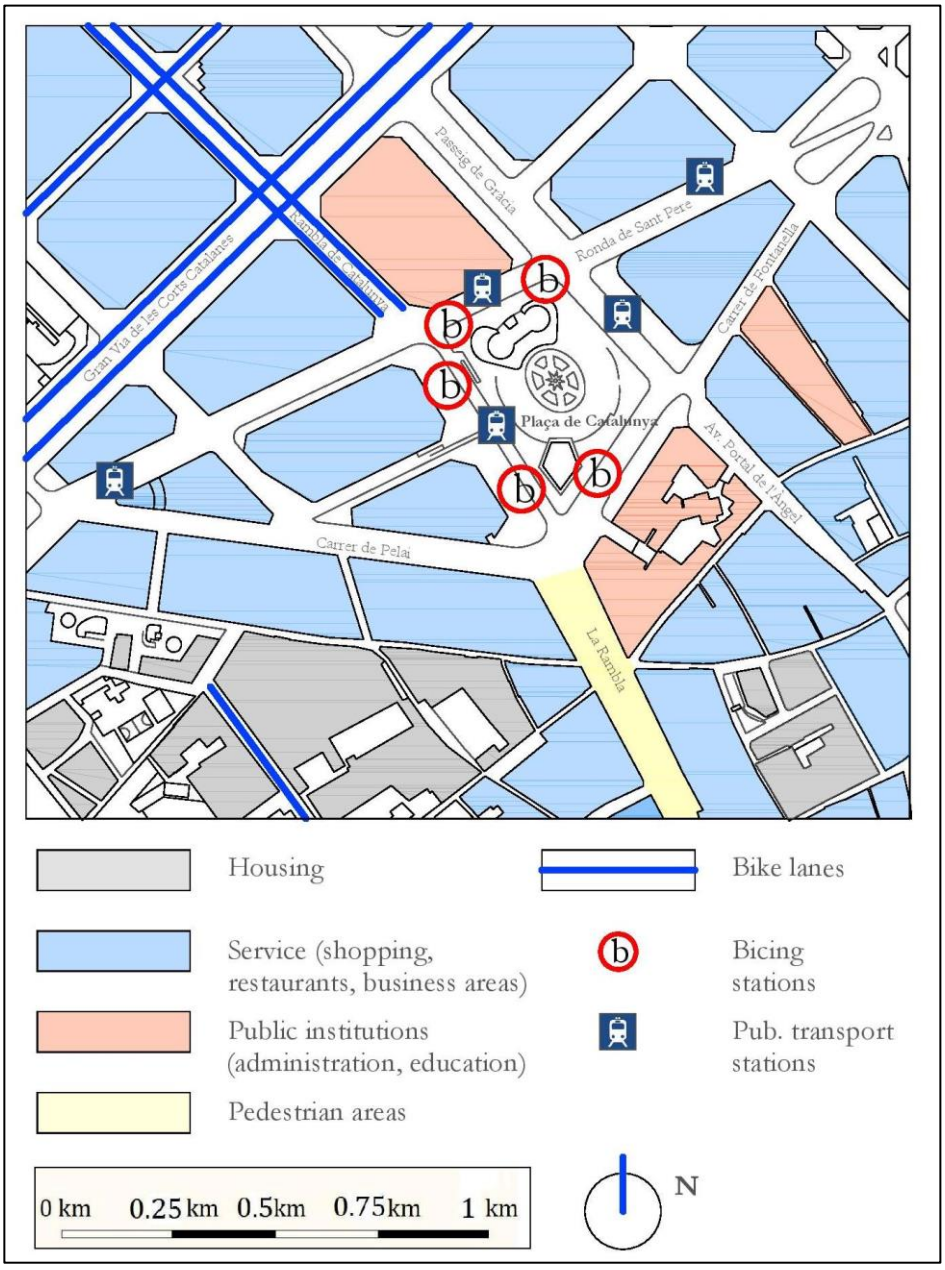


Figure 6. Plaça de Catalunya (own elaboration, base map source: www.icc.cat)

Related to **traffic and transport infrastructure**, this location and its main square (Figure 6) is surrounded by two-lane roads (Ronda de Sant Pere on the north, Carrer de Fontanella on the south, Avinguda de Portal de l'Àngel on the east, and streets Bergara and Pelai on the west of the square), pedestrian paths (La

Rambla, Rambla de Catalunya and Passeig de Gràcia), but also there are pavements for pedestrians on both sides of the roads. Bike lanes are hardly present in this area, i.e. they are built north of the square along with streets Gran via de les Corts Catalanes, La Rambla and Rambla de Catalunya. These are the only locations with bike lanes.

Public transport in this area provides the spine of the city's traffic connectivity. Plaça de Catalunya contains stations of all public transport modes (metro, bus, train and tram) and also stations of Barcelona's bike-sharing system **Bicing**. From this location it is possible (sometimes it is the only way) to reach all parts of the city and the wider region by any types of transport ("El web de la ciutat de Barcelona," n.d.). Five stations of **Bicing** are surrounding the square making it accessible from all directions of the city.

This location representing the central business district of the city is filled with **tertiary economic activities and functions**, i.e. the main activities at Plaça de Catalunya are banks, business centres, shopping centres, educational institutions and touristic info points. These activities are affecting the purposes of trips of people using different modes of transport. Accordingly, this location is most of the time characterised by an enormous circulation of people and traffic participants.

The terrain of Plaça de Catalunya is mostly flat, with a slight inclination towards the sea side in the south. In general, it is completely suitable for all types of transport, also the bicycle since cyclists generally dislike going up inclines of more than 5 per cent and avoid inclines greater than 8 per cent (Midgley, 2011).

5.2.2. SOCIAL CHARACTERISTICS OF PLAÇA DE CATALUNYA

Plaça de Catalunya is a part of Eixample neighbourhood which counts around 265.000 people, out of which 53.8% are female and 46.2% male (Ajuntament de Barcelona, 2013). The age structure of neighbourhood is as it follows:

- 0 – 14 (10.8%)
- 15 – 24 (8.4%)
- 25 – 64 (59%)
- 65 and older (21.9%).

In this area are all functions and activities that are typical for central business district of any city. The position of Plaça de Catalunya is geographically centric, but also its characteristics are predominantly tertiary economic activities: shopping and business centres, institutions of authorities, educational centres as well as main traffic and transport points. According to that, the presence of people at this location is closely related to functions and activities. A circulation of the people in all types of transport is very rapid and intensive.

5.2.3. RESULTS OF THE RESEARCH AT THE PLAÇA DE CATALUNYA

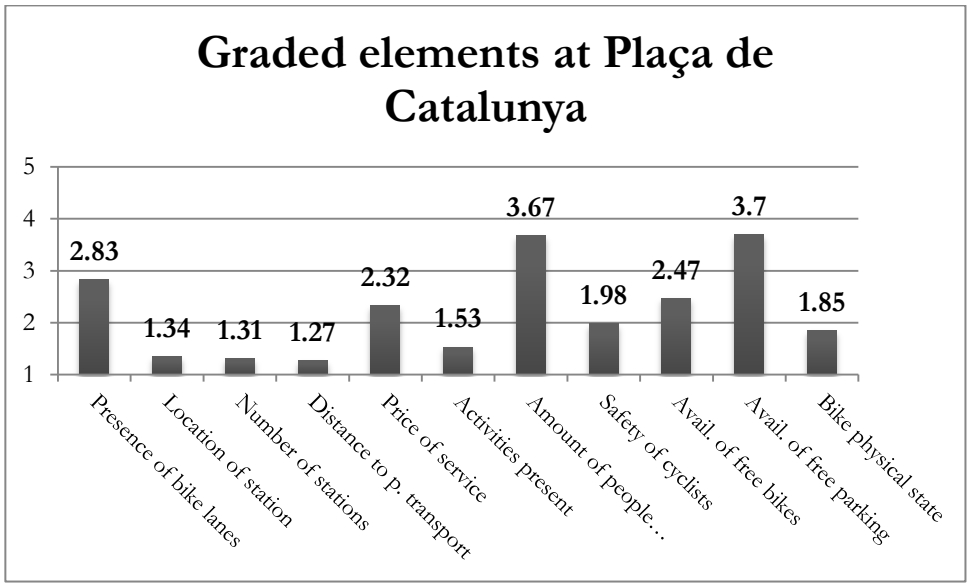


Figure 7. Average grades of the factors, graded by the respondents (Plaça de Catalunya)

After grading of the different factors by respondents of the survey, at this area the biggest obstacles for users of Bicing are: **availability of free parking slots, amount of people present and passing by the area**, and **absence of bike lanes** (Figure 7).

The availability of free parking slots is the biggest issue for Bicing users according to the survey. This problem is very important since in case of unavailability of parking and exceeding 30 minutes of usage of the system a user is obliged to pay a fine. That fact is the main reason why users at Plaça de Catalunya do not use Bicing. When taking into account results of a second (open) question it is clear that users want more time of free usage of Bicing, partly because of the cases of unavailable free parking.

Users are also quite frustrated by the amount of people that are present and that pass by through Plaça de Catalunya, since it is the main traffic and meeting point in the city. An enormous number of pedestrians, tourists and vehicles make biking in general at this area very difficult. At this zone, the majority of respondents in a second (open) question desired that there are less people, and that exactly that would encourage them to use Bicing more often at this area.

Present bike lanes are insufficient for the amount of cyclists, since at many places cyclists are obliged to share the road with pedestrians and vehicles. Bike lanes would physically separate cyclists from other participants in traffic and make biking and Bicing usage easier and more appropriate. This fact was stated by respondents through their answer to the open question the survey. The elements that have no negative effect on Bicing users are distance to public transport, location and number of stations, since this area is surrounded by public transport and Bicing stations and there are five Bicing stations at the zone with capacity of average 27 bicycles per stations.

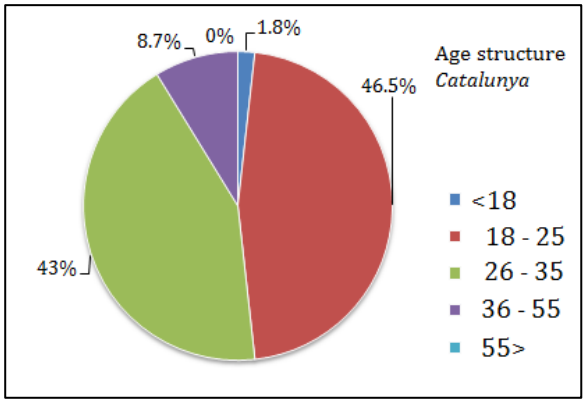


Figure 8. Age structure of users (Plaça de Catalunya)

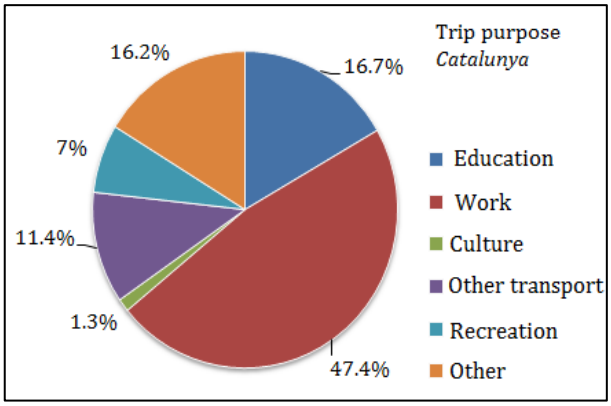


Figure 9. Age structure of users (Plaça de Catalunya)

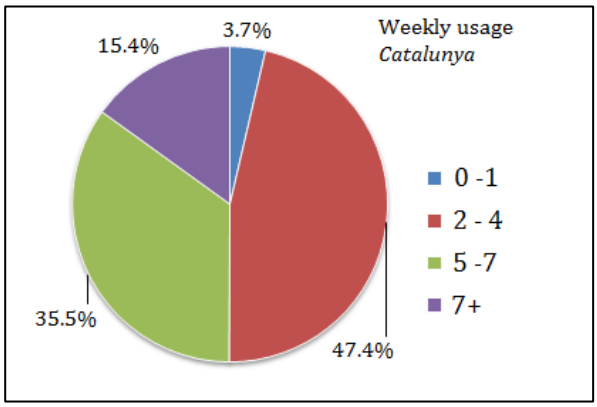


Figure 10. Gender representation (Plaça de Catalunya)

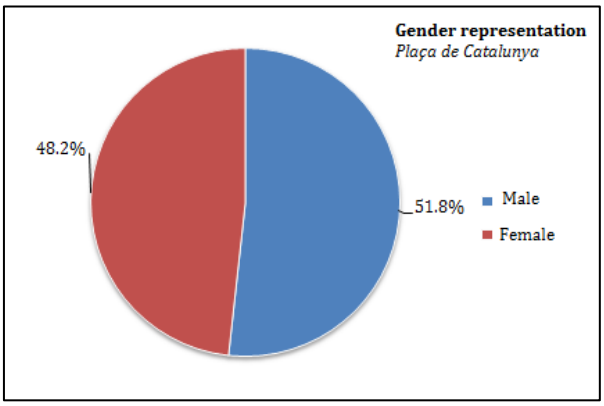


Figure 11. Frequency of usage (Plaça de Catalunya)

After taking a look at the characteristics of users and trips, it is clear that the users of Bicing are young people, mostly between 18 and 35 years of age (Figure 8). Besides that, the main trip purposes of the users are work and education (Figure 9), which is understandable when comparing to major age group of respondents. The users mostly use Bicing several times a week (Figure 10). In this area the average trip length is **15.95 minutes**.

The second open question of the survey (**What would encourage you to use Bicing more often at this area?**) gave following results, ranked by the number of times stated by the respondents:

- **Less people** (17 times stated)
- **More bike lanes** (15 times stated)
- **Less tourists** (14 times stated)
- **Less traffic** (13 times stated)
- **More parking available** (12 times stated).

The observation part of the survey gave following information about Plaça de Catalunya:

- At the location there are four Bicing stations with the capacity of 21, 21, 27 and 33 bicycles.
- Bike lanes are only partly present at the area with approximate average width of 80 cm.
- Physical states of bicycles are marked as **without defects**.
- The Bicing stations are characterised **without any problems during taking and dropping off the bicycles**.
- The distance of Bicing stations to the public transport stations are less than 100 meters.

5.3. CHARACTERISTICS OF GRÀCIA

5.3.1. URBAN CHARACTERISTICS OF GRÀCIA

Gràcia is the area in the north of the city which still kept its organic form and tight streets. This location was not included in the big city transformation in the past century. It is a very quiet and peaceful neighbourhood excluded from traffic jams and daily city noise.

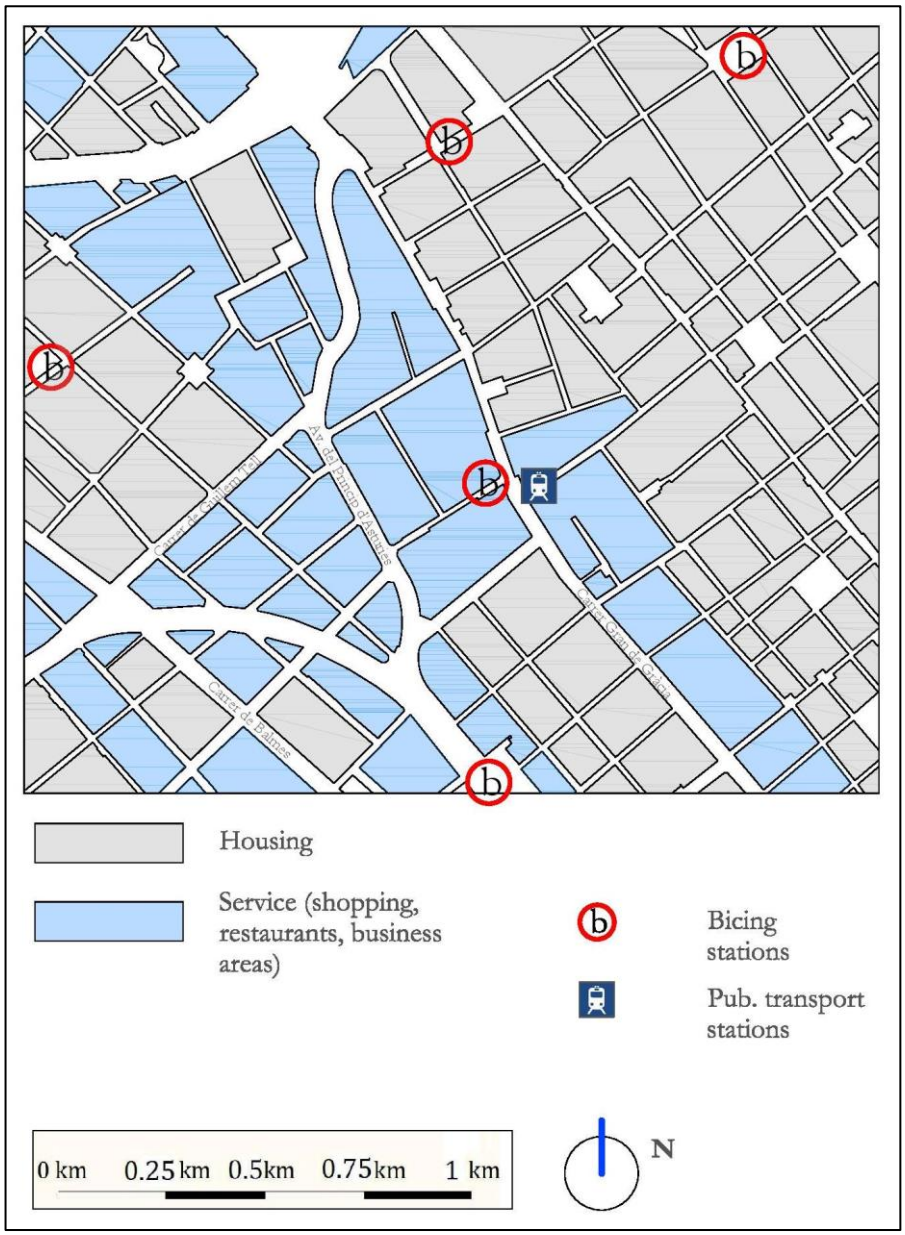


Figure 12. Neighbourhood of Gràcia (own elaboration, base map source: www.icc.cat)

Traffic infrastructure consists of one-way streets with an approximate width of 3.5 m. As is it case in the whole city, pedestrian pavements are present on both sides of the roads. Bike lanes at this area do not exist since the location was not part of urban transformation and in the past this type of infrastructure was neither planned nor built.

Public transport stations are present at this area. Many metro and bus stations are located at this area, even though they are not densely spread and from some parts of neighbourhoods not easily reachable (Figure 12).

Bicing stations are also present, and as the public transport, stations are not densely installed at the area. At the some points they are not easy reachable also caused by Gràcia's topography.

Gràcia is known as a quiet area mostly consisting of **housing and small businesses** (shops, bars). Besides that, this location contains many areas for education, recreation and tourism. This influences trip behaviour of people who mostly go to other areas for business and work, but come here for recreation and fun.

Terrain at Gràcia is diverse. At the locations that are closer to centre (south) the terrain is flat and very acceptable for transport, especially biking. By going towards the north, the neighbourhood's inclination is growing such that at certain point it becomes unpleasant for walking or biking (Figure 13 and 14). That is why cyclists avoid using bicycles at these areas.

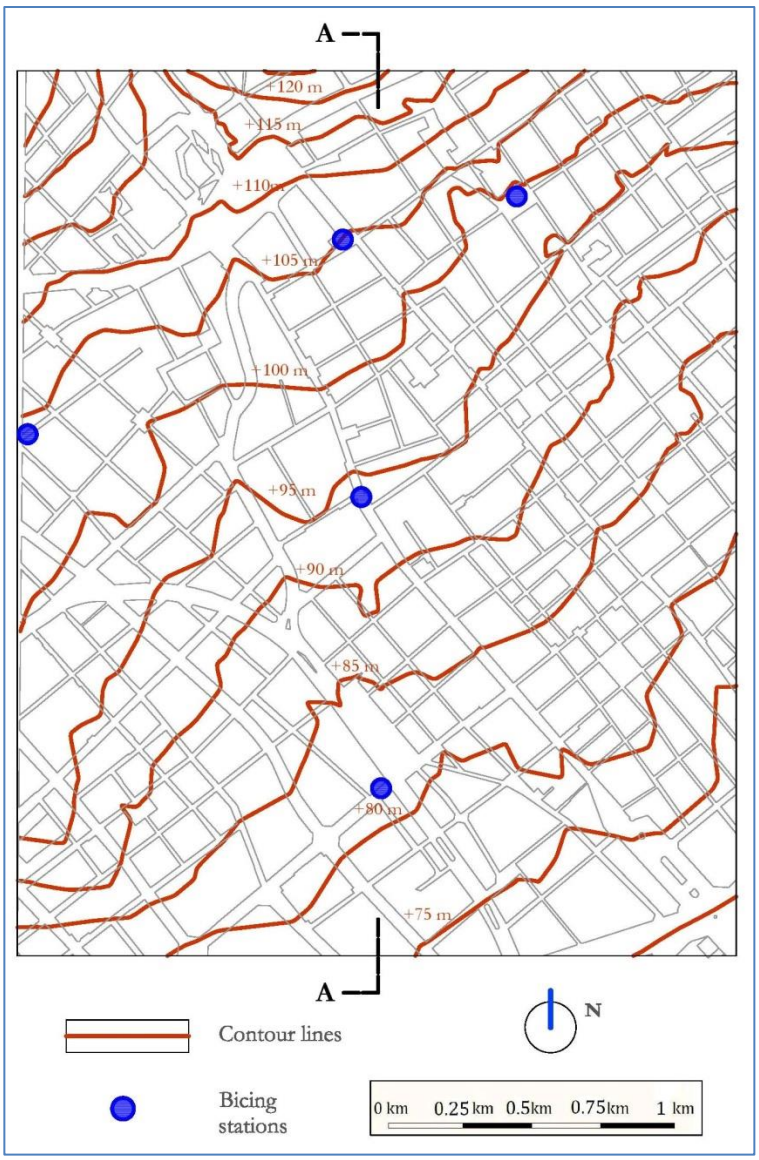


Figure 13. Topography map of Gràcia and Bicing stations locations (own elaboration, base map source: www.icc.cat)

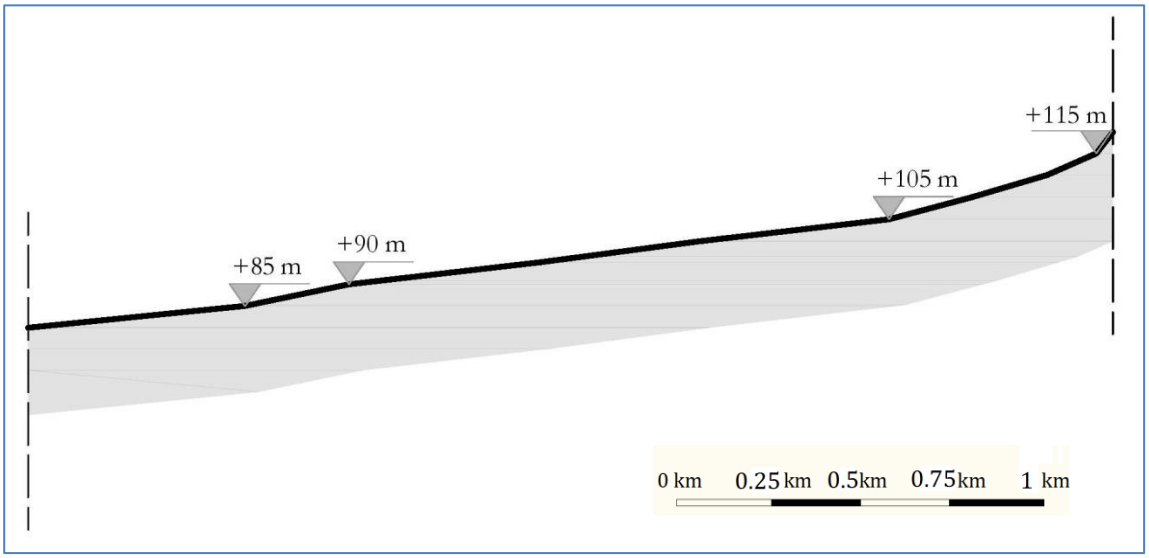


Figure 14. Cross section of topography of Gràcia (own elaboration, base map source: www.icc.cat)

5.3.2. SOCIAL CHARACTERISTICS OF GRÀCIA

Gràcia is a part of Barcelona positioned at the north of the city bordering with mountains and suburbs of this metropolitan area. The population of Gràcia is around 120.000 people and the gender structure is: female 54.1% and male 45.9% (Ajuntament de Barcelona, 2013). The age structure at Gràcia is represented in the following form:

- 0 -14 (11.7%)
- 15 – 24 (7.6%)
- 25 – 64 (59.2%)
- 65 and older (21.4%).

This neighbourhood is very different from the previous one (Plaça de Catalunya) as it is a part of the city which is very quiet and calm. This is related to functions present here: housing and primary contents related to housing (primary schools and kindergartens, small shops and offices). Besides that, traffic at this location is less intensive and congested due to the location of Gràcia, its size and type of roads as well as the activities present here, which determine movement of people to and from this location. In other words, contents at Gràcia cause movement of local people of the neighbourhood and people who pass by through Gràcia, but do not attract a high number people from other parts of Barcelona to come here, like at Plaça de Catalunya.

5.3.3. RESULTS OF THE RESEARCH AT GRÀCIA

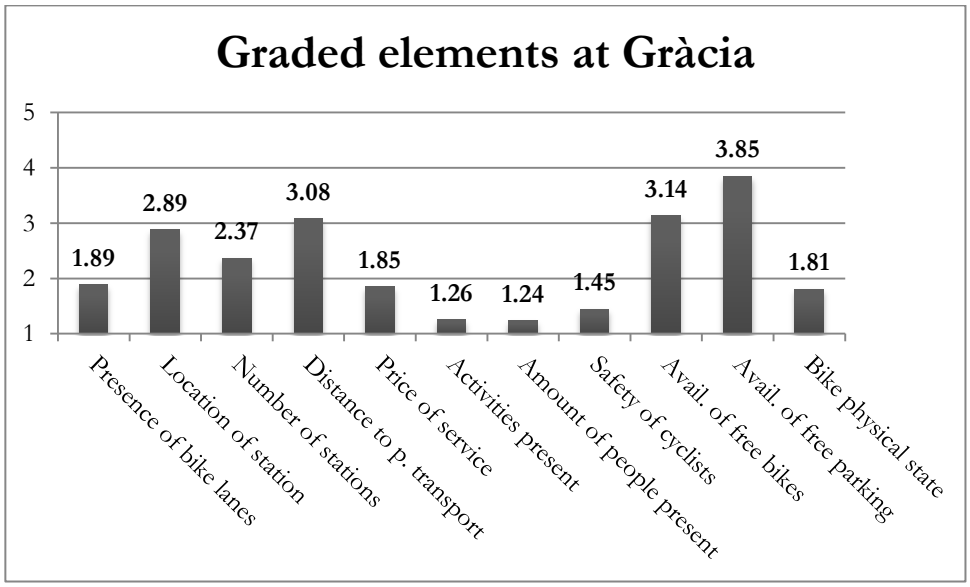


Figure 15. Average grades of elements, graded by respondents (Gràcia)

At this area the elements that have the most negative effect on users are the availability of free bikes and parking, and distance to public transport (Figure 15).

Availability of free bikes and parking slots has two different dimensions discovered through the second (open) question of the survey. Since the neighbourhood of Gràcia has partly hilly terrain, users mostly complained about unavailability of free parking slots at downhill parts of the area and unavailability of free bikes at the uphill areas of Gràcia.

Distance to the stations of public transport is a huge issue for users, since many Bicing stations are quite far from stations of all types of public transport (metro, bus, and tram).

Since Gràcia is quite a quiet neighbourhood without dense traffic, users find it very pleasant for using bicycles in many aspects like activities and amount of people present at the zone.

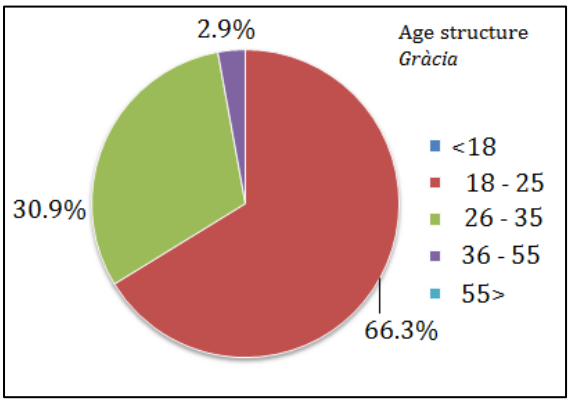


Figure 16. Age structure of users (Gràcia)

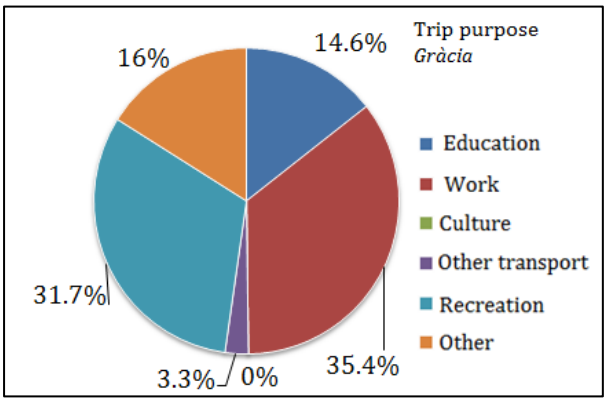


Figure 17. Trip purpose of users (Gràcia)

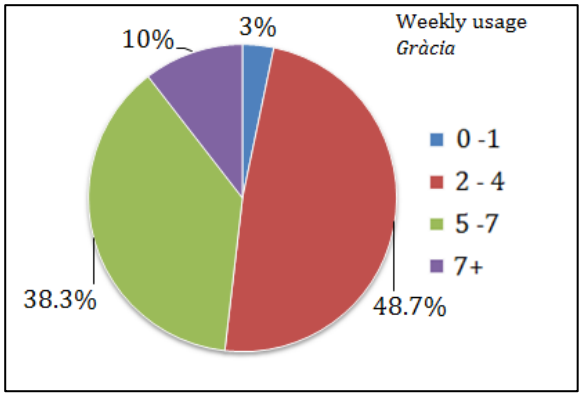


Figure 88. Usage frequency (Gràcia)

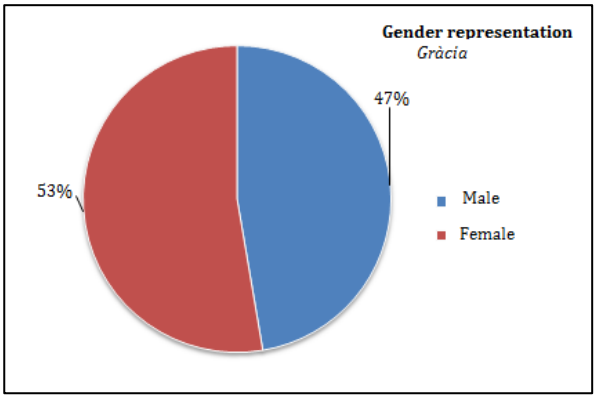


Figure 19. Gender representation (Gràcia)

Related to features of users and trips, as in other zones, Bicing is used mostly by young people between 18 and 35 (Figure 16). Trip purpose defers a bit from the previous area, since in Gràcia the main trip purposes are work and recreation/fun, which is expected according to the age group of users (Figure 17). At this zone as well, Bicing is used several times a week (Figure 18), and average trip length is **20.19 minutes**. This is normal since this neighbourhood is a little bit further from city centre and its main activities.

The second open question of the survey (**What would encourage you to use Bicing more often at this area?**) gave following results, ranked by the number of times stated by the respondents:

- **More parking available** (45 times stated)
- **More time gratis** (23 times stated)
- **More parking downhill available** (12 times stated)
- **More bikes available** (9 times stated)
- **Lower penalties (fines)** (7 times stated).

The observation part of the survey gave following information about Gràcia:

- At the location there are five Bicing stations with the capacity of 21, 24, 27, 27 and 27 bicycles.
- Bike lanes are not present at the area.
- Physical states of bicycles are marked as **without defects.**
- The Bicing stations are characterised **with minor difficulties during and dropping off the bikes.**
- The distance of Bicing stations to the public transport stations is more than 500 meters.

5.4. CHARACTERISTICS OF MAGÒRIA-LA CAMPANA

5.4.1. URBAN CHARACTERISTICS OF MAGÒRIA-LA CAMPANA

Magòria – La Campana is the location situated in the west of the Barcelona area, considered as the neighbourhood outside of the city centre. According to that there is no huge fluctuation of pedestrians or bikers, but there is a considerable amount of vehicles at the roads here that connect Barcelona with other areas of the region and province.

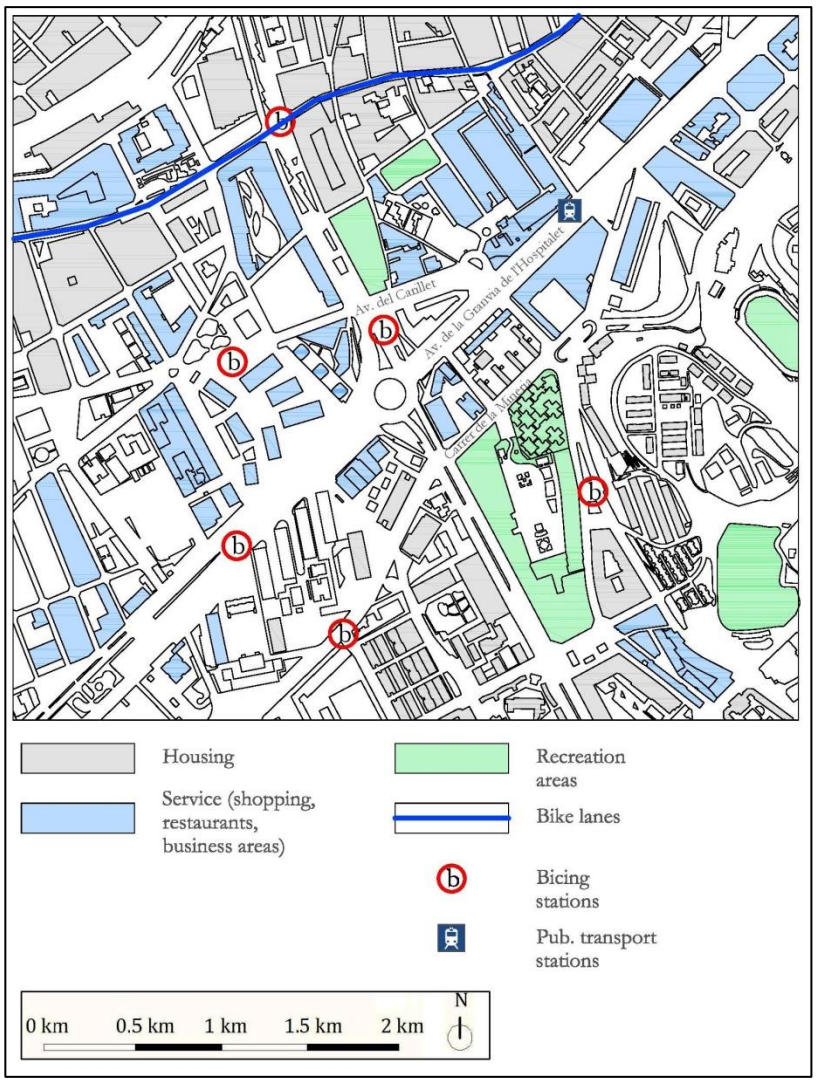


Figure 20. Neighbourhood of Magòria (own elaboration, base map source: www.icc.cat)

Magòria is a very important area since it is the bridge between the city centre and the west part of the suburbs and Catalonia. According to that, **traffic infrastructure** is well developed and through the location there is a high way consisting of six lanes (three lanes in one direction). Besides that, there are other roads followed by pedestrian pavements. **Bike lanes** are present only along the road Gran via de l'Hospitalet and partly at some smaller streets in the neighbourhoods (Figure 20).

Bicing public stations are present and spread over the area, even though not densely which is understandable according to the amount of people present at the location. A few Bicing stations at this location were eliminated recently due to lack of profitability.

Magòria is a location **without rich and diverse activities** present. The area consists of housing, small retail shops and huge roads passing through the neighbourhood. In order to work or study, the population mostly visits other parts of Barcelona's region, at the same time, intentional visitors are rare.

The terrain of Magòria is very pleasant for all kinds of transport and movement (walking and biking). The topography is constant, without changes and hilly parts.

5.4.2. SOCIAL CHARACTERISTICS OF MAGÒRIA – LA CAMPANA

Magòria is at the western part of Barcelona's neighbourhood called Sants-Montjuic which has 182.000 people. At this location 52% of the inhabitants are female and 48% are male. (Ajuntament de Barcelona, 2013). Related to age, the population is structured like this:

- 0 – 14 (11.7%)
- 15 – 24 (8.8%)
- 25 – 64 (59.7%)
- 65 and older (19.8%).

Since this area is partly considered as a suburb, residents at this area usually move to other locations in order to fulfil their daily needs and obligations (work and education). Local transport within the area is moderate and not intensive, but transit traffic (roads which pass through Magòria and connect city and rest of Catalonia) is of high intensity, but has no huge effect on movement within Magòria. The neighbourhood is quite calm due to a lack of large fluctuation of people, since main activities and activities are related to everyday local living needs, like in Gràcia (primary schools, small shops and offices).

5.4.3. RESULTS OF THE RESEARCH AT MAGÒRIA

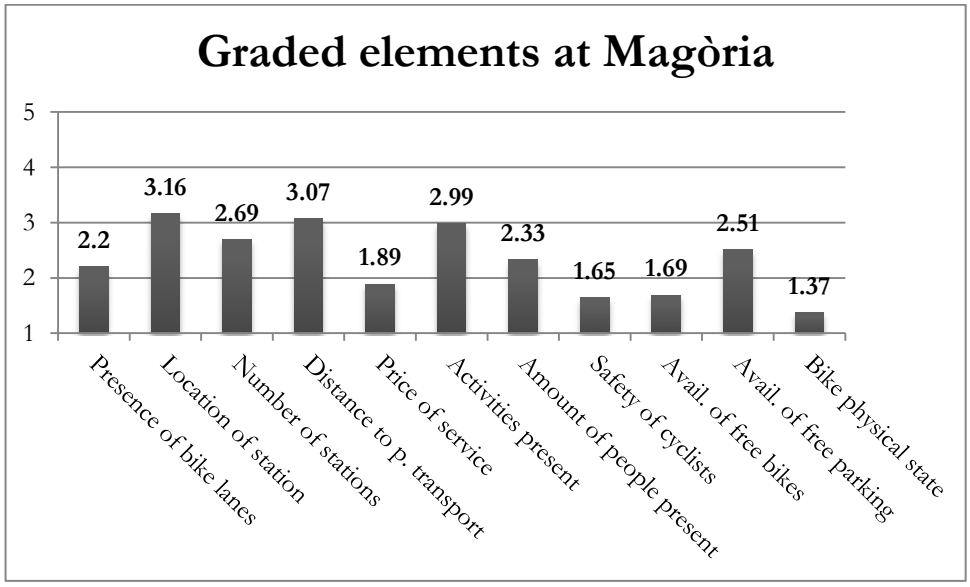


Figure 21. Average grades of factors, graded by respondents (Magòria)

In Magòria the biggest obstacles for Bicing users are the location of Bicing stations, distance to public transport and activities present at the zone (Figure 21).

Since this zone is located relatively far from the centre, two Bicing stations were eliminated; the coverage of the area by Bicing stations is worsened. Magòria mostly consists of housing, green areas and roads, it is clear that there are not many functions and activities that would attract Bicing users to the system here.

According to features of Bicing usage, availability of free bikes and parking are not a big issue at this area.

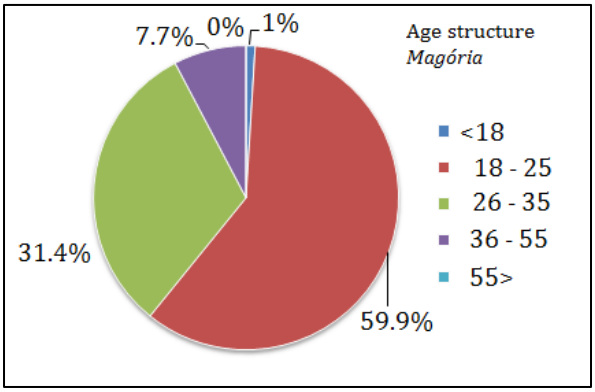


Figure 22. Age structure of users (Magòria)

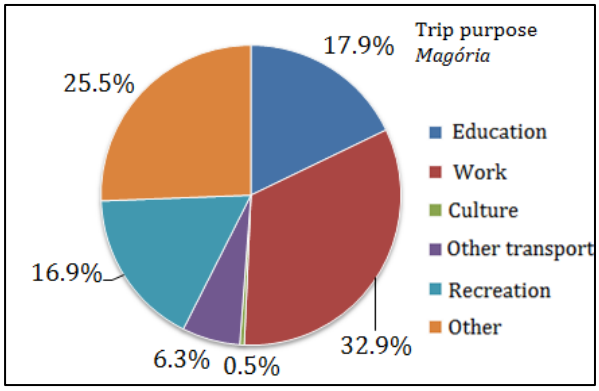


Figure 23. Trip purpose of users (Magòria)

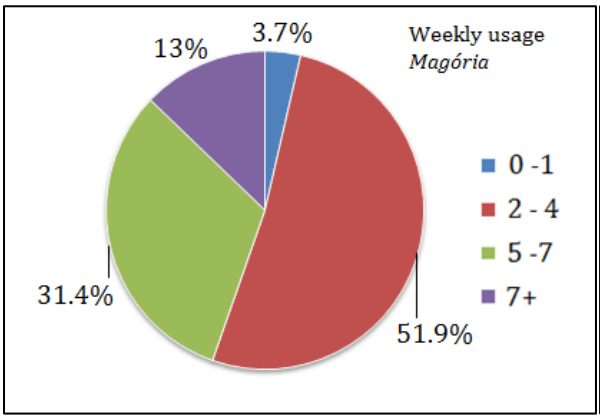


Figure 24. Usage frequency (Magòria)

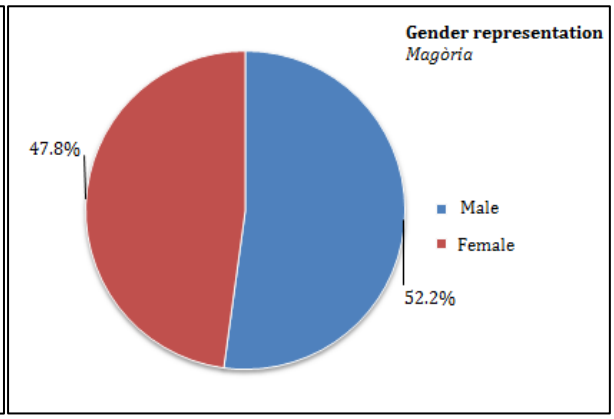


Figure 25. Gender representation (Magòria)

At this zone, as in previous areas, users are young people (Figure 22) who use this system mostly for reaching to work and education points (Figure 23), several times a week (Figure 24) how much is the average usage of Bicing by respondents. Average duration of trip is **20.99 minutes.**

The second open question of the survey (**What would encourage you to use Bicing more often at this area?**) gave following results, ranked by the number of times stated by the respondents:

- **If Bicing stations are closer to metro** (30 times stated)
- **Less traffic** (24 times stated)
- **More parking available** (22 times stated)

- **More time gratis** (17 times stated)
- **If Bicing stations are closer to city centre** (12 times stated).

The observation part of the survey gave following information about Magòria:

- At the location there are four Bicing stations with the capacity of 21, 27, 33 and 33 bicycles.
- Bike lanes are partly present at the area with average width of 70 cm.
- Physical states of bicycles are marked as **with minor defects.**
- The Bicing stations are characterised **without difficulties during and dropping off the bikes.**
- The distance of Bicing stations to the public transport stations is more than 500 meters.

5.5. DISCUSSION OF THE FIELDWORK RESULTS AND BARCELONA'S URBAN FORM

5.5.1. PRESENCE OF BIKE LANES

Bike lanes are a crucial part of any bicycle network infrastructure, and according to that they have an enormous effect on potential and current bicycle users. An aspect that emerges from the literature is that many people tend to declare that they would actually like to use a bike for their daily needs in the city (for example, to work or to school), but that they may be discouraged by several practical obstacles, such as the absence of cycling facilities and/or the bad quality of existing ones (Passafaro et al., 2014). However, depending on circumstances it does not have to be always the case nor the bike lanes have to be essential. It is not the network length that matters, it is the fact that such a network exists and is in good repair (Midgley, 2011).

In this particular case results related to the presence of bike lanes are quite diverse, depending on the location and its urban form characteristics. In the city's central business district, known as Plaça de Catalunya, it was shown that the absence of bike lanes present has a negative effect (average grade of 2.83 in survey) on bike users and their will to use both Bicing or private bicycle. In this case, it is closely related to social characteristics of the area, since cyclists require bike lanes to be physically separated from pedestrians and vehicles whose number and intensity are very high, in order to be able to use the bicycle without any obstacles (Figure 26).

At Gràcia the absence of bike lanes got the average grade of 1.89 meaning that it has no big negative effect on cyclists. The reason for this is that even though there are no bike paths, traffic intensity is very low (both pedestrians and vehicles) so Bicing and bicycle users have no problems with using this type of transport.

At Magòria the presence of bike lanes in the conducted survey has an average grade of 2.2 which means that their presence or absence in some parts have important role, still not crucial. Areas that do not have bike lanes at this location force cyclists to share the path with traffic participants that they want to avoid. Since the traffic at Magòria is not intensive, Bicing users in average have big issues with sharing roads with vehicles or pedestrians.

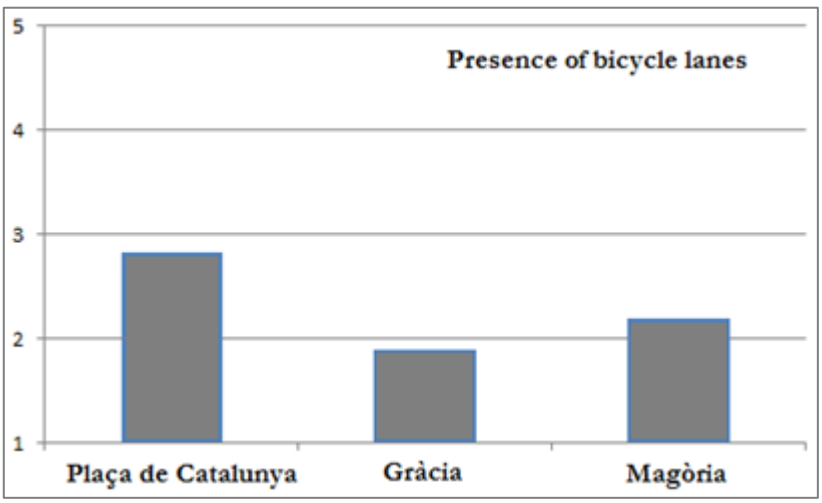


Figure 96. Average grade of presence of bike lanes

5.5.2. LOCATIONS OF THE STATIONS

Urban space is not homogeneous, as locations and places with different gravitational forces draw more, or less, attention from the users of the city. Each social group has its own travel necessities that are unequal and are defined by their demographic and socioeconomic status. These characteristics determine daily needs, for which people are willing to spend more or less time, depending on their personal schedule. Uneven access to the different modes of transport, clearly, affects travel behaviour and, ultimately, people's travelled distances (Marquet and Miralles-Guasch, 2014). In case of Plaça de Catalunya locations of stations were graded on average 1.34 which means that Bicing users are very satisfied with it (Figure 27). It is understandable since stations at this area are no more than 50 m away from all main roads and paths, business and educational centres, and other important locations for residents, but also stations are densely distributed (Figure 28). At Gràcia there is a different situation where location of stations got an average grade of 2.89 making it a significant negativity of the system here, since stations are not densely distributed (Figure 29), often far from residents' place of living or places of interest (schools, traffic points, and work or recreation points). At Magòria it is even more important, since the average grade is 3.16, making it a significant obstacle (Figure 30).

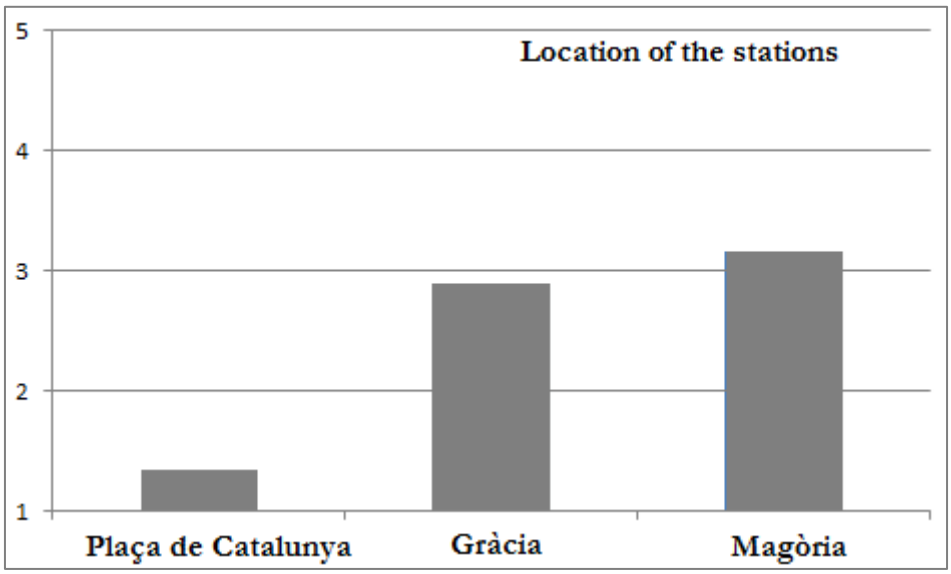


Figure 27. Average grade of locations of stations

The bicycle sharing systems are specially adapted in case of cities with steep slopes because the cyclists can use the bicycle in one direction and use other transport modes (such as buses) for the opposite direction. In these cases the main problem of the bike-sharing system sponsors is the relocation of bicycles that must be carefully designed. The slopes have a negative effect on cyclists' will to cycle, since grades greater than 5% are uncomfortable for many cyclists (because the ascents are difficult to climb and the descents induce excessive speeds), but they may be used in short sections (Frade and Ribeiro, 2014). Locations of Bicing stations are very important since travel distance by mode varies from country to country and city to city, most people are willing to walk up to 10 minutes. In cities with slopes under 4 per cent, topography is not a limiting factor. However, with slopes between 4 per cent and 8 per cent, the topography does become a significant constraint.

Cyclists will go down the slope but will refuse to go up. Bicycle-sharing stations at higher elevations will tend to be empty, while those at lower elevations will tend to be filled up (Midgley, 2011). This fact is very evident at Gràcia, whose topography is in some parts inadequate for pedestrians and especially for cyclists.

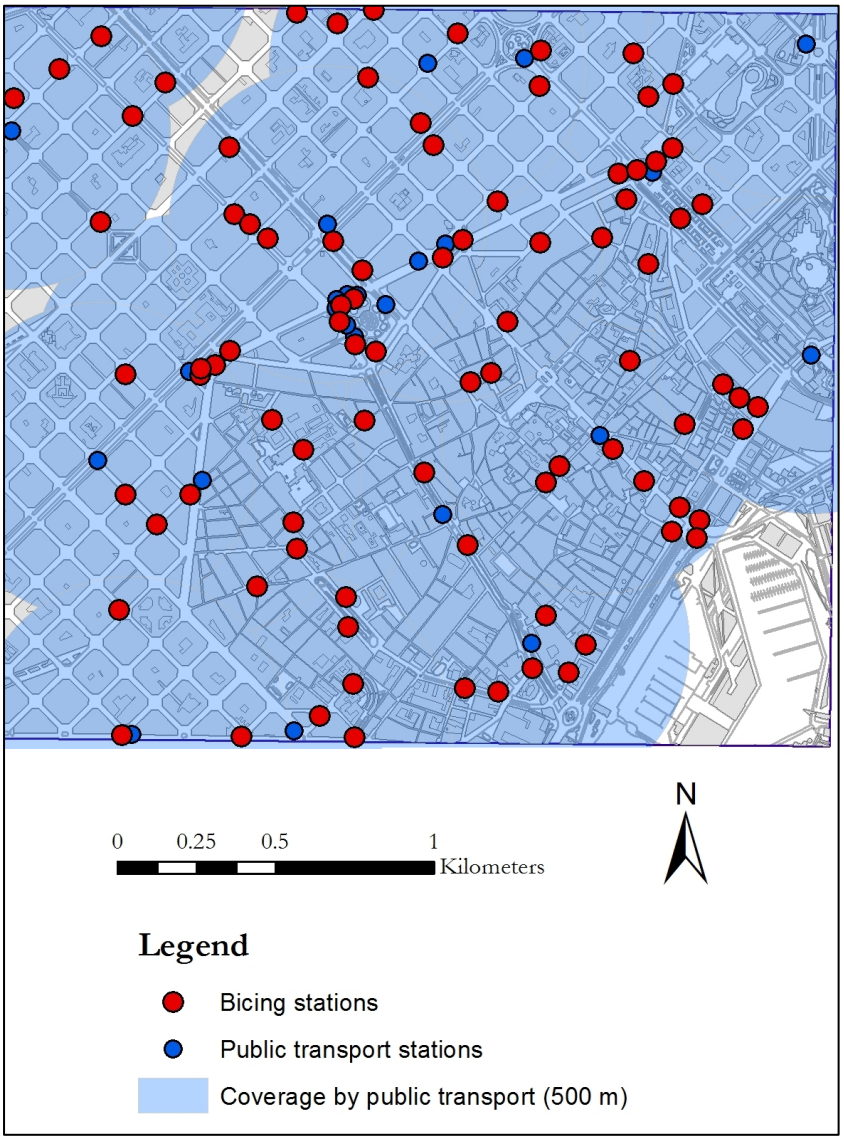


Figure 108. Coverage of Pl. de Catalunya by public transport, walking distance of 500 m (own elaboration, base map source: www.icc.cat)

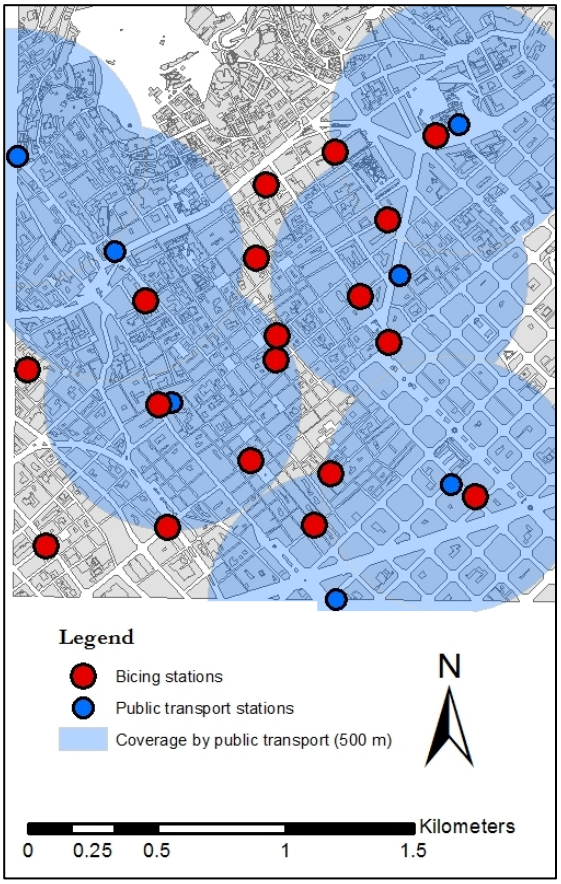


Figure 29. Coverage of Gràcia by public transport, walking distance of 500 m (own elaboration, base map source: www.icc.cat)

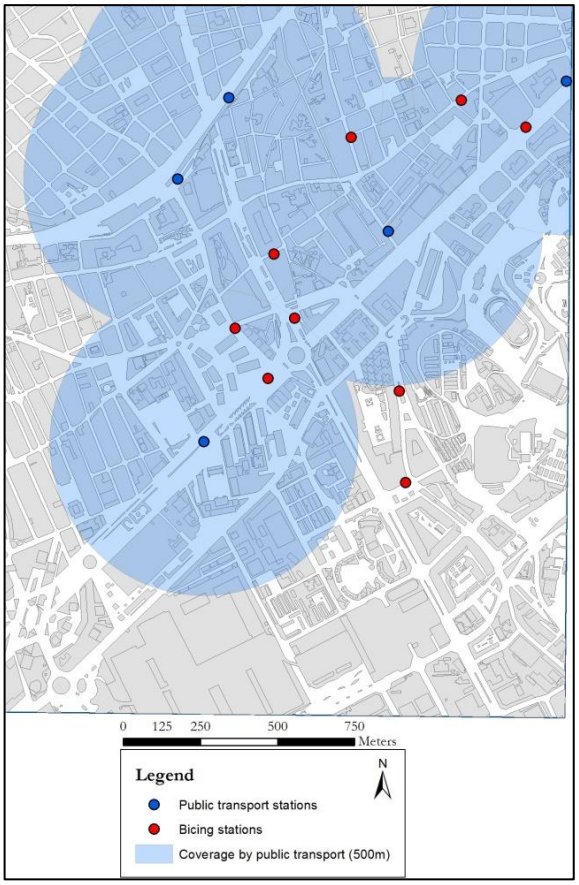


Figure 30. Coverage of Magòria by public transport, walking distance of 500 m (own elaboration, base map source: www.icc.cat)

5.5.3. NUMBER OF STATIONS

This element is closely related to density and location of stations distribution and their proximity to points of interest. Existing examples show that the bicycle stations should not be located more than 300–500 m from important origins and destinations of traffic (Lin, Yang, and Chang, 2013). At Plaça de Catalunya number of stations got the average grade of 1.31 (Figure 31) meaning that the number is satisfying and the stations are easy approachable from all sides of the area (Figure 32). The area of Gràcia, related to number of stations, has an average grade of 2.37. This means that respondents in the survey consider that number of Bicing stations is insufficient and that coverage of the area by stations should be improved. At Magòria survey respondents stated by a grade of 2.69 that the number of stations (or at least distribution) does not satisfy their needs. Figure 32 shows the density of Bicing stations, which is mostly high and as that, stated in the survey results. Bicing stations at Gràcia (Figure 33) are not so densely distributed at the area. Hence, the respondents in the survey in average graded it with medium satisfaction level. At Magòria (Figure 34), among these three locations, Bicing stations are the least densely distributed, which received the highest level of dissatisfaction by the users who participated in the survey.

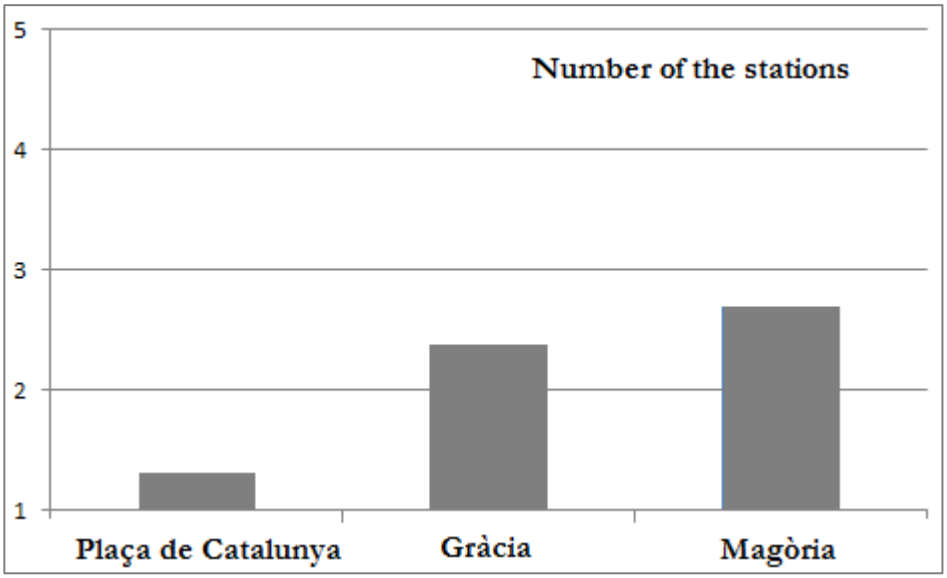


Figure 31. Average grade of number of stations

The number of stations in the central business area is normally higher than in other areas. It is also crucial for the success of the system that users can easily find bicycle stations within a convenient walking distance. The system needs a sufficient number of bicycle stations to be positioned in the right locations for users to take a bicycle near their origins and to park it in a station near their destinations (Lin, Yang, and Chang, 2013).

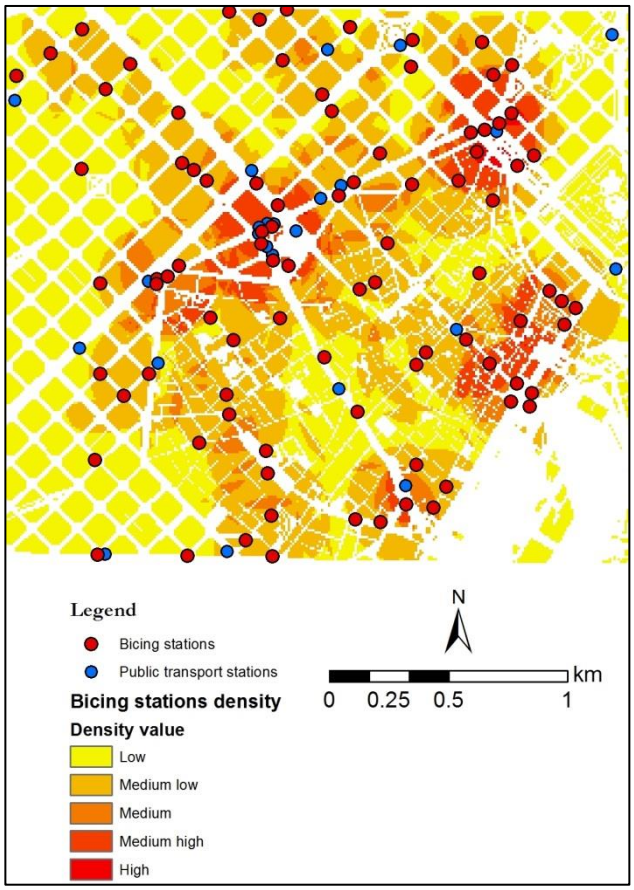


Figure 32. Density of Bicing stations at Plaça de Catalunya (own elaboration, base map source: www.iccc.cat)

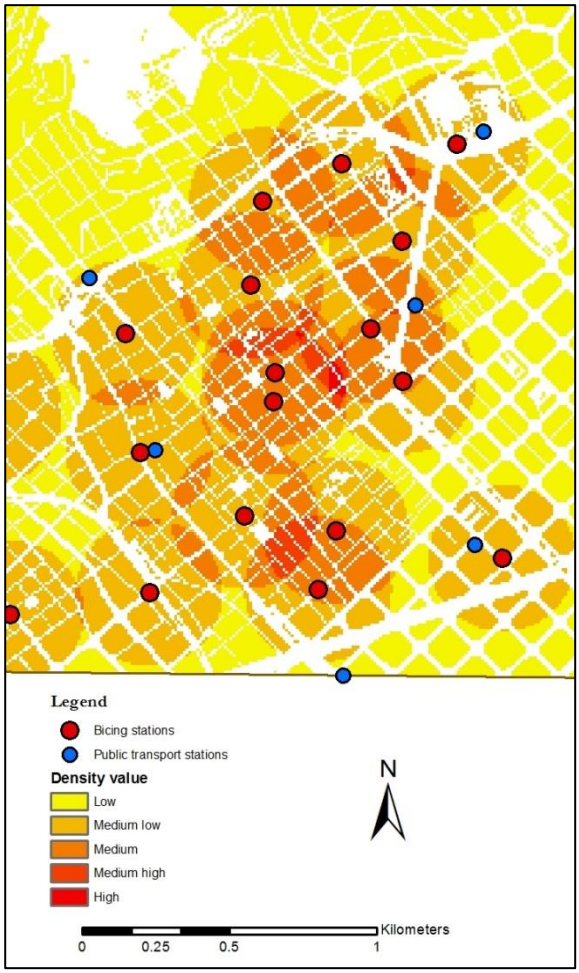


Figure 33. Density of Bicing stations at Gràcia (own elaboration, base map source: www.iccc.cat)

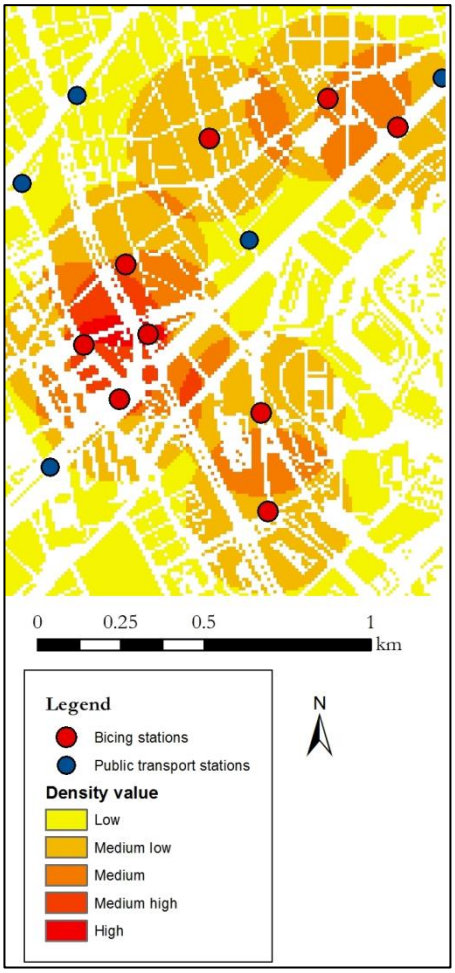


Figure 34. Density of Bicing stations at Magòria (own elaboration, base map source: www.iccc.cat)

5.5.4. BICING STATIONS' PROXIMITY TO PUBLIC TRANSPORT STATIONS

The location of a public transport stop or station can have a substantial influence on the level of bike-and-ride. Faster and higher quality types of public transport, such as train and buses, attract more bike-sharing users than slower and lower quality types of public transport, and according to that future policies need to pay additional attention on combined use of bicycle and public transport, which can be encouraging factor for bike-sharing users (Martens, 2004). According to that, the closer the Bicing stations are to public transport stations, the more it will encourage people to use Bicing and combine it with other modes of transport. At Plaça de Catalunya the proximity to public is graded as excellent (1.27) since the area contains stations of all types of public transport in Barcelona, no further than 100 m (Figure 32). At Gràcia the situation is quite worse since public transport stations are poorly distributed over the area, resulting in a grade of 3.08, i.e. combination of public transport and Bicing is not easy to manage. The reason for such situation is that Gràcia is less populated than other neighbourhoods of Barcelona, and that movement of its residents is mostly limited and

expected to be inside the neighbourhood. Magòria has a similar grade as Gràcia (3.07) resulting in dissatisfaction of Bicing users by Bicing stations' proximity to public transport. Urban form and location of Magòria as a transit point within the city results in a lower number of both Bicing and public transport stations, but also their spatial balance.

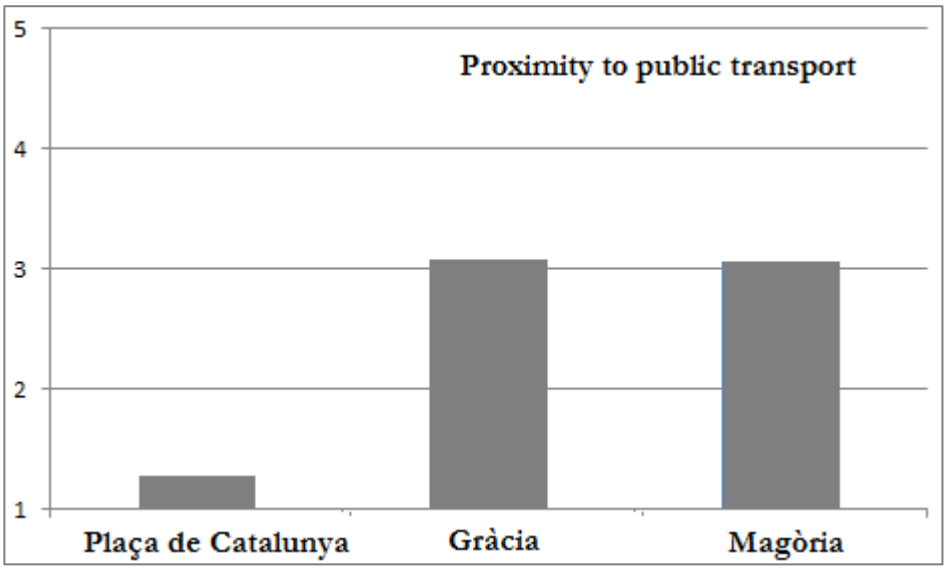


Figure 35. Average grade of distance to the public transport

5.5.5. PRICE OF BICING SERVICE

The price of the Bicing service (which is on annual basis) has no connection with an urban form of any part of the city, but with expectations and quality of service. The respondents at all three locations considered the price as relatively acceptable (grade 2.32, 1.85 and 1.89) as it can be seen on Figure 33. The main remark of the users was the duration of free-of-charge usage of the system, as well as the amount of penalties after exceeding half an hour of usage, often caused by system failures, like unavailability of free parking slots.

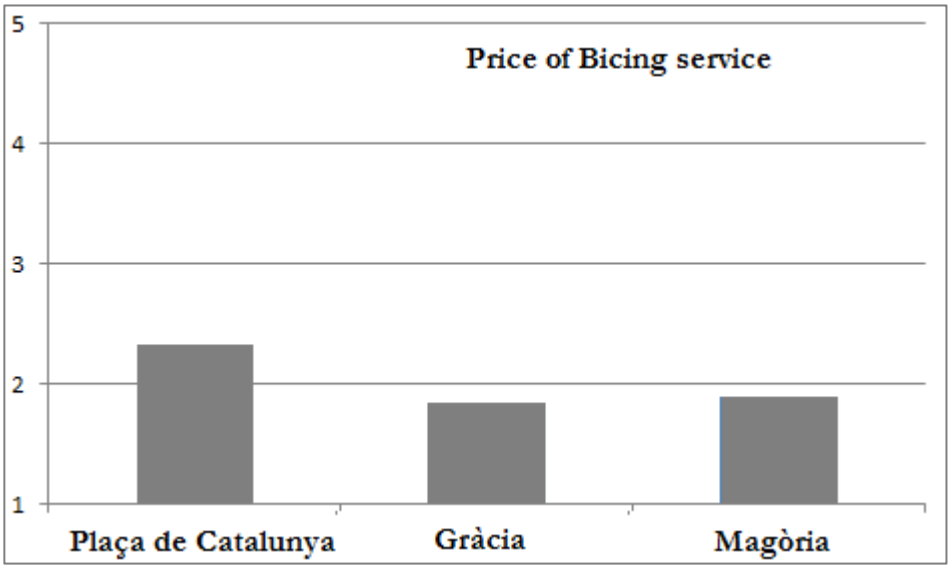


Figure 36. Average grade of the price of Bicing service

5.5.6. ACTIVITIES PRESENT AT THE AREAS

Activities and functions at any area sometimes can be very important for attracting people to come to a certain area. Temporal constraints lead people to rely more often to the local scale, in search of easily accessible opportunities, available inside their micro location (Marquet and Miralles-Guasch, 2014). According to that, Plaça de Catalunya offers to its residents many functions and contents, which makes often unnecessary for them to leave the area (Figure 34). That was confirmed by the survey also; where respondents indicate that this location offers them a variety of activities, which was graded with 1.53. The bicycle circulation is expected to decrease when we go farther from central business district, since restaurants, other commercial activities, and universities near a station significantly affects the arrival and departure rates of the bike-sharing system station (Faghih-Imani, Eluru, El-Geneidy, Rabbat, and Haq, 2014). According to the previous statement, it is clear that any location far from Plaça de Catalunya will have less satisfying results related to activities and contents present at a certain location. At Gràcia, the average grade of present activities is 1.26, which is understandable when it is taken into account that the majority of respondents are situated at Gràcia and they find all their daily needs here. On the other hand, 66.3% of users questioned belong to the age group from 18 to 25, and 67.1% of the respondents here use Bicing for recreation, fun and work. Exactly these activities make Gràcia specific and acceptable for this age group and their needs. At Magòria the satisfaction with contents and activities is quite low (average grade is 2.99), since the majority of daily needs and obligations have to be found elsewhere in the city.

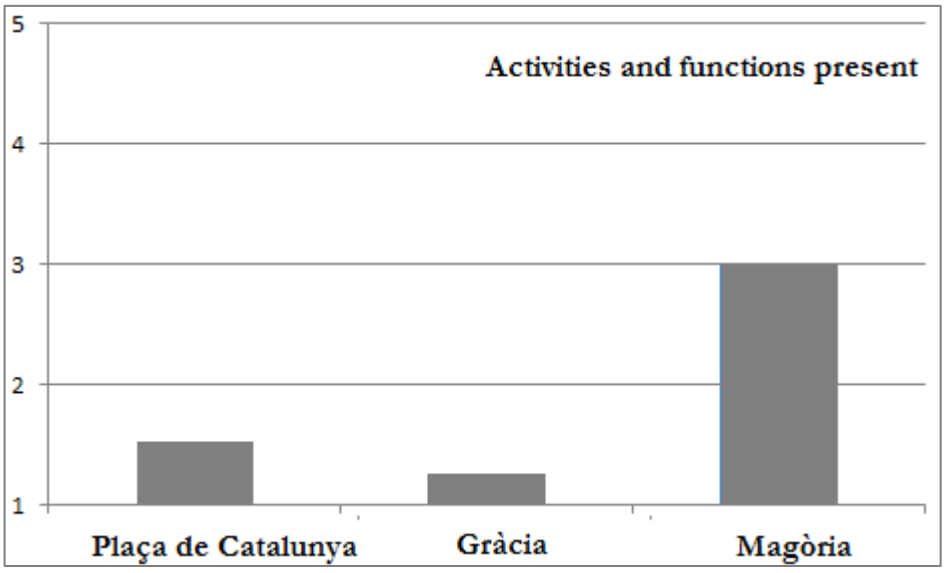


Figure 37. Average grade of the activities present

5.5.7. AMOUNT OF PEOPLE PRESENT AND PASSING BY THROUGH AREA

The amount of people present at any area makes the area attractive until a certain point. Plaça de Catalunya, its urban form and activities makes this location extremely attractive. Here, this element was graded with 3.67 making it very unsatisfying for cyclists and cycling, since that amount of people makes biking at Plaça de Catalunya almost impossible. Besides that, absence of bike lanes that would physically separate cyclists and other people present here, makes this issue very important (Duarte, 2007). Gràcia does not have problems related to the amount of people present, since it is popular as a quiet and peaceful area and obtained the grade of 1.24, as shown on Figure 35. Magòria faces problems related to the amount of people passing by, in this case not pedestrians but the number of vehicles (average grade of 2.33), which is closely related to safety and its perception that will be explained in further text.

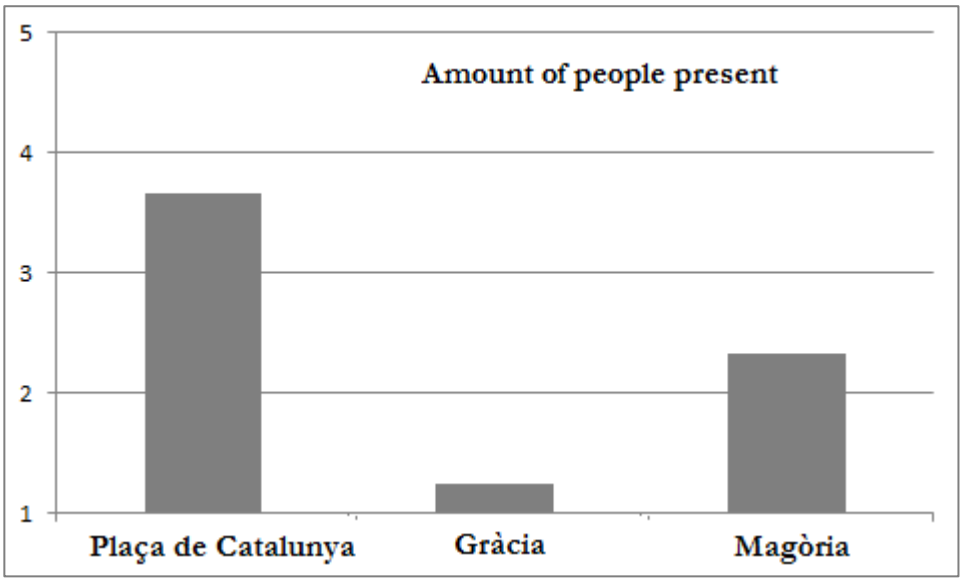


Figure 38. Average grade of the amount of people present

5.5.8. SAFETY OF CYCLISTS

Safety in all three areas is graded as quite satisfying (Figure 36) since the grades are 1.98, 1.45 and 1.65. The traffic volume and proximity between bicycle infrastructures and motorized traffic are directly related with the perceived security and cyclist's comfort.

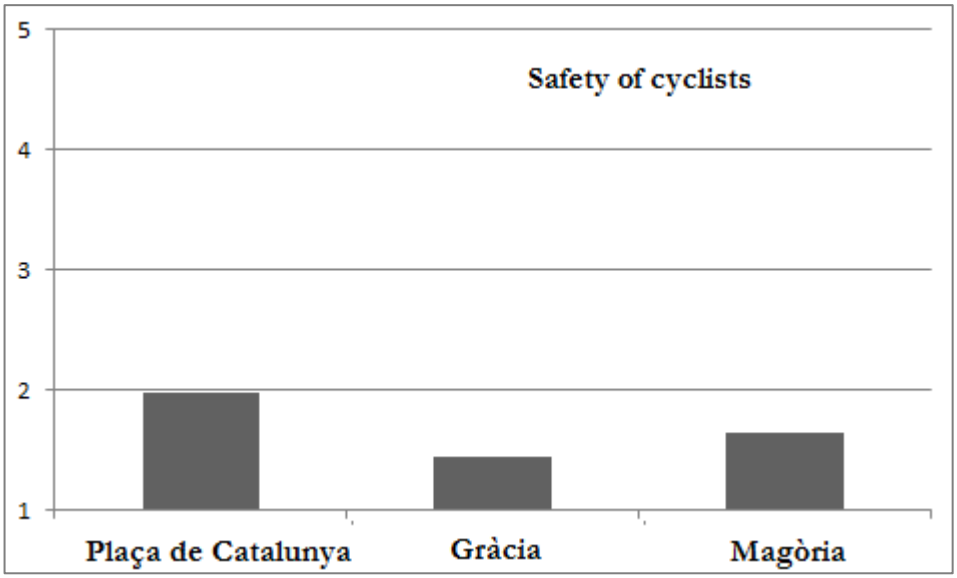


Figure 39. Average grade of the safety of cyclists

On the other hand, there are studies that state that an increase in available bicycle infrastructures will cause a rise in the number of cyclists, e.g. if more bicycle lanes are built, it is expected that the population will use them. The reason for this is that the presence of a bike lanes can increase a cyclist's perceived security (Romero, Ibeas, Moura, Benavente, and Alonso, 2012). In fact, when people talk about traffic safety, there are two meanings in their words, actual safety and perceived safety. Actual safety is based on number of accidents, while perceived safety represents a person's subjective feeling of safety and it is not necessarily the same as actual safety. For example, providing separate bicycle infrastructure increases perceived safety, even if it is not clear whether actual safety is improved. But potential and future bicycle users prefer to have separate bike lanes (Liu, Jia, and Cheng, 2012).

5.5.9. AVAILABILITY OF FREE BIKES AND FREE PARKING SLOTS

The two biggest problems detected, which cause user frustration, are the impossibility to find a bike when a user wants to start his/her journey and the impossibility to leave the bike in the user's destination due to full stations (Kaltenbrunner, Meza, Grivolla, Codina, and Banchs, 2010). In this survey also these two factors are stated as the biggest obstacle for Bicing users. Availability of free bikes got grades (Figure 37) at Plaça de Catalunya 2.47, at Gràcia 3.14 and at Magòria 1.69.

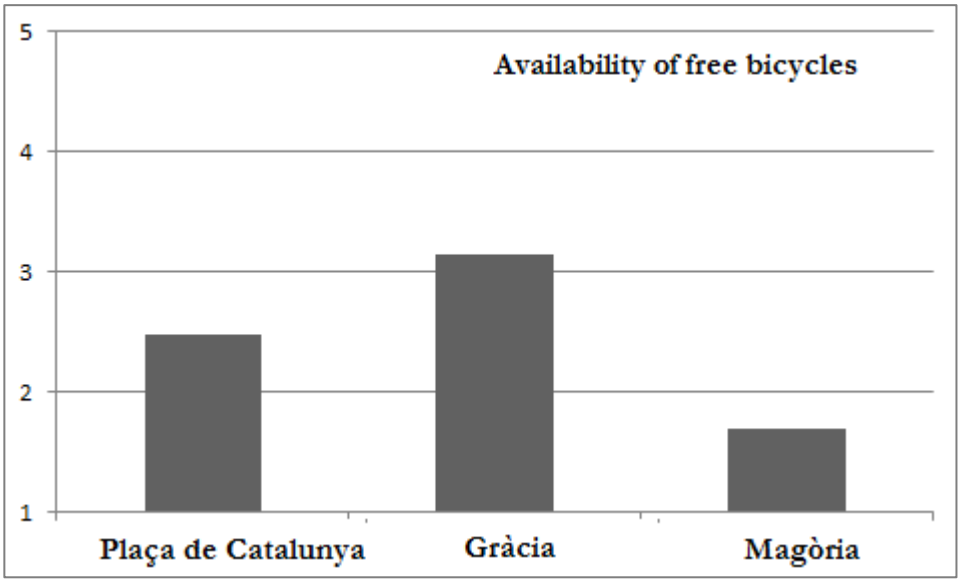


Figure 40. Average grade of the availability of bikes

At Plaça de Catalunya the reason for being unable to take a free bike or park a bike is the fact that there is a high number of users during the day, while at Gràcia users happily take bicycles downhill into town but take other modes of transportation to go back uphill, leaving the bicycles behind, which is related to the location's topography (Midgley, 2011). At Magòria there are enough free bikes for users, since the area is not popular among Bicing users, so the frequency of usage is low. Unavailability of parking the bikes is an enormous problem for all areas since it got grades 3.7, 3.85 and 2.51, making it the biggest obstacle at Gràcia and Plaça de Catalunya (Figure 38).

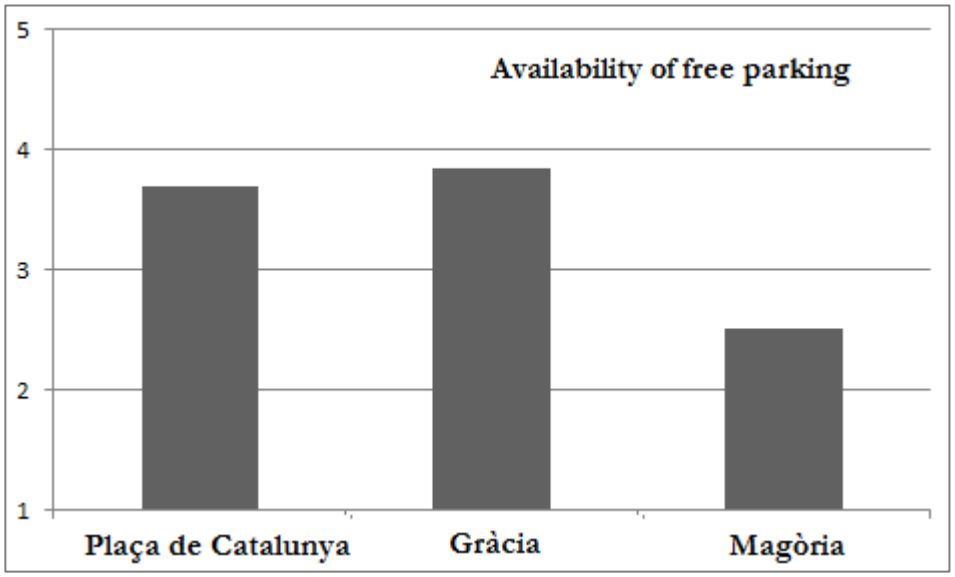


Figure 41. Average grade of the availability of free parking

5.5.10. PHYSICAL STATE OF BICING BICYCLES

The physical state of bicycles is related directly to certain parts of the city, even though vandalism is more present at central parts of the city. Average grades of this element are 1.85, 1.81 and 1.37. According to the survey the physical state of bicycles is not an obstacle for Bicing users (Figure 39). Nevertheless, theft and vandalism have run higher than expected in Barcelona, where the operator has replaced thousands of bicycles at a cost of 3 to 6 million euros per year, also affecting some users who took a bike inadequate for usage due to vandalism (Antoniades and Chrysantho, 2009).

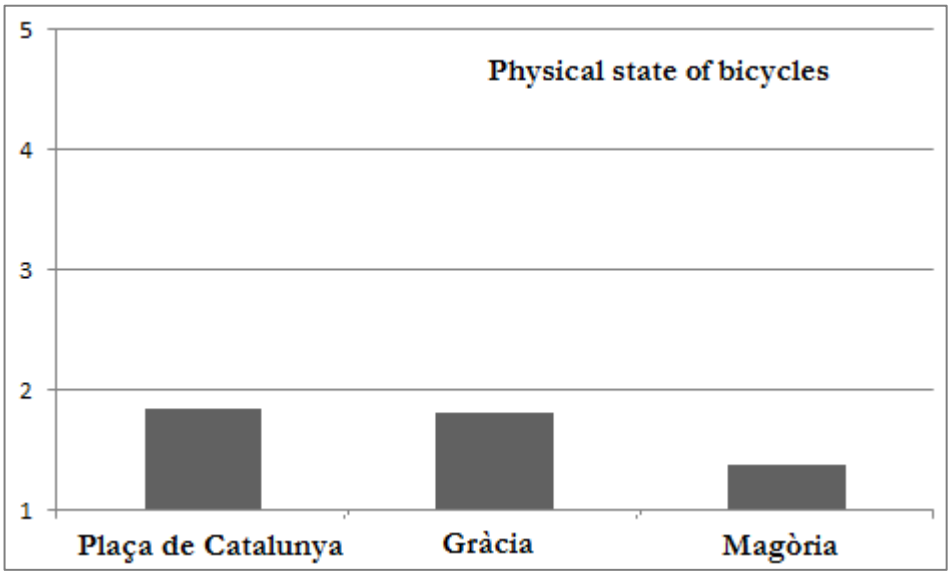


Figure 42. Average grade of the physical state of bikes

5.6. DISCUSSION OF THE FIELDWORK RESULTS AND BARCELONA'S SOCIAL CHARACTERISTICS

In 2012, Barcelona city centre had 1.6 million inhabitants, one million of them being of working age (16–64 years old). In Barcelona, 353.078 people between the ages of 16 and 64 years have no access to a car. This accounts for 37% of the total population in this age range. Depending exclusively on walking, biking and public transport does not make them move less; furthermore, they are responsible for 41% of the total trips made every day (Catalán, Saurí, and Serra, 2008). This fact explains why the highest number of the survey respondents belongs to "working age". Besides that, the age group is strongly related to the purpose of not only Bicing, but daily trips in general. According to that, in all three locations in the city the main trip purpose by Bicing are education, work and recreation/fun, shown in Table 3. Education and work are trip purposes that require constant, strong and fast connection of all transport modes from an origin to a destination. Bicing stations and its proximity to public transport stations are extremely crucial for this age group of Bicing users, so it is not surprising that the highest dissatisfaction of this element is experienced by this age group at Gràcia and Magòria, and high satisfaction at Plaça de Catalunya. As previously stated safety is partly considered as physical separation from other participants in traffic (Liu, Jia, and Cheng, 2012). When it is taken into account that Plaça de Catalunya does not have enough bike lanes (Table 2) and at the same time has a very high number people present at the area, it is understandable that at this location perception of safety is worse than at Gràcia or Magòria, which was the result of the survey, related to safety. Since the majority of respondents use Bicing for reaching work or education institutions it is understandable that they need Bicing stations that are not more than 500 m away from public transport stations or their final destination (Lin, Yang, and Chang, 2013). According to that, the results of the survey where users of Bicing at Plaça de Catalunya have the biggest reason to be satisfied with location of Bicing stations (which is proven in the survey), while on the other hand Bicing users at Gràcia and Magòria have more issues reaching certain transport mode or final destination, which was stated in the survey made in these areas.

Table 2. Satisfaction and spatial characteristics in three different areas

The aspects affected by spatial characteristics / **Urban area**	**Plaça de Catalunya**	**Gràcia**	**Magòria**
Presence of bike lanes	**Dissatisfaction by the users**	**Medium satisfaction by the users**	**Medium satisfaction by the users**
Bike lanes and their width	**Partly present** (average width: 80cm)	**Not present**	**Partly present** (average width: 70cm)
Location of stations	**Satisfaction by the users**	**Dissatisfaction by the users**	**Dissatisfaction by the users**
Distance from Bicing to public transport stations	**Less than 100m**	**More than 500m**	**More than 500m**
Number of stations	**Satisfaction by the users**	**Medium satisfaction by the users**	**Dissatisfaction by the users**
Distance from public transport	**Satisfaction by the users**	**Dissatisfaction by the users**	**Dissatisfaction by the users**
Availability of bikes	**Medium satisfaction by the users**	**Dissatisfaction by the users**	**Satisfaction by the users**
Availability of parking	**Dissatisfaction by the users**	**Dissatisfaction by the users**	**Dissatisfaction by the users**

Satisfaction by the users (grade from 1 to 1.8)
Medium satisfaction by the users (grade from 1.81 to 2.5)
Dissatisfaction by the users (grade from 2.51 and more)

Table 3. Satisfaction and social characteristics in three different areas

The aspects affected by social characteristics	**Urban form**	**Plaça de Catalunya**	**Gràcia**	**Magòria**
Activities present at the location		**Satisfaction by the users**	**Satisfaction by the users**	**Dissatisfaction by the users**
Amount of people present at the location		**Dissatisfaction by the users**	**Satisfaction by the users**	**Medium satisfaction by the users**
Safety		**Medium satisfaction by the users**	**Satisfaction by the users**	**Satisfaction by the users**
Main age group of Bicing users		**18 – 35** (89.5%)	**18 – 35** (97.1%)	**18 – 35** (91.1%)
Main trip purpose using Bicing		**Education and work**	**Work and recreation**	**Education and work**
The most frequent number of Bicing usage per week		**2-4 times** (47.4%), **5-7 times** (35.5%)	**2-4 times** (49.4%) **5-7 times** (38.3%)	**2-4 times** (52.7%), **5-7 times** (32.4%)
Average trip length		**15.95 min**	**20.19 min**	**20.99 min**

Satisfaction by the users (grade from 1 to 1.8)

Medium satisfaction by the users (grade from 1.81 to 2.5)

Dissatisfaction by the users (grade from 2.51 and more)

6. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSIONS

This research had the main objective to identify spatial, social and physical aspects that can explain the functioning of Bicing. According to that, using relevant literature, many factors were defined and identified, but only the most important and most relevant ones were selected for further research. Related to spatial aspect, following factors were selected: presence or absence of bike infrastructure, location and number of Bicing stations; and proximity of Bicing stations to public transport stations. Social factors in the research are: price of Bicing service, activities and functions present at locations, amount of people present and passing by through area; and perception of safety of cyclists. Physical aspects are consisted of availability of free bicycles and parking, but also physical state of bicycles.

Since the study areas were three different locations within the city of Barcelona, hence the aspects and their influence on Bicing users vary. According to their effect, at Plaça de Catalunya the biggest influence on Bicing users have unavailability of free bicycles and parking slots, but also the amount of people that is present and passing by through this central business area. At Gràcia the most influential aspects are unavailability of free bikes and parking slots, but at the same time it was proven that the location of Bicing stations are inappropriate according to the respondents in the survey. Like at Gràcia, also at Magòria the location of Bicing stations are also inadequate, especially in a relation with public transport. In addition, respondents in the survey expressed their dissatisfaction with activities and functions that are present or missing at this area. According to previously stated, unavailability of free parking slots and free bicycles have to be centre of future system analysis and eventual improvement, since the availability of parking and bikes make the spine of functionality of all bike-sharing system (Raviv and Kolka, 2013).

The characteristics of spatial aspects vary according to a location of the certain city part. This means that the Bicing users' needs need to be tailored according to the specific locations, since they cannot be applied in the same way throughout the city. In a relation to that, Plaça de Catalunya was characterised as an area with appropriate locations of Bicing stations and their proximity to public transport stations, but at the same time, Plaça de Catalunya is lacking biking infrastructure, which is important obstacle for Bicing users according to infrastructure's encouraging effect on bikers (Faghih-Imani, Eluru, El-Geneidy, Rabbat, and Haq, 2014). At Gràcia and Magòria, spatial factors have different dimension, i.e. location of Bicing stations and their number are inadequate, but even though there are missing bike lanes, it does not have huge negative effect on the users of this bike-sharing system at these locations. However, special focus on Bicing functioning at Gràcia and Magòria need to be put on stations locations, as one of the crucial element of successful functioning of any bike-sharing system (Martens, 2007).

The social factors are proven to have an important effect in all three study areas for Bicing users. The aspects that have common and similar value in all three zones are safety and price of the service, which are considered that do not have enormous negative effect. On the other hand, at Plaça de Catalunya amount of people present and passing by through the area have very important negative effect on Bicing users, a little bit less at Magòria, but not at all at Gràcia. Vice versa, activities and functions at areas have no

negative effect at Plaça de Catalunya and Gràcia, but it presents an obstacle for current users of Bicing at Magòria. Lack of attractive points of interest of citizens at Magòria, negatively influences presence of not only Bicing users, but visitors in general (Marquet and Miralles-Guasch, 2014).

According to the results of the survey made on the fieldwork and research in general, recommendations for Bicing's improvement are made and presented. Recommendations and suggestions are based on both specific Barcelona case, on the city level and on specific locations, but at the same general directions for improvement that can be applied on Bicing and other bike-sharing systems that face the same or similar issues.

6.2. DIRECTIONS AND SUGGESTIONS FOR IMPROVEMENT OF BICING'S PERFORMANCE BY ELEMENTS PRESENTED IN FIELDWORK SURVEY ON SPECIFIC LOCATIONS

- **BICYCLE INFRASTRUCTURE** – Biking infrastructure is one of the crucial elements of any bike-sharing system. Bike lanes not only make physical space for bicycle usage but they also physically separate bikers from the rest of the traffic participants. That is closely related to **SAFETY** of cyclists, but at the same time, it has an enormous effect on perception of safety of all current and potential bikers in the future. The demand for additional bike lanes is especially visible at Plaça de Catalunya (according to the survey) where interviewed Bicing users expressed their dissatisfaction by current network of bike lanes. At this location it is very important since the Bicing users are dealing with a huge number of pedestrians and vehicles, very often preventing them from cycling without obstacles. Sharing the road with pedestrians and vehicles is closely related to perception of safety, especially among younger Bicing users. At Magòria Bicing users are facing the same issue, but in this case their problem is sharing road with vehicles, since the amount of pedestrians is not enormous. According to that, Barcelona's bike network is lacking bicycle infrastructure on many locations, but most important ones are the central areas with the highest number of traffic participants and with the most intensive traffic in general. Some of the locations that should be first in a line for a future bike lane construction are central business areas (Plaça de Catalunya, Plaça de Espanya and Plaça de Universitat), but also areas around important touristic attractions, in order to separate cyclists and increasing number of tourists in Barcelona. Another possible solution for improving the quality of bike infrastructure is to transform existing vehicle roads. This transformation can include closing certain roads for vehicles, so that those roads can be used for biking. Mentioned improvement can be conducted full time, or the roads can be closed for vehicles at certain part of day or week (e.g. in the afternoon or on weekends).
- **LOCATION OF BICING STATIONS** – One of the essential aspects of functioning of Bicing is the location of its stations. They should be only placed near the important buildings and objects, but also to make it as an extension of public transport since the use of public bicycles increases potentially when they are complemented with other transportation modes

(Frade and Ribeiro, 2014). At Gràcia and Magòria Bicing users marked current locations of Bicing stations as inappropriate and insufficient according to their distance from public transport stations and their points of daily interest (work, education and recreation). For bicycle-sharing to be an attractive option in any city, the following urban mobility element is essential: an effective public transport system which can be integrated physically and operationally with bike-sharing (Midgley, 2011). According to that, new stations and the existing ones should be situated to form a bridge between public and transport in general, and points of interest of all Bicing users, like schools, universities and shopping centres. This requires an evaluation of every neighbourhood separately, and its characteristics in order to obtain adequate location of each bike-sharing system station. Hence, it cannot be done on a city level. For bike-sharing stations in the hilly parts of the city, electric bicycles can be introduced in order to popularise bike-sharing system in these areas. According to that, stations for electric bicycle need to be different from the regular ones, in order to prevent users from using electric bikes in areas suitable for regular biking (plane areas).

- **PRICE OF BICING SERVICE** – Annual price of Bicing today is not an issue for its users. The fact that affects users is the amount of penalties that Bicing users need to pay after exceeding the half an hour free usage. This can be improved easily by increasing the free usage time, even partly, where it is known that the problems of unavailability of free parking occur, i.e. give an opportunity to use Bicing bikes longer than usual if used on certain areas of the city, like it is done in Paris (Antoniades and Chrysantho, 2009). Certain discounts for some group of people can be provided, for example, students or retired persons. This aspect has no direct connection with individual characteristics of locations, but the system and the city in general.

- **AVAILABILITY OF FREE BIKES AND PARKING** – This element is considered, and proven in this survey, as the most problematic for Bicing users since these aspects were marked as unsatisfying at all three locations, making it in top three biggest obstacles for users of this bike-sharing system. If we take a look into other bike-sharing systems some solutions can be applied. To encourage people to return bikes to underused stations, Paris recently announced a 15-minute credit for returning bicycles to specific stations, particularly those on hills (Antoniades and Chrysantho, 2009). By this, not only the issue of free bikes and parking can be improved, but also an element related to price and situation at the stations uphill and downhill (Gràcia). Also, without oversizing the system, there are basically two ways to solve these problems: inform the user in advance about the best places to pick up or leave the bikes and improve the redistribution of bikes from full to empty stations. (Kaltenbrunner, Meza, Grivolla, Codina, and Banchs, 2010). Besides mentioned, an analysis can be done of the whole system in order to define the most problematic stations (related to parking and bike availability) and intensify the redistribution of bicycles by trucks in certain locations. Increasing the number or capacity of stations at the most popular locations can be one of the

steps of resolving this important issue. Also, in situation where a certain station has no free bicycles of free parking slots, stations themselves can inform a user about closest bike-sharing station with free bikes or available parking, using GPS tools.

- **ACTIVITIES PRESENT AT THE AREAS** – In survey conducted at the location of Magòria users expressed their dissatisfaction with activities present at this area. In other words, respondents stated that Magòria region does not have enough activities or functions that would attract people to come here (in this case using Bicing) and that people who live here need to go other parts of the city to fulfil their daily needs. On the other hand, Bicing users at Plaça de Catalunya showed their frustration by enormous amount of people they face on daily basis. The both issues can be solved by long term planning and reconstruction of these city parts. According to this Magòria region can be enriched by additional activities like shopping centres, education institutions or some other points of interest that local population need. By doing this not only that Magòria will be more interesting and attractive for Bicing users, but also it would lead to relieving of people present at Plaça de Catalunya to Magòria. These mentioned actions should be part of future plans for both areas, but also the city in general.
- **PHYSICAL STATE OF BICYCLES** – Even though survey respondents at all three locations expressed their satisfaction with physical state of Bicing bicycles, still there are people who dealt with bicycle inappropriate for riding. Most of the defects and damages on these public bikes are caused by vandalism, which leads us to another possible intervention in order to improve Bicing service. As it is the case with many points of public good, also Bicing stations can be put and protected by video surveillance. By doing this not only Bicing users will face less technical problems with bikes, but also it will decrease expenses of city council for reparation of Bicing fleet.

6.3. GENERAL DIRECTIONS AND SUGGESTIONS FOR IMPROVEMENT OF BICING'S PERFORMANCE ON A CITY LEVEL

General directions for Bicing improvement are the result of, in the first place, the survey and the opinion of the respondents about many Bicing elements, but they are also based on the literature where experiences from other bike-sharing systems are described.

For cities, who consider the introduction of bike-sharing systems, some key conditions for implementation are:

- promotion of bike-sharing and cycling in general;
- bicycle infrastructure;
- guaranteed available bicycles at the stations (Midgley, 2009).

When taking into account a bigger picture of metropolitan region of Barcelona, it is clear that there are many neighbourhoods, or their parts, which are not covered by Bicing service. That means that authorities should consider possible extension and sprawl of Bicing in order to increase number of users, but also the profit. But before doing that there should be made detailed analysis of potential demand and need for Bicing, since at the fieldwork we have witnessed many stations that are very rarely used due to lack of demand or inadequate position of the station within the city. Besides that, making Bicing stations more dense can be an improvement, or increasing the capacity of certain stations that are analysed before and proved that need some type of change, in this case increase of capacity.

In cooperation with different levels of authorities, improvements can be made in prevention of vandalism and other types of damage of the Bicing system, by paying attention to better supervision of its inventory.

Informing the population and potential users about Bicing, its advantages, but also biking in general can be of great importance for this bike-sharing system. Therefore, the greatest impact on public bike users' perceived quality will be achieved by improving these two factors: safety and information (Bordagaray, Ibeas, and dell'Olio, 2012).

Finally, this research gives an insight into which elements should be evaluated on city level and which ones need attention on neighbourhood level. However, combinations of both of these approaches have to be considered, at first, during planning, later during implementation and, in the end, during the eventual improvement of any bike-sharing system.

LIST OF REFERENCES

Ajuntament de Barcelona (2013). *Estadística.* Retrieved December 08, 2014, from http://www.bcn.cat/estadistica/angles/

Ajuntament de Barcelona, Barcelona de Serveis Municipals, S.A. (2014). *Información Bicing.* (URL: https://www.bicing.cat/es/content/%C2%BFqu%C3%A9-es-bicing, accessed 2014-May-23)

Antoniades, P., & Chrysantho, A. (2009). European best practices in bike sharing systems. *T. aT.-Students Today, Citicens Tomorrow*, (June). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:European+Best+Practices+in+Bike+Sharing+Systems#0

Bordagaray, M., Ibeas, A., & dell'Olio, L. (2012). Modeling User Perception of Public Bicycle Services. *Procedia - Social and Behavioral Sciences*, *54*, 1308–1316. doi:10.1016/j.sbspro.2012.09.845

Brunet, F. (1995). An economic analysis of the Barcelona '92 Olympic games: resources, financing and impact. Retrieved December 02, 2014, from http://olympicstudies.uab.es/pdf/od006_eng.pdf

Catalán, B., Saurí, D., & Serra, P. (2008). Urban sprawl in the Mediterranean? *Landscape and Urban Planning*, *85*(3-4), 174–184. doi:10.1016/j.landurbplan.2007.11.004

Corcoran, J., Li, T., Rohde, D., Charles-Edwards, E., & Mateo-Babiano, D. (2014). Spatio-temporal patterns of a Public Bicycle Sharing Program: the effect of weather and calendar events. *Journal of Transport Geography*, *41*, 292–305. doi:10.1016/j.jtrangeo.2014.09.003

Duarte, C. (2007). Transforming metropolitan Barcelona: between the postindustrial and the knowledge city. *International Conference, Sustainable Urban Areas,* …. Retrieved from http://www-cpsv.upc.es/documents/W11_paper_Marmolejo.pdf

Invest in Barcelona. (2014). *Economy of Barcelona*. Retrieved December 08, 2014, from http://investinbarcelona.com/economy

El web de la ciutat de Barcelona. (2014). Retrieved December 04, 2014, from http://www.bcn.cat/

Faghih-Imani, A., Eluru, N., El-Geneidy, A. M., Rabbat, M., & Haq, U. (2014). How land-use and urban form impact bicycle flows: evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography*, *41*(August 2012), 306–314. doi:10.1016/j.jtrangeo.2014.01.013

Frade, I., & Ribeiro, A. (2014). Bicycle Sharing Systems Demand. *Procedia - Social and Behavioral Sciences*, *111*, 518–527. doi:10.1016/j.sbspro.2014.01.085

Frank, L., Bradley, M., Kavage, S., Chapman, J., & Lawton, T. K. (2007). Urban form, travel time, and cost relationships with tour complexity and mode choice. *Transportation*, *35*(1), 37–54. doi:10.1007/s11116-007-9136-6

Garcia-López, M.-À., & Muñiz, I. (2012). Urban spatial structure, agglomeration economies, and economic growth in Barcelona: An intra-metropolitan perspective*. *Papers in Regional Science*, *92*(3), no–no. doi:10.1111/j.1435-5957.2011.00409.x

García-Palomares, J. C., Gutiérrez, J., & Latorre, M. (2012). Optimizing the location of stations in bike-sharing programs: A GIS approach. *Applied Geography*, *35*(1-2), 235–246. doi:10.1016/j.apgeog.2012.07.002

Handy, S. L., Xing, Y., & Buehler, T. J. (2010). Factors associated with bicycle ownership and use: A study of six small U.S. cities. *Transportation*, *37*, 967–985. doi:10.1007/s11116-010-9269-x

INE. (2012). *Population of Barcelona*. Instituto Nacional de Estadistica. Retrieved from http://www.ine.es/jaxi/tabla.do

Kaltenbrunner, A., Meza, R., Grivolla, J., Codina, J., & Banchs, R. (2010a). Urban cycles and mobility patterns: Exploring and predicting trends in a bicycle-based public transport system. *Pervasive and Mobile Computing*, *6*(4), 455–466. doi:10.1016/j.pmcj.2010.07.002

Kaltenbrunner, A., Meza, R., Grivolla, J., Codina, J., & Banchs, R. (2010b). Urban cycles and mobility patterns: Exploring and predicting trends in a bicycle-based public transport system. *Pervasive and Mobile Computing*, *6*(4), 455–466. doi:10.1016/j.pmcj.2010.07.002

Lin, J.-R., & Yang, T.-H. (2011). Strategic design of public bicycle sharing systems with service level constraints. *Transportation Research Part E: Logistics and Transportation Review*, *47*(2), 284–294. doi:10.1016/j.tre.2010.09.004

Lin, J.-R., Yang, T.-H., & Chang, Y.-C. (2013). A hub location inventory model for bicycle sharing system design: Formulation and solution. *Computers & Industrial Engineering*, *65*(1), 77–86. doi:10.1016/j.cie.2011.12.006

Liu, Z., Jia, X., & Cheng, W. (2012). Solving the Last Mile Problem: Ensure the Success of Public Bicycle System in Beijing. *Procedia - Social and Behavioral Sciences*, *43*, 73–78. doi:10.1016/j.sbspro.2012.04.079

Marquet, O., & Miralles-Guasch, C. (2014a). The Walkable city and the importance of the proximity environments for Barcelona's everyday mobility. *Cities*, 1–9. doi:10.1016/j.cities.2014.10.012

Marquet, O., & Miralles-Guasch, C. (2014b). Walking short distances. The socioeconomic drivers for the use of proximity in everyday mobility in Barcelona. *Transportation Research Part A: Policy and Practice*, *70*, 210–222. doi:10.1016/j.tra.2014.10.007

Marshall, T. (2004). EBL Reader - Transforming Barcelona: The Renewal of a European Metropolis. Retrieved May 22, 2014, from http://ezproxy.utwente.nl:2181/(S(kpsw4vg2s1pjnww4pzp1sfhz))/Reader.aspx?p=200168&o=1200&u=wo0EbLQsMzC%2fvrodIuz66A%3d%3d&t=1400780630&h=CB6D3B0ABF5CE9E5EB8A5452E17C6ABBDF06B68B&s=23337340&ut=3997&pg=1&r=img&c=-1&pat=n&cms=-1#

Martens, K. (2004). The bicycle as a feedering mode: experiences from three European countries. *Transportation Research Part D: Transport and Environment*, *9*(4), 281–294. doi:10.1016/j.trd.2004.02.005

Martens, K. (2007). Promoting bike-and-ride: The Dutch experience. *Transportation Research Part A: Policy and Practice*, *41*(4), 326–338. doi:10.1016/j.tra.2006.09.010

Meng, M., Koh, P. P., Wong, Y. D., & Zhong, Y. H. (2014). Influences of urban characteristics on cycling: Experiences of four cities. *Sustainable Cities and Society*, *13*, 78–88. doi:10.1016/j.scs.2014.05.001

Midgley, P. (2009). The Role of Smart Bike-sharing Systems in Urban Mobility. *Journeys*, *19th Sessi*(8), 23–31. Retrieved from http://www.ltaacademy.gov.sg/doc/IS02-p23 Bike-sharing.pdf

Midgley, P. (2011). Bicycle-sharing schemes : enhancing sustainable mobility. *Commission on Sustainable Development*, *19*(8), 1–26.

Mut, C. (2010). *Valoració de la rendabilitat econòmica i social del Bicing a Barcelona*. Universitat Politècnica de Catalunya.

Nakamura, H., & Abe, N. (2014). Evaluation of the hybrid model of public bicycle-sharing operation and private bicycle parking management. *Transport Policy*, *35*, 31–41. doi:10.1016/j.tranpol.2014.05.009

Passafaro, P., Rimano, A., Piccini, M. P., Metastasio, R., Gambardella, V., Gullace, G., & Lettieri, C. (2014). The bicycle and the city: Desires and emotions versus attitudes, habits and norms. *Journal of Environmental Psychology*, *38*, 76–83. doi:10.1016/j.jenvp.2013.12.011

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: an international review. *Preventive Medicine*, *50 Suppl 1*, S106–25. doi:10.1016/j.ypmed.2009.07.028

Raviv, T., & Kolka, O. (2013). Optimal inventory management of a bike-sharing station. *IIE Transactions*, *45*(10), 1077–1093. doi:10.1080/0740817X.2013.770186

Romero, J. P., Ibeas, A., Moura, J. L., Benavente, J., & Alonso, B. (2012a). A Simulation-optimization Approach to Design Efficient Systems of Bike-sharing. *Procedia - Social and Behavioral Sciences*, *54*, 646–655. doi:10.1016/j.sbspro.2012.09.782

Romero, J. P., Ibeas, A., Moura, J. L., Benavente, J., & Alonso, B. (2012b). A Simulation-optimization Approach to Design Efficient Systems of Bike-sharing. *Procedia - Social and Behavioral Sciences*, *54*, 646–655. doi:10.1016/j.sbspro.2012.09.782

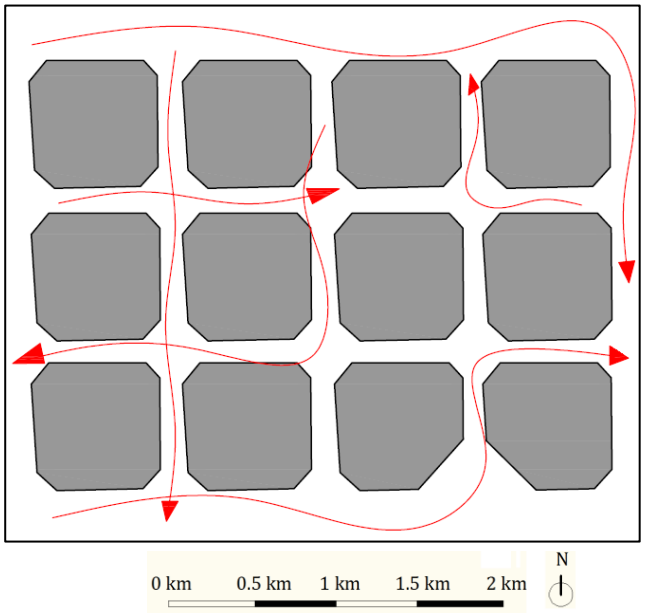
Schepel, S., & Zuidgeest, M. (2009). Cycling-Inclusive Policy Development : A Handbook form — and how urban form shapes us, (April).

7. APPENDICES

APPENDIX 1: Three selected urban forms relevant for research and their characteristics

- **NEW BARCELONA (PLAÇA DE CATALUNYA)**

Scheme 1: Scheme of typical urban form of the new Barcelona part (source: own elaboration)



Characteristics of urban area

Large and rapid fluctuation of people and traffic participants

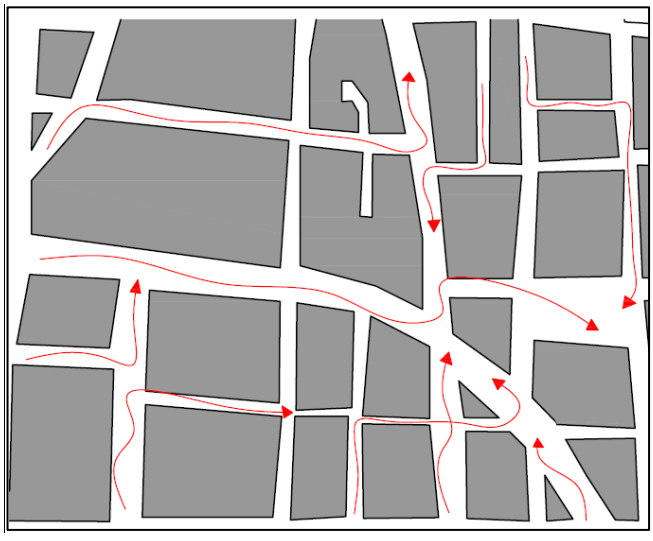
Area is mostly consisted out of business, education and cultural functions

High density and presence of population

Bike lanes are partly present

- **OLD BARCELONA (GRÀCIA)**

Scheme 2: Scheme of typical urban form of the old Barcelona part (source: own elaboration)



Characteristics of urban area

Large and rapid fluctuation of people and traffic participants

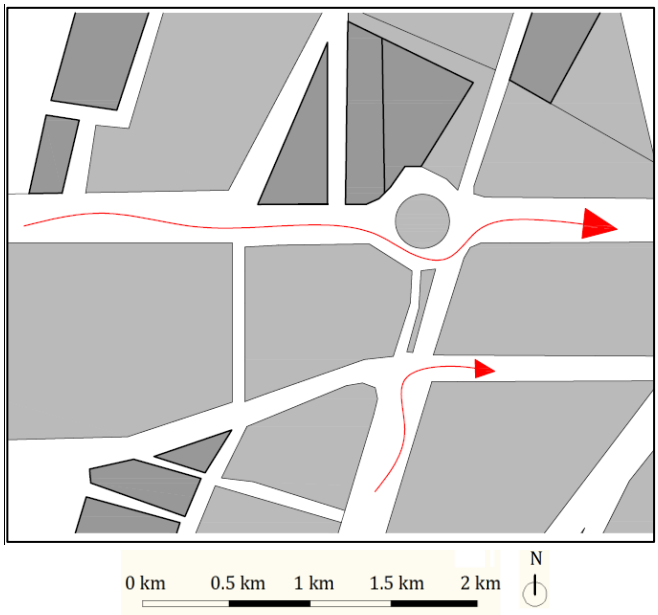
Area is mostly consisted out of collective and individual housing. Minor part involves business areas.

High density and presence of population

Bike lanes are not present and the roads are for mixed bicycle and vehicle use. Lanes' width is approx. 3.5 m.

- **SUBURB AREA (MAGÒRIA)**

Scheme 3: Scheme of typical urban form of the suburban Barcelona part (source: own elaboration)



Characteristics of urban area

Small and moderate fluctuation of people and traffic participants

Area is mostly consisted out of collective housing and green areas. Minor part involves business areas.

Low density and presence of population

Bike lanes are only partly present and the rest of roads are for mixed bicycle and vehicle use.

APPENDIX 2: Example of one conducted survey at Plaça de Catalunya (in Catalan)

ENQUESTA SOBRE L'ÚS DEL BICING

L'objectiu d'aquesta enquesta és identificar quins dels factors presentats tenen més influència (positiva o negativa) en els usuaris actuals del Bicing, a l'àrea de la Plaça de Catalunya.

PREGUNTA 1

1. QUINS ELEMENTS ET LIMITEN DE FER SERVIR EL BICING MÉS SOVINT EN AQUESTA ZONA?

1.1. Presència dels carrils bici
1.2. La ubicació de les estacions a la zona
1.3. El nombre d'estacions a la zona
1.4. La distància de les estacions fins al transport públic més proper
1.5. El preu del servei del Bicing
1.6. Els continguts i activitats presents en aquesta zona
1.7. La quantitat de la gent presenta i la gent passant per l'àrea
1.8. La seguretat per als ciclistes
1.9. Disponibilitat de les bicicletes lliures
1.10. La disponibilitat de places d'aparcament a les estacions
1.11. L'estat físic de les bicicletes del Bicing

PREGUNTA 2

2. QUINS FACTORS L'ANIMARIEN A FER SERVIR MÉS SOVINT EL BICING EN AQUESTA ZONA?

MÉS APARCAMENT

PREGUNTA 3

3. CARACTERÍSTIQUES DE L'USUARI I EL VIATGE

3.1. Edat
3.2. El propòsit del viatge
3.3. Freqüència en l'ús del Bicing (per setmana)
3.4. Durada del viatge (minuts) 15
3.5. Sexe