Predictors to the frequency of using an electric bicycle sharing system

A case study to the influence of socio-demographics, lifestyle, motivations and barriers for using BiciMAD – the electric bicycle sharing system of Madrid

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Preface

From childhood on, I am used to travel by bicycle. My parents lived in Badhoevedorp, while my school and sport club was located in the city of Amsterdam. Every day, I cycled up and down to school, and in the evening I jumped on my bicycle again to go to my hockey club. My friends who were already living in the city, sometimes felt sorry for me; but I never understood their feelings (unless there was wind force 12). I have always loved my bicycle trips: it was a good way to wake up in the morning and an even better way to do something active after a long day at school. Above that, cycling was the perfect warming-up before and cooling-down after my hockey training in the evening.

During the minors 'Urban Studies' and 'Urban Geography' I followed at the University of Amsterdam and during my research master 'Human Geography and Planning' at the University of Utrecht, I learned a lot about cycling in the city. I was so interested in this topic that I wanted to incorporate it in my research thesis. I wanted to challenge myself to encourage many more people around the world to go by bicycle. Indeed, cycling is not only an efficient means of transport in the city, but it's also healthy and fun!

My choice for a suitable research location was quickly made. Since my primary school, I convinced myself that later 'when I am a real adult' I wanted to live in Spain. Spending a period abroad in Spain during my research was for me the first step towards this dream. In this way, I came into contact with TRANSyT – a research institute of the Universidad de Madrid focusing on transportation. Under proper guidance and a nice buzz, I have been working on my thesis there for 4½ months. I would love to thank Andrés Monzón, director of TRANSyT, for his warm welcome and all his help in collecting my data. Without him, the cooperation with Bonopark/BiciMAD would have never been realized. Partly because of him, I was able to gain experience in doing research and my confidence as being a researcher increased enormously.

In addition, I would – of course – want to thank Dick Ettema, my supervisor from Utrecht University, for his valuable knowledge on previous and ongoing studies to urban cycling. All his knowledge inspired me a lot when I was writing my research proposal. He was always there for me when I ran against a small problem by giving a useful tip or suggestion. Thanks for all the time and feedback I have received from you!

I would also like to thank two persons of TRANSyT in particular. Andrés García ("el pelirrojo"), thank you so much for all your help and knowledge of BiciMAD. It was so lovely to have a person like you around who I could always ask for help when I ran into a problem. And Pablo, I want to thank you for all you have done for me to feel at home at TRANSyT. After a long day at the research institute, you suddenly invited me to join you to your squash club. Unfortunately I lost that squash match, but I am so grateful to have such a good friend since that day. Thanks!

After these words, there is only one thing left to mention. I hope everyone who will read my master thesis experiences just as much pleasure as I had during my entire research project.

Kind regards,

Veerle Korse

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Summary

Many contemporary societies, and especially dense urban areas, have put finding a solution to the high levels of air pollution and the high amount of overweight people (due to physical inactivity and sedentary lifestyles) high on their political agendas. One way to overcome these problems is to set in motion a switch in the travel mode choices that urban residents make. Substituting a significant amount of the trips traveled by private motorized travel modes trips for more active travel modes such as walking and (e-)cycling is a possible way to influence reduce air pollution and increase participation in physical activity. As a result, many cities are trying to promote the use of bicycles by its residents.

However, not every city is designed for the introduction of cyclists on the road. Spatial characteristics such as the lack of bicycle infrastructure, large travel distances, and differences in topography often discourage people to travel by bicycle. To overcome these spatial barriers, a new type of bicycle with electric assistance had been developed, the so-called electric bicycle (or e-bicycle). As a result, many cities – especially European, Chinese and North-American cities – offer their residents the opportunity to use electric bicycles as part of a bicycle sharing system with electric bicycles. And many more cities will follow in the near future. Therefore, it is useful to gain insight into the preferences and necessities that urban residents have when using these electric bicycles. Which type of people are using an electric bicycle sharing system? And what type of trips do they mainly use the bicycles for? What motivates people to use an electric bicycle, and what are the remaining barriers that people perceive while using the bicycle sharing system? Based on these questions, this study aims meet the following research goal:

"To explore the predictors to the use of an electric bicycle sharing system in order to develop a strong and reliable model in predicting the frequency of using an e-bicycle system among urban residents."

This study examined data of users of the electric bicycle sharing system of Madrid, called BiciMAD. This city was mainly chosen because it was the first European city to introduce a bicycle system with electric bicycles. A total sample of 514 BiciMAD-users successfully completed an online questionnaire. This questionnaire measured six types of predictor variables and their influence on the frequency of using BiciMAD: socio-demographics, lifestyle aspects, people's frequency of using other travel modes, spatial determinants, motivations and barriers. Three regression models were developed in order to measure to what extent those predictor variables influence the frequency of using BiciMAD for three different travel purposes: (1) work/school commutes, (2) trips in leisure time, and (3) trips at night.

The main outcome of this study is that motivations to use an electric bicycle sharing system (e.g. because the system is convenient in its use or because of social influence from friends/family) and the barriers that people perceive while using the system have a much stronger influence on the frequency of using the bicycle system of Madrid compared to socio-demographic and spatial variables. In other words, the importance of subjective predictors outweighs the role of personal or spatial characteristics in the frequency of which someone uses a bicycle sharing system.

Based on the findings of this study, the most important recommendation to increase the amount of trips traveled by shared electric bicycles is meeting the motivations and overcoming the barriers that current users have. People will use a bicycle sharing system more often when they perceive it as a practical travel mode – that is, the locations of docking stations are well chosen, the system is 24/7 accessible, and the user costs aren't too high. In addition, people will use the system more frequently when the availability of bicycles meets the demand of users. A final recommendation to future studies is to gain more insight in the predictors to e-cycling. For example, this study showed evidence for a relationship between someone's lifestyle and his/her frequency of e-cycling, but future studies should explore the nature of this relationship in more detail.

Key words: electric bicycles, bike sharing system, lifestyle, motivations and barriers, Madrid

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1. Introduction

1.1 Introduction

Worldwide, cities deal with environmental problems such as air pollution and societal problems such as sedentary lifestyles and health problems (e.g. obesity, cardiovascular diseases, and cancer). It is often confirmed that transportation choices play a major role in worsening but also solving these two types of problems. Increased traffic of (private) motorized travel modes (mainly cars) has resulted in many negative environmental effects such as air pollution, traffic noise, daily peak hours and the emission of greenhouse gases (Lowe, 1990, p.7-9; Stern, 1992). As a result, many cities have put the goal to improve current environmental conditions by reducing the amount of car traffic on their political agenda (Garvill, Marell, Nordlund, 2003). One way to reduce car traffic is by offering and promoting more sustainable travel modes to urban residents. For example, by encouraging people to realize a shift from (private) motorized vehicles to more sustainable travel modes such as walking and cycling. In this way, not only the amount of motorized traffic will reduce, but the amount of people's participation in physical activity will also increase. According to the Dutch Institute for Sport & Movement (NISB), meeting the daily recommended amount of physical activity of 30 minutes (for adults) has many health benefits: lower chance of being overweight, it may prevent diseases as cancer and diabetes, it reduces stress and depression, and it contributes to your social life.

In theory, the shift from (private) motorized vehicles to active travel modes seems an easy task, but in practice it isn't. Spatial characteristics such as landscape elevation, large travel distances, and absence of proper and safe infrastructure are often experienced as barriers to cycling by many urban residents. For city planners it is difficult and often impossible to change the spatial environment in order to make cycling more attractive, and that's why alternative plans had to be introduced. One of these plans was the development of a rather new travel mode, namely the electric bicycle (or e-bicycle). The main difference between an electric bicycle and a traditional bicycle is that e-bicycles overcome most spatial barriers to cycling. The electric assistance of e-bicycles makes users less sensitive to both landscape elevations and large travel distances. Especially since the last decade, many cities have introduced electric bicycle sharing systems – mainly European, Chinese and North-American cities. Nowadays, there are already over 800 bicycle sharing systems worldwide (Meddin, 2015 as cited by Fishman et al., 2015). At the moment, many more cities are planning to introduce such a system in the near future.

So far, it can be concluded that most bicycle sharing systems have been introduced successfully, based on the statistics that many urban residents make use of these innovative bicycle sharing systems. However, most cities still wish to increase the amount of trips with shared bicycles. It is often the case that urban residents after subscription to system-use do not use the bicycle sharing system that much. For example, Spanish statistics on the bicycle sharing system of Madrid

(BiciMAD) show that on an average day in February 2016 7.271 bicycles are used even though 61.500 people are subscribed to the bicycle system (Ayuntamiento de Madrid, 2016). In some way, this group of people is discouraged (or not motivated enough) to use the bicycle sharing system. The amount of bicycle sharing trips that people make can only be increased when we have more knowledge of the issues that affect the frequency of using a bicycle sharing system. So far, it is still not clear which factors influence the frequency of using a bicycle sharing system, and therefore this thesis seeks to examine a variety of factors.

1.2 Relevance

1.2.1 Societal relevance

Contemporary societies, especially densely urbanized areas, are looking for solutions to reduce levels of air pollution and to increase public health (e.g. obesity and sedentary lifestyles). One way in overcoming these problems is to encourage its residents to use active travel modes instead of private motorized travel modes (e.g. cars). As a result, more and more cities have introduced bicycle sharing systems in the last decade. Firstly, (electric) bicycles are seen as an environmental-friendly travel mode as they do not cause air pollution or traffic congestion – especially compared to private motorized vehicles such as cars. Taylor and Fergusson (1998) compared exposure to air pollutants for commuters of different travel modes. They found that cyclists in Amsterdam still have 2 to 3 times lower exposure to air pollutants than car drivers, even when these two types of commuters are on the same roadway (Taylor & Fergusson, 1998). And secondly, the use of an (e-) bicycle can help people in meeting the daily amount of physical activity that is recommended. According to the Dutch Norm for Healthy Physical Activity (NNGB), performing 30 minutes of physical activity a day is already enough for an adult (Gelinck, 2015). For many people, commuting from home to work by (e-) bicycle is already enough to meet the daily amount of physical activity that is recommended.

The main aim of this study is to get insight into the predictors to the frequency of using an electric bicycle sharing system. The results will be useful for city municipalities and urban planners in two ways. Firstly, this study provides insight in the travel necessities and travel habits of current users of an electric bicycle sharing system. Cities that are planning to introduce a bicycle sharing system in the near future can apply these insights when developing and planning the system in order to increase the likelihood that urban residents will often use the bicycle sharing system. In other words, this study enables city planners to adapt characteristics of the bicycle sharing system to the preferences and necessities of future users before introducing the system in practice. Secondly, this study provides insight to cities that have already recently implemented a bicycle sharing system, but aim to improve the system and increase system-use. Knowing which aspects discourage current users to use a bicycle system may be useful for policy aiming to promote and increase the amount of trips by shared (e-)bicycles. To conclude, this study is useful for contemporary societies because it reveals

suggestions that might help city planners to ensure a bicycle sharing system that fits better into the preferences and necessities of urban residents, resulting in both a healthier population and lower levels of air pollution.

1.2.2 Scientific relevance

Many transportation studies have examined the socio-demographics of cyclists and the variables that are associated with higher bicycle rates. Two main types of research can be distinguished within the literature on cycling. On the one hand, there are studies that examine the relationship between personal characteristics (also called socio-demographics) and the decision to use a bicycle. For example, many studies confirm that the majority of cyclists are 25-45-year old men. On the other hand, many transportation studies examine the influence of spatial characteristics (e.g. travel distance, city size, elevational landscapes) on cycling rates. Most of these studies confirm that people living in large cities with relative large distances and/or strong differences in landscape elevation are less likely to go by bicycle compared to people living in relative small cities without any elevation.

So far, both strands of the literature have only been applied to traditional cycling and traditional cyclists, but not to electric bicycles. Given that more and more people start using electric bicycles and that many cities are introducing electric bicycle sharing systems, the existing literature on cycling needs to be extended by including this new travel mode. Up to now, research on the use of electric bicycle sharing systems in cities is quite scarce, and little is known about the type of people that make use of an electric bicycle sharing system. This study will complement the existing literature on cycling by focusing on e-cycling and e-cyclists. E-bicycles differ on several important aspects from traditional bicycles, and therefore, we expect that the predictors to cycling will also differ from the predictors to e-cycling. For example, cycling may be too exhausting for elderly people, but they are still able to use electric bicycles because of the electric assistance. Also spatial characteristics that may play a role for cycling may no longer be relevant for e-cycling. For example, most people do not travel larger distances than 15 kilometer by a traditional bicycle, whereas larger travel distances are no issue when a bicycle has electric assistance.

In addition, this study complements the existing literature by examining two other types of predictors. Firstly, this study examines whether someone's lifestyle influences the use of an electric bicycle sharing system based on existing evidence that lifestyles influence travel mode choice (Scheiner and Holz-Rau, 2007). Because (e-)bicycles are often promoted as environmentally-friendly travel modes and as being beneficial for your health, it may be expected that having a healthy and conscious lifestyle influences the use of a bicycle sharing system. The second type of predictors to e-cycling that this study examines consists of the subjective opinions and experiences of e-cyclists. These subjective predictors are included in this study because of existing evidence that travel decisions do not only depend on fixed personal characteristics (e.g. age, gender, and education) but

also on someone's opinions on and attitude towards a particular travel mode. A theory that has received good empirical support in the domain of transportation studies is the Theory of Planned Behavior, formulated by Ajzen in 1991. According to this theory, human action is guided by three kinds of considerations: attitude, subjective norm and perceived behavioral norm. In general, a favorable attitude, a positive subjective norm and a great perceived behavioral control towards a specific travel mode, increases the likelihood that someone will use that travel mode (Bamberg, Ajzen & Schmidt, 2003). In addition to this theory, Brown, O´Connor and Barkatsas (2009) confirmed that motivations to cycling strongly influence cycling behavior. Based on this evidence, this study explores what motivates current users of an electric bicycle sharing system to use this travel mode. In this way, it will become clear which subjective motivations play a role in the decision to use an electric bicycle sharing system.

Finally, this study differs from previous research programs as it takes travel purpose of cyclists into account. We do not only examine the frequency of using shared electric bicycles, but a distinction is made between three types of system-use: (1) work/school commutes, (2) trips in leisure time, and (3) trips at night. Travel purpose is often missing in previous research programs. Based on the assumption that predictors to the frequency of using a bicycle sharing system may differ when travel purpose is taken into account, this variable is included in this study.

To conclude, the use of electric bicycles is highly increasing in contemporary societies. The transportation literature should adapt to the rise of electric bicycles, but so far, little is known about this relatively new type of travel mode. More knowledge on e-cycling and e-cyclists complements the existing literature and ensures that the existing literature is up-to-date again. This study aims to contribute to complement the knowledge on e-cycling by examining which variables play a role in the use of an electric bicycle sharing system.

1.3 Research goal and research questions

The main goal of this study is to explore the relevant predictors to the use of an electric bicycle sharing system in order to contribute to the development of a strong and reliable model in predicting the frequency of using an electric bicycle sharing system among urban residents. In order to meet our research goal, the following five research questions need to be answered:

1. **How can BiciMAD-users be characterized in terms of their lifestyle and their general travel habits?**

2. **How do BiciMAD-users describe and assess the spatial factors related to the frequency of using BiciMAD and/or cycling in Madrid?**

3. **What motivates BiciMAD-users to use the bicycle sharing system?**

4. **What are the remaining barriers that BiciMAD-users have for not using the bicycle sharing system more often?**

5. **How do lifestyle, travel habits, motivations and barriers influence the frequency of using BiciMAD, and how does this relate to travel purpose?**

1.4 Structure of the thesis

This chapter outlines the background of this study and shows on which research questions this study is based. Chapter two gives an overview of the relevant literature for this study and mainly focuses on the literature and evidence that exists for cycling as the literature on e-cycling is relatively small. In chapter three the research strategy, data collections and data analysis are discussed. The results and interpretation of data collection are analyzed in chapter four. Finally, in chapter five the main conclusions and future recommendations of this study are discussed.

2. Theoretical framework

2.1 Socio-demographics and cycling

Many transportation studies show evidence that variables such as age, gender, household composition and employment status play a role in travel mode choice (e.g. Scheiner and Holz-Rau, 2007). More specifically, studies that have examined the personal characteristics of cyclists confirm that various socio-demographics also play a significant role in the decision to travel by bicycle or not. Most studies find similar outcomes, but there are some contradictions within the literature. Below the existing evidence on the influence of socio-demographics on cycling is discussed in three subsections. First, the influence of age and gender on cycling is discussed, followed by employment situation and household composition in the second subsection. In the final part, the focus is on the influence of having access to other travel modes (e.g. owning a car) on the likelihood to travel by bicycle.

2.1.1 Gender and age

For example, Curtis and Perkins (2006) showed that men are more likely to travel to work in private vehicles, whereas women travel more to destinations that involve the upkeep of household members (e.g. taking children to school). In addition, they found that women are more likely to adopt sustainable transport modes and reduce car use because of environmental concerns than men. Furthermore, Johnson and Rose (2013) found a significant influence of gender and age among their sample of Australian owners of electric bicycles (N=529): 71% of their sample was male and roughly 55% was aged 41-60 years. Other studies show dissimilar results. Dutch statistics show that the majority of its e-cycling population consists of middle-aged women and people older than 60 years (Fietsberaad, 2013). And according to the municipality of Madrid, most users of BiciMAD are aged between 26-35 years (39.7%) followed by the age group of 36-45 years (26.5%) (Ayuntamiento de Madrid, 2016). In addition, we discuss another study that examined the socio-demographics of users of BIXI, an electric bicycle sharing system in Canada. Fuller and colleagues (2011) found that those aged 35 years or older were less likely to use this system compared to 18-24 year-olds. They did not found significant differences among system use of men and women.

2.1.2 Employment situation and household composition

Many transportation studies have examined the influence of 'household composition', 'employment situation', and 'income level' on travel mode use. However, their outcomes are not consistent. We will therefore discuss some important findings of transport studies that have examined this relationship. Curtis and Perkins (2006) found that middle-income full-time employees, students, unemployed people and part-time employees without children are most likely to use public and non-

motorized travel modes. Households with children were more likely to use cars and tend to use public and non-motorized modes more for leisure travelling. Furthermore, they found evidence that households consisting of older people, retirees and high-income earners were least likely to use public and non-motorized travel modes; they tend to rely exclusively on private travel modes. These findings are mostly in line with the evidence found by Scheiner and Holz-Rau (2007). Among their sample, a high social status (being employed and/or having a high job position) was positively associated with the use of motorized vehicles: car and motorcycle use ($R=0.13$, $p<.05$), and public transport trips ($R=.05$, $p<.05$). In addition, they found that people with a low social status (being unemployed or having a low job position) are more likely to travel with non-motorized vehicles ($R=0.19$, $p<.05$).

Because non-motorized trips consist of both walking and cycling trips, we discuss the study of Krizek et al. (2005) who have specifically examined the influence of employment status on bicycle use. Surprisingly, their results are not in line with the results of two studies by Curtis & Perkins (2006) and Scheiner & Holz-Rau (2007): they found a positive association between employment status and bicycle use. Among the female cyclists in their sample 85% was employed; and for male cyclists 81% seemed to be employed. More specifically, Johnson and Rose (2013) examined the relationship between 'employment situation' and 'use of electric bicycles'. Their findings show some similarity with the findings of Curtis and Perkins: the majority (55%) of their sample consisting or electric bicycle owners are full-time employees, whereas retired people tend to use e-bikes to a lesser extent (17%). On the other hand, the fact that students (3%) and part-time employees (17%) are not highly represented in their sample is not in line with the evidence of Curtis & Perkins that these two groups are most likely to use public and non-motorized travel modes. To conclude, full-time employees use e-bicycles most often (Johnson and Rose, 2013), whereas traditional bicycles are also often used by students, unemployed people and part-time employees (Curtis & Perkins, 2006).

This different influence that employment situation has on cycling and e-cycling can be explained by the specific characteristics of electric bicycles. That is, they can be seen either as motorized vehicles or as non-motorized vehicles. Even though they provide motor assistance, they differ on a lot of aspects with traditional motorized vehicles such as cars and public transportation. And while electric bicycles are often seen as active travel modes, they are not as active as traditional bicycles or walking. In that way, including employment situation and household composition as variables in our model might reveal interesting outcomes.

2.1.3 Access to other travel modes

As stated earlier in this paper, electric bicycles blur the strong distinction between motorized and non-motorized travel modes. In other words, electric bicycles can be seen as a combination of characteristics of both motorized and non-motorized vehicles. Therefore, they can replace motorized

travel modes as well as non-motorized travel modes. To examine the influence of access to other travel modes have (both motorized and non-motorized vehicles) on the use of electric bicycles, four variables are included in the research model. Two variables measure participants' access to private motorized travel modes: 'driver's license' and 'car/motorcycle ownership'. The third variable measures access to traditional (non-electric) bicycles: 'traditional bicycle ownership'. And finally, the fourth variable measures access to the 'public transportation system'.

Johnson and Rose (2013) examined characteristics among a sample of 529 Australian electric bicycle owners, and found that having a driver's license and owning a car are associated with e-bicycle ownership. 93% of their participants indicated having a driver's license (p=.05), and 90% indicated owning a car (p=.08). Even though these outcomes may also apply for our model, we decided to include 'driver's license' and 'car ownership' as variables in our model because our sample is different. Instead of examining characteristics of people that have bought their own private electric bicycle, our sample consists of people that share electric bicycles. In other words, our study may reveal different outcomes for these two variables as our research population differs.

So far, the literature on electric bicycle usage does not cover any associations between either 'traditional bicycle ownership' or 'access to public transportation' and the use of electric bicycles. As the use electric bicycles may be influenced by having access or not to either a private bicycle or the public transportation system, we decided to include these two variables in our model as well. For example, one could imagine that someone without a public transportation card will be more likely to travel by electric bicycle compared to someone that does own such as card, and thus has access to the public transportation system.

2.2 Lifestyle aspects and cycling

This second section focuses on the existing literature on lifestyle and cycling. Scheiner and Holz-Rau (2007) confirmed that, in addition to socio-demographics, someone's lifestyle also influences his/her travel mode choice. In many studies, the concept of lifestyle is undefined or vaguely described. In this study, the concept is approached in such a way that it relates to (e-) cycling. Therefore, the concept of lifestyle is subdivided into three lifestyle domains that are expected to play a role when using an (e-) bicycle. The first lifestyle domain is called 'leisure time preferences', and is characterized by the activities that people prefer to perform in their leisure time. The second domain is 'participation in physical activity', referring to the amount of physical activity that people perform. 'International residence' is the final lifestyle domain, referring to the countries where people have lived. Below the relationship between these three lifestyle domains and using the (e-) bicycle is discussed.

2.2.1 Leisure preferences and cycling

Melinda Craike (2007) found that having a preference for participation in Leisure-Time Physical Activity (LTPA) has a direct effect on regularity of participation in leisure-time physical activity (β = .557, p = .000). A preference for participating in LTPA is an attitude that implies the person likes physical activity more than other types of leisure. In other words, the higher the person´s preference for LTPA over other types of leisure, the more likely he/she is to participate regularly in LTPA. Four items were designed to assess where LTPA was rated in relation to other (non-active) leisure activities. Regularity of participation in LTPA refers to participation in at least three physical activity sessions per week. A physical activity refers to an activity that requires physical effort for at least 20 minutes. This study confirms that preference predicts 31.0% of the regularity of participation. However, the formation of a preference does not express a plan or commitment to participate in LTPA, merely that the person considers it favorable in comparison to other leisure activities (Craike, 2007). Cycling can be seen as a leisure-time physical activity, and therefore it can be argued that having preferences for LTPA increases the amount of regular participation in cycling.

Burton, Khan, Brown & Turrell (2012) used another approach to look for associations between leisure preferences and physical activity (or active travelling). They examined the association between time spent in sedentary leisure activities and physical activity levels among middle-aged adults. They looked at three types of sedentary leisure: (1) watching television, DVDs, videos or video games (2) using a computer at home, and (3) other sitting activities than watching television and using a computer, such as hobbies, reading, or dining out. A measure of overall sedentary leisure time was derived by summing the time of these three contexts. Physical activity was divided into five categories (no activity, low activity, recommended activity, high activity, and very high activity) and calculated by the time spent on walking, moderate and vigorous activity. Overall, few associations between time spent in sedentary leisure and physical activity levels were found. In other words, participation in sedentary leisure does not preclude meeting physical activity recommendations. The only significant negative associations they found were between watching television on a week day and high activity among men, and home computer use on a week day and very high activity among men. For both men and women, they found significant positive associations between overall sedentary leisure time on a week day and very high activity, home computer use on a week day and very high activity, and general leisure on a week day and most activity levels. There is no clear explanation for these contradictive associations, and this paper intends to contribute to the clarification of the relationship between leisure time preferences and cycling behavior.

2.2.2 Participation in physical activity and cycling

Most studies that have examined the relationship between levels of physical activity and the use of active travel modes have taken children or young adolescents as their sample. In 2009, Garrard gave an overview of the existing evidence on active transport use among children and young adolescents. He states that children who actively commute to school seem to have higher levels of physical activity compared to children who do not walk or cycle to school. This association between active travelling to school among children and higher levels of physical activity after school was also confirmed by Cooper and colleagues (2003). Furthermore, active travel to school among children is associated with higher levels of active travel to other destinations (Dollman and Lewis, 2007). However, this positive influence of using active travel modes on the participation in PA does not imply that this relationship also exists in the opposite direction: participation in PA significantly increases the use of active travel modes. Like previous studies, this study builds on the assumption that active travelling stimulates participation in physical activity, and vice versa. Therefore, the variable 'participation in PA' is included as an independent variable in our research model based on the argument that e-cycling is a relatively new active travel mode, and the relationship between participation in PA and using this travel mode has not been investigated so far.

2.2.3 International residence and cycling

Worldwide, there are large differences in bicycle use. Countries with the lowest share of bicycle trips (±1%) are Australia, Canada and the United States. Countries with the highest bicycle share are located in the northern part of Europe. For example, 26% of all the trips travelled in The Netherlands are covered by bicycle, followed by 18% in Denmark, and ±9% in Germany, Finland, Sweden, and Belgium (see Figure 1). Even though these national differences do not show variations in cycling levels on city level, we could state that – with a few exceptions – these national percentages are representative for their cities as well, meaning that the most bike-oriented cities in Australia, Canada and the US have lower levels of cycling than the least bike-friendly cities in The Netherlands, Denmark, and Germany. Recently, a list of 700 cities (covering 40 countries) was published showing the percentages of total trips covered by bicycle. Not surprisingly, the lowest 250 cities on this list are all located in the US, except for one city in Canada. The 50 cities with the highest rate of bicycle share are mainly located in North-European countries such as The Netherlands, Germany, Denmark, Sweden and Belgium (City Clock Magazine, 2014).

The higher share of bicycle trips in Dutch, Swedish, Danish and German cities may partly be explained by shorter trip distances than in American, Canadian, and Australian cities due to more mixed-use development, less suburban sprawl, and higher population densities in Europe (Heinen, Van Wee, and Maat, 2010). A second explanation for these major international differences may be related to culture and travel habits. In North-Europe, people travel by bicycle for other purposes than

in America, Canada and Australia. In The Netherlands, for example, people use the bicycle for practical or utilitarian purposes such as work commute trips whereas people living in countries with a significant lower bicycle share mainly use the bicycle for recreational purposes (Buehler & Pucher, 2012).

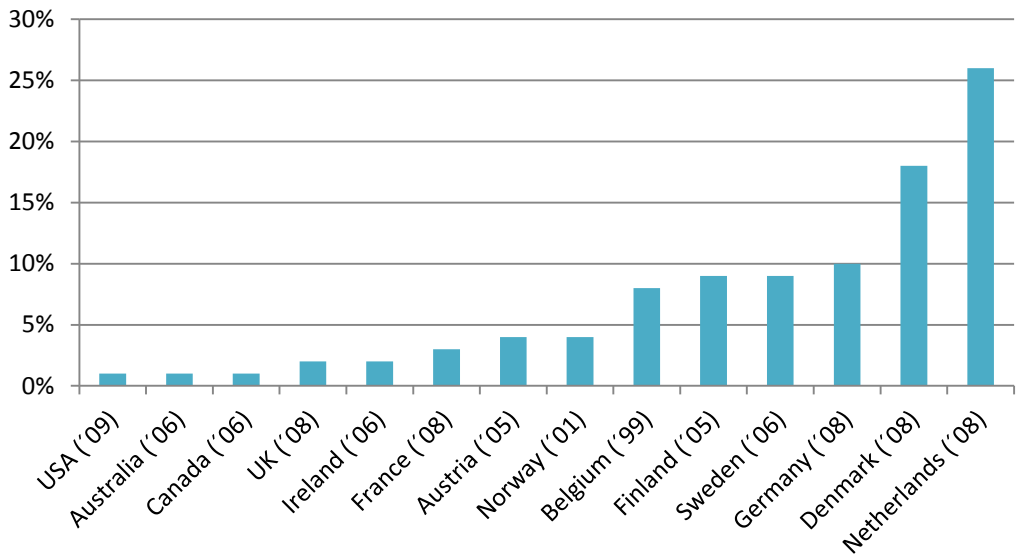

Figure 1: Percentages of all daily trips covered by bicycle in Europe, North America and Australia, 1999-2008. Source: Pucher, J., Buchler, R. (eds). City Cycling. Cambridge, MA: MIT Press, 2012

Having spent a significant amount of time in a country where cycling is an often-used travel mode (e.g. The Netherlands, Denmark, Germany) may result in a so-called 'cycling habit' (Heinen, Maat, & Van Wee, 2011). In other words, being used to travel by bicycle in one country may increase the likelihood that you will also travel by bicycle in other countries even though cycling is not a common way of travelling there. To examine whether having lived in a country where cycling is a common travel mode influences the use of electric bicycles in the city of Madrid where cycling is only used for about 1% of all the daily trips (Ayuntamiento de Madrid, 2016), we have included the variable called 'international residence' in our research model.

2.3 Spatial determinants for cycling

In the previous two paragraphs we have discussed personal characteristics that may influence the use of shared electric bicycles. This paragraph discusses some spatial factors that might play a role in the use of shared e-bicycles. Before examining these factors in more detail, we shortly discuss a social geographic approach which gained attention across the social science and many transportation studies during the 1970s: "Space-Time Geography" (e.g. Lenntorp, 1976 cited by Corbett, 2005). This theory was introduced by Torsten Hägerstrand and assumes that people can to a certain degree influence their travel paths themselves, for example, by choosing a specific transport mode:

travelling by car is faster than walking for relative large distances. However, people are not completely free to create their own travel paths and depend on various external factors (e.g. infrastructure, distance and the location of docking stations). Hägerstrand (1970) formulated three types of constraint that influence people's travel paths (see Table 1). By using this theory as a background, the remaining parts of this paragraph discuss the role of various spatial constraints influencing the use of an electric bicycle sharing system.

Type of constraint	Definition	Examples BiciMAD
Capability constraints	The limitations on human movement due to physical or biological factors	*Physically you have to be fit enough to cover the travel distance by bicycle. *You have to feel safe and be confident enough to travel by bicycle. *Daily time constraints in which there is not enough time for long(er) bicycle trips.
Coupling constraints	The need to be in one particular place for a given length of time, often in interaction with other people	*You can only pick up a bicycle and leave your bicycle behind at particular/fixed places (docking stations).
Authority constraints	People are dependent from general rules, laws, economic barriers, and power relationships which determine who does or does not have access to specific domains at specific times to do specific things	*Your travel path depends on the bicycle infrastructure in Madrid as you may only cycle where bicycles are allowed.

Table 1: Definitions of the three types of constraints within the Space-Time Geography (Pred, 1977). Including examples for the case of BiciMAD

2.3.1 Walking distance to and location of docking stations

Bicycle sharing systems consist of fixed locations where people can pick up and leave bicycles – so-called docking stations. In 2011, Fuller et al. examined the influence of having a docking station close to your home location on the likelihood to use the system. They found that having one docking station (OR=2.03, 95% CI = 1.31, 3.16) or more than one docking station (OR=1.73, 95%CI = 1.04, 2.88) within 250 meters from your home location was significantly related to a greater likelihood to use the system. More recently, Schoner and Levinson (2013) studied how people navigate from their starting location to their final location by using a bicycle sharing system. In line with the findings from Fuller et al., they also found that the distance between residential location and docking station was important to people as they prefer to use the closest station near their residential location – even though this station is not on their route. About 83% of their respondents choose the closest docking station followed by 11% that choose the 2nd closest station. In addition, they showed that the average time people walk from their home location to a docking station is 2.83 minutes which is, on average, 25% of the total travel time. Unfortunately, there is no evidence within the literature concerning the distance/time people are willing to walk from their arriving docking station to their final destination, but we assume that the previous results about the distance between the home

location and the closest docking station also apply to the distance between the final station and the destination.

2.3.2 City size and travel distance

The size of a city is highly relevant for the decision to cycle or not. In general, it is argued that cycling in smaller cities is easier compared to cycling in larger cities due to the following reasons. Firstly, smaller cities have shorter trip distances than larger cities. Travel distance is a main factor in the decision to cycle. Most studies confirm that, in general, bicycle trips are less than 15 km. For example, Van Wee et al. (2006) argued that an increase in distance discourages people to take the bicycle because of the increasing physical effort that is needed. However, very short trip distances (<2 km) also discourage people to go by bicycle because many people prefer to walk these shorter distances (Keijer and Rietveld, 2000). For e-cycling, travel distance is a less influential factor compared to traditional cycling, though it is still relevant. Dutch statistics confirm that, on average, e-cyclists cycle 31 km per week, whereas owners of traditional bicycles cover 18 km per week (Fietsberaad, 2013), indicating that e-cyclists are less discouraged because of travel distance (Hendriksen, Engbers, et al., 2008). This can be explained by the fact that e-cycling requires less physical effort than cycling due to the electric assistance they have. However, there are two important footnotes to mention here as the distance that users of shared e-bikes travel may differ from the distance that users of private e-bikes travel. First, shared e-bicycles have to be picked up and left behind at fixed locations. These fixed locations determine – to some extent – the area in which these bicycles can be used. Private e-bicycles, on the other hand, can be used everywhere and therefore these people are able to travel further and longer. Second, people using shared e-bicycles have to pay for the amount of time they use the bicycles while people using their private e-bicycle do not have to pay. The fact that you have to pay may also result in spending less time on a bicycle trip.

A second advantage for smaller cities is that it is easier to implement transportation policies and introduce innovative transportation programs such as a bicycle sharing system. In general, larger cities comprise many local governments and multiple layers of bureaucracy which make it more difficult to develop and introduce transportation policies and innovations such as the implementation of new bicycle infrastructure. And finally, larger cities have, generally spoken, public transportation services that are far more extensive than in smaller cities. It often occurs that the existing transportation network of a large city works so well that introducing bicycle infrastructure or a bicycle sharing system remains unused by residents. Although cycling and public transportation can work together (e.g. by using the bicycle for “last mile problems” from the bus/metro/train station to your final destination), they may also compete with each other over short and intermediate trip distances (Handy, Heinen & Krizek, 2012; Buehler & Pucher, 2012; Pucher et al., 2012).

As Madrid is a big city, we hypothesize that some distances may be too large to travel by bicycle, and thus influence the frequency of using BiciMAD. Furthermore, it is hypothesized that the extensive and well-organized public transportation system of Madrid (especially the metro network) may result in a lower use of the bicycle sharing system.

2.3.3 Bicycle infrastructure and safety

A third important spatial determinant for cycling is the presence of bicycle infrastructure, which strongly relates to traffic safety for cyclists. Worldwide, studies on cycling confirm that one of the most frequently cited reasons for low levels of cycling is fear of sharing the road with motorized vehicles (Fishman, Washington & Haworth, 2012). The literature confirms that cyclists are more likely to go by bicycle when there are separate cycle lanes (e.g. Winters, Davidson, Kao, Teschke, 2011; Parkin, Wardman, Page, 2007). However, many cities deal with problems with the introduction of new separated bicycle lanes due to the difficulty of implementing a bicycle network within a city that was previously designed for cars and pedestrians only.

In 2003, Pikora and colleagues examined physical environmental factors influencing cycling. Their study confirms that many factors having a significant relationship with cycling have to do with presence and quality of the bicycle infrastructure. For example, the continuity of cycle paths, the elevation of cycle paths, the traffic volume, traffic speed, and the design of intersections. In addition, they found factors related to safety to also have a significant influence on cycling. For example, the presence of lighting on cycle paths, presence of crossing aids for cyclists, and the presence of marked cycle lanes (Pikora, Giles-Corti, Bull, Jamrozik, Donovan, 2003).

Fishman, Washington & Haworth (2012) formulated the following recommendations to improve safety for cyclists and to reduce their perceptions of risk: (1) create separated bicycle lanes, (2) marking bicycle lanes, (3) set-up awareness campaigns of the presence of cyclists on roads, and (4) implement speed limit reductions.

2.4 Travel behavior

Fishman, Washington, Haworth, and Mazzei (2014) performed a multi-city evaluation of the travel impacts of bicycle sharing programs. They used data on the travel modes that had been replaced by the bicycle sharing from five cities: Melbourne, Brisbane, Washington, London, and Minneapolis/St.Paul. As Figure 2 illustrates, they found that a large portion of the trips that are currently taken by shared bicycle programs were found to substitute for public transport and walking – a finding that in in line with a previous case study to the bicycle sharing system in Hangzhou, China (Shaheen et al., 2011). The transfer from sedentary modes (e.g. car, public transport, taxi) to bicycle sharing ranges from 51% of trips in Minneapolis/St.Paul to 68% in both Brisbane and London.

Minneapolis/St.Paul's relatively low rate of transfer from sedentary modes is primarily due to very high rates of mode substitution from walking.

London has the lowest level of car substitution, which makes sense as less trips in this city are undertaken by car compared to the other cities they analyzed. On the other hand, London recorded a very high rate of mode substitution from public transport, whereas Brisbane, Melbourne and Minneapolis/St.Paul each recorded relatively high rates of car more substitution, which is consistent with higher rates of car use in these cities. The percentages illustrated in this figure belong to bicycle sharing systems that make use of traditional bicycles instead of electric bicycles. These percentages probably apply to electric bicycle sharing system as well, although the percentages of motorized vehicles that have been substituted may turn out to be slightly higher due to the electric assistance of bicycles. Based on these results, it is hypothesized that most BiciMAD-users have also replaced public transportation trips and walking trips for the trips they now travel by shared electric bicycles.

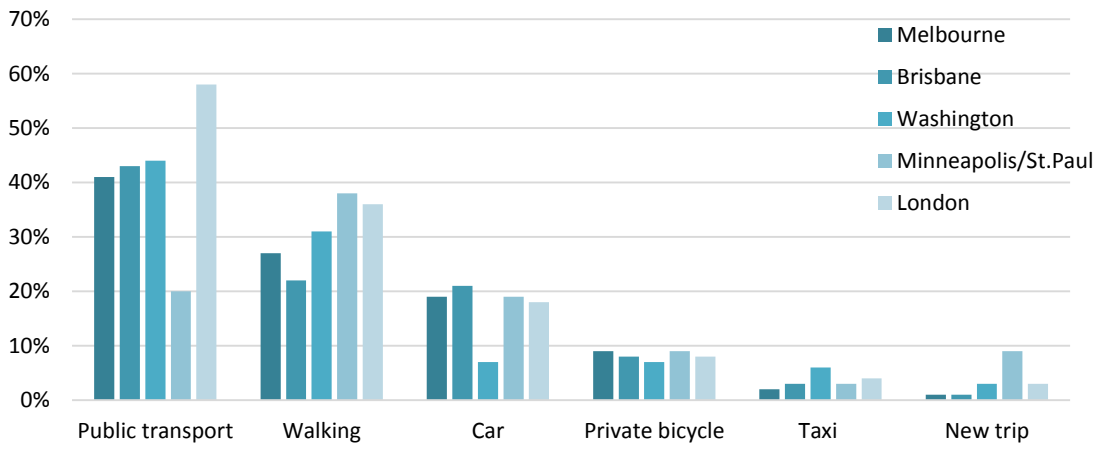

Figure 2: Percentages of travel mode substation due to the introduction of bicycle sharing systems in five cities. Source: Fishman, Washington, Haworth & Mazzei 2014, p.7.

2.5 Motivations to cycling

Brown, O´Connor and Barkatsas (2009) identified five motivational factors for organized cycling: (1) social factors, (2) embodiment, (3) self-presentation, (4) exploring environments and (5) physical health outcomes. Table 2 shows a selection of the items belonging to these factors. The following five sections offer a short overview of the literature on these motivations to cycling. The sixth section discusses another motivational factor which is found to influence the decision to use a bicycle in the literature (e.g. Olsson et al., 2013; Friman, et al., 2013): ´dissatisfaction with other travel modes´.

Social factors	Embodiment	Self-presentation	Exploring environments	Physical health outcomes
I consider cycling to be a social activity	Cycling allows me to feel refreshed & invigorated	I get satisfaction from beating someone up a hill	I cycle to get to and from places	I cycle so that I can eat whatever I like
Cycling allows me to spend time with others who have similar goals	I enjoy the feeling of exhilaration after I have ridden my bike	Cycling allows me to test myself in competition	I cycle because it is an efficient form of transport	I cycle because it is less stressful on the body
The presence of others motivates me to ride	I enjoy the sensation of moving fast whilst cycling	I like others to think of me as cyclist	Cycling allows me to be environmentally friendly	Cycling prevents me from developing injuries

Table 2: Five motivational factors to travel by bicycle with three randomly selected items belonging to these factors (Brown, O´Connor & Barkatsas, 2009)

2.4.1 Social factors and social support

Social support can be defined as *´the perceived support for physical activity received from others, such as family and friends´* (Anderson et al., 2006). The Social Cognitive Theory (SCT) developed by Albert Bandura (1977) is a theoretical perspective assuming that people learn behavioral aspects by observing others. In other words, people acquire new behaviors and knowledge by observing a social-cognitive model – a person demonstrating behavior. The SCT is often applied as a theoretical background to the field of physical activity (Anderssen & Wold, 1992; Courneya & McAuley, 1995; Anderson et al., 2006; Sallis & Owen, 1999, p.127/p.133). For example, Duncan and colleagues (2005) distinguished three types of models that affect physical activity among youth: parents, siblings and friends. In addition, they distinguish five behavioral ways in which models may stimulate physical activity: encouragement to participate in PA, do PA with you, watch you participating in PA, talk with you about PA, and provide transportation to PA locations. Their main conclusion was that social support– especially from friends – is positively related to youth PA (Duncan, Duncan and Strycker, 2005). Other studies, however, found evidence for stronger influence of family support on participation in physical activity among children and adolescents (Beets and colleagues; 2010, Sallis, Prochaska & Taylor; 2000). The strong positive influence of family and friends on physical activity is also confirmed by studies on adults (Rakowski, 1988; O´Reilly and Thomas, 1989; Treiber et al, 1991; Sallis et al, 1992; Felton and Parsons, 1994) and 60+ populations (Booth et al., 2000). For elderly, first, through social reinforcement, that is, having people around you telling you that physical activity is good for your appearance. Second, through social modelling, that is, having a social environment around you in which physical activity is a common occurrence. Also Eyler, Brownson, Donatelle, King, Brown and Sallis (1999) indicate that people with high levels of Physical Activity Social Support (PASS) are significantly less likely to be sedentary than those with low support.

So far, we have discussed the relationship between social support and physical activity. Cycling can also be seen as physical activity, but also as a means of transportation. Therefore, we will

also discuss some studies that have specifically focused on the influence of social support on travel behavior or travel mode choice (e.g. Scheiner & Holz-Rau, 2007; De Bourdeaudhuij et al., 2005). An often applied theory that links social influence to travel mode choice is the 'Theory of Planned Behavior' formulated by Ajzen in 1991. According to this theory, human action is guided by three considerations, of which 'subjective norm' is one consideration. Subjective norm is a social factor that refers to 'the perceived social pressure to perform or not to perform a specific behavior' (e.g. cycling). For example, if the majority of your friends or colleagues travel by bicycle, you may feel the social pressure to travel by bicycle as well. A study by De Geus and colleagues (2008) confirms that people reporting high levels of social support of friends and family are more likely to cycle compared to people receiving less social support. More specifically, they found that cyclists indicate to have more often a cycling partner who cycles with them than non-cyclists (*social influence*). Other significant outcomes were that cyclists more often indicate that others stimulate them to cycle compared to non-cyclists (*social norm*), more often have people that go cycling with them (*social accompany*) and more often have relatives who cycle compared to non-cyclists (social *modeling*).

A common way to measure social support is the Social Support Questionnaire (Sarason, Levine, Bashman, Sarason; 1983). This is a 27-item questionnaire designed to measure perceptions of social support and satisfaction with that social support. However, these items are formulated in such a way that it is too general to measure social support for a specific activity such cycling. Therefore, a more common way to measure social support on PA or active transport behavior is to develop items on which respondents indicate their agreement on a 5-point Likert scale. For example, "My parents give me helpful reminders to exercise" or "My friends offer to exercise with me" (Sallis et al., 1987).

2.4.2 Embodiment

In general, embodiment refers to *"the biological and physical presence of our bodies, which are a necessary precondition for subjectivity, emotion, language, thought and social interaction"* (Hargreaves, Miell, & MacDonald, 2002). Even though the term ´embodiment´ is often used in transportation studies – for example, when comparing the experienced embodiment among different travel modes – these studies often lack a clear definition of the term. Brown, O´Connor and Barkatsas (2009) describe ´embodiment´ as a factor that represents kinesthetic feelings, feelings of accomplishment and the process of learning new activities (Brown, O´Connor and Barkatsas, 2009). For example, driving a car might give you a positive embodied experience because of the high speed or because it gives you confidence. On the other hand, cycling might give you a positive embodied experience because it removes you physically from busy roads or because you achieve new goals related to fitness.

2.4.3 Self-presentation and social identity

Self-presentation according to Leary (1992) is *"the presentation and omission of aspects of the self in order to optimize a favorable social impression and where undesirable impressions will be avoided"*. In other words, self-presentation is the process of directing the impression that a person makes on others by creating and controlling it. So, all the actions undertaken in order to communicate images of oneself to others are part of someone´s self-presentation (Goffman, 1959; Leary, 1996; Tedeschi & Lindskold, 1976). In the context of cycling, self-presentation might take the form of using the technologically advanced equipment of cycling, being a member of a cycling club or enjoying the notion of others thinking of themselves as cyclists (Brown, O´Connor and Barkatsas, 2009).

Self-presentation is an aspect of social identity. Lois et al. (2015) used three items to examine the influence of social identity on the decision to travel by bicycle: (1) I identify myself as a cyclist, (2) I can envisage myself as a cyclist, and (3) I have some things in common with cyclists. In line with the theory of Planned Behavior, social identity increases behavioral action, and thereby, motivates action (Fielding, McDonald & Louis, 2008). In the context of cycling, the process of presenting yourself or identifying yourself with ´cyclists´ as a social group could increase the frequency of your bicycle use.

2.4.4 Exploring environments and environmental concerns

This factor refers to environmentally-related arguments that cyclists have to travel by bicycle. According to Brown, O´Connor & Barkatsas (2009), this factor consists of four items related to the environment or to environmental benefits of travelling by bicycle: (1) I cycle to get to and from places, (2) I cycle because it is an efficient form of transport, (3) cycling allows me to exercise and get to places at the same time, and (4) cycling allows me to be environmentally friendly. Especially in the last decade, a lot of research has focused on the association between environmental concerns and travel mode choice. In general, most studies confirm that people having concerns about the environment (e.g. air pollution or greenhouse gases) prefer to use non-motorized travel modes (see Van Vugt et al., 1995; Gardner & Abraham, 2008; Prillwitz & Barr, 2011, 2012; Steg and Gifford, 2005; Dickinson and Dickinson, 2006). For example, Gardner and Abraham found that attitudes against car-use were indeed influenced by environmental-related cognitions.

Several types of environmental cognition have been measured: environmental problem awareness (Steg & Vlek, 1997 cited by Steg, 2005); concern for the environment (Polk, 2003); perceived severity of the environmental problem (Tanner, 1999); perceived threats of environmental damage to the individual, society, or the biosphere (Collins & Chambers, 2005, de Groot & Steg, 2007; Tanner, 1999), perceived responsibility or feelings of guilt for the environmental problem (Bamberg, Hunecke & Blöbaum, 2007); perceived utility of car-use reduction for lessening the environmental problem (Steg & Sievers, 2000); and beliefs in one´s ability to exert influence over the problem through transportation decisions (Tanner, 1999).

Shaheen et al. (2011) looked at differences in environmental attitudes among three population groups: (1) members of the bicycle sharing system in Huangzhou, (2) prospective members, and (3) persistent non-members. Of these groups, prospective members of the bicycle sharing system were most aware of environmental problems and expressed the highest willingness to change their travel behavior. In general, members were also strongly aware of environmental problems. In contrast, persistent non-members were much less aware about environmental problems and were less willing to change their travel habits.

2.4.5 Physical and mental health benefits

The factor of ´physical health benefits´ consisted of five items: (1) I cycle so that I can eat whatever I like, (2) I cycle because it is less stressful on the body, (3) cycling allows me to stay free from ´lifestyle´ diseases, (4) I use cycling to control my weight, and (5) cycling prevents me from developing injuries. In 2011, Oja and colleagues conducted a systematic review of the literature on the physical health benefits of cycling. They included cross-sectional studies, longitudinal studies and intervention studies. Overall, almost all the studies included in their review showed that cycling provided health benefits. More specifically, one could speak of a consistent and positive relationship between cycling and improvements in cardiorespiratory fitness, disease risk factors. In addition, cycling is associated with significant risk reduction for all-cause and cancer mortality and for cardiovascular, cancer, and obesity morbidity. The outcome that cycling is associated with health improvements might, therefore, be a motivational factor for people to choose to travel by bicycle (Fuller, Gauvin, Kestens, Morency & Drouin, 2013).

In addition to these direct physical health benefits, a number of studies have suggested that physical activity (or cycling specifically) also has mental health improvements. For example, cycling may have a restorative influence on the person in question compared to travelling by car in rush-hour. In 2009, Mead et al. concluded – after a systematic review of the relationship between physical activity and depression – that PA indeed improves depressive symptoms (see also Penedo and Dahn, 2005). PA is also linked to improvements in cognitive functioning, memory functioning, motor functioning and educational attainment (Åberg et al, 2009; Sibley and Etnier, 2003; Scarmeas et al., 2009; Angevaren et al., 2008). Other psychological factors that are often mentioned as motivations to use a bicycle are relaxation, stress reduction, anxiety reduction, fun, enjoyment, enhanced wellbeing and social interaction (Garrard, Rissel, & Bauman, 2012, p.37-40).

Though there is enough evidence that cycling is beneficial for both physical and mental health conditions, it is not clear whether the wish to improve or upkeep (physical and/or mental) health is also a motivation for people to use the bicycle. So far, enough evidence lacks to conclude that people are motivated to use (e-)bicycles because they want to improve/upkeep their health. As

such, this study will test whether health plays a role in the frequency of using a bicycle sharing system.

2.4.6 Dissatisfaction with previous travel mode

Most studies that compare travel satisfaction among users of different travel modes argue that, in general, walking and cycling result in more travel satisfaction than cars and public transit (e.g., Olsson et al., 2013; Friman, et al., 2013). One possible explanation for this is that walkers and cyclists live closer to work, which makes the work commute less time-consuming. Another explanation is that walking and cycling are perceived as healthy activities (Frank et al., 2006). A third explanation is that short commutes serve as a buffer between the work and private spheres (Jain and Lyons, 2008). And fourthly, people may see traffic congestion as a downside of car use (Jakobsson, Bergstad et. al, 2011). On the other hand, there are also a number of studies highlighting positive aspects of motorized travels. For example, car use might offer comfort, driving pleasure and a feeling of self-control (Jakobsson, Bergstad et al., 2011) or people travelling by public transit might experience the travel as pleasant because of the ability to do other activities during the trip such as reading or working (Ettema et al, 2012).

From the previous paragraph, it becomes clear that a broad variety of factors influence travel satisfaction, and in that way motivate people to use a specific travel mode. Travel dissatisfaction, on the other hand, can motivate people to choose another travel mode. For example, dealing with traffic jams on daily basis might cause dissatisfaction with car use, and in that way travel dissatisfaction may result in a motivation to use another travel mode such as the bicycle. In other words, being dissatisfied with your current way of travelling is likely to result in an alternative travel mode choice. Weinert et al. (2008) explored which motivations have resulted in a shift from either traditional bicycles or buses to e-bicycles. They found that almost 80% of the respondents used e-bicycle because it is faster than a traditional bicycle, and more than 40% because they no longer have to wait for the bus. Three other arguments that were often mentioned are: (1) e-bicycles are comfortable, (2) the bus is too crowded, and (3) the distance is too long for a traditional bicycle. Unfortunately, no studies have examined which motivations have resulted in a shift from private motorized travel modes (cars, motorcycles) to e-bikes. This research examines which conveniences users of an electric bicycle sharing system experience when they compare the use of electric bicycles with their previous travel mode that they have substituted.

2.6 Barriers to cycling

Travel studies confirm that travel mode choice depends on a number of factors. In comparison to users of other travel modes, cyclists depend on much more factors influencing travel mode choice. For example, cyclists decide whether they go by bicycle or not by taking into account changing daily factors such as the weather or having to carry things on your way (Heinen, Maat, Van Wee, 2010; 2011). This chapter gives an overview of the literature concerning the main barriers that people have for travelling by bicycle. It is important to note that this study does not refer to barriers as general factors, but defines the concept as risk factors or thresholds that prevent people to use a bicycle sharing system. The first three paragraphs discuss 3 major barriers to cycling in general: (1) climate and weather conditions, (2) travel distance and other route characteristics, and (3) psycho-social barriers such as the perception that cycling is dangerous or uncomfortable. The fourth paragraph concerns barriers that are specifically related to using a bicycle sharing system instead of using a private bicycle.

2.6.1 Climate and weather conditions

Most studies concerning the predictors to cycling, do not make a clear distinction between the concepts of 'climate' and 'weather'. Weather refers to the daily weather conditions, whereas the term climate describes the weather over a year (Heinen et al 2010). Short-term weather conditions and long-term climate conditions have a major but different influence on cycling, and that's why both concepts should be examined separately. We start with discussing the literature on the influence of climate conditions on cycling, and then discuss the influence of the weather on cycling.

One clear example showing how climate conditions influence cycling rates is that cycling in summer is more common than in other seasons. Nankervis (1999) examined the influence of climate conditions on cycling among several groups of tertiary students in Melbourne, Australia. His study confirms that more people cycle in summer and autumn compared to winter and spring (Nankervis, 1999). In other words, seasonal weather variation does have an effect on commuting, though the effect is less marked than might be expected. Over the year, it appears that cycling is at its highest in summer/autumn, declines in winter, and has a resurgence in spring, though not regaining its peak again till the following year. This can partly be explained by temperature: regions with low winter temperatures show sharper cycling decreases in winter. However, seasons are not only related to differences in temperature, but also to hours of daylight. Darkness seems to have a negative effect on bicycle commuting, in particular for women (Heinen et al 2010).

As said before, weather conditions vary from day to day, and in that way affect the daily decisions of cyclists (Heinen et al, 2010; Hunecke and colleagues, 2007). For example, people may be less likely to travel by bicycle on a rainy day – even on a summer day on which the climate conditions (temperature and daylight) are pleasant. The most negative weather condition as a reason for not

cycling is precipitation – the chance of rain. While precipitation is the most negative weather aspect, a number of other weather conditions also affect bicycle use. For example, an increase in temperature results in higher cycling percentages, meaning that cyclists perceive cold temperatures as more unpleasant than hot temperatures. In 2011, Flynn and colleagues examined the impact of weather conditions on the individual decision to commute to work by bicycle among adults in the US. Consistent with other research, their results show that the likelihood of bicycle commuting increased in the absence of rain (odds ratio = 1.91; 95% confidence interval 1.42, 2.57) and with higher temperatures (1.03; 1.02, 1.04). Contrary to expectations from preliminary research, their results show that the likelihood of commute cycling decreased with snow (0.90; 0.84, 0.98) and wind speed (0.95; 0.92, 0.97). Overall, their results thus indicate that precipitation, temperature, wind and snow conditions have significant and substantial effects on the odds of cycling to work by bicycle among adult commuters. Nankervis (1999) also examined effects of short-term weather conditions on bicycle commuting in additions to the long-term seasonal variation patterns discussed before. He distinguished three elements of weather that were considered to be influential: wind, rain and temperature. All three were found to be significant in relationship to rider numbers, suggesting that these elements may affect the number of cyclists. The number of cyclists is especially sensitive to temperature (R=0.363; p=.000). For wind (R=-0.209; p=0.011) and rain (R=-0.160; p=0.052), he also found significant relationships, suggesting that the greater the likelihood of wind speed or rain, the less commuters ride. A final study worth mentioning has examined temporal variations of bicycle demand in the Netherlands (Thomas, Jaarsma and Tutert, 2009). Their observations show that most cyclists value the weather in a similar way, but recreational demand is much more sensitive to weather than utilitarian demand.

2.6.2 Route characteristics and bicycle infrastructure

As already shortly mentioned in section 2.3, spatial factors such as travel distance and bicycle infrastructure influence cycling behavior. In this paragraph, we take a closer look at how these route characteristics can become barriers to cycling for people. Firstly, travel distance can become a barrier to cycling. An increase in trip distance results in cycling having a much lower share in mode choice and for commuting (Van Wee et al., 2006). So, distance can be a daunting factor for cyclists, and has a negative influence on whether individuals choose to commute by bicycle. A second barrier to cycling that many studies have found is 'landscape elevation': elevated landscapes have a negative effect on bicycle use (e.g. see Pucher et al., 1999; Rietveld & Daniel, 2004; Rietveld & Daniel, 2004; Vandenbulcke, et al., 2009) because cyclists need to put more physical effort when cycling through elevated landscapes. Thirdly, we discuss the importance of a well-connected and safe bicycle infrastructure for cyclists. It's mainly bad and unsafe bicycle infrastructure causing feelings of traffic unsafety among cyclists that discourages people to go by bicycle. In this study, the concept of bicycle

infrastructure refers to all elements in the spatial environment that are relevant for cyclists: from the existence & quality of bicycle paths to the presence of traffic lights, and from crossing aids to available parking places for cyclists. Previous research confirms that the type of bicycle infrastructure matters. Potential users prefer bicycle paths to curb lanes, and prefer bicycle paths to both bicycle lanes and roads without bicycle facilities. Comparative analyses by Pucher (2001) suggest that those countries with more cycling facilities have a higher modal split share of cycling and a higher level of bicycle safety. The issue of bicycle infrastructure is highly related to the perceived safety or unsafety of cyclists. Akar & Clifton (2008) found a range of improvements that would encourage university members of a campus in Washington (including staff members, graduate students, and undergraduate students) to cycle. Respondents emphasized the following three improvements that would increase the encouragement to cycle: (1) dedicated bike lanes, (2) trails and pathways separated from the roadways, and (3) more secure or covered bike parking. These three are all related to bicycle infrastructure, suggesting its importance for cycling. Other improvements in the bicycle infrastructure that were mentioned by respondents to encourage them to cycle, were more convenient bike parking and better lighting.

2.6.3 Psycho-social barriers

Heinen et al (2010) mention a wide range of psychological factors that are identified as reasons not to cycle in the literature. We have subdivided them into four groups that we will discuss here. The first group of psychosocial factors that can be seen having a negative influence on cycling, and thus may be barriers to cycle, is called 'perception of safety'. Both non-cyclists and cyclists often mention cycling being dangerous as a reason for them not to cycle. A heightened risk of having an accident results in the fact that people will cycle less. The fact that people perceive cycling as dangerous can be the result of many aspects, but bad bicycle infrastructure is definitely the main cause (as shown in 2.6.2). The second group of psychosocial factors is called 'social stigma'. The literature confirms that the bicycle being an uncommon transportation mode discourages people to cycle. When cycling is not a characteristic way of travelling, people might consider cycling as not cool or deviant. The third group of psychosocial barriers refers to 'planning'. Many people consider cycling as an inconvenient or uncomfortable way of travelling. For example, because they have to carry things on their way or because they have to take their children to school. People argue that, in some cases, driving is easier as they experience less difficulties in trip-chaining. 'Lack of fitness or knowledge' is the fourth and final group of psychosocial factors. For many people, lack of physical fitness or lack of physical effort is a reason not to cycle, especially when considering long distances or elevated landscapes. Lack of knowledge or lack of bicycle skills is another reason that people often mention as a barrier to cycle.

2.6.4 Dysfunctions in the system

So far, we have discussed the main barriers that people have for cycling. This final paragraph looks more specifically at the barriers that people have for not using a bicycle sharing system. People will only use the system when they find it convenient. On the contrary, perceiving too many inconveniences will decrease the likelihood that they will use the system. Here, we discuss four aspects of bicycle sharing systems that are often mentioned as barriers for using it: (1) no station near the home location/destination, (2) unavailability of bicycles at stations/no parking space at stations, (3) the general state of the bicycles, and (4) travel costs for using the system.

As discussed in chapter 4.1, the **location of docking stations** is highly relevant for (potential) users. The likelihood that people will use the system decreases significantly when their home location is located too far from a docking station (Schoner & Levinson, 2013; Fuller et al., 2011). But it's not only the distance between someone's residence and a docking station that can be a barrier; the distance between a docking station and someone's final destination can be another barrier. For example, campus members from a University in Washington confirmed they would use the bike sharing system more often when stations were located near the campus (Akar & Clifton (2008). Recently, Fishman et al. (2015) also confirmed that "docking station inconvenience" – referring to *'a too large distance between either home-station or station-destination'* – significantly influences people's decision to use a bicycle sharing system or not.

A second system-related barrier refers to the **unavailability of bicycles or vacant parking places** at docking stations. One of the main complaints heard from users of bike-sharing systems regards to unavailability of bicycles and unavailability of lockers at their destination (e.g. Lu, 2013; Raviv, Tzur, Forma, 2013; Chemla, Meunier, and Wolfler, 2011). The ability to meet the fluctuating demand for bicycles and for vacant lockers at each stations is a crucial factor for the success of a bicycle sharing system. In addition, the system should also provide enough vacant lockers so that people are able to return the bicycles at their destinations. Recently developed bicycle sharing systems meet this demand through a repositioning operation which consists of removing bicycles from some stations and transferring them to other stations, using a dedicated fleet of trucks (Raviv, Tzur, Forma, 2013; Zhao, 2015). If the bicycle sharing system cannot ensure that there are bicycles or free lockers available, it is assumed that users might abandon that particular docking station, or even worse, might abandon the entire bicycle sharing system. So, in others words, there are two sources or user dissatisfaction that may result in a lower frequency of using a bicycle sharing system, namely shortage of bicycles and shortage of parking places (Kaspi, Raviv, Tzur, 2015).

The third barrier we discuss relates to the **general state of the bicycles**. One could imagine that bicycles with broken brackets or no lights discourage people to use them as such bicycles are unsafe or uncomfortable. Therefore, bicycles in a bad state can be a barrier for people to use them. In practice, bicycle sharing systems deal with bicycles that become unusable and require repair on

daily basis. The presence of unusable bicycles goes hand in hand with the service given to users of the system. Evidence demonstrates that user dissatisfaction highly increases with the presence of unusable bicycles. One way to overcome this type of user dissatisfaction is by offering users of the system accurate information regarding the usability of bicycles (Kaspi, Raviv, Tzur, 2015). Broken brackets and no lights are two typical examples that may cause user dissatisfaction resulting in not using a bicycle sharing system. Electric bicycles, however, are even more complicated than traditional bicycles (e.g. an electric motor), and therefore the chance that electric bicycles deal with problems is also larger.

Finally, the fourth system-related barrier refers to **travel costs**. In general, most bicycle sharing systems keep membership and user fees low in order to encourage people to use the system. The majority offers the first 30 minutes free of charge with increasing prices for each additional 30 minutes. However, BiciMAD is one of the few bicycle sharing system that asks its members to also pay for the first 30 minutes. Many bicycle blogs and forums, but also transportation studies (e.g. Fishman et al., 2015) confirm that people find using bicycle sharing systems too costly, meaning that travel costs/user fees are seen as a barrier for using the system. Table 3 offers a comparison of user costs of for five European bicycles sharing systems: Vélo'v (Lyon), Vélib (Paris), Bicing (Barcelona), Nextbike (Berlin), and BiciMAD (Madrid).

User Costs	**Vélo'v, Lyon**	**Vélib, Paris**	**Bicing, Barcelona**	**Nextbike, Berlin**	**BiciMAD, Madrid**
Registration	€25	€29	€47,16	Free	€25/€15
1st 30 minutes	Free	Free	Free	€1,00	€0,50
2nd 30 minutes	€0,75	€1,00	€0,74	€1,00	€0,60

Table 3: A comparison of user fees of five European bicycle sharing systems. Sources: http://www.nextbike.de/en/berlin/prices/, https://www.bicing.cat/es/content/tarifas, http://en.velib.paris.fr/Subscriptions-and-fees/Usage-charges, http://www.velov.grandlyon.com/en/subscribe.html, http://www.bicimad.com/index.php?s=tarifas

To conclude, the literature so far has distinguished four major barriers regarding bicycle sharing systems that discourage people to use the system: (1) the location of docking stations, (2) unavailability of bicycles or vacant parking places, (3) the general state of the bicycles, and (4) dysfunctions in the system. All studies referred to in this section on barriers to cycling (Section 2.5) have based their results among a sample of non-users of bicycle sharing systems. In other words, no studies are found that included users of a system when asking about the barriers they perceive for using it more often. This study intends to complement the literature by including users as well, so that we can gain insight in the factors that tend to decrease the likelihood of their system-use.

2.7 Conceptual model

Figure 3 illustrates the conceptual model that is derived from the theoretical background. This study uses this model to predict the frequency of using an electric bicycle sharing system for three types of travel purposes: (1) work-/school-commutes, (2) trips in leisure time, and (3) trips at night. Some of the variables included in our research model are based on existing literature, but other variables are relatively 'new' within the field of transportation and/or cycling.

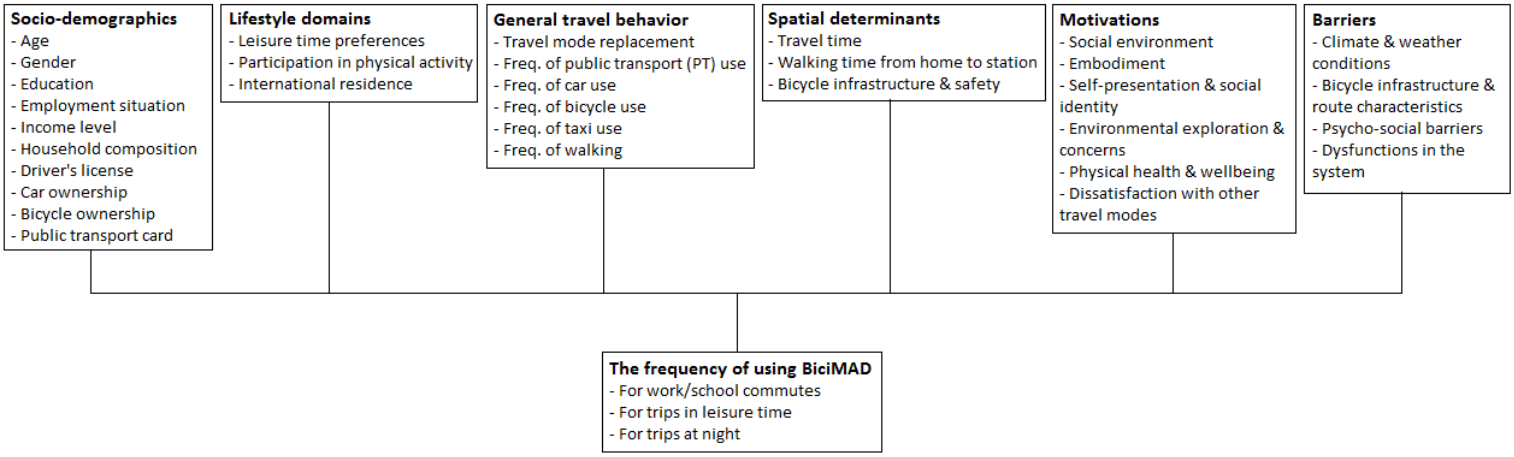

Figure 3: Conceptual model, illustrating six types of predictor variables and the dependent variables (subdivided into three travel purposes)

3. Methodology

This chapter shows which methods are used for answering the research questions of this study. After discussing the research strategy and design, the second section of this chapter discusses the research population, research location, and the pilot study that was performed before data collection. Section three discusses how data is collected and section four how data was analyzed. Finally, the reliability and validity of the results of this study are discussed in section five.

3.1 Research strategy and research design

Based on the formulation of the research goal and questions, this study uses a quantitative research strategy. This strategy is often used in studies that want to collect data from a large amount of respondents. This study also aims to collect data from a large research sample because that increases the reliability of the results. Conclusions about the influence of personal or environmental variables on the use of an electric bicycle sharing system are only reliable and valid when data is collected from a large amount of respondents. Above that, almost all transportation studies that have examined the use of particular travel modes have used a quantitative strategy. Applying a quantitative research strategy makes it easier to compare the results of this study with results from previous studies in order to find out how this study complements the existing literature on cycling. The quantitative research method that is used in this study is a questionnaire (see section 3.3.1).

The research design used in this study is a 'case study'. A case study is characterized by a detailed and intensive analysis of one specific case related to the topic of the research. In this study the focus is more on the people that use an electric bicycle sharing system than on the characteristics of a specific e-bicycle sharing system. The selection of the case used in this study – the e-bicycle sharing system in Madrid – is argued in section 3.2.2.

3.2 Research population and location

This section first discusses the total research population, the sample size, and discusses why this study is performed in Madrid. The final part of this section discusses the process of gaining access to the respondents that have participated in this study.

3.2.1 Research sample size

The most recent data on BiciMAD-users show that 56.342 people had an annual BiciMAD-membership at the 30st of September 2015 (Ayuntamiento de Madrid, 2016). In order to generalize our findings to the entire research population, we have to make sure we have a representative sample size. A research population of 56.342 persons requires a sample size of at least 381 respondents with a 95% Confidence Level and a Confidence Interval (Margin of error) of 5. As will be

shown in section 3.2.4, this study collected data from 514 respondents, making the outcomes externally valid.

3.2.2 Research location

Data was collected in Madrid, the capital of Spain. This city was selected as the research location of this study for two reasons. The main reason for selecting Madrid as a research location was that the municipality of Madrid was the first European that introduced a bicycle sharing system with electric bicycles in June 2014. In 2008, the municipality of Madrid developed a policy plan called 'Plan Director de Movilidad Ciclista' to promote the bicycle as a travel mode among its citizens. The main goal of this plan was to make residents aware of three major benefits that bicycle have. Bicycles contribute to a better health, bicycles improve environmental conditions and bicycles occupy less urban space on the roads. Part of this policy plan was to introduce a bicycle sharing system in the city (Ayuntamiento de Madrid, 2008). The municipality hired the company 'Bonopark' to arrange and introduce this bicycle system called BiciMAD. Directly after implementation of BiciMAD, many residents subscribed and the number of subscribers is still increasing. In addition, the area that the bicycle system comprises is also growing as more and more docking stations are built. Given that the number of BiciMAD-members is still growing and given that the amount of trips covered by BiciMAD is still increasing, one could say that the introduction of this bicycle sharing system has been successful. The large amount of BiciMAD-members makes it easier to collect data from sufficient respondents, resulting in strong and reliable research outcomes.

The second reason for selecting Madrid to be the research location was a more practical reason. In order to develop a good and accessible questionnaire for respondents, knowledge of the native language is a high requirement. Given that the researcher of this study speaks the Spanish language fluently, there was a strong preference to perform this study in a country were Spanish is the native language. Above that, it was possible to collect data during an internship of 4½ months at a Transportation Research Institute (TRANSyT) at the Universidad Politécnica de Madrid.

3.2.3 Pilot study

Before starting data collection, a pilot study was conducted from 4-10 November to detect possible shortcomings or avoid overlooking errors within the questionnaire. Of the 31 pilots, 14 were current BiciMAD-users. As a result of this pilot study, several questions were reformulated because of misunderstandings, and other questions were deleted from the questionnaire because of the relatively large amount of time people had spent to complete the survey. The final version of the questionnaire that was used for collecting data can be found in Appendix H.

3.2.4 Sampling

Data was collected in two phases due to the fact that two different types of samples were taken from the research population. In the first phase, access was gained to our research population by means of an existing database of BiciMAD-users that have already participated in earlier questionnaires on BiciMAD performed by TRANSyT, the Transportation Research Institute of the 'Universidad Politécnica de Madrid'. This database contained the mail addresses of 417 current BiciMAD-users. So, in this first phase of the survey data was collected through non-probability, convenience sampling. This sample was approached through an email invitation to the questionnaire that was put online on SurveyMonkey. The questionnaire was available from 16 November until 30 November, and a reminder was sent to all respondents on the 25th of November. Figure 4 shows the progress of data collection in this first phase.

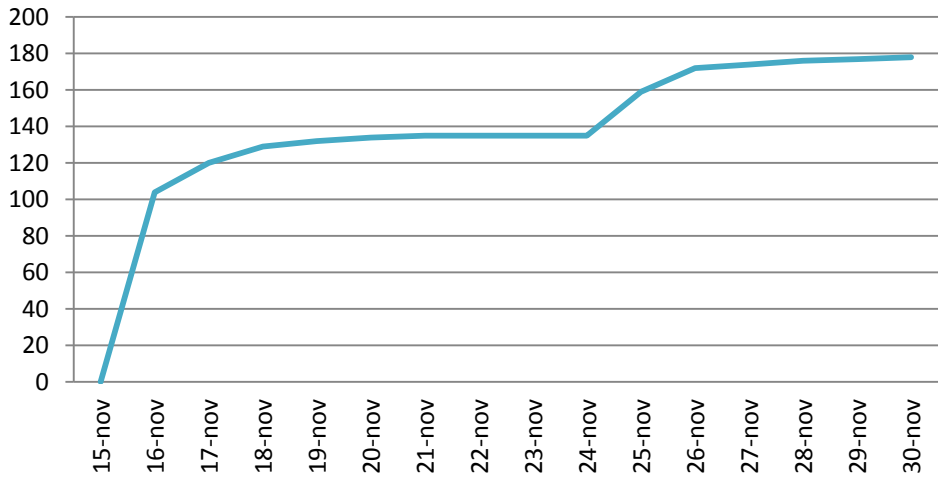

Figure 4: Progress of completed questionnaires in phase 1 of data collection

The second phase of data collection started with a meeting with the directory of Bonopark, the company that owns BiciMAD. Bonopark and the Municipality of Madrid were interested in the results of this study on the use of BiciMAD, and were willing to corporate. As a result, the survey was sent to a large sample (N=2.400) of current BiciMAD-users. They had access to the questionnaire through a public link to the survey from 14 December to 29 December. This second phase of data collection was through stratified, probability sampling. Firstly, the research population (current BiciMAD-users) was divided into 'strata' based on age and postal code. Age was subdivided into 4 groups:

1. <18 years
2. 18-24 years
3. 25-44 years
4. >45 years

All postal codes in the city of Madrid were grouped into three strata. The first contains all postal codes located in the city-center of Madrid. The second stratum contains all postal codes located in the periphery of the city, and the third stratum contains all other postal codes:

1. Group 1: 28004, 28012, 28013, 28014
2. Group 2: 28001, 28007, 28009, 28010, 28015
3. Group 3: other postal codes

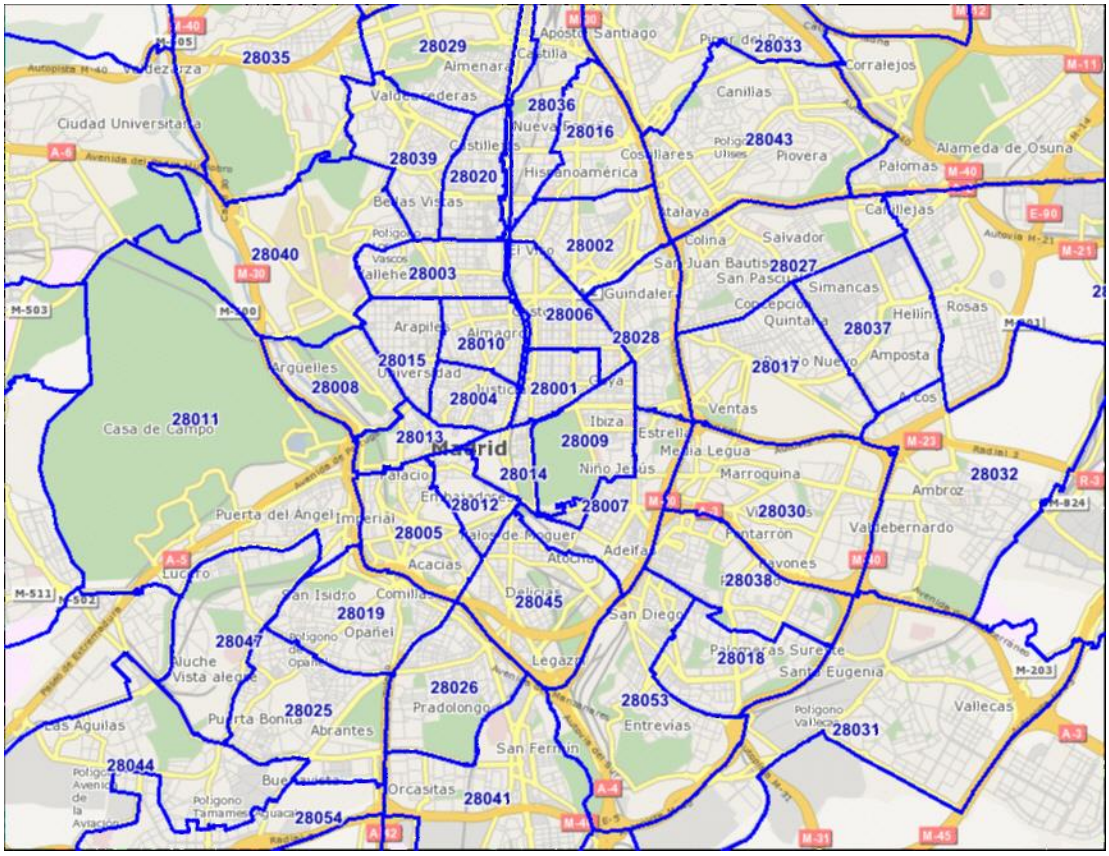

Figure 5: Map of Madrid's community, including the classification of neighborhoods based on postal code

When the four age-groups and three postal code-groups are taken together, our stratified sample consists of 3 x 4 = 12 strata. From each stratum, a representative simple random sample was selected. For example, one group was: BiciMAD-users aged between 18-24 years, living in a postal code within the Periphery (Group 2). So the final sample of 2.400 BiciMAD-users was established as follows:

	Centre	*Periphery*	*Rest*	**Total**
<18 years	100	100	100	**300**
18-24 years	100	100	191	**391**
25-45 years	300	399	569	**1.268**
>45 years	100	112	229	**441**
Total	**600**	**711**	**1.089**	**2.400**

Table 4: Classification of 2.400 randomly selected BiciMAD-users into 12 strata based on age and postal code

Respondents are, thus, collected by a combination of convenience sampling and stratified probability sampling. Taken respondents from both samples together, we have a total sample size of 417 + 2.400 = 2.817 respondents. Among the first (non-probability) sample, the response rate was 37%. In other words, 156 people of the non-probability sample have completed the entire questionnaire. In the second sample (public link), the response rate was 15% (358 completed questionnaires). Altogether, a total of 156 + 358= 514 complete questionnaires was collected– clearly meeting the required sample size of 381 complete questionnaires.

Given that our research sample consists of two types of sampling, the two samples may differ from each other on some aspects. As a result, this may to some extent influence the research outcomes. Although no striking differences are found between the two samples, one aspect is worth to mention. The first sample, consisting of people that are willing to participate in questionnaires concerning BiciMAD, seems to use the bicycle sharing system more often compared to the second sample. This can be explained by the fact that people that are willing to participate in questionnaires are, in general, quite satisfied with the service of BiciMAD or are willing to contribute to improve the service. Even though the first sample is relatively small in comparison with the second (stratified) sample, this may influence the regression output to some extent.

3.3 Data collection

3.3.1 Online questionnaire

Within social-scientific research, data is often collected through a questionnaire. Recently, online questionnaires that are available on the Internet are a more popular way to collect data compared to offline questionnaires that respondents have to fill in on paper. However, online questionnaires have both advantages and disadvantages compared to offline questionnaires. The two biggest advantages of online questionnaires are that they require less time and money for the researcher and that respondents can make the questionnaire in their own time at home on their mobile phone or computer. However, a big disadvantage of online questionnaires compared to offline questionnaires is that respondents are more likely to not fill in the questionnaire, resulting in a low response rate. This study used an online questionnaire for two reasons. Firstly, an offline questionnaire would not have been able within the amount of time and money that was available for this study. And secondly, the easiest way to gain access to the respondents was by e-mail, and therefore a public link to the questionnaire was desirable.

The online questionnaire consisted of 39 questions that were subdivided into 6 parts (see Appendix H): (1) General use and opinion on BiciMAD, (2) Motivations and barriers to using BiciMAD, (3) Work-/school-commutes, (4) Trips in leisure time, (5) Trips at night, and (6) Personal characteristics and lifestyle. In collaboration with Bonopark – the company that owns BiciMAD –

three prices were distributed among all respondents that participated and fully completed (N=514) the questionnaire. These three prices were three free annual subscriptions to use BiciMAD in 2016.

3.3.2 Operationalization concepts

The theoretical framework that is used in this study has resulted in the conceptual model (see section 2.7). To meet the final research goal, it is necessary to operationalize the concepts included the model. These concepts are measured by corresponding questions in the questionnaire. Below, the operationalization process of each concept is described. In Appendices A-G, one can find an overview of all variables with their corresponding answer categories (Codebook SPSS).

Socio-demographic variables

The socio-demographic variables included in the questionnaire are age, gender, education, employment situation, income level, household composition, driver´s license, access to a car/motorcycle, access to a private bicycle, and access to the public transport. These ten socio-demographics are all measured by categorical variables with 2 or more answer-categories. In Appendix A, one can find the complete operationalization scheme of these variables.

Lifestyle domains

As illustrated in the conceptual model, three lifestyle domains are distinguished: (1) leisure time preferences, (2) participation in physical activity, and (3) international residence. To measure leisure time preferences, respondents were asked to select from a list of leisure activities which activities the like to perform in their leisure time. This list contained 15 leisure activities – ranging from individual to social and from sedentary to active leisure activities. The second lifestyle domain, participation in physical activity (PA), was measured by three questions in the questionnaire: *´How often do you participate in vigorous exercise?´*, *´How often do you participate in low-intense exercise?´*, and *´Do you consider cycling with BiciMAD as physical activity?´*. This last question was a yes/no question; the other two questions contained five categories: (1) daily, (2) several times a week, (3) once a week, (4) once a month, and (5) never. Finally, the third lifestyle domain, international residence, was included because of the major international differences on bicycle shares and on the cultural acceptance of cycling (see Chapter 2.3). Having lived for a significant amount of time in, for example, The Netherlands, may increase the likelihood of using a bicycle sharing system in other countries. The questionnaire contained two questions to measure this lifestyle domain. First, respondents were asked to indicate whether they have ever lived in another country than Spain. Here, 'living' was defined as spending more than 3 consecutive months in another country. The respondents that answered this question with 'yes' had to identify this/these country/countries. After data collection, these countries were divided into three groups based on the

daily cycling share of each country. Group 1 consisted of countries where the bicycle share is above 15% (The Netherlands, Denmark and Germany). Group 2 consisted of countries with a bicycle share between 5% and 15%, and group 3 consisted of all countries with a bicycle share below 5% (excl. Spain). Appendix B shows the operationalization scheme of these three lifestyle domains.

Spatial determinants

The distance that current users of a bicycle sharing system travel is measured by one question in the questionnaire. Respondents were asked to indicate the maximum amount of time (in minutes) they had spent on a BiciMAD-trip in the past month. This variable is thus measured in time units instead of distance units, based on the argument that people often find it more difficult to give a clear estimation of distance than time. Another question was included in the questionnaire for measuring 'walking time from the home location to the closest docking station'. Due to the same reason, this item was also measured in minutes instead of distance units. Finally, four items were included to measure respondents' opinion on the bicycle infrastructure (and safety) in Madrid. Respondents had to indicate to what extent they are satisfied with the following characteristics: 'the location of docking stations in Madrid', 'the bicycle paths in Madrid', 'the parking places for cyclists in Madrid', and 'the road signals for cyclists in Madrid'. These four items were measured on a 5-point Likert scale ranging from 1 (very unsatisfied) to 5 (very satisfied). The operationalization schemes of all spatial variables can be found in Appendix C.

Travel behavior

Replaced travel mode was measured as a categorical variable by the following question: *"In general, which travel mode did you use before you started using BiciMAD?"* This question was included for two reasons. Firstly, to see how the introduction of the bicycle sharing system in Madrid changes the travel mode share in Madrid. And secondly, to see which of the travel mode switches results in the highest frequency of using BiciMAD. For example, that a switch from car to BiciMAD results in a higher frequency of using BiciMAD than a switch from taxi to BiciMAD.

To measure respondents' use of other travel modes than BiciMAD, they were asked to indicate how often they use the following five travel modes: 'car/motorcycle', 'public transportation', 'private bicycle', 'taxi', and 'walking'. Five answer categories were created for this: always, often, sometimes, barely, never. This question was asked for 3 different travel purposes – namely, work-/school-commutes, trips in leisure time, and trips at night. So, a total of 15 (5 travel modes x 3 travel purposes) questions were included to measure respondents' frequency of using other travel modes than the bicycle sharing system. The operationalization scheme belonging to these 18 questions can be found in Appendix D.

Motivations

Six types of motivations to travel by bicycle were derived from the literature: social influence, embodiment, self-presentation & social identity, environmental exploration & environmental concerns, physical health & wellbeing, and dissatisfaction with other travel mode. For each type, items were included in the questionnaire, and altogether the questionnaire consisted of 36 motivational items. These 36 items were all measured on a 5-point Likert scale in which 1 refers to 'highly disagree' and 5 refers to 'highly agree'. An overview of these 36 items is given in Appendix E. The large majority of all items are derived from previous studies that measured motivations to cycling. For example, the items measuring environmental concerns are derived from a widely applied instrument to measure this concept: The Commitment to Environmental Sustainability Scale (CESS). This scale consists of 7 items measuring environmental cognition, but some of these items are reformulated in the questionnaire of this study so that they apply better to the specific case of cycling.

Barriers

For every travel purpose (work/school commutes, trips in leisure time, trips at night), respondents were asked to indicate which barriers they perceive while using BiciMAD, and thus, result in less system-use. A list of barriers was developed based on existing evidence on barriers to cycling, and respondents were asked to select from this list the strongest barrier they perceive. Some examples of these arguments were: *´There is no BiciMAD station close to my residence/destination´*, *´I can never be sure whether there are bicycles available/free parking spaces´*, *´Inconvenient weather conditions´*, *´Travelling by BiciMAD is uncomfortable (e.g. due to clothes/bags I have to carry)´*, and *´I have to take my children to school before I go to my work´*. The complete list of arguments that were included in the questionnaire can be found in Appendix F.

Frequency of using BiciMAD

Finally, to measure the dependent variables in our research model, the frequency of using BiciMAD, respondents were asked to indicate how often they use the bicycle sharing system for three travel purposes: (1) work-/school-commute trips, (2) trips in leisure time, and (3) trips at night time. These questions were measured by a 5-point scale ranging from a value of 1 (always) to 5 (never). The operationalization scheme of these three variables can be found in Appendix G.

3.4 Data analysis

To analyze the data collected through the online questionnaire, this study made use of the program IBM SPSS Statistics 23. First, the research sample is examined by analyzing the descriptive statistics of all respondents so that research questions 1 and 2 can be answered. For answering the other three research questions, a factor analysis was performed and regression models were developed. These two statistical methods are explained into more detail in the following two sections.

3.4.1 Factor analysis

To answer the third research question, factor analysis was performed. In the questionnaire, 36 items were included to measure the motivation that current BiciMAD-users have for using the bicycle sharing system. These items were mainly derived from existing literature on the motivations that people have for traditional cycling, but some items were newly developed as they specifically deal with aspects related to electric bicycle sharing systems. Factor analysis is performed to find out whether several items measure the same type of motivation and can be grouped into one overarching factor. The goal is to reduce the 36 motivational items to less factors so that these factors can be used in a regression analysis in a later stadium. This study used principal component analysis (PCA), which is one of the most applied types of factor analysis. The steps that were taken during this PCA and the extraction of factors are described in section 4.2.

3.4.2 Regression analysis

Finally, to answer questions 4 and 5, a statistical method called 'regression analysis' is used. According to Field (2009), '*the essence of regression analysis is to fit a model to your data and use this model to predict values of the dependent variable from one or more independent variables'* (Field, A., 2009, p.198). In other words, regression analysis is a way of predicting the frequency of using BiciMAD from one or more predictors. As shown in the research model (see section BLABLA), this study contains three dependent variables. As such, three regression models have to be created. These three dependent variables are ordinal variables, and therefore, ordinal regression analyses have been performed.

Because this study deals with a large amount of independent variables, a decision had to be made on how to select predictor variables. The predictors that are included in the model and the way in which they are entered into the model have a great impact (Field, 2009, p.212). This study selected variables by means of a backward method. This means that the initial model contains all independent variables present in this study. These variables have been added to the model in such a way that it corresponds with this study's conceptual model. First, all socio-demographic variables are entered, followed by variables measuring lifestyle and general travel behavior. Then, spatial variables were entered, and in the last step the motivational factors (see section 3.4.1) and the barriers were

entered. All categorical variables are entered into the model as 'Factors', but the motivational factors are entered as 'Covariates' as these are scale-variables. If a predictor variable does not significantly contribute to the model in predicting the dependent variable, it is removed from the analysis and the model is re-estimated for the remaining predictor variables. This stepwise method is repeated until the model only contains significant predictor variables.

3.5 Reliability and validity of the study

The foundation of every research is to answer a specific question. A right answer can only be found, when the results of the study are valid and reliable. Validity refers to whether the research instrument – in this case, an online questionnaire – measures what it is designed to measure (Field, A., 2009, p.11). Reliability of a study refers to the ability to produce the same results under the same conditions (p.12). Below, both the validity and the reliability of this study are discussed.

Two types of validity are distinguished, namely internal validity and external validity. Internal validity refers to the overall quality of the research: the processes of data collection and data analysis have to be performed in such a way that the final conclusions are valid. In this study, data was collected by an online questionnaire so that a large amount of data could be collected. In addition, the large majority of all respondents that participated in this study are selected by stratified random sampling so that the sample is a valid reflection of the total research population. External validity refers to whether it is possible to generalize the research findings to a wider context. For example, whether the conclusions from this study also apply to bicycle sharing systems in other cities. One of the main disadvantages of case study designs is that the research findings are often not generalizable. Therefore, it could be stated that the external validity of this research is not very high. However, one of the reasons to select this case of Madrid has been to insure external validity as this bicycle sharing system is a representative case for all bicycle sharing systems.

It could be concluded that the reliability of this research is strong when it meets the following two assumptions. Firstly, the outcomes should be the same when another research sample was approached to fill in the questionnaire. Based on the fact that this study used a random stratified sample, this assumption is met. And secondly, the outcomes of this study should be the same when this study was performed at another moment in time. The questionnaire was sent to the respondents in winter (November and December, 2015). Literature confirms that cyclists are highly sensitive to seasonal weather conditions, resulting in less bicycle use in winter than in summer. Therefore, the results of this study may be affected by the period in which data was collected. A recommendation to future studies is to perform the same study during the summer months to see whether different results come up.

4. Results

4.1 Descriptive statistics

The questionnaire was sent to 2.817 BiciMAD-users. A total of 585 respondents have participated in the survey of which 514 have completed the questionnaire. In this section, an overview is given of the six groups of independent variables as presented in our research model.

4.1.1. Socio-demographics

Tables 5 and 6 show the descriptive statistics of the socio-demographics of our respondents (N=585). Our sample contained 67% male and 33% female respondents. Taking into account that the total population of Madrid contains 54% women and 46% men in 2015 (Ayuntamiento de Madrid, 2015, p.35), the gender percentages indicate that men tend to be overrepresented in the sample compared to women. For age, we found that most BiciMAD-members are aged between 25-45 years, namely 59% of our total sample. Considering that only 30% of the total population of Madrid has an age of 25-44 year (Ayuntamiento de Madrid, 2015, p.35), we can conclude that (young-)adults are most often subscribed to BiciMAD, while children (<18 years) and the elderly (>45 years) use the bicycle sharing system less often.

In terms of education, most BiciMAD-users are highly educated: roughly 77% of our respondents has a University Degree or a higher educational level (Master Degree or PhD). In addition, and probably partly explained by the high educational level, the majority has a relatively high income level and is either (self-)employed or a student. Finally, respondents were asked to answer questions related to their access to other travel modes, namely to the public transportation system, a private bicycle, and a car. Of all respondents, 53% has a public transportation card, meaning that 53% of the BiciMAD-users has access to Madrid's public transportation system. Furthermore, the majority of our respondents has access to a private bicycle (57%) and access to a car (67%).

Variable	Frequency	Missings	Percentage
Total	**585**	**-**	
Gender	**518**	**67**	**100.0%**
Male	344		66.4%
Female	174		33.6%
Age	**518**	**67**	**100.0%**
<18 years	14		2.7%
18-24 years	68		13.1%
25-45 years	307		59.3%
>45 years	129		24.9%
Education	**518**	**67**	**100.0%**
Primary school	3		0.6%
Secondary school	13		2.5%
Bachillerato	54		10.4%
Ciclos formación profesional	47		9.1%
University Degree	214		41.3%
Master degree	167		32.2%
PhD/Doctorate	20		3.9%
Income level	**516**	**69**	**100.0%**
<1.300 euros	102		19.8%
1.300-2.500 euros	191		37.0%
>2.500 euros	223		43.2%
Employment situation	**529**	**56**	**100.0%**
Employed	301		56.9%
Self-employed	84		15.9%
Unemployed	31		5.9%
Retired	4		0.8%
Student	98		18.5%
Housekeeper	4		0.8%
Other	7		1.3%

Table 5: Descriptive statistics of socio-demographic variables

Variable	Frequency	Missings	Percentage
Household composition	**516**	**69**	**100.0%**
1 person	85		16.5%
2 persons	186		36.0%
3 persons	89		17.2%
4 persons	100		19.4%
5 persons	35		6.8%
6 persons or more	21		4.0%
Private bicycle	**514**	**71**	**100.0%**
Yes	291		56.6%
No	223		43.4%
Car ownership	**514**	**71**	**100.0%**
Yes	281		54.7%
No	172		33.5%
Yes, but I must ask other household members	61		11.9%
Driver's license	**514**	**71**	**100.0%**
Yes	429		83.5%
No	85		16.5%
PT card	**514**	**71**	**100.0%**
Yes	270		52.5%
No	244		47.5%

Table 6: Descriptive statistics of socio-demographic variables

4.1.2. Lifestyle domains

As shown in the research model, the concept of lifestyle is divided into three domains: (1) leisure preferences, (2) participation in physical activity, and (3) international residence. Figure 6 illustrates the percentages of respondents that have indicated to like to perform a particular activity in their leisure time. Among BiciMAD-members, the following leisure activities are popular: visiting friends/family (70%), travelling (68%), going out for lunch/dinner (67%), exercising (61%), and attending cultural events (59%). Rather unpopular activities are: watching/attending sportive events (25%), cooking (33%), shopping (33%), and listening to music or playing an instrument (37%).

Table 7 shows the descriptive statistics of the second domain of lifestyle: participation in physical activities (PA). Here, a distinction was made between physical activities with a high intensity (e.g. playing a football match) and those with a low intensity (e.g. walking). As the percentages from Table 9 show, most BiciMAD-users have a rather active lifestyle. A large majority (46%) participates several times a week in physical activities with a high intensity, and 76% participates either daily or several times a week in low-intense PA.

Table 8 shows the descriptives of our third domain of lifestyle: international residence. This domain is measured by four nominal variables. The first variable measures whether someone has ever lived in another country than Spain. The other three variables measure in which country or countries people have lived. These three variables are based on the daily modal share of cyclists in countries. The first out of the three variables measures whether someone has lived in a country where the modal share for daily cyclists is higher than 15% (The Netherlands, Denmark, Hungary, and Sweden). The second variable measures whether someone has lived in a countries where the modal share is 5-15%, and the third variable measures whether people have lived in another country than Spain where the modal share for cyclists is below 5%. The percentages in Table 10 show that more than 50% of all respondents have also lived in another country than Spain, where having lived is defined as 'spending more than 3 consecutive months in another country'. Only 6% of all our respondents have lived in at least one country where cycling is a very common way of travelling. 15% of all respondents has lived in at least one country where 5-15% of all daily trips are covered by bicycle, and 43% has lived in another country than Spain where cycling also is an uncommon way of travelling. As we will discuss in Section 4.3 in more detail, it will be difficult to find reliable conclusions about the relationship between international residence in a bicycle-oriented country and the frequency of using BiciMAD as only 6% of all respondents has lived in such a country.

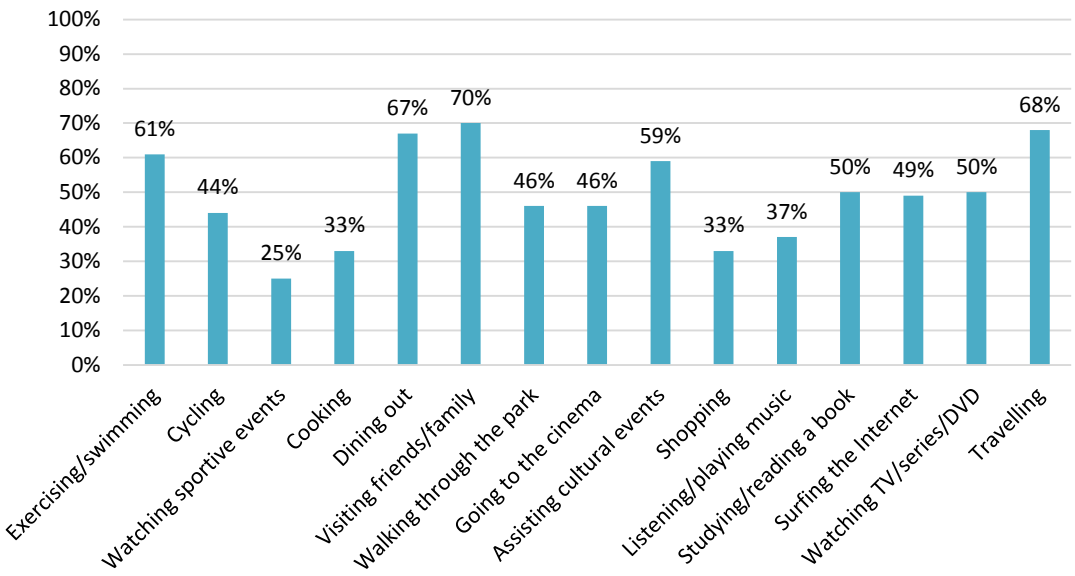

Figure 6: Percentage of respondents that likes to perform a leisure time activity

Variable	Frequency	Missings	Percentage
Total	**585**	**-**	
High-intense sport participation	**514**	**71**	**100.0%**
Daily	42		8.2%
Several times a week	238		46.3%
Once a week	98		19.1%
Once a month	41		8.0%
Never	95		18.5%
Low-intensity sport participation	**514**	**71**	**100.0%**
Daily	184		35.8%
Several times a week	206		40.1%
Once a week	83		16.1%
Once a month	21		4.1%
Never	20		3.9%
Is BiciMAD a sport activity?	**513**	**72**	**100.0%**
Yes	261		50.8%
No	253		49.2%

Table 7: Descriptives on participation in physical activity

Variable	Frequency	Missings	Percentage
Total	**585**	**-**	
Lived in other countries than Spain	**514**	**71**	**100.0%**
Yes	267		51.9%
No	247		48.1%
Countries 1*	**513**	**72**	**100.0%**
Yes	33		6.4%
No	480		93.6%
Countries 2**	**513**	**72**	**100.0%**
Yes	76		14.8%
No	437		85.2%
Countries 3***	**513**	**72**	**100.0%**
Yes	219		42.7%
No	294		57.3%

Table 8: Descriptive statistics on international residence
***Countries with a daily bicycle share >15%**
****Countries with a daily bicycle share 5-15%**
*****Countries with a daily bicycle share <5% (excl. Spain)**

4.1.3. Spatial determinants

Respondents were asked to indicate how much time they spent on their longest BiciMAD trip in the past month. As Table 9 shows, the mean score was 29 minutes and the modal score was 20 minutes (N=571). This mean score suggests that most people are aware of the increasing costs they pay for using the system after the first 30 minutes. Only 4.7% of the respondents use BiciMAD for trips shorter than 10 minutes, whereas only 4.6% use BiciMAD for trips of 60 minutes or more. In other words, the large majority (roughly 91%) uses BiciMAD for trips with a duration of 10 minutes of more, but not longer than one hour. The fact that BiciMAD-users do not seem to use BiciMAD for either very short or very large distances is in line with existing literature stating that the bicycle is often used as a travel mode for distances that are neither too short nor too large. People often prefer to walk for short trips (Keijer & Rietveld, 2000), whereas people prefer motorized vehicles for larger trips (Van Wee et al., 2006).

The second spatial determinant included in our model is 'walking time to closest docking station'. This concept was operationalized by asking respondents to indicate the amount of time (in minutes) they have to walk from their home location to the closest to docking station. As shown in Table 9, respondents (N=571) walk, on average, 7 minutes from their home location to the closest docking station, with a modal score of 5 minutes. A strong decrease (cut-off point) is seen at the walking distance of 10 minutes – meaning that when people have to walk 10 minutes or more from home to a docking station they seem to use BiciMAD considerably less often. In addition, respondents rated their satisfaction with the location of docking stations in Madrid on a 5-point Likert scale, with the average score being 3.64 (see Figure below). So, respondents are quite satisfied with the location of docking stations in Madrid, but there is still room for improvement.

The last spatial determinant in our model is the presence of and quality of the bicycle infrastructure. Three characteristics of the bicycle infrastructure were included in the questionnaire, and respondents had to indicate on a 5-point Likert scale to what extent they were satisfied with these characteristics: 'the bicycle lanes', 'the parking places for bicycles', and 'bicycle signals on the roads'. In Figure 7, the mean scores of these three items was rather low (2.1; 2.3; 2.6 respectively), indicating that most BiciMAD-users are unsatisfied with the current bicycle infrastructure in Madrid.

Variable	N	Missings	Mean	Maximum	Minimum	Mode
Time spent on longest BiciMAD trip	571	14	29	360	0	20
Walking time from residence to closest station	571	14	7	120	0	5

Table 9: Time that current BiciMAD-users spend on their BiciMAD-trips and the time they have to walk from home to the closest docking station

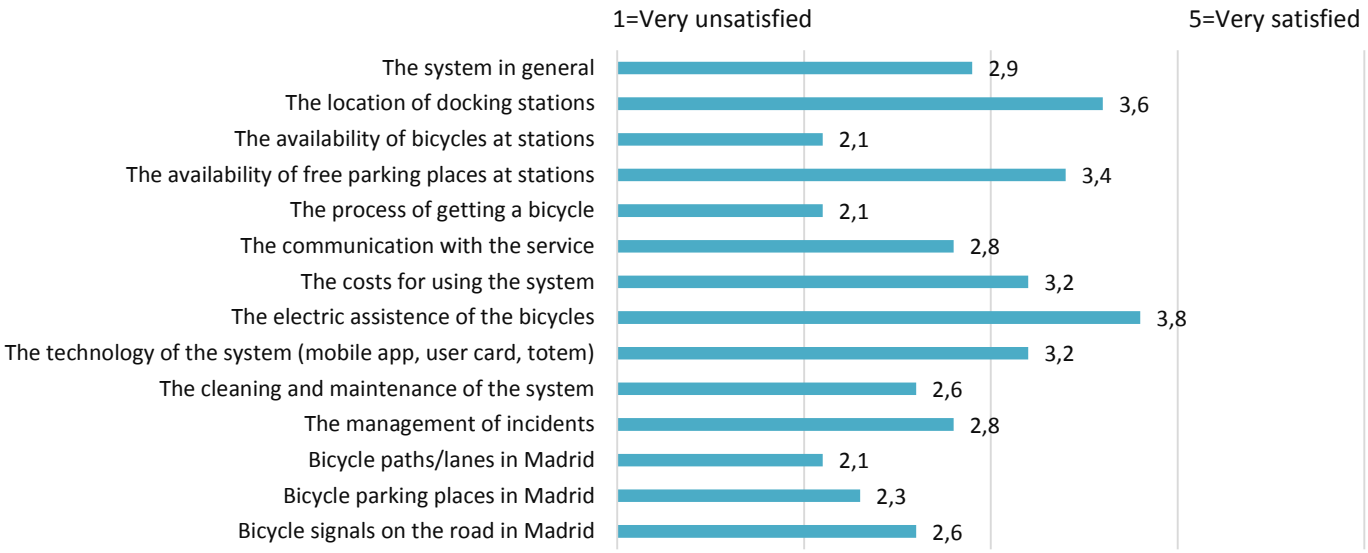

Figure 7: Satisfaction with characteristics of the bicycle sharing system, and with the bicycle infrastructure in Madrid

4.1.4. Travel behavior

The fourth group of independent variables in our research model is 'travel behavior'. Here, we examined the general travel behavior of our respondents. We asked them to indicate how often they use other travel modes than BiciMAD for the three travel purposes. They had to indicate on a 5-point Likert scale ranging from 1 (always) to 5 (never) how often they use a car, public transportation, a private bicycle, a taxi, a combination of BiciMAD with public transportation, and walking. Results are shown in Tables 10, 11, and 12. In addition, respondents were asked which travel mode they used to go with before using BiciMAD. In other words, which travel mode did they replace for BiciMAD? These results are shown in Table 13.

	Always	**Often**	**Sometimes**	**Barely**	**Never**
Public transport combined with BiciMAD	4.6%	8.6%	13.1%	15.4%	58.2%
Car/motorcycle	14.3%	9.7%	10.8%	14.1%	51.1%
Public transport	26.4%	22.8%	20.0%	13.5%	17.3%
Private bicycle	3.4%	6.3%	8.2%	8.4%	73.6%
Walking	13.7%	19.8%	17.9%	10.5%	38.0%
Taxi	0.6%	2.7%	10.8%	22.6%	63.3%

Table 10: Travel mode use for work/school commutes

	Always	**Often**	**Sometimes**	**Barely**	**Never**
Public transport combined with BiciMAD	2.5%	20.6%	25.0%	19.6%	32.3%
Car/motorcycle	3.5%	18.3%	22.3%	24.0%	31.9%
Public transport	11.3%	46.7%	27.1%	9.8%	5.0%
Private bicycle	1.3%	9.0%	12.7%	11.0%	66.0%
Walking	8.8%	51.2%	27.1%	6.3%	6.5%
Taxi	0.4%	5.0%	17.3%	30.0%	47.3%

Table 11: Travel mode use for trips in leisure time

	Always	Often	Sometimes	Barely	Never
Public transport combined with BiciMAD	2.9%	13.5%	20.1%	22.2%	41.3%
Car/motorcycle	4.4%	14.5%	17.8%	20.7%	42.7%
Night bus	3.9%	10.0%	18.0%	24.1%	44.0%
Private bicycle	0.2%	2.7%	6.0%	7.9%	83.2%
Walking	8.9%	42.7%	31.3%	7.7%	9.5%
Taxi	2.7%	18.7%	32.2%	25.1%	21.2%

Table 12: Travel mode use for trips at night

	Frequency	Percentage
Public transport	364	64.8%
Car	43	7.7%
Motorcycle	26	4.6%
Private bicycle	27	4.8%
Walking	82	14.6%
Taxi	11	2.0%
I did not make this trip before	9	1.6%
Missing	23	
Total	585	100%

Table 13: Travel modes that people have replaced by BiciMAD

4.1.5. Motivations

In the questionnaire, 36 items were included to measure the motivations that respondents have for using the bicycle sharing system (see Appendix E). These items were all measured on a 5-point Likert-scale ranging from 1 (highly disagree) to 5 (highly agree). Table 14 shows the mean scores for all 36 items. These mean values indicate that one item has to be rescaled as it measures the underlying concept (motivations for using BiciMAD) in the opposite direction. The direction in which all items have to be scaled is from 1 (indicating a negative attitude towards the frequency of using BiciMAD) to 5 (indicating a positive attitude towards BiciMAD). This item is: "I use BiciMAD because I have no other way to displace myself". After rescaling, the mean value of this item becomes 4.2.

Motivation to use BiciMAD	Frequency	Mean
BiciMAD is faster than the travel mode I have replaced	552	3,8
BiciMAD is more comfortable than the travel mode I have replaced	552	4,2
I have less stress when I travel by BiciMAD compared to my previous travel mode	552	4,3
I have less waiting time when I travel by BiciMAD compared to my previous travel mode	552	2,6
BiciMAD is safer than the travel mode I have replaced	552	2,0
I feel safer when I travel by BiciMAD compared to my previous travel mode	552	3,5
Travelling by BiciMAD is more fun than in the travel mode I have replaced	552	3,5
Travelling by BiciMAD is healthier than the travel mode I have replaced	552	3,7
BiciMAD is a more economic travel mode than the travel mode I have replaced	425	4,0
I use BiciMAD because I prefer the bicycle over motorized vehicles	550	4,0
I use BiciMAD because I prefer to use a shared bicycle over a private bicycle	550	3,7
I use BiciMAD because I live close to a docking station	550	3,8
I use BiciMAD because it's cheap	550	3,2
I use BiciMAD because I can use the system 24 hours a day	550	4,1
I use BiciMAD because I have no other way to displace myself	550	1,8 (4,2)

I use BiciMAD because it's flexible (I can make one-way trips)	550	3,8
I use BiciMAD because it helps me to wake up in the morning	550	3,3
I use BiciMAD to enjoy my surrounding/fresh air	550	3,7
I use BiciMAD because I want to identify myself as a cyclist	550	3,2
I use BiciMAD because it's in line with my lifestyle	550	3,6
I use BiciMAD to improve/upkeep my physical fitness	550	3,5
I use BiciMAD to relax/decrease stress level	550	3,7
I use BiciMAD to improve environmental conditions	538	4,0
I am worried about environmental conditions	538	4,3
In my daily life, I intend to do the best to improve environmental conditions	538	4,1
It requires time and effort to be respectful to the environment	538	3,9
Traffic congestion is one of the main causes of climate change	538	4,1
People should change their travel habits to improve environmental conditions	538	4,4
Increasing the amount of daily cyclists helps improving environmental conditions	538	4,4
I am always accompanied when I travel by BiciMAD	531	2,3
My friends also use BiciMAD	531	3,2
My friends stimulate me to use BiciMAD	531	2,7
When I travel by BiciMAD, I prefer to be with friends than alone	531	2,9
My family also uses BiciMAD	531	2,3
My family stimulates me to use BiciMAD	531	2,3
When I travel by BiciMAD, I prefer to be with family members than alone	531	2,5

Table 14: Motivations to use BiciMAD. A value of 1 refers to strong disagreement whereas a value of 5 refers to strong agreement with the particular item in question.

4.1.6. Barriers

We asked respondents for their strongest argument not to use BiciMAD more often. One barrier clearly stand out as it is selected by 40% of the respondents, namely *'the uncertainty of finding a (well-functioning) bicycle at a docking station or the uncertainty of being able to park your bicycle at your final docking station'*. In practice, it often appears that people intend to travel by BiciMAD but arrive at an 'empty docking station' – a station without any bicycle or a station where the bicycles aren't functioning well. Four other arguments that were all four mentioned by more or less 10% of the respondents were: (1) there is no docking station near my residence, (2) the general state of the bicycles, (3) because of climate conditions, and (4) there is no docking station near my destination.

Barrier	Frequency	Percentage
No station close to destination	45	8.5%
No station close to residence	65	12.3%
I won't be sure whether there are bicycles available that work well or whether I can park my bicycle	212	40.1%
Because of climate conditions (temperature, wind, rain)	48	9.1%
Because of temporary weather conditions	4	1.0%
Using BiciMAD is dangerous	37	7.0%
Using BiciMAD is uncomfortable (clothes/things to carry)	3	0.6%
I prefer to use my own bicycle	4	0.8%
Using BiciMAD is expensive	23	4.3%
I have more certainty with other travel modes	10	1.9%
The general state of the bicycles	51	9.6%
Other (e.g. bad state of stations/totems)	27	5.1%
Total	529	100.0%
Missing	56	
Total	585	

Table 15: Barriers that current BiciMAD-users have for using the bicycle sharing system more often.

In addition, respondents were asked for the reason they don't use BiciMAD more often for three specific travel purposes: (1) work-/school-commutes, (2) leisure trips, and (3) trips at nighttime (see Appendix I). Even though the barriers that people mention are more or less the same for these different travel purposes, two interesting differences are found. Firstly, one barrier clearly stood out for work/school commutes, whereas the perceived barriers for leisure trips and trips at night were valued in a more scattered way. For work/school commutes, 31% of all respondents selected "the absence of a docking station near work/school" as their main barrier. Secondly, the barriers mentioned for the three travel purposes seem to have a different underlying cause. Barriers that were often mentioned for work/school commuting are generally spoken related to aspects of the system of BiciMAD (e.g. the absence of a docking stations or a shortage of bicycles), whereas barriers to use BiciMAD for leisure trips seem to refer more to people's personal or social preferences (e.g. the preference to do other things in leisure time, or travelling with people that cannot use BiciMAD). For night trips, feelings of unsafety are more influential compared to the other two travel purposes.

4.2 Factor analysis

Before performing a regression analysis with the six groups of independent variables, we need to perform a factor analysis with the 36 items measuring 'motivations to use BiciMAD' as discussed in Section 4.1.5. The main goal of this factor analysis is to find clusters of large correlation coefficients between subsets of items that measure the same underlying dimension (also known as factors).

4.2.1. Checking assumptions

First we need to check three assumptions before performing factor analysis. These assumptions can be checked by using statistical tests, as described below. The corresponding output can be found in Appendix J. The first assumption is that all items have to measure the underlying concept of motivation to use BiciMAD in the same direction. As discussed in section 4.1.5., one item had to be rescaled so that all 36 items have the same direction: a value of 1 indicates a negative attitude towards the frequency of using BiciMAD and a value of 5 indicates a positive attitude.

The second assumption that needs to be met is that all items have, to a certain extent, to correlate with each other. This means that any item correlating with no other items ($R<0.3$) should be eliminated. Furthermore, any item with a lot of high correlations with other items ($R>0.9$) may cause problems of multicollinearity. When analyzing the R-matrix, no values are found above 0.9, which is a good sign. On the other hand, a lot of R-values below 0.3 are found, which might suggest small coherence between the 36 items. However, the significance of Bartlett's test ($p=.000$) confirms that there are some relationships between the items, and therefore it is still appropriate and useful to perform factor analysis with the 36 items (Field, 2009, p.660).

A third assumption before performing factor analysis is checking whether the sample size is adequate enough for factor analysis. To check this assumption, we used the KMO statistic with the following rule of thumb: a value between 0.5 and 0.7 is mediocre, a value between 0.7 and 0.8 is good, a value between 0.8 and 0.9 is great, and a value above 0.9 is superb (Hutcheson & Sofroniou, 1999 as cited in Field, A., 2009, p.659). In this case, the KMO statistic has a value of 0.826 which means that the sample size is large enough for factor analysis.

4.2.2. Results Principal Component Analysis

To decide how many factors we want to extract, we take a look at the scree plot (see Figure 8). The scree plot begins to tail off after 5 factors are extracted, and after this strong drop a stable plateau is reached. In other words, the scree plot confirms that the extraction of 5 factors is accurate. Therefore, we told SPSS to extract 5 factors out of the 36 items. We performed a Principal Component Analysis with a Varimax rotation method. Table 16 shows the 5 extracted factors, the names given to them, and the factor loading for each item on every factor.

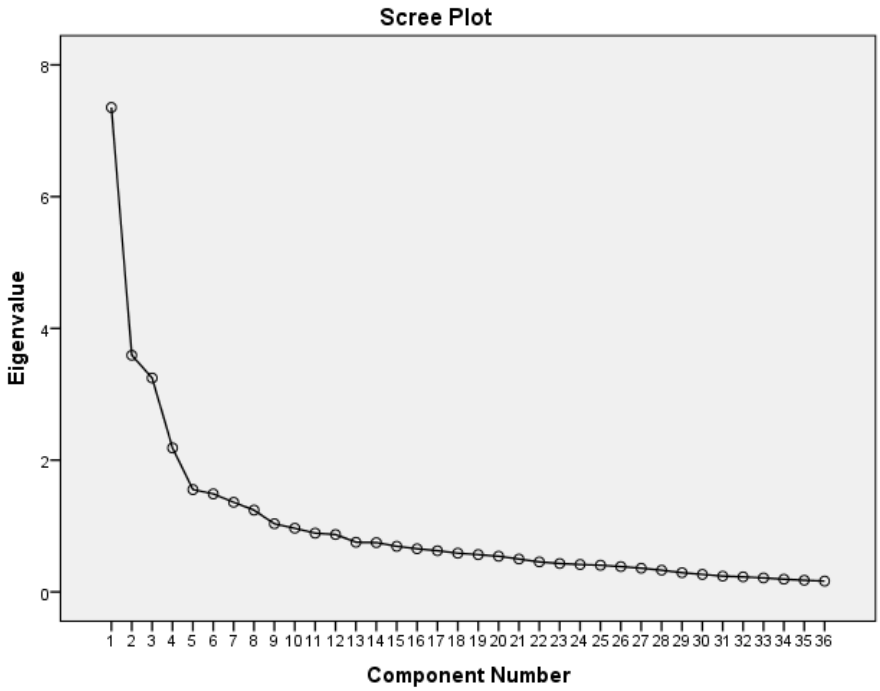

Figure 8: Scree plot of the hierarchical factor analysis, clearly showing a cut-off point after 5 factor are subtracted

	Factor 1: Environ-mental concerns	Factor 2: Personal health benefits	Factor 3: Perceived conveniences compared to previous mode	Factor 4: Social environ-ment	Factor 5: Practical reasons
I have replaced my previous travel mode for BiciMAD because BiciMAD is faster	.074	-.174	.587	-.045	.372
I have replaced my previous travel mode for BiciMAD because BiciMAD is more comfortable	.102	-.073	.541	.021	.479
I have replaced my previous travel mode for BiciMAD because I experience less stress when I travel with BiciMAD	.032	.274	.700	.033	.125
I have replaced my previous travel mode for BiciMAD because I have less waiting time (traffic lights, stations) when I travel with BiciMAD	.009	.023	.690	.045	.269
I have replaced my previous travel mode for BiciMAD because BiciMAD is less dangerous	-.145	.205	.191	.103	.478
I have replaced my previous travel mode for BiciMAD beause I feel safer (robberies, attacks) when I travel with BiciMAD	-.052	.288	.096	.063	.455
I have replaced my previous travel mode for BiciMAD because travelling with BiciMAD is more fun	.063	.096	.808	.080	-.032
I have replaced my previous travel mode for BiciMAD because BiciMAD is healthier	.041	.299	.729	.024	-.126
I have replaced my previous travel mode for BiciMAD because BiciMAD is an economic travel mode	.114	.062	.410	.056	.377
I use BiciMAD because I prefer to travel by bicycle than by motorized vehicles	.503	.296	.151	-.052	.309
I use BiciMAD because I prefer to use a shared bicycle than my own bicycle	.158	.095	.420	-.010	.131
I use BiciMAD because I live close to a docking station	.093	-.026	.086	-.083	.520
I use BiciMAD because it is cheap	.028	.157	.253	.067	.484
I use BiciMAD because I can use it 24 hours a day	.156	.026	.314	.063	.277
I use BiciMAD because I have no other option to travel (RECODED)	.141	-.034	.046	-.141	-.388
I use BiciMAD because it is flexible (I can make on-way trips)	.101	.246	.241	.050	.419
I use BiciMAD because it activates me in the morning	.093	.647	.183	.032	.234
I use BiciMAD because I want to enjoy my surrounding/fresh air	.111	.681	.227	.227	.051
I use BiciMAD because I want to identify myself as a cyclist	.349	.650	-.051	.126	.153
I use BiciMAD because it's in line with my lifestyle	.331	.669	-.006	.055	.219
I use BiciMAD because I want to improve/upkeep my physical fitness	.226	.795	.021	-.007	.035
I use BiciMAD because I want to relax/reduce my stress level	.167	.788	.236	.080	.022
I use BiciMAD to improve environmental conditions (e.g. air pollution)	.693	.310	.124	-.044	-.003
I am worried about environmental conditions (pollution, climate change, etc.)	.795	.177	.061	-.044	-.097
In my daily life, I intend to do anything to improve environmental conditions	.747	.208	.046	-.018	-.030
It takes time and effort to be respectful to the environment	.531	.111	.183	.176	-.149

Traffic congestion is one of the main causes of climate change	.636	.045	.034	.048	.055
People need to change their travel habits in order to improve environmental conditions	.821	.056	.049	.082	.043
Increasing the amount of daily cyclists will improve environmental conditions	.799	.075	.062	.069	.069
I always travel by BiciMAD together with other people	-.001	.035	.016	.735	-.072
My friends also use BiciMAD	.147	-.107	.000	.601	.245
My friends stimulate me to use BiciMAD	.131	-.009	.085	.696	.176
I prefer to travel by BiciMAD with friends than alone	-.027	.022	.084	.788	-.205
My family members also use BiciMAD	.011	.105	-.073	.636	.200
My family members stimulate me to use BiciMAD	-.011	.171	.051	.647	.192
I prefer to travel by BiciMAD with family members than alone	.000	.188	.063	.711	-.144

Table 16: Output Rotated Component Matrix after Varimax-rotation, with all items and their corresponding factor scores

The five factors are saved as new variables. In other words, every case (respondent) has a score/value on all these five motivational factors. This factor score indicates how a respondent scores on factor compared to the mean of all respondents. So, a negative factor score means that the individual scores lower on that factor compared to the other respondents; a positive factor score indicates that he individual values that factor as more important compared to other respondents. Instead of the 36 items measuring motivations to use BiciMAD, we will use these five new factor variables as independent variables in our regression model.

Before running the regression models (see Section 4.3), it is useful to check the reliability of these five factor variables. One way to test this, is by using Cronbach's alpha reliability analysis. This test puts all items belonging to the same factor variable into one model, and in that way reflects whether these items give a well indication of the overarching factor. An alpha-value of 0.8 or higher indicates that the measure is reliable (Field, 2009, p.679). The detailed output of these five reliability analyses can be found in Appendix K. Overall, the reliability analyses show that the reliability of the five factor variables is high. The motivational factors 'environmental concerns', 'physical and mental health', 'perceived conveniences compared to previous travel mode', and 'the social environment' all have high reliabilities, all Cronbach's $\alpha > .8$. However, the motivational factor 'practical reasons' has a relatively low reliability, Cronbach's $\alpha = .43$.

4.3 Regression analyses

Our dependent variable, the frequency of using BiciMAD, is subdivided into three smaller dependent variables when taking travel purpose into account: (1) the frequency of using BiciMAD for work-/school-commuting, (2) the frequency of using BiciMAD in leisure time, and (3) the frequency of using BiciMAD at night. These three variables are all measured on a 5-point Likert scale where 1

means 'I always travel by BiciMAD' and 5 means 'I never travel by BiciMAD'. As such, a higher score indicates that someone uses BiciMAD less frequent.

For all three dependent variables, a regression model has been developed. The significant predictors in each of these three ordinal regression models are shown in Table 17. Here, a positive Estimate-value indicates that people with a high score on the independent variable in question, use BiciMAD less frequent compared to people with a low(er) score on that independent variable. For example, BiciMAD-users than have a public transportation card use BiciMAD less often in their leisure time compared to BiciMAD-users without a public transportation card. On the contrary, a negative Estimate-value indicates that people with a high score on an independent variable, use BiciMAD more often compared to people with a low(er) score on that independent variable. For example, BiciMAD-users aged 18-45 years use BiciMAD more often to go to work/school compared to people aged above 46 years.

	Work/School	**Leisure time**	**Night**
MODEL STATISTICS			
Chi-Square (p-value)	302.272 (.000)	153.618 (.000)	194.447 (.000)
Nagelkerke	.610	.349	.414
THRESHOLD			
BiciMAD=1	-1.477 (0.073)	-.816 (.101)	-3.143 (.008)
BiciMAD=2	.904 (.268)	2.233 (.000)	-.630 (.594)
BiciMAD=3	2.302 (.005)	4.084 (.000)	1.051 (.374)
BiciMAD=4	3.227 (.000)	5.482 (.000)	2.374 (.045)
LOCATION			
Socio-demographics			
Age			
<18 years	-1.086 (.142)		
18-24 years	-1.147 (.013)		
25-45 years	-1.011 (.002)		
>45 years	(base)		
Employment situation			
Employed			-1.639 (.041)
Self-employed			-1.742 (.037)
Unemployed			-1.656 (.065)
Retired			-1.806 (.192)
Student			-2.545 (.002)
Housekeeper			-.268 (.853)
Other			(base)
Private bike ownership			
Yes	.886 (.001)		
No	(base)		
Car ownership			
Yes			.886 (.009)
No			.618 (.078)
Yes, but I share with others			(base)
Public transportation card			
Yes		.512 (.015)	
No		(base)	
Lifestyle			
Leisure time preferences			
Listening to music/playing an instrument		-.432 (.042)	

Watching TV/DVD/series			-.542 (.008)
Participation in vigorous physical activity			
Daily			-.818 (.057)
Several times a week			-.371 (.194)
Once a week			-.387 (.251)
Once a month			-.892 (.028)
Never			(base)
Participation in low physical activity			
Daily	1.156 (.060)		1.226 (.024)
Several times a week	1.549 (.012)		1.030 (.053)
Once a week	1.237 (.055)		.935 (.093)
Once a month	1.465 (.085)		1.172 (.109)
Never	(base)		(base)
Spatial variables			
Trip duration			
<10 minutes		1.624 (.002)	1.527 (.011)
10-19 minutes		.311 (.223)	.100 (.698)
20-29 minutes		.257 (.295)	-.218 (.378)
30 minutes or more		(base)	(base)
Satisfaction with localization of stations			
Very unsatisfied	.430 (.458)		
Unsatisfied	.523 (.171)		
Neutral	1.081 (.002)		
Satisfied	.482 (.132)		
Very satisfied	(base)		
General travel behavior			
Frequency of car use			
Always	2.104 (.000)	2.355 (.000)	1.587 (.003)
Often	.424 (.299)	1.182 (.000)	1.153 (.000)
Sometimes	-.076 (.849)	1.036 (.000)	.419 (.183)
Barely	-.265 (454)	.260 (.354)	.101 (.718)
Never	(base)		(base)
Frequency of private bicycle use			
Always	-.286 (.644)	-1.226 (.137)	-4.145 (.044)
Often	-.939 (.093)	.267 (.497)	.568 (.319)
Sometimes	-1.720 (.000)	-.402 (.209)	.018 (.968)
Barely	-1.045 (.012)	.752 (.029)	.264 (.475)
Never	(base)	(base)	(base)
Frequency of walking			
Always	-1.139 (.009)		-1.116 (.019)
Often	-1.812 (.000)		-.990 (.010)
Sometimes	-1.848 (.000)		-1.253 (.002)
Barely	-2.058 (.000)		-.542 (.296)
Never	(base)		(base)
Frequency of travelling by taxi			
Always	-1.547 (.235)		-.915 (.147)
Often	-.071 (.924)		.532 (.131)
Sometimes	-1.041 (.009)		.720 (.017)
Barely	-.504 (.090)		.619 (.043)
Never	(base)		(base)
Motivations			
Environmental concerns	-.185 (.160)	-.096 (.343)	-.224 (.038)
Personal benefits	-.010 (.937)	-.098 (.343)	.207 (.051)
Perceived conveniences compared to previous mode	-.001 (.996)	-.407 (.000)	-.141 (.172)
Social environment	.341 (.015)	-.345 (.001)	-.289 (.005)
Practical reasons	-.429 (.001)	-.536 (.000)	-.543 (.000)

Barriers			
Travel distance & route characteristics			
Distance is too large	3.549 (.000)		
Distance is too short	2.815 (.000)		
No good places for leisure cycling		1.110 (.023)	
Psycho-social barriers			
It's uncomfortable	2.049 (.007)		
I take my children to school	3.113 (.005)		
Other travel modes provide more security	1.733 (.016)		
I prefer to use my own bicycle	1.747 (.053)		
Cycling is a way of travelling, not a leisure activity		1.426 (.004)	
I am with people that can't cycle or have no BiciMAD-card		2.482 (.005)	
I prefer car/motorcycle		1.579 (.011)	
I prefer walking		2.028 (.025)	
I prefer other leisure activities		1.349 (.005)	
It is dangerous at night			1.593 (.000)
It is not responsible (due to alcohol or tiredness)			.833 (.052)
I always share a car/taxi			.935 (.048)
System-related barriers			
No station near destination	3.495 (.000)		
No station near residence	2.343 (.002)	1.811 (.006)	
Not functioning stations	2.192 (.003)		
No bicycles available at stations	1.085 (.037)		

Table 17: Output ordinal regression models, only showing the significant predictor variables. Significance levels are shown between parentheses

Before interpreting the results from the regression models, it is common to check for multicollinearity. Multicollinearity refers to whether the predictor variables that are included in a regression model correlate with each other. Of course, all the predictors are to some extent correlated with each other, but in case the correlation is too high, that may cause problems. A statistical test to check for multicollinearity is called the 'Variance Inflation Factor' (VIF). Each predictor variable has its own VIF-value, and the rule of thumb is that VIF-values above 10 cause problems of multicollinearity. Among all predictors included in the three regression models, no VIF-values above 10 are found (see Appendices L, M, and N), so there are no problems of multicollinearity. After violating the presence of multicollinearity, we can start discussing the output of our regression model (see Table 17) in the following three sections. First, both significant and unsignificant predictors to the frequency of using BiciMAD for work/school commutes are discussed. Secondly, we focus on the predictors to the frequency of using BiciMAD in leisure time, and in the third paragraph we discuss the predictors to the frequency of using BiciMAD at night.

4.3.1. Predictors to the frequency of using BiciMAD for work/school commuting

Socio-demographics only seem to have a small effect on the frequency of using BiciMAD for work/school commuting. Age and private bicycle ownership are the only two socio-demographics with a significant effect. BiciMAD-users aged 18-24 year or 25-45 year use BiciMAD significantly more often for work/school commuting than BiciMAD-users aged above 45 (R=-1147, p=.013; R=-1.011, p=.002). This finding is in line with previous studies confirming that adolescents and adults bicycle

more often than young children and elderly. In addition, and in line with our expectations, BiciMAD-users that have their own private bicycle use the e-bicycle from BiciMAD less often compared to BiciMAD-users that do not have their own bicycle (R=.886, p=.001). Compared to previous studies on cycling behavior, the influence of socio-demographics in this study on e-cycling to work/school is rather low. Previous studies found other socio-demographics such as gender, education and car ownership to have a significant effect on cycling as well. The rather low influence of socio-demographics found in this study can be explained by two possible scenarios. One way to explain the difference between previous literature and the results of this study, is that socio-demographic predictors to traditional cycling differ from the socio-demographic predictors to shared e-cycling. A second scenario might be that socio-demographic predictors to cycling differ from predictors to the frequency of cycling. For example, it may be that men are more likely to travel by bicycle than women, but when we look only at the frequency of cycling, men and women apparently do not differ from each other.

In terms of lifestyle, 1 of the 3 lifestyle domains distinguished in the research model is significant, namely 'participation in physical activity (PA)'. People that participate in physical activities with a low intensity seem to use BiciMAD less often for work/school commuting compared to people that never participate in low-intense PA. Apparently, people that never participate in low-intense PA (such as walking or cycling for leisure) use BiciMAD more often compared to people with a more active lifestyle. One possible explanation for this may be that people with an inactive lifestyle use BiciMAD to commute to work/school to compensate the fact that they never perform PA. For the other two lifestyle domains, leisure time preferences and international residence, no significant effects were found. In contradiction to our expectations, having spent a significant amount of time in a bicycle-oriented country does not have any effect on your cycling behavior in a country where cycling is uncommon.

While previous studies focusing on the relationship between spatial determinants and cycling behavior have indicated that spatial characteristics such as the bicycle infrastructure and the walking distance to a docking station highly influence someone's decision to use a bicycle sharing system or not, this study revealed that these spatial characteristics do not influence the frequency of using a bicycle sharing system. According to our regression model, only one variable within the spatial environment seems to play a role in the frequency of using BiciMAD for work-/school-commuting, namely how satisfied BiciMAD-users are with the locations of docking station in Madrid. The model shows that BiciMAD-users that are neither satisfied nor unsatisfied with the locations of BiciMAD-stations use the system less often compared to people that are highly satisfied (R=1.081, p=.002).

In terms of the general travel behavior of BiciMAD-users, various significant effects are found. BiciMAD-users who always use the car to go to work/school use BiciMAD significantly less often compared to BiciMAD-users who never go by car (R=2.104, p=.000). In addition, BiciMAD-users

that indicate they sometimes or barely travel to work/school by their own private bicycle, use BiciMAD significantly more often than BiciMAD-users who never go by their own bicycle (R=-1.720, p=.000; R=-1.045, p=.012). Furthermore, the model shows that BiciMAD-users who walk to work/school use BiciMAD significantly more often compared to BiciMAD-users who never walk to work/school. And finally, BiciMAD-users that sometimes go to work/school by taxi, use BiciMAD significantly more often compared to BiciMAD-users that never go by taxi (R=-1.041, p=.009).

The most interesting outcomes are found for the fifth group of independent variables from the research model: motivations to cycling. BiciMAD-users who frequently use BiciMAD to go to work/school, mainly do that because this travel mode is practical for them (R=-.429, p=.001). For example, because they live close to a docking station and because there is another docking station near their destination, or because it is a cheap way of commuting. Another significant motivation that influences the frequency to travel by BiciMAD to work/school is the social environment of BiciMAD-users. However, the effect of this motivation is in the opposite direction, meaning that BiciMAD-users with friends or family members that encourage them to use BiciMAD use the bicycle sharing system less frequent compared to people without social encouragement (R=.341, p=.015). The wish to improve/upkeep physical/mental health, the wish to improve environmental conditions, and advantages of BiciMAD over other travel modes, do not seem to play a role in the frequency of using BiciMAD to work/school.

The frequency of using BiciMAD to commute to work/school can be increased when the main barriers current users have are overcome. The model shows ten barriers of current BiciMAD-users that significantly decrease their frequency of using the bicycle sharing system to commute to work/school. Two of these barriers relate to the travel distance that is either too large (R=3.549, p=.000) or too short (R=2.815, p=.000) for travelling by BiciMAD. Furthermore, the model shows three psycho-social barriers that significantly decrease the frequency of using the bicycle sharing system. Firstly, current BiciMAD-users do not travel by BiciMAD because they have to take their children to school (R=3.113, p=.005). Secondly, they find it an uncomfortable way of travelling (R=2.049, p=.007), and thirdly, they find that other travel modes provide more security (R=1.733, p=.016). A fourth psycho-social barrier that is worth mentioning, though it slightly missed the significance level, is that current BiciMAD-users use the system less frequent because they prefer to go by their own bicycle (R=1.747, p=.053). Finally, the model shows four barriers that are related to aspects of the bicycle system itself. Current BiciMAD-users use the system less often because there is no docking station near their work/school (R=3.495, p=.000), because there is no docking station near their home location (R=2.343, p=.002), because docking stations do not function well (R=2.192, p=.003), or because there are often no bicycles available at docking stations (R=1.085, p=.037). Taken all these barriers together, one main conclusion can be drawn, namely that the frequency of using BiciMAD for work/school commuting can be increased by taking away some barriers. Of course,

travel distance and taking children to school are barriers that are difficult to overcome, but finding a solution to overcome the four system-related barriers is easier. For example, placing more docking stations near big office areas or near the university campus may take away barriers, and in turn, that might result in an increase of BiciMAD-trips.

4.3.2. Predictors to the frequency of using BiciMAD in leisure time

The second dependent variable in the regression model is the frequency with which current BiciMAD-users use the system for trips in their leisure time. These trips are defined as all trips during daytime except work/school commutes. For example, a trip to visit a friend, a trip to the supermarket, or even a leisure trip in the park.

Just like the case for work-/school-commuting, socio-demographics do not seem to play an important role in the frequency of using BiciMAD for leisure trips. Only one significant socio-demographic was found, namely 'access to the public transportation system'. Having a public transport card, and thus having access to the public transportation system of Madrid, significantly decreases the frequency of using the bicycle sharing system (R=.512, p=.015). This may suggest that current BiciMAD users use public transportation instead of BiciMAD when they have a public transportation card. In other words, if they wouldn't have a PT card, they would use BiciMAD more often for trips in leisure time.

In terms of lifestyle, one of the three domains has a significant predictor, namely 'leisure time preferences'. The model shows that current BiciMAD-users that like to listen to music or play an instrument in their leisure time, use BiciMAD significantly more often compared to BiciMAD-users that do not like to perform music-related activities in their leisure time. It could be that people tend to combine their bicycle leisure trip with listening to music on their mobile phone or iPod. However, a clear explanation for this association between music activities and cycling cannot be given by this study, and should be investigated in future research.

Among the spatial variables distinguished in the model, one significant predictor was found: the amount of time spent on a BiciMAD-trip. The regression model shows that BiciMAD-users that generally spend less than 10 minutes on their BiciMAD-trip use the bicycle system significantly less often compared to people that spend 30 minutes or more on their trip (R=1.624, p=.002). In other words, people making larger BiciMAD-trips, use the bicycle sharing system more frequently in their leisure time compared to people that make short trips (<10 minutes). This implies that BiciMAD is not often in people's leisure time for short bicycle trips.

In terms of general travel behavior of current BiciMAD-users, two significant effects are found. Firstly, current BiciMAD-users that travel a lot by car in their leisure time, use BiciMAD significantly less frequent compared to people that never travel by car. This finding is in line with the effect that was found between 'frequency of car use' and 'frequency of using BiciMAD for

work/school commutes'. It seems that the car and BiciMAD compete with each other as travel modes. The use of a car in leisure time results in a lower frequency of using BiciMAD in leisure time, meaning that many BiciMAD-users take the car in their leisure time instead of BiciMAD. The second significant effect was found for the frequency of using a private bicycle in leisure time. The model shows that respondents that barely use their private bicycle in leisure time, use BiciMAD more often compared to respondents that never use their own bicycle (R=-.752, p=.029).

Examining the motivational predictors to the frequency of using BiciMAD in leisure time, 3 of the 5 factorial motivations are found to be significant. Firstly, people that use BiciMAD because they experience benefits in comparison to their previous travel mode, use BiciMAD more often in their leisure time. So, for example, people that have replaced their previous travel mode for BiciMAD because they think BiciMAD is healthier or more comfortable, use BiciMAD more often in their leisure time (R=-.407, p=.000). Secondly, the social environment has a positive effect on the frequency of using BiciMAD in leisure time (R=-.345, p=.001). Being surrounded by friends or family members that also use BiciMAD or that encourage you to use BiciMAD, goes hand in hand with a higher frequency of using the bicycle sharing system in your leisure time. Finally, practical reasons such as living close to a docking station have a positive effect on the frequency of using BiciMAD for leisure (R=-.536, p=.000).

The regression model indicates seven significant barriers that result in a lower frequency of using BiciMAD in leisure time. Amongst them, five are psycho-social barriers, one belongs to travel distance and route characteristics, and the seventh is a system-related barrier. The barrier with the strongest effect is 'being accompanied with people that do not know how to ride a bicycle or that haven't got a BiciMAD card' (R=2.482, p=.005). One possible way to overcome this barrier is to create a BiciMAD user-card that enables more than one user to use the system at the same time, a 'family-card'. Other significant barriers are less difficult to overcome, such as planning appropriate areas or bicycle lanes for leisure cycling in Madrid (R=1.100, p=.023) or creating more docking stations near people's home location (R=1.811, p=.006).

4.3.3. Predictors to the frequency of using BiciMAD at night

Among the socio-demographics, two significant effects on the frequency of using BiciMAD at night are found: 'employment situation' and 'car ownership'. In terms of employment situation, three groups of current BiciMAD-users seem to use BiciMAD with a significant high frequency at night: employees (R=-1.639, p=.041), self-employees (R=-1.742, p=.037), and students (R=-2.545, p=.002). The strongest effect is found for students, which is not surprising as this employment category is the most active group at night. The second significant socio-demographic is car ownership. The model indicates that BiciMAD-users that own a private car/motorcycle use the bicycle sharing system less often at night (R=.886, p=.009).

When looking at lifestyle, the regression model shows significance for two leisure domains: 'leisure time preferences' and 'participation in PA'. One leisure time activity that results in a higher frequency of using BiciMAD at night is 'watching TV/DVD/series in your leisure time' (R=-.542, p=.008). In other words, BiciMAD-users that like watching TV/DVD/series in their leisure time, seem to use BiciMAD more often at night compared to BiciMAD-users that do not like to perform this leisure activity. Furthermore, significance was found for participation in both vigorous and low-intense physical activity (PA). Compared to BiciMAD-users that never participate in vigorous PA, BiciMAD-users that participate either once a month in vigorous PA (R=-.892, p=.028) or on daily basis (R=-.818, p=.057), use BiciMAD more often at night. Surprisingly enough, significance is not found for BiciMAD-users that participate several times a week or once a week in vigorous PA. The opposite effect is found for participation in low-intense PA. Compared to BiciMAD-users that never participate in low-intense PA, BiciMAD-users that participate in low-intense PA on either daily basis (R=1.226, p=.024) or several time a week (R=1.030, p=.053), use BiciMAD less often at night. So, participation in vigorous PA results in a higher frequency of using BiciMAD at night, whereas participation in low-intense PA results in a lower frequency.

Amongst the spatial variables, one significant effect is found, namely for 'trip duration'. According to the regression model, BiciMAD-users that only spend less than 10 minutes on an average BiciMAD-trip, use the bicycle sharing system significantly less frequent at night compared to BiciMAD-users that indicate to spend 30 minutes or more on an average BiciMAD-trip (R=1.527, p=.011). Apparently, people make longer bicycle trips at night. A possible explanation for this may be that night activities are often located at places that require some travel time before getting there. However, this is explanation is not very likely as most discotheques and bars are located in the city center or at central neighborhoods in Madrid. A second explanation may be that the group of people using BiciMAD at night are the most avid system-users – meaning that they tend to use BiciMAD as often as they can, and thus also for longer night trips.

Examining the general travel behavior of current BiciMAD-users, the regression model shows four significant predictors to the frequency of using BiciMAD at night. Two variables result in a lower frequency of using BiciMAD at night, whereas the other two variables result in a higher frequency at night. BiciMAD-users that always (R=1.587, p=.003) or often (R=1.153, p=.000) travel by car at night, use the bicycle sharing system less often compared to BiciMAD-users that never travel by car at night. The second significant effect that results in a lower frequency of using BiciMAD at night is 'the frequency of using a taxi at night'. Compared to BiciMAD-users that never travel by taxi at night, BiciMAD-users that sometimes (R=.720, p=.017) or barely (R=/619, p=.043) travel by taxi at night use the bicycle sharing system significantly less frequent at night. The two remaining significant variables result in a higher frequency of using BiciMAD at night: 'the frequency of using a private bicycle at night' and 'the frequency of walking at night'. The model indicates that, compared to BiciMAD-users

that never travel on their own bicycle at night, BiciMAD-users that always travel on their private bicycle at night, use the bicycle sharing system significantly more frequent at night (R=-4.145, p=.044). And compared to BiciMAD-users that never walk at night, BiciMAD-users that always (R=-1.116, p=.019), often (R=-.990, p=.010) or sometimes (R=-1.253, p=.002) walk at night, use the bicycle sharing system significantly more often at night.

Amongst the five motivational factors, three have a significant effect on the frequency of using BiciMAD at night, and a fourth factor that slightly missed the significance level. Not surprisingly, the motivation to use BiciMAD because it is practical (R=-.543, p=.000) has the strongest effect. It makes sense that people that mainly use the system because they can use it 24 hours a day or because it enables them to make one-way trips, tend to use the bicycle sharing system with more frequency at night. Other significant effects were found for the motivations 'environmental awareness', 'social environment', and 'personal health benefits'. BiciMAD-users that use the bicycle sharing system because they want to contribute to better environmental conditions seem to use BiciMAD more often at night(R=-.224, p=.038), just like the people using the system because their social environment encourages them to use the system (R=-.289, p=.005). Even though the motivation 'personal health benefits' slightly misses the significance level, it is worth mentioning here as it shows to have an unexpected effect. The regression model indicates that BiciMAD-users that use the system because they experience either physical or mental health benefits, seem to use BiciMAD significantly less often at night (R=.207, p=.051). A probable explanation for this opposite effect can be that people that wish to improve/upkeep their physical fitness or their mental wellbeing do not go out that often at night, and in that way, they will also use the bicycle system less often.

Finally, two significant barriers are found to the frequency of using BiciMAD at night, and one that slightly missed the significance level. The strongest effect was found for the barrier that people find it dangerous to use BiciMAD at night (R=1.593, p=.000). In other words, BiciMAD-users that find it dangerous, use BiciMAD significantly less frequent at night. 'I almost always share a car or taxi with other people' was the second significant barrier to using BiciMAD more often at night (R=.935, p=.048). Finally, people that find it not responsible to travel by BiciMAD at night because of the alcohol they have drunk or because they are tired, also seem to use the bicycle sharing system less often at night (R=.833, p=.052). Apparently, people are discouraged to use BiciMAD at night because they find it dangerous. Respondents were not asked which aspects they experienced as dangerous, but it is probably related to bad lighting or because car-/taxi-drivers do not always take cyclists into account – especially not at night.

4.4. Interpretation results and feedback to theory

As discussed in the previous paragraph, this study found several significant predictors to the frequency of using the bicycle sharing system of Madrid when specific travel purposes are taken into account. This paragraph discusses and interprets the influence of these predictors on the general frequency of using BiciMAD (i.e. when travel purpose is not taken into account) in order to find out to what extent the results from this study are in line with previous evidence on cycling, and to what extent this study adds new contributions to the existing literature. This paragraph is built up in the same way as the research model. First, the socio-demographic variables are discussed, followed by the lifestyle domains and the spatial determinants in the second and third section. Fourthly, the influence of general travel behavior on the frequency of using BiciMAD is discussed. Finally, in the fifth and sixth section, the focus is on the motivations and barriers that influence the frequency of using the bicycle sharing system.

4.4.1. Socio-demographics and the frequency of using BiciMAD

Previous transportation studies have concluded that socio-demographics such as gender, age and employment situation significantly influence travel mode choice (Scheiner & Holz-Rau, 2007) and, more specifically, cycling (e.g. Curtis & Perkins, 2006; Krizek et al., 2005; Johnson & Rose, 2013). Most of these studies measured cycling by examining the use of traditional private bicycles; only few studies specifically examined the influence of socio-demographics on the use of shared electric bicycles. In contrast to our expectations based on previous literature, the majority of the socio-demographic variables does not show a significant effect on the frequency of using shared e-bicycles. So, whereas socio-demographic variables seem to play an important role for traditional cycling, they do not influence e-cycling that much. Amongst all socio-demographic variables included in the regression models, only few significant effects are found, namely 'age', 'employment situation', and 'having access to other travel modes'.

The effect that is found for age implies that people aged 18-24 or 25-45 years use the bicycle sharing system more often than other age groups. This finding is completely in line with the existing evidence that 18-24 year-old Canadians use their e-bicycle sharing system more often than 35-year olds (Fuller and colleagues, 2011). However, our finding is not in line with Johnson & Rose (2013) arguing that people aged 41-60 or 60+ years are the age groups owning the most electric bicycles. Based on the different outcomes of these two studies, in combination with the results from our present study, it may be suggested that people buying their own e-bicycle tend to be older whereas people that make use of shared e-bicycles tend to be younger. The second significant socio-demographic in our model was 'employment situation'. Amongst current users of an e-bicycle sharing system, (self-)employees and students seem to use the system most frequently. The third significant socio-demographic predictor in our model was 'having access to other travel modes'. This

study is the first in examining to what extent having access to other travel modes than e-bicycles (e.g. a car, traditional bicycle, public transportation) influences the frequency of travelling by shared e-bicycles, and therefore adds innovative knowledge and insights to the existing literature on e-cycling. The regression models indicates that 'having access to other travel modes' negatively affects the frequency of using BiciMAD. That is, owning a private bicycle, owning a car, or owning a public transportation card all three significantly decrease the frequency of using the bicycle sharing system. So, to conclude, the results from the present study suggest that having access to either a car, a private bicycle or a public transportation card result in a lower frequency of using the bicycle sharing system amongst people that are already a member of the bike sharing system.

To conclude, our present study confirms that socio-demographics influence the frequency of using a bicycle sharing system with electric bicycles, though this effect is only small. Socio-demographics such as 'gender', 'household composition', 'educational level', and 'income level' that significantly influence whether people decide to travel by traditional bicycle or not, do not significantly influence the frequency of using a bicycle sharing system with electric bicycles. So, this study is the first to reveal that socio-demographic predictors to cycling differ from socio-demographic predictors to shared e-cycling. However, it should be taken into account that the present study specifically focused on the frequency of using electric bicycles, and not on the fact whether people e-cycle or not.

4.4.2. Lifestyle and the frequency of using BiciMAD

So far, the literature on the relationship between someone's lifestyle and his/her frequency of cycling was very small. Only few studies have examined the influence of lifestyle characteristics such as leisure time preferences and participation in physical activity (PA) on using active travel modes (e.g. Craike, 2007; Garrard, 2009; Dollman & Lewis, 2007). This study aimed to add to this field of study by exploring the influence of someone's lifestyle on his/her frequency of using a relatively new active travel mode, namely electric bicycles. As the results from the regression models indicate, our study confirms that some lifestyle-aspects play a role in the frequency of using an electric bicycle sharing system. So, this study adds evidence that a relationship between lifestyle and using e-bicycles (or using active travel modes) exists, but the outcomes should be interpreted carefully. For some significant relationships between lifestyle and cycling frequency it is difficult to find an explanation. Given that the results from this study contain some inexplicable associations, reliable conclusions on the relationship between lifestyle-related aspects and the frequency of e-cycling cannot be drawn. For future studies it is recommended to explore the influence of lifestyle on the use of a bicycle sharing system in more detail.

In 2012, Burton and his colleagues confirmed that performing sedentary activities in your leisure time has nothing to do with meeting daily PA recommendations or not. In line with their

findings, our study also didn't find any significant effect for 'watching TV' or 'using the computer'. So, our study confirms that performing sedentary activities in your leisure time (e.g. watching TV, using the computer or reading) does not influence the frequency of using an electric bicycle sharing system. On the other hand, performing active leisure activities (e.g. exercising or walking) is expected to have a positive influence on the use of a bicycle sharing system, based on the study of Craike (2007). However, our present study did not confirm this expectation. No significant effects were found for performing active leisure time activities (e.g. 'exercising/swimming', 'leisure cycling' and 'walking') on the frequency of using of the bicycle sharing system. Apparently, the frequency of using an e-bicycle sharing system is not affected by the activities that people prefer to perform in their leisure time.

The second lifestyle domain, participation in physical activity (PA), was not covered clearly in the literature. Only a few studies confirm the relationship between 'active travelling to school' and higher participation in PA among young children (e.g. Garrard, 2009; Cooper and colleagues, 2001; Dollman & Lewis, 2007). So far, no studies have investigated this relationship in the opposite direction. Our present study was the first study to explore this opposite relationship by including 'participation in PA' as an independent variable and by measuring 'active travelling' by the frequency of using electric bicycles. Our regression model clearly confirms that such a relationship exists. Compared to people that never participate in physical activity with a low intensity (e.g. walking, household tasks), people that do this on daily or weekly basis, tend to use BiciMAD significantly less often. Put differently, people that often participate in low-intense PA, use the bicycle sharing system significantly less often compared to people that never participate in low-intense PA. This finding suggests that people with a more sedentary lifestyle use the bicycle sharing system more often compared to people with a more active lifestyle. A possible explanation for this may be that people that do not have a very active lifestyle (i.e. do not participate regularly in PA) compensate their sedentary lifestyle by frequently using BiciMAD. Participation in vigorous PA, however, is positively influencing the frequency of using BiciMAD.

Finally, the third lifestyle domain, international residence, missed the significance level in all regression models, indicating that the frequency of using the bicycle sharing system in not influenced by international residential patterns. In contrast to the expectations of the present study, having lived in a country where cycling is a normal way of travelling (e.g. The Netherlands, Germany or Denmark) does not affect the frequency of using electric bicycles in Spain – a country where cycling is less common.

4.4.3. Spatial environment and the frequency of using BiciMAD

Within the literature on cycling, there is a lot of evidence showing how important spatial characteristics, such as the presence of a well-designed bicycle infrastructure or the walking distance

from home to a docking station, are to cyclists (e.g. Pikora et al., 2003; Van Wee et al., 2006; Fishman et al., 2012). For example, Fuller and colleagues (2011) found that people that only have to walk 250 meter or less from their home location to the closest docking station tend to use a bicycle sharing system more often compared to people that have to walk a larger distance. A distance of 250 meter will take ±3.5 minutes with an average walking speed of 4,5km/h. The respondents from our case study to BiciMAD indicate to have an average walking distance of 7 minutes from their home to the closest docking station. This is a relatively large walking distance, and in that way it may be presumed that this large distance discourages current BiciMAD-users to use the bicycle sharing system more frequently. However, our regression model did not show any significant effect of the distance people have to walk from their home location to the closest docking station on the frequency with which they use the bicycle sharing system. In other words, our study does not confirm the findings of previous studies (e.g. Fuller and colleagues, 2011; Schoner & Levinson, 2013) that walking distance plays a significant role for using a bicycle sharing system.

For the spatial variable 'trip duration' our model showed a significant influence on the frequency of using BiciMAD for both leisure cycling and cycling at night. In other words, our respondents use BiciMAD significantly less often when they cover relatively short distances (trips of less than 10 minutes) for either trips in leisure time or for trips at night. Finally, and in strong contradiction with previous evidence found by Fishman et al. (2012) and Pikora et al. (2003), variables measuring the effect of the quality of the bicycle infrastructure show no significant effects on the frequency of using the bicycle sharing system. Apparently the frequency of using a bicycle sharing system is not influenced by people's perception of the quality of the bicycle infrastructure: the variables 'satisfaction with bicycle parking in Madrid', 'satisfaction with cycle paths in Madrid', and 'satisfaction with road signals for cyclists in Madrid' all three missed the significance level in our model.

4.4.4. Travel behavior and the frequency of using BiciMAD

When examining the general travel behavior of BiciMAD-members, one main finding stands out. Our model distinguishes two types of travel modes that significantly influence the frequency with which current BiciMAD-users use the bicycle sharing system. On the one hand, the model indicates that private motorized travel modes (cars and motorcycles) significantly decrease the frequency of using BiciMAD. In other words, the more often people travel by car or motorcycle, the less often they use the bicycle sharing system. On the other hand, our regression model places active travel modes (e.g. walking and traditional cycling) that significantly increase the frequency of using BiciMAD. So, the more often people walk or use their own private bicycle, the more often they will also use BiciMAD. To conclude, the use of private motorized travel modes and the electric bicycle sharing system compete with each other, while the use of active travel modes (e.g. walking and bicycling)

strengthens the use of the bicycle sharing system. However, our model shows one exception on this conclusion: people that barely use a private bicycle in their leisure time, use BiciMAD less often compared to people that never use their private bicycle.

In addition to these two outstanding findings, the frequency of using a taxi also showed significance in our regression model. Respondents that indicate they sometimes use a taxi to go to work/school, seem to use BiciMAD more often. However, respondents that indicate they sometimes use a taxi at night, seem to use BiciMAD less often. In other words, taxis and BiciMAD compete with each other for night trips, whereas they do not compete with each other at day time. Finally, no significant effects were found for the frequency of using public transportation on the frequency of using BiciMAD. This implies that, at least in the case of Madrid, the public transportation system and the bicycle sharing system neither compete with each other nor strengthen each other.

4.4.5. Motivations to using BiciMAD

Previous studies have already examined what motivates people to use a bicycle (for an overview see Brown et al., 2009). The present study tried to find whether these motivations also apply to the use of an electric bicycle sharing system. As discussed in Section 4.2, five main motivations that BiciMAD-users have for using the system were subtracted after factor analysis: (1) environmental concerns, (2) physical and mental health, (3) advantages over other travel modes, (4) social environment, and (5) practical reasons. These motivations to e-cycling slightly differ from the motivations to cycling that have been distinguished in the literature so far. For example, 'embodiment' does not seem to play a role for e-cycling while studies confirm that this motivation is associated with traditional cycling (Brown et al., 2009). On the other hand, our present study contributes a new motivation to the existing literature by introducing the factorial motivation 'practical reasons'.

Our five new factor variables were included in the regression models, and it can be concluded that these motivations strongly influence the frequency of using BiciMAD. All five motivations show significant effects on the frequency of using BiciMAD, but two motivations strongly stand out. Firstly, respondents that use BiciMAD because they find the system practical (e.g. they can use the system 24 hours a day or they are able to make one-way trips), use BiciMAD significantly more often compared to people that do not have this type of motivation. This effect is found for all travel purposes distinguished in the regression models: work/school commutes, trips in leisure time, and trips at night. A second motivation that strongly influences the frequency of using BiciMAD is the social support that people perceive from their friends and/or family. Using BiciMAD because your friends/family encourage you to do so, results in a higher frequency of using the bicycle sharing system in practice – for both trips in leisure time and trips at night. Surprisingly, the opposite is true for work/school commutes: people that use BiciMAD because their friends/family encourages them to do so, use the bike sharing system significantly less often for work/school commuting.

The other three remaining motivations only show significance for particular type of trips. These effects are more difficult to interpret. Using BiciMAD because of environmental concerns results in a higher frequency of using the system at night. Using BiciMAD because you want to improve your physical and/or mental health, results in a lower frequency of using BiciMAD at night. It is interesting that this motivation is negatively related to the frequency of e-cycling, because there is much evidence that the wish to improve/upkeep physical fitness or mental wellbeing is positively related to (traditional) cycling (e.g. Oja et al., 2011; Mead et al., 2009; Garrard et al., 2012). Apparently, people do not associate e-cycling with a positive influence on their health or wellbeing. And finally, using BiciMAD because you experience benefits over other travel modes, results in a higher frequency of using the system in leisure time.

4.4.6. Barriers to using BiciMAD more often

Barriers to cycling have been examined before, but most evidence is based on people that do not cycle. This study, however, examines the remaining barriers that cyclists experience when using a bicycle sharing system. Partly based on previous research findings and partly on own expectations, four groups of barriers were distinguished and measured in the questionnaire: (1) climate and weather conditions, (2) travel distance and route characteristics, (3) psycho-social factors, and (4) system-related aspects. Regression analysis reveals that ten barriers negatively influence the frequency of using BiciMAD for work/school commuting. The strongest negative effects are found for system-related aspects (e.g. the absence of a station near someone's destination/residence or the shortage of bicycles at docking stations) and barriers belonging to 'travel distance and route characteristics' (e.g. a distance that is too large or too short). These outcomes clearly meet previous studies arguing that many people do not use a bicycle because of these reasons (e.g. Schoner & Levinson, 2013; Fishman et al., 2014; Van Wee et al., 2006; Akar & Clifton, 2008). Furthermore, the regression model shows four significant psycho-social barriers for work/school commuting. People find it uncomfortable to travel by BiciMAD (e.g. because they have to carry stuff or wear specific clothes) or they combine their trip with taking their children to school. Especially for work/school commutes, planning seems to be an important variable to the frequency of using the bicycle sharing system.

For trips in leisure time, seven significant effects were found. It can be concluded that the strongest effect is found for 'psycho-social barriers' as 5 out of the 7 barriers belong to this group. Many BiciMAD-users do not use the bicycle sharing system more often in their leisure time because they are accompanied with people that do not know how to ride a bicycle or that have no BiciMAD-card. In addition, people do not use BiciMAD because (1) they see it as a way of travelling instead of a leisure time activity, (2) they prefer to go by car/motorcycle, or simply because (3) they prefer to spend their leisure time on other activities. The sixth significant barrier belongs to 'system-related

barriers' as the absence of a docking station near someone's home location decreases the frequency of using BiciMAD in leisure time. And finally, the seventh barrier belongs to 'travel distance and route characteristics': people indicate that there are no – or not enough – appropriate places in Madrid for leisure cycling, and our model shows that this results in a lower frequency of system-use.

For the last dependent variable, the frequency of using BiciMAD at night, three significant barriers are found, namely that BiciMAD-users do not use the system at night because (1) they think it is dangerous, (2) they find it not responsible because of the alcohol consumption or tiredness, and (3) they always share a car or taxi with other people. These are all psycho-social barriers, and are in line with the statement of Heinen et al (2010) that perception of unsafety can be a major barrier to travel by bicycle.

So, to conclude, different travel purposes have are characterized by different barriers. Current BiciMAD-users indicate to not use the bike system more often to commute to work/school mainly because of system-related barriers (such as not having a station nearby or shortage of bicycles), inconvenient travel distances, and issues of planning (e.g. taking your children to school). For trips in leisure time, on the other hand, psycho-social barriers preponderate. For example, respondents have indicated that they do not use BiciMAD more often in their leisure time because they are together with people that do not have a user-card or because they simply prefer other travel modes. For trips at night, issues related to safety outweigh: many people find it dangerous or irresponsible to use BiciMAD at night. Finally, our study shows no significance for climate and/or weather conditions on the frequency of e-cycling, which is completely in contradiction with previous studies confirming the strong influence of temperature, wind speed, chance to rain and hours of daylight (see for example, Nankervis, 1998; Flynn et al., 2011).

5. Conclusions

5.1 Answering research questions

The main goal of this study has been to explore the relevant predictors to the use of an electric bicycle sharing system in order to contribute to the development of a strong and reliable model that predicts the frequency of using an electric bicycle sharing system. In order to meet this research goal, data had been collected through an online questionnaire from current users of the electric bicycles sharing system of Madrid, called BiciMAD. After statistically analyzing the 514 completed questionnaires, the five research questions formulated in Section 1.3 can be answered. Below, one can find these questions and their corresponding answers.

1. **How can BiciMAD-users be characterized in terms of their lifestyle and their general travel habits?**

Among the current BiciMAD-users, two-third are male and one-third are female cyclists. In terms of age, almost 60% of all BiciMAD-users are aged 25-45 year. The age category below <18 year is the least likely to use BiciMAD, as only 3% of all users fall into this category. When looking at the educational level of current BiciMAD-users, it seems that most users are highly educated: 77% of all respondents has a University Degree or even a higher educational level (Master Degree or PhD). Furthermore, the majority of all users has a modal to high income level. In terms of employment situation, the majority of all users (57%) is employed, followed by students (19%) and self-employees (16%). The final four socio-demographics that were examined in this study relate to 'having access to other travel modes': car ownership, having a driver's license, private bicycle ownership, and having a public transportation card. A relatively high percentage of current BiciMAD-users does not own a private car (34%), whereas the remaining 67% owns or shares a private car with other household members. 84% of all users has a driver's license, 57% indicates to own a private bicycle and 53% has a public transportation card.

A clear pattern cannot be found when looking at the activities that current BiciMAD-users prefer to perform in their leisure time. The most popular activities that current BiciMAD-users prefer to perform in their leisure time are: visiting friends/family (70%), travelling (68%) and having lunch/dinner in a restaurant (67%). On the other hand, the least popular activities that respondents perform in their leisure time are: watching/attend sportive events (25%), cooking (33%) and shopping (33%). In addition, current BiciMAD-users were asked how often they participate in (both vigorous and low-intense) physical activity (PA). The results indicate that the majority of BiciMAD-users often participate in PA. 8% of the respondents indicates to participate in vigorous physical activity on daily basis, followed by 46% that participate several times a week and 19% once a week. When looking at the frequency of participating in low-intense PA, 36% participates daily, 40% several times a week, and 16% once a week. The third and final lifestyle aspect that this study explored was

international residence. More than 50% of BiciMAD-users indicate they have also lived in another country than Spain, but only 6% of all respondents has lived in a country where bicycling is a common way of travelling (The Netherlands, Germany or Denmark).

The large majority of all BiciMAD-users has replaced trips by public transport for BiciMAD (65%), followed by 15% that have replaced walking trips. Only a small percentage has replaced car/motorcycle trips (13%). When looking at the use of other travel modes than BiciMAD, public transport is most often used for work/school commuting, walking is most often used for trips at nighttime, and both travel modes are frequently used for trips in leisure time.

2. **How do BiciMAD-users describe and assess the spatial factors related to the frequency of using BiciMAD and/or cycling in Madrid?**

The average time that BiciMAD-users spend on their e-bicycle trip is 29 minutes, whereas most respondents indicate to not spend more than 20 minutes on such a trip. The time people have to walk from their home location to the closest docking station of BiciMAD is, on average, 7 minutes; but the majority of the respondents announces they only have to walk 5 minutes. Even though this walking time is rather long, users seem to be quite satisfied with the locations of docking stations. On a 5-point scale where 1 means 'very unsatisfied' and 5 means 'very satisfied', they valued this item with a score of 3.6. On the contrary, BiciMAD-users are not satisfied with the quality of the bicycle infrastructure in Madrid. They valued their satisfaction with the 'bicycle paths in Madrid' with 2.1, and 'the availability of places to park a traditional bicycle' with 2.3, and 'the road signals for cyclists' with a 2.6.

3. **What motivates BiciMAD-users to use the bicycle sharing system?**

In the questionnaire, 36 items were used to measure what motivates current BiciMAD-users to also use the bicycle system in practice. Factor analysis subtracted 5 main motivations that our respondents have for using BiciMAD. The first motivation is 'environmental awareness'. People are encouraged to travel by BiciMAD because they can contribute to improve environmental conditions due to traffic congestion. The second motivation that was subtracted is 'physical and mental health benefits'. People use the bicycle system because they want to maintain or upkeep their physical fitness or because they wish to reduce stress levels and increase their mental wellbeing. A third main type of motivation that current BiciMAD-users have is the benefits they experience when they compare travelling by BiciMAD with other travel modes. For example, people use BiciMAD because this is a faster travel mode than walking. Another example is that people use BiciMAD because it is cheaper than travelling by car. The fourth motivation is 'social influence of friends and family'. Being surrounded by friends or family members that also use BiciMAD or that encourage you to use BiciMAD, is a fourth motivation that encourages people to choose this travel mode. Finally, the fifth

motivation that was subtracted refers to 'practical reasons' for using BiciMAD. A lot of people simply travel by BiciMAD because they find it a practical travel mode: it enables people to make one-way trips, people can use the system 24 hours a day, or people just live close to a docking station.

4. **What are the remaining barriers that BiciMAD-users have for not using the bicycle sharing system more often?**

In this study, current BiciMAD-users were asked to indicate the main barrier they have for using the bicycle sharing system more frequently. In general, the large majority of all respondents (40%) has selected as their main barrier to using the system more often is that they are never sure whether there will be available bicycles at a docking station. Other barriers that were mentioned by the respondents are the absence of a docking station near the home location (12%), the general state of the bicycles (10%), the absence of a docking station near the destination (9%), climatological conditions (9%), and the perception that using BiciMAD is dangerous (7%).

In addition, respondents were asked for the main barrier they have for three specific travel purposes, namely work/school commutes, trips in leisure time, and trips at nighttime. For work/school commuting, the barrier that is selected by most respondents is 'the absence of a docking station near work/school' (31%). Two other barriers that were often selected were 'the travel distance is too large' (19%) and 'there is often a shortage of (well-functioning) bicycles' (14%). Such an outstanding barrier was not found for trips in leisure time or at nighttime. For these two travel purposes, respondents' barriers were more scattered. For leisure trips, current BiciMAD-users indicate they do not use BiciMAD more often because 'they prefer other leisure activities' (17%), 'they see cycling as travelling and not as a leisure activity' (15%), 'there are no appropriate places to cycle in Madrid' (14%), and 'there is often a shortage of (well-functioning) bicycles' (12%). For trips at night, often-cited barriers are 'I never go out at night' (17%), 'using BiciMAD at night is dangerous' (16%), 'it is irresponsible to use BiciMAD at night because of alcohol consumption or tiredness' (15%), and 'there is often a shortage of (well-functioning) bicycles' (15%).

5. **How do lifestyle, travel habits, motivations and barriers influence the frequency of using BiciMAD, and how does this relate to travel purpose?**

In this study, all predictors to the frequency of using BiciMAD were grouped into six categories: (1) socio-demographics, (2) lifestyle aspects, (3) general travel behavior, (4) spatial determinants, (5) motivations, and (6) barriers. Regression analysis has indicated that most significant predictors belong to the last two categories: motivations and barriers. Only few significant effects are found for socio-demographic or lifestyle-related predictors. Apparently, the frequency of using the electric bicycle sharing system does not strongly depend on personal, behavioral, or spatial characteristics, but more on the opinion and experiences of current BiciMAD-users. In other words, the frequency

with which someone uses the bicycle sharing system does not rely so much on his/her socio-demographics or lifestyle, but more on subjective variables such as the motivation that encourages him/her to use the system or the barrier that discourages him/her to use the system more often.

Within this study, three different travel purposes are examined. In this way, it became possible to identify the different influence of predictors to the frequency of using BiciMAD when travel purposes is taken into account. The following three purposes have been examined: (1) work/school commutes, (2) trips in leisure time, and (3) trips at night. The strongest and most surprising effects will be discussed for each travel purpose.

For work/school commutes, the frequency of using BiciMAD is mainly influenced by the type of motivation that current users have, the barriers they perceive while using the system, and the frequency of using other travel modes. People using the system because they find it a practical travel mode seem to use the system most frequently, whereas the frequency decreases when people's social environment encourages them to use the bicycle system. Other aspects that result in a lower frequency of using BiciMAD for work/school commuting are related to the absence of a station near either someone's residence or destination, the shortage of available bicycles, impossible travel distance, and the planning daily travel patterns. Finally, the car is a travel mode that competes with the bicycle sharing system, whereas traditional bicycles and walking reinforce the frequency of using BiciMAD.

Trips in leisure time are in this study defined as trips to visit friends/family, go shopping or just leisure trips to relax. Like the case for work/school commutes, the frequency of using the bicycle sharing system mainly relies on the type of motivation and barrier that current users have. Here, again, only a few personal, behavioral and spatial variables are found to significantly influence the frequency of using BiciMAD in leisure time. The regression model shows that the frequency increases due to the following three types of motivations: (1) BiciMAD is a practical travel mode, (2) my social environment encourages me to use BiciMAD, and (3) BiciMAD is a better and more convenient travel mode compared to other modes. On the contrary, the frequency of using the bicycle sharing system decreases due to some barriers that current users perceive. The strongest barriers mentioned by respondents were the preference to walk or use another travel mode, being with people that do not have a BiciMAD user-card, the absence of appropriate cycling places in Madrid, and the absence of a station near the home location.

For trips at night, the influence of socio-demographic and lifestyle-related variables is stronger compared to the previous two travel purposes. It can be concluded that (self-)employees and students use BiciMAD significantly more often at night; car-owners, on the other hand, use the bicycle sharing system significantly less frequent. In terms of lifestyle, a significant effect is found for participation in physical activity (PA). Current BiciMAD-users that indicate to participate often in low-intense PA seem to use BiciMAD less often at night. In contrast, participation in vigorous PA results in

a higher frequency of using BiciMAD. When examining the use of other travel modes at night, the car and taxi compete with BiciMAD, whereas the private bicycle and walking strengthens BiciMAD-use at night. Furthermore, three types of motivations increase the frequency of using BiciMAD for night trips: (1) BiciMAD is a practical travel mode, (2) my social environment encourages me to use BiciMAD, and (3) environmental concerns. Surprisingly, using BiciMAD because it is beneficial for your physical fitness and/or mental wellbeing is found to significantly decrease the frequency of using the bicycle system at night. This opposite effect can be explained as follows. It might be that people using the system to improve their physical/mental health tend to behave in a rather conscious and healthy-oriented way, which may imply that they do not go out often at night. Finally, the frequency of BiciMAD-use at night is decreased due to the fact that people find it either dangerous or irresponsible to use the system at night time.

5.2 Theoretical reflection and future recommendations

So far, most studies on e-cycling have only examined socio-demographics and/or spatial environmental variables. The literature on other types of predictor variables to e-cycling is, on the other hand, very small. This research has been the first to conduct an extensive study on the frequency of using an electric bicycle sharing system. In this study, a large variety of new predictor variables to e-cycling are added to the research model in order to gain more insight into the variables that influence e-cycling behavior. Another main contribution to the existing literature is that the dependent variable is approached in a slightly different way compared to previous studies on e-cycling. This study did not focus on the variables predicting whether people use electric bicycles or not, but instead focused on the frequency of using electric bicycles. Below, the most important and interesting findings of this research are compared with previous literature.

One of the main conclusions of this study is that predictors that significantly influence traditional cycling do not automatically account for predicting the use of electric bicycles. Whereas previous studies clearly confirm the influence of socio-demographics (e.g. age and gender) and spatial environmental aspects (e.g. travel distance and bicycle infrastructure) on cycling behavior, these two types of variables are, according to our regression models, not significant to e-cycling. Put differently, the evidence that exists for traditional cycling cannot be generalized to the case of e-cycling. Previous studies have presumed that inconvenient spatial characteristics (e.g. differences in topography and large travel distances) are overcome by introducing bicycles with electric assistance. Based on the findings that these spatial variables do not meet significance level in this study, it can tentatively be concluded that spatial characteristics are indeed less important to e-cycling than to traditional cycling. So, we can state that electric bicycles help to overcome spatial barriers that exist for cycling, and therefore offering urban citizens the opportunity to use electric bicycles is a good way to increase the amount of trips covered by active travel modes.

The second main conclusion of this study is that other types of variables than socio-demographics and spatial variables do show a clear relationship with the frequency of using electric bicycles. For all travel purposes distinguished in this research (work/school commutes, trips in leisure time, and trips at night), motivations and barriers to cycling are the most influential predictors to the frequency of using electric bicycles. People seem to use the electric bicycles significantly more often when they perceive it as a practical travel mode. For example, because it enables them to make one-way trips or because they live close to a docking station. Even though the existing theories on motivations to use electric bicycles is still very small, that confirm convenience is a main motivating factor (e.g. Bachand-Marleau et al., 2012; Fishman, Washington, Haworth & Watson, 2015). In addition to the convenient practicalities of the electric bicycle sharing system, this study confirms that the frequency of system-use also increases when people are encouraged by friends/family. This findings has not been identified by previous studies, and thus adds new evidence to the motivations for e-cycling. Barriers, on the other hand, are also significantly influencing system-use, though in the opposite direction: they result in a lower frequency of system-use. By taking away the main barriers, people will be less quickly discouraged to use electric bicycles. For example, by building more docking stations in residential areas, by providing enough bicycles at docking stations, and by improving the safety for cyclists.

A third conclusion deals with the relationship between lifestyle and e-cycling. This case study in BiciMAD confirms a relationship between lifestyle and e-cycling as several significant lifestyle predictors are found to significantly influence the frequency with which people use the electric bicycle system. For example, people with an active lifestyle (based on regular participation in physical activity) seem to use electric bicycles more often compared to people with a more sedentary lifestyle. However, the true nature of this relationship cannot be clearly identified in this study as some effects are difficult to interpret. For instance, that people who like to watch TV in their leisure time seem to use the electric bicycle system more often at night. So, although our study confirms that lifestyle influences system-use, this relationship asks for more exploration by studies on e-cycling in the near future.

Another recommendation to future studies on the use of electric bicycle sharing systems is to incorporate the distinction of different travel purposes while analyzing data. Our study took three travel purposes into account, and for each purpose, different predictors were identified by the regression model. For example, some predictors significantly influence the frequency of using BiciMAD for work/school while they do not affect the frequency of using BiciMAD in leisure time or at night. As such, it is highly recommended that future studies take the influence of travel purpose into account when examining the frequency of using an electric bicycle sharing system.

5.3 Reflection on research methodology

In this section, the researcher briefly reflects on the entire research process. Given that this was the first time a quantitative research of such a large scale was performed by the researcher, the overall reflection on the entire research is highly positive. Below, the most positive experiences during this study are discussed, but we also shed light on some aspects that would have been better in case they were performed differently.

After successfully building a theoretical framework and a conceptual mode, the next stage was to operationalize the constructs derived from the theory. In this stage, some difficulties were faced, namely that it was not always an easy task to find good measures for the concepts included in the research model. For several concepts included in the model (for example, lifestyle), the existing evidence was quite small. As such, a lot of time and effort was needed in order to create reliable and valid variables to measure these concepts.

Overall, the process of data collection went very well. After revising the questionnaire a few times before officially sending it to the research sample, it can be argued that the final version of the questionnaire was of high-quality – based on the positive feedback that respondent gave after completing it. Given the large amount of variables included in the research model, it was quite a challenge to develop a questionnaire that would take respondents only about 7 minutes to complete. Furthermore, the process of data collection went well due to the collaboration with the municipality of Madrid and the company of Bonopark. As such, a larger and more representative research sample was invited to the questionnaire. The inclusion of this group of participants highly increased the external validity of this research compared to the situation in which only the first group of participants from the first sample was invited to the questionnaire. The involvement of these two stakeholders also resulted in financial support by Bonopark. The collaboration resulted in the distribution of three prices among all respondents that successfully completed the questionnaire. This was a great incentive to participate for people that were invited to make the survey.

A final reflection deals with the process of data analysis. In this stage, it became clear that it would have been better if the dependent variables were measured as scale variables instead of ordinal variables. Scale would have given a better a clearer indication of how frequent people use the bicycle system. Now that the dependent variables are measured on an ordinal scale, the issue of perception comes to light. Respondents may differ from each other in their interpretation of the categorical answers. For example, one person may define ‘often’ as 5 times a week, whereas another person interprets 3 times a week as ‘often’.

5.4 Case-specific recommendations

Based on the conclusion that the frequency of using BiciMAD increases when people find the system a practical and/or convenient way of travelling, this study recommends to make the system more accessible to it users. Here, 'more accessible' refers to making the system easier to use. Both the municipality of Madrid and the company Bonopark will have to play a major role in this process.

On the one hand, the municipality has to invest in the development of a more extensive bicycle paths. At the moment, there are still many roads where cyclists either have to share the road with motorized vehicles or have to cycle on the sidewalks. By investing in a proper bicycle network with continuous and separated bicycle paths and safe crossing, both objective and subjective safety indices will increase, resulting in many more residents that will travel by BiciMAD.

On the other hand, the company Bonopark should also contribute to making the system more accessible. The company especially has to pay attention to the following three focus points. First, they need to meet the demand-levels of BiciMAD-users. Right now, too many people indicate not using the system as they often reach so-called 'empty docking stations' where there are no bicycles available. Ensuring your users that they will find a bicycle when they reach a docking station, makes system-use more inviting. Second, they should invest in building new stations near popular city locations. Even though the entire city center contains docking stations, it is highly recommended to build new stations near locations where many people work/study. For instance, not one docking station can be found near the big University campus of Madrid. By building several new stations on the campus, system-use will definitely increase among students. And thirdly, this study recommends Bonopark to create a 'family user-card', enabling people to rent more than one bicycle at the same time. Many respondents argue not to use BiciMAD because they often travel together with people that cannot use of the system because they have no user-card. Offering users the opportunity to rent more bicycles at the same time will be a simple solution to this.

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Appendices

Appendix A: Operationalization Socio-demographic variables

Concept	Variable	Categories
Gender	What is your gender?	Male Female
Age	What year were you born?	
Educational level	What is you educational level?	Primary education Secondary education Bachillerato/High school Ciclos formativos profesional/Vocational training University Degree Master Degree PhD
Employment situation	What is your employment situation?	Employed Self-employed Unemployed Retired Student Housekeeper Other
Income level	What is the income level of your household per month?	<1300 1300-2500 >2500
Household composition	How many persons are living in your household (incl. yourself)?	
Driver's license	Do you have a driver´s license?	Yes No
Access to car/motorcycle	Do you own or have access to a car or motorcycle?	Yes Yes, but I have to negotiate with household members No
Access to private bicycle	Do you own or have access to a private bicycle?	Yes No
Access to public transport	Do you have a public transportation card?	Yes No

Appendix B: Operationalization Lifestyle domains

Concept	Variable	Categories
Leisure time preferences	Which activities do you prefer to do in your leisure time?	Exercising/swimming Cycling Watch sports/attend sportive events Cooking Having lunch/dinner out of the home Visiting friends/family Walking through the park Going to the cinema Assist cultural events (e.g. concerts, expositions) Shopping Listening to music/playing an instrument Studying/reading a book Surfing the Internet Watching TV/DVDs/series Travelling Other
Participation in physical activity	How often do you participate in physical activity with a high intensity?	Daily Several times a week Once a week Once a month Never
	How often do you participate in physical activity with a low intensity?	Daily Several times a week Once a week Once a month Never
	Do you consider cycling with BiciMAD as physical activity?	Yes No
International residence	Have you ever lived in another country than Spain for more than 3 consecutive months?	Yes No
	Have you ever lived in a country where the daily bicycle share is above 15%? (Netherlands, Germany, Denmark)	Yes No
	Have you ever lives in a country where the daily bicycle share is 5-15%? Finland, Belgium, Germany, Slovenia, Czech Republic, Lithuania, Slovakia, Poland, Romania, Austria, Croatia, Italy, Latvia, Estonia.	Yes No
	Have you ever lived in a country other than Spain where the daily bicycle share is below 5%?	Yes No

Appendix C: Operationalization Spatial determinants

Concept	Variable	Categories
Walking time to station	How much time do you have to walk from your residence to the closest docking station of BiciMAD?	
Travel distance	What is the maximum amount of time you have spent on a BiciMAD trip in the past month?	
Location docking stations	How satisfied are you with the location of docking stations in Madrid?	Very unsatisfied Unsatisfied Neutral Satisfied Very satisfied
Bicycle infrastructure & safety	How satisfied are you with the cycle paths in Madrid?	Very unsatisfied Unsatisfied Neutral Satisfied Very satisfied
	How satisfied are you with the parking places for traditional bicycles in Madrid?	Very unsatisfied Unsatisfied Neutral Satisfied Very satisfied
	How satisfied are you with the traffic signals for cyclists on the road?	Very unsatisfied Unsatisfied Neutral Satisfied Very satisfied

Appendix D: Operationalization Travel behavior

Concept	Variable	Categories
Replaced travel mode	In general, which travel mode did you use before you started using BiciMAD?	Public transport Car Motorcycle Private bicycle Walking Taxi I didn't make this trip before
Car/motorcycle use	How often do you use the car/motorcycle to go to work/school?	Always Often Sometimes Barely Never
	How often do you use the car/motorcycle to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use the car/motorcycle to travel at night?	Always Often Sometimes Barely Never
Public transport use	How often do you use public transport to go to work/school?	Always Often Sometimes Barely Never
	How often do you use public transport to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use public transport to travel at night?	Always Often Sometimes Barely Never
Private bicycle use	How often do you use your private bicycle to travel to work/school?	Always Often Sometimes Barely Never
	How often do you use you private bicycle to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use you private bicycle to travel at night?	Always Often Sometimes Barely Never
Walking	How often do you walk to travel to work/school?	Always Often Sometimes

		Barely Never
	How often do you walk to in your leisure time?	Always Often Sometimes Barely Never
	How often do you walk to travel at night?	Always Often Sometimes Barely Never
Taxi use	How often do you use a taxi to travel to work/school?	Always Often Sometimes Barely Never
	How often do you use a taxi to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use a taxi to travel at night?	Always Often Sometimes Barely Never
Public transport in combination with BiciMAD	How often do you use public transportation in combination with BiciMAD to travel to work/school?	Always Often Sometimes Barely Never
	How often do you use public transportation in combination with BiciMAD to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use public transportation in combination with BiciMAD to travel at night?	Always Often Sometimes Barely Never

Appendix E: Operationalization Motivations

Variable	Dimensions	Indicators	Items
Motivation to use BiciMAD (36 items)	Environmental concerns (7)	Tráfico (4)	*I use BiciMAD to improve environmental conditions (e.g. air pollution) *Traffic congestion is one of the major causes of climate change *People should change their travel habits in order to improve the environment *Increasing the amount of habitual cyclists will improve environmental conditions
		General environmental concerns (3)	*I am concerned about the environment (pollution, climate change, etc.) *In my daily life, I try to do the most I can to improve environmental conditions *One needs time and effort to be respectful to the environment
	Physical Health (1)	Improve/maintain fitness (1)	* I use BiciMAD to improve/maintain my physical fitness
	Mental Health (1)	Relax/reduce stress (1)	* I travel by BiciMAD to relax/reduce stress
	Social Support (7)	Social accompany (3)	* I am always accompanied by others when I travel by BiciMAD * I prefer to travel by BiciMAD with friends over cycling alone * I prefer to travel by BiciMAD with family members over cycling alone
		Social modelling (2)	* My friends also use BiciMAD * My family also uses BiciMAD
		Social norm (2)	* My friends stimulate me to use BiciMAD * My family stimulates me to use BiciMAD
	Dissatisfaction previous travel mode (9)	Travel time/costs (3)	* Travelling by BiciMAD is faster (travel time) * BiciMAD is a more economic travel mode (travel costs) * When I travel by BiciMAD I experience less waiting time (e.g. less traffic lights, less transfers) (consistency of travel time)
		Trip experience (2)	* Travelling by BiciMAD is more comfortable than travelling "…" (comfort) * Travelling by BiciMAD is more fun than travelling "…" (extra: fun)
		Personal health (2)	* When I travel by BiciMAD I experience less stress compared to travelling "…" (extra: stress) * Travelling by BiciMAD is healthier than travelling "…" (extra: healthier for me)
		Safety (2)	* Travelling by BiciMAD is less dangerous than travelling "…" (safety from traffic) * When I travel by BiciMAD I feel safer (crime/unwanted attention) compared to when I travel "…" (safety from crime and unwanted attention)
	Self-presentation (2)	Self-presentation (2)	* I use BiciMAD because I want to identify myself as a cyclist * I use BiciMAD because it is in line with my lifestyle
	Embodiment (2)	Embodiment (2)	* I use BiciMAD because it helps me to activate myself in the morning * I use BiciMAD to enjoy the surrounding/fresh air
	Practical reasons (7)	Type of vehicle (2)	* I use BiciMAD because I prefer travelling by bicycle over motorized travel modes * I use BiciMAD because I prefer a public or shared bicycle over a private bicycle
		Location of station (1)	* I use BiciMAD because I live close to a docking station
		Travel costs (1)	* I use BiciMAD because it´s cheap
		Anytime availability (3)	* I use BiciMAD because I can use it 24/7 * I use BiciMAD because I have no other option to travel * I use BiciMAD because it is flexible (I am able to make one-way trips)

Appendix F: Operationalization Barriers

Concept	Dimensions	Items
Barriers to using BiciMAD more often	Climate and weather conditions	*Because of climatological conditions *Because of short-term weather conditions
	Travel distance and route characteristics	*Using BiciMAD is dangerous *The distance is too large to go by bicycle *The distance is too short to go by bicycle *In Madrid, there are no appropriate places for leisure cycling
	Psycho-social barriers	*Using BiciMAD is uncomfortable *I prefer to use my own private bicycle *I have more certainty when I travel with other modes *Almost nobody travels by BiciMAD *I have to take my children to school before I go to work *Cycling is a way of travelling, not a leisure activity *I prefer to go by car/motorcycle *I prefer to do other things in my leisure time *I don't want to pay for cycling in my leisure time *I never go out at night *I always share a car/taxi at night *Using BiciMAD at night is dangerous *Cycling at night is not responsible (e.g. alcohol consumption or tiredness)
	Dysfunctions in the bicycle system	*There is no docking station near my residence *There is no docking station near my destination *I won't be sure whether there are bicycle available/places to park my bicycle *Using BiciMAD is expensive *The general state of the bicycles

Appendix G: Operationalization The frequency of using BiciMAD

Concept	Variable	Categories
The use of BiciMAD	How often do you use BiciMAD to travel to work/school?	Always Often Sometimes Barely Never
	How often do you use BiciMAD to travel in your leisure time?	Always Often Sometimes Barely Never
	How often do you use BiciMAD to travel at night?	Always Often Sometimes Barely Never

Appendix H: Questionnaire

Dear participant,

Thank you very much for your participation in this survey! This questionnaire is meant for people having an annual BiciMAD-membership. We would like to gain insight in your necessities and preferences related to BiciMAD in order to get to know better the service BiciMAD offers to its users.

This questionnaire is the result of the collaboration between the Department ´Human Geography and Planning´ of the University of Utrecht (Holanda), the Transportation Research Centre (TRANSyT) of the ´Universidad Politécnica de Madrid´, and Bonopark (the owning company of BiciMAD).

Completing this questionnaire will take about 10 minutes.
Among all participants we will divide THREE ANNUAL BICIMAD MEMBERSHIPS 2016 (with a value of 25 euros). Your answers will be completely anonymous and the information you provide will be stored securely. Please, try to complete the questionnaire as accurate as possible.

In case you have any question, you can contact us at the following e-mail address:
bicimad@caminos.upm.es

Thank you for your collaboration!

Universiteit Utrecht

TRANSyT POLITÉCNICA

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1. **Please, indicate your personal code which you can find in your e-mail invitation of this survey:**

….

2. **Since when do you have a BiciMAD membership?**

One year or more
Between 6 and 12 months
Between 3 and 6 months
Less than 3 months

3. **In general, how many times do you use BiciMAD per week (incl. the weekend)?**

…

In relation to your trips on BiciMAD in the past month:

4. **How much time did you have to walk from your residence to the closest docking station of BiciMAD?**

… minutes

In relation to your trips on BiciMAD in the past month:

5. **How long did your longest travel with BiciMAD take you?**

… minutes

6. **Please, indicate whether you are satisfied or not with the following aspects of BiciMAD. Apply a 5-point scale in which 1 means ´very unsatisfied´ and 5 ´very satisfied´.**

	1	2	3	4	5
The system in general					
The location of the docking stations					
Availability of bicycles at docking stations					
Availability of parking places at stations					
The process of getting a bicycle					
Communication with the service (by phone or email)					
The price of using the system					
The electric assistance of the bicycles					
The technology of the system (mobile app, contactless card, totem, etc.)					
The cleaning and maintenance of the system (bicycles, totems, etc.)					
The management of incidents					

7. **Please, indicate whether you are satisfied or not with the following aspects of the bicycle infrastructure in Madrid. Apply a 5-point scale in which 1 means ´very unsatisfied´ and 5 ´very satisfied´.**

	1	2	3	4	5
The cycle lanes in Madrid					
Parking places for bicycles in Madrid					
Road signs for bicycles in Madrid					

The following questions focus on your motivations for using BiciMAD.

8. **In general, what travel mode did you use before using BiciMAD?**

By public transport (bus or metro)
By car
By motorcycle
By private bicycle
Walking
By taxi
None, before I did not make the trips I now make by BiciMAD (→pass to question 10)

We are interested in your motivations for replacing your previous travel mode by BiciMAD. Rate the importance of the following factors on a 5-point scale, in which 1 means ´I totally disagree´ and 5 ´I totally agree´.

9. **I started to use BiciMAD instead of [answer question 8], because:**

	1	2	3	4	5
travelling by BiciMAD is faster					
travelling by BiciMAD is more comfortable					
I experience less stress when I travel by BiciMAD					
I have less waiting time (e.g. traffic lights, transfers) when I travel by BiciMAD					
travelling by BiciMAD is less dangerous					
I feel more secure (e.g. due to crime/unwanted attention) when I travel by BiciMAD					
travelling by BiciMAD is more fun					
travelling by BiciMAD is healthier					
It is an economic public transport mode					

Please, rate the importance of the following motivations for using BiciMAD. Apply a 5-point scale in which 1 means ´I totally disagree´ and 5 ´I totally agree´.

10. I use BiciMAD, because:

	1	2	3	4	5
I prefer cycling over travelling by motorized travel modes					
I prefer using a public bicycle over my private bicycle					
I live close to a docking station					
it is cheap					
I can use BiciMAD 24/7					
I have no other option to travel					
it is more flexible (I am able to make one-way trips)					
it helps me to feel actived in the morning					
I want to enjoy the surrounding/fresh air					
I want to identify myself as a cyclist					
it is in line with my lifestyle					
I want to improve/keep up my physical fitness					
I want to relax/decrease stress					

Please, indicate to what extent you agree with the following statements on environmental conditions in the city.

11. Apply a 5-point scale in which 1 means ´I totally disagree´ and 5 ´I totally agree´.

	1	2	3	4	5
I travel by BiciMAD to improve environmental conditions (e.g. air pollution)					
I am concerned about the environment (pollution, climate change, etc.)					
In my daily life, I try to do the best to improve environmental conditions					
One needs time and effort to be respectful to the environment					
Traffic pollution is one of the major causes of climate change					
People need to change their travel habits in order to improve the environment					
Increasing the amount of bicycle trips will improve environmental conditions					

Is your use of BiciMAD related to your social environment (friends and family)? Please, indicate to what extent you agree with the following statements.

12. Please, apply a 5-point scale in which 1 means ´I totally disagree´ and 5 ´I totally agree´.

	1	2	3	4	5
I always travel with others when I travel by BiciMAD					
My friends also use BiciMAD					
My friends stimulate me to use BiciMAD					
I prefer to travel by BiciMAD with friends than cycling alone					
My family also uses BiciMAD					
My family stimulates me to use BiciMAD					
I prefer to travel by BiciMAD with family members than alone					

13. **In addition, we are interested in the motivations you have for NOT using BiciMAD for trips within Madrid. Please, select your strongest motivation for NOT using BiciMAD more often.**

There is no BiciMAD station near my residence
There is no BiciMAD station near my destination
I am never sure whether there are bicycles available/free parking spaces at the station
Because of climate conditions (temperature, wind, rain)
Because of short-term weather conditions (weather changes between morning and afternoon)
Using BiciMAD is dangerous
Using BiciMAD is uncomfortable (e.g. because of clothes/bags I have to carry)
Using BiciMAD is expensive
I prefer to use my own private bicycle
I have more certainty when I travel by other travel modes
Other (specify): …

Your commute trip to work/school

We are very interested in the trips you make in Madrid. Specifically, in the trips you make to your work/school/study center.

14. **What is your current employment status?**

Employed
Self-employed
Unemployed (→pass to question 19)
Retired (→pass to question 19)
Student (→pass to question 16)
Housekeeper (→pass to question 19)
Other (specify): … (→pass to question 19)

15. **In which sector do you work?**

Financials
Health Care
Information Technology
Industrials
Energy
Materials
Telecommunication Services
Utilities
Consumer Staples
Consumer Discretionary
Other (specify): …

16. **How much time do you spend on your trip from your residence to your work/school when you travel by the mode you use most often?**

… minutes

17. **Please, indicate how often you use the following travel modes for travelling to your work/school.**

	Always	Often	Sometimes	Barely	Never
BiciMAD					
BiciMAD in combination with public transport					
Car/motorcycle					
Public transport					
Private bicycle					
Walking					
Taxi					

18. **Why don´t you travel more <u>often to work/school</u> by BiciMAD? Please, select your strongest motivation for not using BiciMAD more often when you travel to work/school.**

There is no BiciMAD station near my work/study center
The distance is too large to travel by bicycle
The distance is too short to travel by bicycle
Travelling by BiciMAD to work/school is uncomfortable (e.g. due to clothes/laptop I have to carry)
Almost nobody from work/school travels by BiciMAD
I have more certainty when I travel by other travel modes
Because I have a car from the company/my boss pays my public transportation use
I prefer to use my private bicycle
Because I combine my commute trip with taking my children to school
Other (specify): …

<u>Leisure trips</u>

19. **In case you make <u>a leisure trip</u> (e.g. a trip to relax, to go shopping or to visit friends/family), how often do you use the following travel modes?**

	Always	Often	Sometimes	Barely	Never
BiciMAD					
BiciMAD in combination with public transport					
Car/motorcycle					
Public transport					
Private bicycle					
Walking					
Taxi					

20. **Why don´t you use BiciMAD more often <u>in your leisure time</u>? Please, select the strongest motivation you have for not using BiciMAD more often in your leisure time.**

Cycling is a way of travelling; not a leisure activity
I prefer to make leisure trips by car/motorcycle
I prefer to use my private bicycle
I prefer to do other things in my leisure time
Almost nobody travels by BiciMAD for leisure
I don´t want to pay for using BiciMAD in my leisure time
There are no good places for leisure cycling in Madrid
Other (specify): …

Travelling at night

The following questions focus on your travels in Madrid at nighttime.

21. **Please, indicate how often you use the following travel modes for travelling at night in Madrid.**

	Always	Often	Sometimes	Barely	Never
BiciMAD					
BiciMAD in combination with public transport					
Car/motorcycle					
Public transport					
Private bicycle					
Walking					
Taxi					

22. **Why don´t you travel more often by BiciMAD at nighttime? Please, select the strongest motivation you have for not using BiciMAD more often at night.**

Because I barely/never go out at night
Because I almost always share a car or taxi with others
Travelling by BiciMAD is dangerous at night
Because I don´t think it is responsible to travel by bicycle after going out (e.g. due to alcohol or tiredness)
Almost nobody travels by BiciMAD at night
There is no BiciMAD station near my origin
There is no BiciMAD station near my destination
Other (specify): …

The final part of this survey focuses on your socio-economic characteristics and personal interests.

23. **What is your gender?**

Male
Female

24. **In which year were you born?**

….

25. **What is your educational level?**

Primarios
Enseñanza secundaria
Bachillerato
Ciclos formación Profesional
Grado Universitario
Master
PhD/Doctorado

26. **How many persons are living in your household (incl. yourself)?**

…

27. **How many persons in your household have a BiciMAD membership (incl. yourself)?**

…

28. **What is the income level of your household per month?**

Less than 1.300 euros
1.300-2.500 euros
More than 2.500 euros

Leisure Activities

29. **What type of activities do you prefer to do in your leisure time? You may select more answers.**

Exercising/swimming
Cycling
Watch sport/attend sportive events
Cooking
Dining out
Visit friends/family
Walk through the park
Go to the cinema
Attend cultural events (e.g. concerts, expositions)
Shopping
Listen to music/play an instrument
Read a book/study
Surf the Internet
Watch TV/DVD/series
Travelling
Other (specify): …

Frequency of exercising

30. **How often do you perform activities with high intensity (e.g. running, playing a soccer match)?**

Daily
Several times a week
Once a week
Once a month
(Almost) never

31. **How often do you perform activities with low intensity (e.g. walking, leisure cycling)?**

Daily
Several times a week
Once a week
Once a month
(Almost) never

32. **Do you consider cycling by BiciMAD as a sport activity?**

Yes
No

33. **Have you ever lived in another country than Spain for more than 3 months?**

Yes
No (→pass to question 35)

34. **Please, mention the country/countries you have lived in. In case you have lived in more than 5 countries, mention the 5 countries in which you have lived the most time.**

1:
2:
3:
4:
5:

35. **Do you own or have access to a private bicycle?**

Yes
No

36. **Do you have a driver´s license?**

Yes
No

37. **Do you own or have access to a car or motorcycle?**

Yes
Yes, but I have to negotiate with others living in my household
No

38. **Do you have a public transportation card?**

Yes
No

39. **What is your postal code?**

….

Thank you very much for your time!

On the 1st of December 2015, we will announce the three personal codes of the three winners that have won the BiciMAD membership 2016 (or PRICES of equivalent value) on the following web page:
http://bicimad.transyt-projects.com/
In addition, we will contact the winners personally by e-mail.

In case you have any question, please contact us through the following e-mail address:
bicimad-survey@hotmail.com

THANK YOU FOR YOUR COLLABORATION!

Appendix I: Descriptive statistics Barriers per travel mode

Barriers Work/school commutes	Frequency	Percentage
No station close to work/school	146	31.0%
Distance is too large	88	18.7%
Distance is too short/I work at home	47	10.0%
It's uncomfortable (clothes/laptop)	16	3.4%
Nobody from work/school goes by BiciMAD	3	0.6%
I have more certainty with other travel modes	19	4.0%
I have a lease car/my company pays PT costs	2	0.4%
I prefer to use my own bicycle	11	2.3%
I also have to take my children to school	8	1.7%
There are no bicycles available or functioning	66	14.0%
Mistakes at station/totems/service/user card	17	3.6%
No station close to residence	14	3.0%
Other	34	7.2%
Missing	114	
Total	471	100.0%

Barriers Trips in leisure time	Frequency	Percentage
BiciMAD is a way of travelling, not a leisure activity	76	14.6%
I prefer to go by car/motorcycle	25	4.8%
I prefer to use my own bicycle	54	10.4%
I prefer to do other things in my leisure time	89	17.1%
Nobody uses BiciMAD in his/her leisure time	10	1.9%
I don't want to pay for cycling in my leisure time	57	11.0%
In Madrid, there are no places for leisure cycling	72	13.9%
There is no station close to my residence	17	3.3%
Lack of available bicycles or totems/user card does not work	62	11.9%
I am with people who can't cycle/have no user card	13	2.5%
Because I also like walking/prefer walking	10	1.9%
Other	34	6.6%
Missing	66	
Total	519	100.0%

Barriers Trips at night	Frequency	Percentage
Because I (almost) never go out at night	88	17.0%
Because I always share a taxi/car with others	61	11.8%
Travelling by BiciMAD at night is dangerous	83	16.0%
It's not responsible to cycle (due to alcohol/ tiredness)	78	15.1%
Almost nobody uses BiciMAD at night	5	1.0%
There is no BiciMAD station near my origin	31	6.0%
There is no BiciMAD station near my destination	40	7.7%
Lack of available bicycles/system doesn't function	78	15.1%
I always go walking	14	2.7%
Other	40	7.7%
Missing	67	
Total	518	100.0%

Appendix J: Factor analysis – Bartlett's test & KMO statistic

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,826
Bartlett's Test of Sphericity	Approx. Chi-Square	6448,237
	df	630
	Sig.	,000

Appendix K: Reliability analyses

Factor variable 1: Environmental concerns

Reliability Statistics

Cronbach's Alpha	N of Items
,871	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I use BiciMAD because I prefer a bicycle over motorized travel modes	29,16	25,587	,478	,871
I use BiciMAD to improve environmental conditions (e.g. air pollution)	29,17	23,963	,668	,850
I am worried about environmental conditions (contamination, climate change, etc.)	28,92	23,703	,746	,842
In my daily life, I try to do anything to improve environmental conditions	29,07	24,152	,699	,847
It takes time and effort to be respectful to the environment	29,26	24,914	,492	,872
Traffic congestion is one of the main causes of climate change	29,12	24,999	,546	,864
People should change their travel habits to improve environmental conditions	28,79	24,348	,727	,845
Increasing the numbers of cyclists helps to improve the environment	28,77	24,550	,716	,847

Factor variable 2: Physical and mental health benefits

Reliability Statistics

Cronbach's Alpha	N of Items
,859	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I use BiciMAD because it activates me in the morning	17,70	20,648	,579	,849
I use BiciMAD because I want to enjoy my surrounding/fresh air	17,25	19,844	,628	,840
I use BiciMAD because I want to identify myself as a cyclist	17,73	19,862	,635	,839
I use BiciMAD because it's in line with my lifestyle	17,35	20,406	,670	,832
I use BiciMAD because I want to improve/upkeep my physical fitness	17,47	20,104	,693	,828
I use BiciMAD because I want to relax/reduce stress	17,23	20,151	,706	,826

Factor variable 3: Perceived conveniences compared to previous travel mode

Reliability Statistics

Cronbach's Alpha	N of Items
,807	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
I have replaced my previous travel mode because BiciMAD is faster	26,40	26,845	,538	,451	,783
I have replaced my previous travel mode because BiciMAD is more comfortable	26,74	26,566	,538	,403	,783
I have replaced my previous travel mode because I have less stress when I travel with BiciMAD	26,88	24,742	,600	,428	,772
I have replaced my previous travel mode because I have less waiting time (e.g. traffic lights, stations) with BiciMAD	26,86	24,881	,614	,451	,770
I have replaced my previous travel mode because travelling with BiciMAD is more fun	26,02	26,469	,635	,472	,771
I have replaced my previous travel mode because BiciMAD is healthier	26,15	26,138	,555	,443	,780

I have replaced my previous travel mode because BiciMAD is an economic public transport mode	26,55	27,251	,391	,173	,805
I use BiciMAD because I prefer a shared bicycle over a private bicycle	26,58	28,148	,332	,117	,813

Factor variable 4: Social environment

Reliability Statistics

Cronbach's Alpha	N of Items
,824	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I always travel with BiciMAD together with other people	15,82	26,697	,595	,796
My friends also use BiciMAD	14,92	28,151	,463	,817
My friends encourage me to use BiciMAD	15,40	26,886	,571	,800
I prefer to be with friends when I use BiciMAD	15,26	25,202	,636	,789
My family also uses BiciMAD	15,86	26,291	,533	,807
My family encourages me to use BiciMAD	15,85	27,040	,562	,802
I prefer to use BiciMAD together with family members	15,64	25,932	,613	,793

Factor variable 5: Practical reasons

Reliability Statistics

Cronbach's Alpha	N of Items
,429	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I have replaced my previous travel mode because BiciMAD is less dangerous	21,75	11,015	,222	,382
I have replaced my previous travel mode because I feel safer when I travel with BiciMAD	21,10	10,611	,237	,372
I use BiciMAD because I live close to a docking station	19,88	9,557	,202	,392
I use BiciMAD because it's cheap	20,53	9,307	,351	,302
I use BiciMAD because I can use the system 24/7	19,57	10,101	,272	,352
I use BiciMAD because I have no other way to travel	19,52	13,873	-,232	,563
I use BiciMAD because the system is flexible (I can make one-way trips)	19,87	9,526	,360	,303

Appendix L: Regression output – Work/school commuting

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1011,419			
Final	709,147	302,272	45	,000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1293,648	1363	,910
Deviance	709,147	1363	1,000

Link function: Logit.

Pseudo R-Square

Cox and Snell	,575
Nagelkerke	,610
McFadden	,299

Link function: Logit.

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Trab_biciMAD = 1]	-1,477	,823	3,219	1	,073	-3,090	,136
	[Trab_biciMAD = 2]	,904	,816	1,226	1	,268	-,696	2,503
	[Trab_biciMAD = 3]	2,302	,821	7,856	1	,005	,692	3,912
	[Trab_biciMAD = 4]	3,227	,828	15,171	1	,000	1,603	4,850
Location	FAC1_1	-,185	,132	1,971	1	,160	-,444	,073
	FAC2_1	-,010	,128	,006	1	,937	-,262	,241
	FAC3_1	-,001	,128	,000	1	,996	-,251	,250
	FAC4_1	,314	,129	5,878	1	,015	,060	,568
	FAC5_1	-,429	,133	10,381	1	,001	-,690	-,168
	[Age=1]	-1,086	,740	2,156	1	,142	-2,536	,364
	[Age=2]	-1,147	,464	6,116	1	,013	-2,056	-,238
	[Age=3]	-1,011	,330	9,388	1	,002	-1,657	-,364
	[Age=4]	0[a]	.	.	0	.	.	.
	[Disp_bici=1]	,886	,279	10,115	1	,001	,340	1,432
	[Disp_bici=2]	0[a]	.	.	0	.	.	.
	[Deporte_baja=1]	1,156	,615	3,533	1	,060	-,049	2,361
	[Deporte_baja=2]	1,549	,617	6,299	1	,012	,339	2,759
	[Deporte_baja=3]	1,237	,645	3,672	1	,055	-,028	2,502
	[Deporte_baja=4]	1,465	,850	2,971	1	,085	-,201	3,131
	[Deporte_baja=5]	0[a]	.	.	0	.	.	.
	[Satis_localización=1]	,430	,579	,551	1	,458	-,705	1,564
	[Satis_localización=2]	,523	,382	1,875	1	,171	-,225	1,271
	[Satis_localización=3]	1,081	,357	9,150	1	,002	,381	1,782
	[Satis_localización=4]	,482	,321	2,263	1	,132	-,146	1,111
	[Satis_localización=5]	0[a]	.	.	0	.	.	.
	[Trab_coche=1]	2,104	,549	14,668	1	,000	1,027	3,181
	[Trab_coche=2]	,424	,408	1,079	1	,299	-,376	1,224
	[Trab_coche=3]	-,076	,402	,036	1	,849	-,865	,712
	[Trab_coche=4]	-,265	,354	,561	1	,454	-,958	,428
	[Trab_coche=5]	0[a]	.	.	0	.	.	.
	[Trab_bici=1]	-,286	,620	,213	1	,644	-1,502	,929

[Trab_bici=2]	-,939	,560	2,817	1	,093	-2,036	,158
[Trab_bici=3]	-1,720	,465	13,697	1	,000	-2,631	-,809
[Trab_bici=4]	-1,045	,418	6,250	1	,012	-1,863	-,226
[Trab_bici=5]	0[a]	.	.	0	.	.	.
[Trab_andar=1]	-1,139	,436	6,827	1	,009	-1,993	-,284
[Trab_andar=2]	-1,812	,380	22,692	1	,000	-2,558	-1,067
[Trab_andar=3]	-1,848	,377	23,986	1	,000	-2,587	-1,108
[Trab_andar=4]	-2,058	,415	24,596	1	,000	-2,871	-1,245
[Trab_andar=5]	0[a]	.	.	0	.	.	.
[Trab_taxi=1]	-1,547	1,302	1,413	1	,235	-4,099	1,004
[Trab_taxi=2]	-,071	,744	,009	1	,924	-1,530	1,388
[Trab_taxi=3]	-1,041	,396	6,899	1	,009	-1,818	-,264
[Trab_taxi=4]	-,504	,298	2,866	1	,090	-1,088	,080
[Trab_taxi=5]	0[a]	.	.	0	.	.	.
[Trab_no=1]	3,495	,517	45,631	1	,000	2,481	4,510
[Trab_no=2]	3,549	,579	37,571	1	,000	2,414	4,684
[Trab_no=3]	2,815	,630	19,967	1	,000	1,580	4,050
[Trab_no=4]	2,049	,763	7,204	1	,007	,553	3,545
[Trab_no=5]	,859	1,436	,357	1	,550	-1,956	3,674
[Trab_no=6]	1,733	,718	5,824	1	,016	,326	3,140
[Trab_no=7]	1,124	2,004	,314	1	,575	-2,804	5,052
[Trab_no=8]	1,747	,905	3,729	1	,053	-,026	3,520
[Trab_no=9]	3,113	1,118	7,750	1	,005	,921	5,304
[Trab_no=10]	1,085	,519	4,368	1	,037	,067	2,103
[Trab_no=11]	2,192	,735	8,903	1	,003	,752	3,632
[Trab_no=12]	2,343	,746	9,861	1	,002	,881	3,806
[Trab_no=13]	0[a]	.	.	0	.	.	.

Link function: Logit.
a. This parameter is set to zero because it is redundant.

VIF-check

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2,575	,554		4,648	,000		
	REGR factor score 1 for analysis 1	-,089	,060	-,065	-1,483	,139	,873	1,145
	REGR factor score 2 for analysis 1	-,024	,060	-,016	-,391	,696	,941	1,062
	REGR factor score 3 for analysis 1	-,060	,062	-,042	-,973	,331	,891	1,122
	REGR factor score 4 for analysis 1	,165	,062	,116	2,652	,008	,875	1,143
	REGR factor score 5 for analysis 1	-,216	,060	-,157	-3,610	,000	,886	1,129
	Based on variable nacimiento	,129	,091	,066	1,422	,156	,770	1,299
	¿Dispone de bicicleta privada?	-,303	,129	-,107	-2,360	,019	,817	1,225
	¿Con qué frecuencia hace ejercicio con una intensidad baja (ej. andar, montar en bici por ocio)?	-,005	,059	-,004	-,087	,931	,924	1,082
	Satisfacción con la localización de estaciones	-,054	,051	-,046	-1,058	,291	,863	1,158

Indique con qué frecuencia usa coche o moto para viajar a su trabajo/centro de estudios.	-,137	,042	-,150	-3,293	,001	,806	1,241
Indique con qué frecuencia usa bicicleta privada para viajar a su trabajo/centro de estudios.	,163	,060	,129	2,727	,007	,742	1,348
Indique con qué frecuencia anda para viajar a su trabajo/centro de estudios.	,174	,043	,184	4,081	,000	,815	1,227
Indique con qué frecuencia usa el taxi para viajar a su trabajo/centro de estudios.	,239	,074	,145	3,211	,001	,815	1,227
¿Por qué no viaja en BiciMAD al trabajo/centro de estudios con más frecuencia? Por favor, marque su motivo más importante.	-,123	,014	-,377	-8,655	,000	,879	1,138

a. Dependent Variable: Indique con qué frecuencia usa BiciMAD para viajar a su trabajo/centro de estudios.

Appendix M: Regression output – Trips in leisure time

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1058,941			
Final	905,323	153,618	29	,000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1830,359	1523	,000
Deviance	905,323	1523	1,000

Link function: Logit.

Pseudo R-Square

Cox and Snell	,326
Nagelkerke	,349
McFadden	,145

Link function: Logit.

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Ocio_biciMAD = 1]	-,816	,497	2,695	1	,101	-1,791	,158
	[Ocio_biciMAD = 2]	2,233	,514	18,890	1	,000	1,226	3,239
	[Ocio_biciMAD = 3]	4,084	,538	57,523	1	,000	3,029	5,139
	[Ocio_biciMAD = 4]	5,482	,573	91,537	1	,000	4,359	6,605
Location	FAC1_1	-,096	,101	,899	1	,343	-,294	,102
	FAC2_1	-,098	,103	,900	1	,343	-,300	,104
	FAC3_1	-,407	,104	15,360	1	,000	-,611	-,204
	FAC4_1	-,345	,103	11,151	1	,001	-,548	-,143
	FAC5_1	-,536	,109	24,305	1	,000	-,750	-,323
	[Abono_TP=1]	,512	,210	5,951	1	,015	,101	,923
	[Abono_TP=2]	0[a]	.	.	0	.	.	.
	[Ocio_musica=1]	-,432	,212	4,148	1	,042	-,848	-,016
	[Ocio_musica=2]	0[a]	.	.	0	.	.	.
	[Tardar_viajeCAT=1]	1,624	,532	9,329	1	,002	,582	2,666
	[Tardar_viajeCAT=2]	,311	,255	1,485	1	,223	-,189	,811
	[Tardar_viajeCAT=3]	,257	,245	1,097	1	,295	-,224	,737
	[Tardar_viajeCAT=4]	0[a]	.	.	0	.	.	.
	[Ocio_coche=1]	2,355	,569	17,162	1	,000	1,241	3,470
	[Ocio_coche=2]	1,182	,324	13,319	1	,000	,547	1,817
	[Ocio_coche=3]	1,036	,293	12,503	1	,000	,462	1,609
	[Ocio_coche=4]	,260	,280	,858	1	,354	-,290	,809
	[Ocio_coche=5]	0[a]	.	.	0	.	.	.
	[Ocio_bici=1]	-1,226	,825	2,210	1	,137	-2,842	,390
	[Ocio_bici=2]	,267	,394	,461	1	,497	-,504	1,039
	[Ocio_bici=3]	-,402	,320	1,580	1	,209	-1,028	,225
	[Ocio_bici=4]	,752	,344	4,786	1	,029	,078	1,426
	[Ocio_bici=5]	0[a]	.	.	0	.	.	.
	[Ocio_no=1]	1,426	,496	8,265	1	,004	,454	2,397
	[Ocio_no=2]	1,579	,622	6,439	1	,011	,359	2,799

[Ocio_no=3]	1,009	,549	3,373	1	,066	-,068	2,085
[Ocio_no=4]	1,349	,478	7,963	1	,005	,412	2,286
[Ocio_no=5]	1,304	,802	2,645	1	,104	-,267	2,876
[Ocio_no=6]	,458	,519	,781	1	,377	-,558	1,475
[Ocio_no=7]	1,110	,487	5,199	1	,023	,156	2,064
[Ocio_no=8]	1,811	,665	7,406	1	,006	,507	3,115
[Ocio_no=9]	,834	,491	2,883	1	,090	-,129	1,796
[Ocio_no=10]	2,482	,879	7,968	1	,005	,759	4,206
[Ocio_no=11]	2,028	,905	5,026	1	,025	,255	3,801
[Ocio_no=12]	0[a]	.	.	0	.	.	.

Link function: Logit.
a. This parameter is set to zero because it is redundant.

VIF check:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3,820	,360		10,612	,000		
	REGR factor score 1 for analysis 1	-,065	,046	-,065	-1,425	,155	,943	1,060
	REGR factor score 2 for analysis 1	-,023	,046	-,022	-,494	,622	,967	1,034
	REGR factor score 3 for analysis 1	-,161	,046	-,160	-3,472	,001	,921	1,086
	REGR factor score 4 for analysis 1	-,151	,045	-,149	-3,328	,001	,980	1,020
	REGR factor score 5 for analysis 1	-,225	,046	-,224	-4,866	,000	,925	1,081
	¿Tiene abono de transporte público?	-,215	,095	-,106	-2,275	,023	,899	1,112
	¿Le gusta escuchar música o tocar un instrumento en su tiempo libre?	,204	,094	,097	2,173	,030	,979	1,021
	categories of the variable Tardar_viaje	-,131	,051	-,116	-2,572	,010	,963	1,038
	¿Si realiza un viaje en su tiempo libre (ej. un viaje para relajarse, ir de compras o visitar amigos/familiares), con qué frecuencia utiliza el coche?.	-,222	,040	-,267	-5,603	,000	,862	1,160
	¿Si realiza un viaje en su tiempo libre (ej. un viaje para relajarse, ir de compras o visitar amigos/familiares), con qué frecuencia utiliza su bicicleta privada?.	,035	,043	,039	,809	,419	,866	1,154
	¿Por qué no utiliza BiciMAD con más frecuencia en su tiempo libre? Por favor, marque su motivo más importante.	-,032	,015	-,100	-2,171	,031	,919	1,088

a. Dependent Variable: ¿Si realiza un viaje en su tiempo libre (ej. un viaje para relajarse, ir de compras o visitar amigos/familiares), con qué frecuencia utiliza BiciMAD?

Appendix N: Regression output – Trips at night

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1173,540			
Final	979,092	194,447	50	,000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1691,779	1502	,000
Deviance	979,092	1502	1,000

Link function: Logit.

Pseudo R-Square

Cox and Snell	,393
Nagelkerke	,414
McFadden	,166

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Noche_biciMAD = 1]	-3,143	1,189	6,992	1	,008	-5,474	-,813
	[Noche_biciMAD = 2]	-,630	1,183	,284	1	,594	-2,948	1,688
	[Noche_biciMAD = 3]	1,051	1,182	,790	1	,374	-1,267	3,368
	[Noche_biciMAD = 4]	2,374	1,186	4,010	1	,045	,050	4,698
Location	FAC1_1	-,224	,108	4,285	1	,038	-,437	-,012
	FAC2_1	,207	,106	3,825	1	,051	,000	,415
	FAC3_1	-,141	,103	1,869	1	,172	-,342	,061
	FAC4_1	-,289	,104	7,732	1	,005	-,493	-,085
	FAC5_1	-,543	,108	25,439	1	,000	-,755	-,332
	[Situ_laboral=1]	-1,639	,800	4,194	1	,041	-3,207	-,070
	[Situ_laboral=2]	-1,742	,833	4,372	1	,037	-3,375	-,109
	[Situ_laboral=3]	-1,656	,899	3,394	1	,065	-3,417	,106
	[Situ_laboral=4]	-1,806	1,385	1,701	1	,192	-4,520	,908
	[Situ_laboral=5]	-2,545	,834	9,310	1	,002	-4,180	-,910
	[Situ_laboral=6]	-,268	1,452	,034	1	,853	-3,114	2,577
	[Situ_laboral=7]	0[a]	.	.	0	.	.	.
	[Disp_coche=1]	,886	,340	6,791	1	,009	,220	1,552
	[Disp_coche=2]	,618	,351	3,099	1	,078	-,070	1,305
	[Disp_coche=3]	0[a]	.	.	0	.	.	.
	[Ocio_tele=1]	-,542	,203	7,111	1	,008	-,941	-,144
	[Ocio_tele=2]	0[a]	.	.	0	.	.	.
	[Deporte_alta=1]	-,818	,430	3,612	1	,057	-1,661	,026
	[Deporte_alta=2]	-,371	,286	1,687	1	,194	-,931	,189
	[Deporte_alta=3]	-,387	,337	1,318	1	,251	-1,047	,274
	[Deporte_alta=4]	-,892	,405	4,841	1	,028	-1,686	-,097
	[Deporte_alta=5]	0[a]	.	.	0	.	.	.
	[Deporte_baja=1]	1,226	,543	5,088	1	,024	,161	2,291

[Deporte_baja=2]	1,030	,533	3,731	1	,053	-,015	2,076
[Deporte_baja=3]	,935	,557	2,814	1	,093	-,158	2,028
[Deporte_baja=4]	1,172	,731	2,571	1	,109	-,261	2,604
[Deporte_baja=5]	0[a]	.	.	0	.	.	.
[Tardar_viajeCAT=1]	1,527	,598	6,513	1	,011	,354	2,700
[Tardar_viajeCAT=2]	,100	,257	,151	1	,698	-,404	,603
[Tardar_viajeCAT=3]	-,218	,247	,776	1	,378	-,702	,266
[Tardar_viajeCAT=4]	0[a]	.	.	0	.	.	.
[Noche_coche=1]	1,587	,528	9,016	1	,003	,551	2,623
[Noche_coche=2]	1,153	,316	13,294	1	,000	,533	1,772
[Noche_coche=3]	,419	,315	1,774	1	,183	-,198	1,036
[Noche_coche=4]	,101	,278	,131	1	,718	-,445	,646
[Noche_coche=5]	0[a]	.	.	0	.	.	.
[Noche_bici=1]	-4,145	2,061	4,044	1	,044	-8,184	-,105
[Noche_bici=2]	,568	,570	,991	1	,319	-,550	1,685
[Noche_bici=3]	,018	,444	,002	1	,968	-,853	,888
[Noche_bici=4]	,264	,369	,511	1	,475	-,460	,988
[Noche_bici=5]	0[a]	.	.	0	.	.	.
[Noche_andar=1]	-1,116	,477	5,475	1	,019	-2,050	-,181
[Noche_andar=2]	-,990	,385	6,622	1	,010	-1,743	-,236
[Noche_andar=3]	-1,253	,397	9,944	1	,002	-2,032	-,474
[Noche_andar=4]	-,542	,519	1,090	1	,296	-1,559	,475
[Noche_andar=5]	0[a]	.	.	0	.	.	.
[Noche_taxi=1]	-,915	,631	2,101	1	,147	-2,152	,322
[Noche_taxi=2]	,532	,353	2,275	1	,131	-,159	1,223
[Noche_taxi=3]	,720	,300	5,740	1	,017	,131	1,308
[Noche_taxi=4]	,619	,306	4,093	1	,043	,019	1,219
[Noche_taxi=5]	0[a]	.	.	0	.	.	.
[Noche_no=1]	,412	,429	,919	1	,338	-,430	1,253
[Noche_no=2]	,935	,473	3,900	1	,048	,007	1,862
[Noche_no=3]	1,593	,438	13,226	1	,000	,734	2,452
[Noche_no=4]	,833	,429	3,778	1	,052	-,007	1,673
[Noche_no=5]	-,546	1,039	,276	1	,599	-2,582	1,490
[Noche_no=6]	,886	,541	2,686	1	,101	-,174	1,947
[Noche_no=7]	,208	,484	,185	1	,667	-,740	1,156
[Noche_no=8]	-,052	,424	,015	1	,902	-,884	,779
[Noche_no=9]	,599	,714	,705	1	,401	-,800	1,998
[Noche_no=10]	0[a]	.	.	0	.	.	.

Link function: Logit.
a. This parameter is set to zero because it is redundant.

VIF check:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	4,283	,527		8,128	,000		
	REGR factor score 1 for analysis 1	-,062	,055	-,052	-1,140	,255	,915	1,093
	REGR factor score 2 for analysis 1	,148	,054	,122	2,715	,007	,966	1,035
	REGR factor score 3 for analysis 1	-,101	,054	-,085	-1,853	,065	,923	1,084
	REGR factor score 4 for analysis 1	-,130	,055	-,109	-2,385	,018	,929	1,077
	REGR factor score 5 for analysis 1	-,299	,054	-,252	-5,575	,000	,949	1,054

¿Cuál es su situación laboral?	-,037	,034	-,054	-1,110	,268	,829	1,206
¿Dispone de coche o motocicleta?	-,226	,082	-,131	-2,749	,006	,858	1,165
¿Le gusta ver la tele/series/DVD en su tiempo libre?	,242	,106	,102	2,287	,023	,984	1,016
¿Con que frecuencia hace ejercicio con una intensidad alta (ej. correr, jugar un partido o entrenamiento de fútbol)?	,042	,044	,044	,966	,335	,931	1,074
¿Con qué frecuencia hace ejercicio con una intensidad baja (ej. andar, montar en bici por ocio)?	-,113	,054	-,097	-2,080	,038	,895	1,117
categories of the variable Tardar_viaje	-,057	,060	-,043	-,957	,339	,968	1,033
Indique con qué frecuencia usa el coche para viajar por la noche en Madrid	-,192	,044	-,205	-4,368	,000	,877	1,140
Indique con qué frecuencia usa su bicicleta privada para viajar por la noche en Madrid.	,061	,075	,039	,813	,417	,863	1,159
Indique con qué frecuencia usa el taxi para viajar por la noche en Madrid.	-,071	,050	-,065	-1,424	,155	,930	1,075
¿Por qué no utiliza BiciMAD con más frecuencia por la noche? Por favor, marque su motivo más importante.	-,073	,018	-,179	-3,964	,000	,949	1,054

a. Dependent Variable: Indique con qué frecuencia usa BiciMAD para viajar por la noche en Madrid.