An Inquiry Into the Potential and Sustainability Benefits Derived From the Expansion of Bike Sharing System in Porto, Portugal

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An Inquiry into the Potential Benefits Derived from the Expansion of a
Bike Sharing System in Porto, Portugal

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A Thesis in the Field of Sustainability
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Abstract

The primary goal of this research was to model the potential of a bike sharing program (BSP) in Portugal and more specifically within the city of Porto. For many years, the topic of BSP has been heavily debated as the preferred mode of transportation for many urban cities across the globe due to several reasons, such as that they are environmentally friendly, cost-effective, convenient, safe, and more.

While the derived benefits of BSP are not yet clearly justified in academic research, many politicians believe that BSP is good for locals as well as tourists. As a result, several major cities such as New York, Paris, London and more have justified this public policy when it comes to the adoption of various schemes of BSP.

While other cities around the world are finding ways to manage an overgrowing tourist population, the trend is something fairly new for Portugal and the city of Porto. In order to alleviate these problems, an introduction of a green mode of transportation like BSP, if implemented successfully, could help the city of Porto to better manage its global popularity as well as solidify the city as a sustainable tourist destination.

The research questions addressed by this thesis were: Under what conditions could the expansion of BSP in Porto, Portugal become financially successful when looking at future conditions and possible technological advancement? What are some predictive factors of success beyond the baseline and alternative scenario models? Hypotheses include: 1) There are predictive variables associated with past BSP case studies and 2) BSP can be financially viable for the city of Porto. Ultimately, the
implementation of a successful bike sharing scenario would improve the well-being of the citizens of Porto, as well as help to mitigate the influx of international tourists, by providing them with a viable mode of transportation which in the end will result in various sustainable and economic benefits to the city of Porto.

In order to measure the potential of BSP in Porto, case studies from various cities around the world with similar characteristics to Porto were collated into a large database for a comparative analysis. From the published data and primary sources, a system dynamics model was created in order to predict the feasibility of implementing BSP in Porto. These data were assembled into two spreadsheets. The primary spreadsheet includes various scenarios regarding BSP implementation over a period of 15 years while the secondary spreadsheet focused on multiple factors in order to provide additional input as well as emphasize the outcome relating to detailed study of BSP in Porto.

Bike sharing in the city of Porto has the potential to become economically viable but only through the implementation of the 4th Generation Electric Dockless Bikes with Parking Stalls. This scenario is the most effective because it is the only one that is profitable with a net profit at approximately $5.2 million after a 15 years projection. In addition, a multiple regression analysis was performed on historical data from 23 cities around the world which resulted in no significant effect of different variables in driving the success of BSP. Upon completing a quantitative as well as a qualitative analysis of the situation, I determined that the implementation of BSP in Porto has the potential to succeed; however, more tailored research as well as transparency when it comes to business operations and financing are needed in order to ensure optimal success.
Dedication

To my family and loved ones, thank you for always believing in me.

Porto, Portugal

“Times change, as do our wills, What we are - is ever changing; All the world is made of change, And forever attaining new qualities.”

“Mudam-se os tempos, mudam-se as vontades, Muda-se o ser, muda-se a confiança; Todo o mundo é composto de mudança, Tomando sempre novas qualidades.”

- Luís Vaz de Camões
I would like to start by thanking Dr. Mark Leighton and Dr. Thomas Gloria whom have helped me tremendously throughout this journey. Through a coincidence, Professor Gloria visited me in Porto, Portugal where we briefly discussed bike sharing while watching the sunset over the Atlantic Ocean. As a Thesis Director, he was there every step of the way as a helpful mentor and a constructive teacher. I would like to also thank the Administration at Harvard Extension School, including Lacey Klingensmith, who helped me to meet deadlines and answer numerous questions whenever needed. Thank you to my Mom for listening and believing in my ability, and to my Papa for his continuous support. Finally, I would like to thank my partner Nicholas for being with me through every step of the way and helping me move forward one day at a time.
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Definition of Terms

BSP: Bike Sharing Programs

CDUP: University of Porto Sports Center

EU: European Union

ECF: European Cyclists’ Federation

ITDP: Institute for Transportation & Development Policy

GHG: Greenhouse Gas Emissions

MUBi: The Association for Urban Mobility by Bicycles

NPV: Net Present Value

OECD: Organisation for Economic Co-operation and Development

PO SEUR: Operational Program for Sustainability and Efficiency in the Use of Resources

U.N: United Nations

UNWTO: United Nations World Tourism Organization

V.N Gaia: Vila Nova de Gaia
Chapter I

Introduction

According to the Organisation for Economic Cooperation and Development (OECD), around the world, various methods of Bike Sharing Programs (BSP) are used in an effort to reduce greenhouse gas emissions (GHG) from vehicle usage and to solve other problems relating to urban mobility, such as traffic congestion, environmental health issues, and more (Weston et al., 2012) (OECD, 2011). Since 2007, bike sharing has continuously been the fastest growing mode of urban transportation with a growth rate of 45% per year (Lopes, 2015). BSP are often comprised of short-term bike rental schemes which allow users to pick up and drop off bikes at any self-service station, making BSP ideal for round trips or point-to-point trips. Since their introduction in the 1960s, BSP has drastically changed with multiple schemes and innovative technologies. The very first generation of BSP was introduced in 1965 in Amsterdam (White Bicycles), in 1976 La Rochelle (Yellow Bicycles), and in 1993 Cambridge (Green Bicycles) where bikes were free to borrow and return from any location (O’Neill & Caufield, 2012). The main reason that the concept is attractive is that users can use these shared bikes whenever they need without the costs and responsibilities that comes with bike ownership (Shaheen, Guzman, & Zhang, 2010).

While the concept of bike sharing is popular in other countries, especially in European countries such as the Netherlands, Denmark, Germany and France, in Portugal, the development of bike sharing is fairly new. The reason is due to a lack of
infrastructure, demand, and other unfavorable factors for cycling. Despite being located in the European Union (EU) and having an optimal natural environmental and a preferable climate for cycling, over the years various cities in Portugal have struggled with fully integrating BSP as an urban mobility option (Global Sustainability Initiative, 2008) (European Environment Agency, 2014). Undeterred by these issues, there has been several grassroots initiatives spearheaded by The Association for Urban Mobility by Bicycles (MUBi) and other cycling industry associations to encourage citizens to bike and to raise awareness for cycling throughout Portugal (MUBi, 2009).

Research Significance and Objectives

The aim of my research was to look at why some forms of BSP implementation were not successful in the past, what factors could increase the chances for BSP implementation to succeed in the future, and if so, will these success factors work in the case of Porto based on its policies and natural environment. The research examined historical trends and available public data from past case studies in order to forecast various future scenarios which spans over 15 years. By modeling different scenarios and analyzing the results, I identified factors driving success based on various natural and human variables. My objectives were to:

- Analyze whether the Municipality of Porto can successfully implement bike sharing for the public by determining what factors and conditions are the most favorable in order for the implementation to be economically feasible.
- Track to see which BSP have been successful and establish a spreadsheet that comprise of future scenarios based on different measures of success.
- Determine how effective Porto has been in the past regarding improvement relating to cycling infrastructure or the introduction of any forms of BSP.
- Determine necessary steps in establishing policies, business collaborations and other factors that could help to implement BSP.

Background

As of June 2014, some form of BSP were available in 50 countries and 712 cities, and at one point there were approximately 806,200 bicycles and 37,500 stations in operation around the world (Shaheen, Martin, & Cohen, 2013). BSP have greatly evolved over the years, starting from coin based systems to IT-based systems where users can rent and locate bikes using their mobile devices. More innovative cities incorporate additional capabilities with demand-responsive and multi-modal systems allowing them to receive real-time information on bicycle availability and their locations (Shaheen, Guzman, & Zhang, 2010). There are many different models of BSP; however, not all of them have been successful. In fact, some cities such as Amsterdam and Paris have faced numerous challenges when it comes to maintaining a working BSP.

In Portugal, BSP has been slow to take off since the country is still recovering after the financial crisis which started in 2001. With the help of EU funding and a more stable government interested in technology and sustainability, the country is rebuilding economically by revitalizing several key infrastructures. In Portugal, there is a potential for BSP to thrive since Europe is leading the way in terms of the number of BSP with 414 programs (62%), followed by Asia with 164 programs (25%), North America with 50
programs (8%), South America with 22 programs (4%), and Africa and Australia with a combined less than 1% (Lopes, 2015) (Figure 1).

Figure 1. World bike sharing programs by continent (Lopes, 2015).

Concept of Bike Sharing

The concept of BSP has drastically changed over the years and has taken many different forms and used various implementation strategies (OECD, 2016). Below are a few examples of BSP:

- Bikes are available for users to use on a shared basis for free or for a fee.
- Users can check for availability and location of bikes within the network through their mobile devices.
• In larger cities where there are multiple operators, users have the option to choose from several different networks including regular bikes, dockless bikes, and electric bikes.

• Users can unlock the bike using a coin-based-system or by entering their payment information depending on the technology.

• Short trips are made from Point A to Point B, where users often end the trip by returning the bike to a docking station or leaving it on a street near their home if the bike is dockless.

The concept of bike sharing is straight-forward and innovative because it is ideal for short distances and point-to-point trips which work well in cities with good infrastructure and a growing population (Clark University, 2016). For many metropolitan cities around the world, combining bike sharing with public transportation is an ideal concept to improve the attractiveness of the city as well as increase the quality of urban life. Bike sharing is different than a traditional bike rental system because it allows users to go from point A to point B without having to return the bike to the original rental location at the end of their trip and is often used with the traditional public transportation system in order to complete the “last mile” (Croci & Rossi, 2014). Figure 2 shows a timeline of bike sharing technology from the 1960’s until now.
Figure 2. The evolution of bike sharing technology (Great Rivers Greenway, 2014).

Benefits of Bike Sharing

Researchers have pointed out that the implementation of BSP often has a positive impact on commercial areas consisting of hotels, shopping malls, and entertainment (Zhang, Thomas, & Brussel, 2016). Often when the concept of BSP is introduced to a city, there are many sustainability benefits that come with it, such as reducing the carbon footprint, reducing traffic congestion, and fostering a healthier lifestyle (Pucher & Buehler, 2008). A survey conducted in regards to BSP in Washington, D.C. found that 31.5% of users reported that bicycling lowered their stress level and 30% of individuals
had lost weight (Alberts, Palumbo, & Pierre, 2012). Table 1 showcases the direct and indirect benefits as a result of cycling, the study was conducted by the Civitas Initiative (2017) with support from the EU.

Table 1. Direct and indirect benefits from cycling (Civitas Initiative, 2017).

<table>
<thead>
<tr>
<th>Direct benefits</th>
<th>Indirect benefits</th>
</tr>
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<tbody>
<tr>
<td>Health benefits</td>
<td>Health benefits</td>
</tr>
<tr>
<td>Advertising opportunities</td>
<td>Make cycling more visible</td>
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<tr>
<td>Additional mobility option</td>
<td>Encourage cycling infrastructure development</td>
</tr>
<tr>
<td>Congestion avoidance</td>
<td>Reduce CO₂ emissions</td>
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<tr>
<td>Employment opportunities</td>
<td>Positive city image</td>
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<td>Increase cycling modal share</td>
<td>Improve cycling safety</td>
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<tr>
<td>Increase attractiveness for tourist</td>
<td>Liveable streets</td>
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<tr>
<td>Manage public transport demand</td>
<td>Savings with reduction of car infrastructure</td>
</tr>
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</table>

Many people often find bicycling enjoyable, relaxing and safe. A study in the Netherlands by the Knowledge Institute Mobility (Ministerie van Verkeer en Waterstaat, 2007) showed that cycling can produce the highest level of positive emotions such as joy and lower negative emotions such as anger and agitation compared to using other modes of transportation. Cycling is thought to be much more environmentally friendly in comparison to other modes of transportation such as by automobile, bus, train, and airplane. As a result, many municipalities around the world often support some sort of cycling infrastructure in an effort to reduce their carbon footprint.
Dockless Bikes

While BSP could possibly be good for the environment, there has been rising concerns in regards to the environmental costs relating to dockless bikes. For many Municipalities with limited budgets, dockless BSP options are often introduced because they cost less to launch and maintain over time. Despite the low capital costs, there are a multitude of issues that come with dockless bike sharing. In recent years in Amsterdam, 5,500 unregulated dockless bikes flooded the streets and were labeled by the local population as vuilnis, which means garbage in Dutch (Ahmed, 2018). In the Netherlands, recent statistics show that there are 22 million bikes for 17 million people; therefore, despite having one of the best cycling infrastructures and policies in the world, there is simply no more room for any additional bikes in the Netherlands (Ahmed, 2018). In other cities, numerous dockless bikes are often discarded in rivers and vandalized due to over production and a lack of demand. Overproduction of bikes and lack of care is a major issue for BSP, especially in China where the population is over 1 billion people.

Since dockless bikes are lighter, they are often prime targets for vandalism, especially when they are viewed as more of a public nuisance in comparison with traditional bikes that are parked at docking stations. In the past, many private bike share companies often implemented their version of bike sharing without proper consultation because from a business perspective the scheme is profitable through revenue sources such as user fees, sponsorships and advertising (Buckley, Card, Norris, & Hinkle, 2014).
While there is no financial burden from a government perspective for setting up most dockless bike schemes, most of these implementations have not been successful and resulted in a large maintenance costs. The risk of failure could largely be minimized as long as public opinions were being consulted prior to the launch of a BSP. In the case of Porto, it is important to explore several different options when it comes to bike sharing. There are some benefits with being late in implementing bike sharing, such as that Porto could avoid making the same mistakes that other cities already made.

Porto’s Rise in Tourism

According to the United Nations World Tourism Organization (UNWTO), in 2006, Portugal welcomed 6.8 million international visitors, while in 2017 that number tripled to 21.2 million (UNWTO, 2018). For Portugal, positive growth in international

Figure 3. Discarded bicycles in China (The Guardian, 2017).
tourists can have several positive impacts: increasing employment opportunities, improving urban development projects, and promoting international imports and exports. As Portugal continues to be a popular destination in Europe, the city of Porto has been elected Best European Destination in 2012, 2014 and 2017 (Best European Destination, 2017). In 2014, Porto saw an increase of 16.7% in tourists arriving through its airport which is the equivalent of about 1.2 million passengers more than the previous record of 8.1 million passenger (Vinci Airports, 2015).

While a spike in tourism could inject a large amount of revenue into the economy, there are also several detrimental effects to the environment that must be taken into consideration such an increase in pollution from transportation alone. Bike sharing can help to mitigate environmental effects as a direct result of tourism by leveraging revenues from tourists in order to construct better roads and implement educational programs so that cyclists and drivers can co-exist safety together.

Cycling and BSP in Portugal

Ironically, Portugal is home of one of the largest producers of bicycles in Europe, yet, many bikes produced in Portugal often leave the country. On the other side of the city of Porto is the neighboring city of Vila Nova De Gaia (V.N. Gaia) which contains the largest bicycle assembly plant in Europe for bicycles. The plant is owned by a Portuguese company called RTE with 700 employees that produce over 1 million bicycles every year (RTP, 2018). In this manufacturing plant, 95% of products leave Portugal for either Spain, France, or Italy (Duraes, 2019).
Despite being the leader in the production of bicycles, Portugal falls behind in terms of bicycle usage with only 0.4% of trips being made by bicycles and 67.6% made by cars according to a national survey that was made in Lisbon and Porto in 2017 (Instituto Nacional de Estatistica, 2017). There are several reasons as to why Portugal lags behind in terms of bicycles usage, some of which are due to lack of government support, lack of infrastructure, and lack of awareness or interests in cycling possibly due to safety concerns.

Figure 4. RTE bicycle manufacturing plant in V.N. Gaia (Duraes, 2019).

Local Interests in Cycling

Currently, Porto does not have any BSP; however, there has been public interest in creating a bike sharing library through the launch of U-Bike Porto as well as several local petitions to support bicycles as a mode of urban transportation. The first ever true
bike sharing concept in Portugal was recently launched in Lisbon in 2017 (Lisboa Camara Municipal, 2018). Gira, Lisbon’s version of BSP reported over 136 incidents in the first year of operation which resulted in 44 injuries; however, none of these were serious incidents according to the Municipal Mobility and Parking Company (EMEL) (Lisboa Camara Municipal, 2018) (Duraes, 2019). In addition, on February 1 of 2019, in Lisbon, a petition titled Petition No. 236 / XIII / 2 requested the right to cycle safely was created in order to increase awareness when it comes to cycling in Portugal (Assembly of the Republic of Portugal, 2019).

The petition calls for the following policies (MUBi, 2018):

- An increase in monitoring dangerous driving behaviors such as speeding, overtaking cyclists, illegal parking and blocking of bicycle paths.
- A revision of signals and traffic regulations including signs to protect pedestrians and bicycle users.
- More education measures especially when obtaining a driver license in order to improve the relationships between drivers and cyclists.

Not only in Lisbon and Porto but all over Portugal, there have been several grassroots movements in order to raise awareness for bicycling and as a result the U-Bike Project was developed in order to promote cycling as a mode of sustainable transportation within the academic community (Pinto, 2017). Each city has its own sub project under the U-Bike Portugal umbrella and in Porto, the project is called U-Bike Porto and is primarily managed through the University of Porto Sports Center (CDUP).

With funding from the Operational Program for Sustainability and Efficiency in the Use of Resources (PO SEUR), U-Bike Porto allows students from the University of
Porto and its affiliates to have access to bicycles for personal use as long as they register online ahead of time. This program is especially innovative for the city of Porto since it encourages bike sharing and allow researchers to gage if there are possible interests in bike sharing.

U-Bike Porto

Since there are no BSP available for public use in Porto, U-Bike concept can raise awareness and interests for bicycling especially through the University of Porto. The project is restricted for use only amongst the academic community in Porto and is part of a wider Portugal 2020 project in partnership with the European Commission where Portugal will receive several payments equal to 25 billion euros by 2020 in order to stimulate economic growth and job creation including in the area of sustainability (POSEUR, 2016) (Portugal 2020, 2013). The Portugal 2020 initiative runs from 2014-2020 and includes the scheme of “Sustainability and Efficiency in the Use of Resources” as one of its primary thematic operational programs. It focuses on several key areas including the promotion of energy efficient mode of transportation such as energy efficient public transportation, smart vehicles, and bicycles (Portugal 2020, 2013).
Figure 5. U-Bike Portugal objective (Cunha, 2018).

Stemming from Portugal 2020, approximately 6 million euros were invested into the U-Bike Portugal program (U-Bike Portugal, 2015). Across the country, 3,234 bicycles (2,096 electric and 1,138 conventional) would be expected to be distributed amongst the municipalities with the city of Porto receiving 265 bicycles (220 electric and 45 conventional) (U-Bike Portugal, 2016). While there has been talks about the project dating back to 2015, U-Bike Porto has suffered numerous delays due to administrative setbacks. Despite setbacks and several potential issues, the buzz around the U-Bike project has shown that there is a potential in a future bike sharing program in the city of Porto. Hundreds of individuals registered for the program and some were even put on a waiting list. José Miguel Moreira, Coordinator of the program believes that while there is
a lack of investment and infrastructures, the initiative can raise awareness so that citizens can be mindful of car usage (Iberica, 2018).

In Porto, the automobile is the first-choice mode of transport with 43% usage, while public transport is at 25% and 32% for walking (Cunha, 2018). According to the 2011 governmental census, 17.7% of individuals traveled by foot in Portugal in comparison to 12.6% for the rest of Europe (Cunha, 2018). Despite not having a traditional BSP, the launch of the U-Bike project shows that there is interest amongst the community to use bicycles as a mode of transportation.

In Lisbon, the U-Bike initiative finally distributed the bicycles to its academic users in January 2019 and U-Bike Porto is expected to do the same later in 2019. While the buzz around the project is exciting, it is vastly different than a traditional BSP approach because each user can keep the bicycles anywhere from 6 months to 9 months making it closer to a bike loan or bike library concept (Pinto, 2017). The U-Bike Porto project contains 220 traditional bikes as well as 45 electric bikes to be used for its participants without any cost during the rotation period between 6-12 months (Pinto, 2017). In order to maximize the program’s effectiveness, users are strongly encouraged to bike at least 10 km/day; otherwise, they will no longer be able to keep the bike (Sampaio, 2019). In Porto, there is great potential for the implementation of BSP, especially in the downtown area as well as in the coastal neighborhoods of Matosinhos and Foz since they already have existing cycling infrastructure.
In addition to U-Bike, the Climate Change Leadership supported by the Porto Protocol has brought the topic of climate change and sustainable mobility to the forefront of the conversations in Porto and the rest of Portugal. Key figures such as Barack Obama and Al Gore have been some of the past key note speakers (The Porto Protocol, 2019). The Porto Summit brings thought leaders and entrepreneurs together around the world to Porto in order to discuss ways to make businesses more sustainable. Due to these reasons, it is plausible to assume that in the future when a BSP program launches, the community including citizens, thought leaders as well as businesses would be likely to support it.
Prior to determining whether bike sharing would be successful in Porto, I made contact with several key members from the University of Porto, University of Aveiro, Gira Bikes, MUBi, local bike shop owners and representatives from the cycling community in Porto and Portugal. The overall consensus opinion indicated that there is a strong interest for cycling in Portugal and especially in the two main cities of Lisbon and Porto.

According to local bike shop owners, in Porto, there has always been interest in cycling; however, the policy has been slow to implement several key factors to improve
cycling in Porto which are to increase cycling lanes, educate drivers and improve safety regulation. As a result, the citizens of Porto recently created a movement called “Por um Porto mais cicavel” which translates to “For a more cycling Porto” in which a petition was launched in 2018 in order to request more bicycle lanes, pedestrian streets, safer regulations for cyclists (Publico, 2018).

Research Questions, Hypotheses, and Specific Aims

My research addressed these questions: 1) Under what conditions could the expansion of BSP in Porto, Portugal become financially successful when looking at future conditions and possible technological advancement? 2) What are some predictive factors of success beyond the baseline and alternative scenario models? In answering these, I examined the following hypotheses: 1) There are predictive variables associated with past BSP case studies; and 2) BSP can be financially viable for the city of Porto.

Specific Aims

To test these hypotheses, and explore related issues, my specific aims were to:

• Create a financial model to predict the feasibility for the Municipality of Porto in order to implement the best option of bike sharing

• Establish projections of various scenarios and measure their impacts

• Determine success factors by looking at different metrics
Chapter II
Methods

In my pursuit to determine whether it is financially feasible to implement bike sharing in Porto, I created two spreadsheets, a Comparison Analysis Model spreadsheet and a Predictive Scenarios Model spreadsheet. These two spreadsheets provide a full picture of the state of bike sharing through the comparison of other cities that have similar characteristics that of Porto. The comparison analysis spreadsheet helps to compare past successful and unsuccessful programs through the examination of 23 different cities: London, Paris, Lyon, Barcelona, Milan, Dublin, Oslo, Madrid, Amsterdam, Porto, Lisbon, Boston, New York City, San Francisco, Seattle, Denver, Portland, Boulder, Madison, Washington D.C, Chicago, Montreal, Toronto. Once data were entered and the comparison between the cities completed, I deliberately chose certain cities with robust data in order to create the second spreadsheet, the Predictive Scenarios Model spreadsheet.

Comparison Analysis Spreadsheet

This spreadsheet was used as an influential assessment for future hypothetical scenarios as well as to provide additional factors based on data from past case studies. Through this method of statistical analysis, I examined various factors involved in the implementation of a BSP based on case studies from other cities in Europe and North America because these regions are similar to Portugal culturally and economically. In
order to better analyze the data, I created a baseline model based on the investigation of 23 cities throughout North America and Europe. The research examined the state of bike sharing in other cities so that a baseline could be created to best represent the city of Porto. Below are some descriptions of the state of bike sharing in some of these cities, all units have been converted to American metric system if they have not been done so.

- **London**: The city has a long history with bike sharing dating back to 2007 when the Mayor of London, Ken Livingstone, announced his plan for bike sharing (Peracha, 2019). The city was one of the first to attempt a roll out of BSP based on the Paris Velib model. While the initial phase was promising, it was not until 2010 that the project received its first sponsor, Barclays Bank (Transport for London, 2018). The project was expected to cost $180 million USD (all figures will be given in US dollars, unless otherwise noted) excluding operating costs for the first six years in order to roll out 5,000 bicycles and 315 docking stations (Standard, 2010). However, due to the high cost of implementation which included the cost of $37,000/bike as well as $260,000/station, it was difficult to sustain and expand (Loeb, 2016) (Transport for London, 2018) despite receiving additional $33 million (£25 million). Currently, the scheme is called Santander Cycles; however, many Londoners still refer to the system as Boris bikes after Boris Johnson, the Mayor who introduced the scheme in 2010 (The Economist, 2011).

- **Paris**: Launched in 2007, Paris Velib was a large scale public bike sharing system with over 14,500 bicycles and 1,230 stations (The Guardian, 2018). The system was operated by JCDecaux and was one of the biggest systems in the world. The
price per bike has been stated anywhere from $336 to $3,900 with each bike weighing approximately 22.5 kilograms (50 pounds) (Poirier, 2007). Prior to the launch, JCDecaux agreed to pay the startup cost in order to secure future income from advertisement. Over the next few years, as the scheme progressed, there were other costs that were not factored in such as the costs of thefts and vandalism. In the first year, 3,000 bikes were stolen and by 2009 a total of 20,600 bikes were added in order to replace lost or damaged bikes (Beardsley, 2009).

From the scheme, it is thought that as many as 80% of the bikes were stolen and many of them ended up in shipping containers heading for North Africa (Belton, 2018). At this point, JCDecaux made a statement claiming that they have underestimated the true cost of vandalism and thefts in Paris. Due to issues surrounding poor management and a lack of financial incentives, the Paris Velib program is no longer in existence. Currently, a new program called Velib Metropole will be taking over with a more improved management and bike share technologies. The program is being run with a new French Spanish Consortium called Smovengo and is set to cost about $781 million over the next 15 years (The Guardian, 2018). The new program was originally set to launch for January 2018; however, once again there are unexpected delays and it is uncertain if the program will succeed or fail like its predecessor.

- Lyon: Lyon’s Velo V was launched in 2005 and was the first bike sharing system in France (Le Progres, 2019). Currently, it has a network of 4,000 bikes across 348 stations in Lyon and its neighboring cities (Crouzet, 2017). The current plan is to replace all old generation bikes with 5,000 new bikes where half of which are
the latest generation of technologies by 2020 (Crouzet, 2017). This upgrade will hope to increase more users and profitability through better management and improved technologies.

- Barcelona: Bicing is Barcelona’s official bike sharing system that started in 2007 and is operated by Clear Channel (Auto Facil, 2019). The annual fee is approximately $53 and covers approximately 70% of the city (Ajuntament de Barcelona, 2019). The system is not profitable because it requires support from other areas of funding such as from the on-street car parking revenues collected by Barcelona.

- Milan: BikeMi was launched in 2008 and is operated by Clear Channel. Currently, the system has over 4,560 bikes and 280 stations (Comune Di Milano, 2019). It costs $40 to join an annual membership or simply $5 for a one day subscription (Comune Di Milano, 2019). It is uncertain if the scheme is profitable or not since the operators have not released up-to-date financial information.

- Dublin: The city has been operating its bike sharing scheme since 2009; however, the system has been losing about $422,000/year due to a lack of revenue. Despite receiving $22 million sponsorship deal from Coca Cola as well as $5.8 million form the National Transport Authority, the company is still unable to break even. Recently, there has been efforts to revive the program through security bigger sponsorships; however, it is unsure if the efforts will be enough (Dublin City Council, 2019).

- Oslo: Oslo Bysykkel began back in 2003; however, due to the dated technology and high capital costs, the system never became successful. In 2015, the city of
Oslo announced a complete overhaul of the system with brand new bikes, infrastructure and brand-new marketing campaigns in order to encourage bike users to take advantage of the system (Capo Velo, 2015). The Oslo Bike Strategy Plan will be in effect from 2015-2025 and will receive $500 million from government funding (Capo Velo, 2015).

- Madrid: BiciMad is Madrid’s main bike sharing system 1,560 bikes and 123 stations maintain (Accessibe Madrid, 2019). The system was founded in 2014 and there are limited data in terms of capital costs and other financial information. Citizens have complained that at a $6 million/year operating costs, the system is simply too expensive to maintain (Accessibe Madrid, 2019).

- Amsterdam: While Amsterdam might seem like the prime candidate for BSP, the city actually has more bikes than people, there is officially no BSP in Amsterdam at the moment. Scattered throughout the city, there are small companies that operate without proper licenses; however, they often get shut down by the city of Amsterdam. When visiting the city, the local government often encourages tourists to visit local bike shops and rent from there.

- Porto: Currently, Porto does not have any BSP; however, there is a bike library called U-Bike where 220 electric bikes and 45 regular bikes have been distributed to the academic community of the University of Porto in early 2019 (University of Porto, 2019).

- Lisbon: The city recently launched Gira Bikes in 2017 with funding from the E.U. The operator for this program is a Portuguese company called EMEL and they are contracted through a capital investment of $16 million by the City of Lisbon. The
program has seen setbacks as well as delays (Gira, 2019). Originally, the program was supposed to be launched earlier; however, due to difficulties in regulations, financial managements as well as communications, the project was delayed. Since the program is new, there is only a limited amount of data available for the public; therefore, it would be difficult to assess whether or not, the program is successful.

• Boston: The city was one of the first major cities in the U.S. to launch a bike sharing system back in 2011 (Motivate International, 2019a). The system was originally called Hubway and was later changed to Bluebikes in 2017. The program was fully funded through grants by the Federal Transit Administration and was later sponsored by New Balance (Motivate International, 2019a). Currently, there are 2,500 bikes and 260 stations in the Boston metro area (Motivate International, 2019a). The program is one of the few in the U.S that offers low income membership for $50/year or $5/month instead of the regular pricing of $99/year (Motivate International, 2019a). Recently in 2018, the system announced its new 6-year partnership with Blue Cross Blue Shield of Massachusetts in hope of alleviating the $5.4 million/year in operating expenses which is why the name was change to Bluebikes (Motivate International, 2019a). The program is currently, running at a loss; however, with the new partnership it is yet to be determined if it will be successful in the future.

• New York City: The program was started in 2008, and it is one of the best examples of BSP because it is the only city within the study where bike sharing is profitable (Motivate International, 2019b). New York City is unique because it is home to major corporations and international banks; therefore, when it comes to
finding a major sponsor, the city did not have any problems finding one.

Currently, Citi Bike is one of the biggest BSP in the country with 12,000 bikes, 750 stations, in 60 neighborhoods (Motivate International, 2019b). Taking advantage of the high influx of tourists, Citi Bike has one of the highest membership costs at $169/year (Motivate International, 2019b). The high membership costs and revenues from sponsors allow the City of New York and Motivate to work together to ensure the smooth operation of the entire system. Financially and environmentally, this particular system is one of the most successful with over $210 million in revenue over the system’s lifetime as well as a total of 50 million total trips by 2017 (Motivate International, 2019b). The system is constantly updating and reviving with revenues from sponsorships and memberships; therefore, it would be a good case for the city of Porto to look at and model after its success.

- San Francisco: San Francisco Ford GoBike began its operation back in 2013 as Bay Area Bike Share. The program is operated by Motivate which is the same company for New York Citi Bike. Currently, the system has 7,000 bikes and 540 stations throughout 5 cities (San Francisco, San Jose, Oakland, Berkeley, Emeryville) in the Bay Area (Motivate International, 2019c). The pricing is quite affordable at $15/month, $10/day, and $2/trip. Initially, the system received $11 million through public funding; however, in 2017 it was revamped under sponsorship through Ford Motor with $50 million in order to improve and expand (Goebel, 2016). While the system might not have been profitable in the past, the future is promising through more funding and better management.
• Seattle: Seattle is a newcomer to bike sharing and is a unique case because the idea did not come from the city of Seattle. Instead, bike sharing operator Lime bikes pitched their model to the Seattle Municipal Government at no cost back in 2017 (Seattle Department of Transportation, 2019). Lime bikes quickly flooded the streets of Seattle with their free-floating bikes. Since the company is private, it is difficult to gather data. It is uncertain if it is profitable for the company to operate in Seattle; however, that did not deter other companies such as Jump and Lyft to quickly enter the market (Seattle Department of Transportation, 2019).

• Denver: Denver B-Cycle was founded in 2010 and was first thought to be one of the most successful bike share systems in the U.S. Over time, due to a decline in memberships and high maintenance costs, it is uncertain how long the program will continue to run. Since 2014, the number of rides declined by at least 9% and in some areas of the city there are no growth or support for the system (Kenney, 2019).

• Portland: In 2016, Portland became a newcomer to bike sharing and in the past the city has been heavily criticized for not implementing BSP sooner. The system has 1,000 bikes and 125 stations (Motivate International, 2019d). As an environmentally friendly city with low traffic, Portland was a prime candidate for bike sharing; however, taking the time to research might have been proven to be a positive aspect for the system. Since the system is fairly new, it is still operating with a loss; however, with potentially more sponsoring revenues from local companies such as Nike, Colombia Sportswear, and other natural Resources companies – the system has the potential to expand.
Boulder: Founded in 2011, the system consists of 305 bikes and 43 stations. Other than the capital cost of $500,000 there are limited information when it comes to the operating expenses and profitability of the program.

Madison: Founded in 2011, the system is slightly larger than Boulder with 350 bikes and 44 stations. The capital cost was $500,000 and the program is being operated by B-Cycle. The system is managed in a similar way as Boulder; however, there are limited financial data available to the public.

Washington D.C.: Capital Bikeshare is often cited in numerous literature due to its popularity and robust expansion. Currently there are 4,300 bikes and over 500 stations in the Washington D.C. area. The program began operation in 2010 and was one time the largest until New York Citi Bike came along. During the time of implementation, each bike costs about $1,000 and each station costs between $41,000 and $50,000 (Motivate International, 2019e). Partially funded by the United States Department of Transportation for $6 million during the first phase, the system has been steadily expanding. Despite these positive outlooks, it is uncertain if the program is profitable due to a lack of data surrounding revenues stream.

Chicago: Chicago Divvy currently has 5,800 bikes and over 580 stations. Inspired by the Paris Velib program back in 2007, the City of Chicago launched the bike share system in 2013. Planned expansion has been delays due to a lack of finance and difficulties in management. As a result, only recently in 2019 when Lyft took over as the city’s exclusive operator that there were talks of possible expansion. Lyft has proposed an investment of $50 million towards a 6 years expansion
project (Wisniewski, 2019). However, it is uncertain if the expansion will be completed since Uber also would like to expand in the City of Chicago. The competition between the two companies resulted in bureaucratic delays and disagreements over exclusive rights to the contract (Wisniewski, 2019).

- Montreal: Montreal has had a turbulent relationship with bike sharing dating back to 2009 when the program was launched (Montreal Gazette, 2019). The program was initiated by Public Bike System Company (PBSC) and was North America’s first large scale bike sharing system which was operated by BIXI. There were multiple issues with management such as large-scale system including financial mismanagement, vandalism, defective technologies, poor designs, and many other setbacks. PBSC eventually filed for bankruptcy in 2014 and was later renamed to PBSC Urban Solutions (Montreal Gazette, 2019). The financial mismanagement resulted in a lawsuit between the City of Montreal and Bixi leading back to a $37 million loan in 2011 from Bixi to the city of Montreal (Montreal Gazette, 2019). Courts ruled that the city of Montreal must pay back $16 million to Litwin Boyadjian, which is the legal entity handling the bankruptcy affairs (Montreal Gazette, 2019). The City of Montreal disputed the court rulings stating that the business deal was illegal and until this day, the city of Montreal has not fully recuperated its losses from this bad business deal. In 2019, Bixi is set to relaunch with more improved technologies, better management and more affordable pricing.

- Toronto: Similar to Montreal, the city of Toronto also had its bike sharing system launched in 2011 under the BIXI brand. In 2013, the city of Toronto was unable
to recuperate $3.9 million of the loan from PBSC. As a result, the city has faced a few setbacks and delays in terms of expansion. In 2014, thanks to a sponsorship deal by TD Canada Trust which took care of all operating costs, the city of Toronto was able to move forward and expand the program with additional funding. Currently, the system has 3,750 bikes and 360 stations throughout Toronto.

The general outlook from analyzing these cities showed that there are some common issues when it comes to all BSPs. These issues are: financial mismanagement, difficulties with bureaucracy, lack of revenues, lack of interests and lack of incentives, amongst others. Nearly every single bike share system has either shut down or is still operating at a loss. Upon analyzing 23 of these cities and the different contributing factors, I was able to refer relevant materials and data points to the Predictive Scenarios Model spreadsheet. Variables that were calculated were costs, revenues, pricing, weather, the life span of the program, among others. The additional analysis was meant to finalize the results obtained from the predictive model scenarios spreadsheet and to give a more detailed outlook into the potential of bike sharing.

Regression Analysis

A multiple regression analysis was conducted to see if bike ridership is dependent on various factors. The set of cities provided a sample set of 23 cities and 52 factors between 2003 to 2017 where various BSP were initiated and discontinued throughout the world. By analyzing various factors and their relationship to the success of BSP, I determined key success factors that might improve the implementation of BSP for
potential cities that are looking to adopt them. For this analysis, the independent variables were different potential success factors. The dependent variable was annual trips per bike. This was calculated by importing the spreadsheet with all the values into SPSS Software then using that data in order to perform an ANOVA test.

The set of independent variables used in the multiple regression model were:

- Monthly salary after tax: the average monthly salary for residents who reside within the city limit. The salary is defined as the average middle household income for a nuclear family with two children.
- Population density: calculated as the population of the residents living within the official city limits divided by the size of the area of that city; population density = Number of people/Land Area (in km²)
- Average year round humidity: the average humidity level based on the weather of that city throughout the entire year.
- Average windchill factor during winter: the average windchill factor in Fahrenheit of that city throughout the entire year.
- Density of station area per service area: Since some cities might not be able to service the entire area, popular locations such as downtown and nearby train stations should have an adequate number of bikes that need to be available and ready for use. This factor is defined as the number of bikes per the promised service area.
- Heat index: the average heat index throughout the entire year in the particular city.
- Usage density: the total city population divided by the number of available bikes.
• Annual membership cost: average membership cost per year for users.
• Average winter temperature: average temperature during winter in Fahrenheit.
• Average summer temperature: average temperature during summer in Fahrenheit.

**Baseline Model Scenario for BSP Implementation**

The spreadsheet was created to calculate the profitability of BSP in Porto using a baseline model in order to analyze and compare potential scenarios. Using published materials, I compiled a spreadsheet that represented a 15-year projection for small to medium scale launch of a bike sharing program. In order to establish a baseline NPV for Porto, I created a model that included mainly costs and revenues. Using the collected information, I compiled a financial spreadsheet that represented what the 15-year projections would be for a small to medium scale city such as that of Porto. After all the information was compiled for the baseline model, I conducted cost benefit analyses for other scenarios.

Based on influencing factors and data, the baseline cost-benefit model contained management options and parameter values for the most realistic estimates. To assess how each variable impacted net profitability (NPV), I conducted a variations analysis on the types of bikes that would be implemented on the future scenarios spreadsheet. The figures used throughout the models are all estimates based on published case studies and academic materials from other cities throughout Europe and North America with similar populations and topographies as that of Porto. Since most of the publications have been published in North America using American system of measurements and monetary
value, I tried to stay true to the original published material by carrying over the same units of measurements into my analysis.

The organization of the modeling is based on a traditional 3rd generation of bike sharing with docking stations for launch in a small to medium scale city. The reason that I picked the 3rd generation model is because it has traditionally been the most common type of BSP to be implemented for a newcomer to bike sharing. In addition, there are plenty of historical data from past case studies that have used this concept for their own BSP implementation.

The baseline model is derived from a hypothetical and relatively common set up of a small BSP that is appropriate for the context of a small to medium size city such as Porto. Since capital costs are one of the biggest barriers when it comes to launching a BSP, the baseline model covered the purchase of equipment including stations, kiosks, bikes, docks, and more. For the model, I evaluated the potential of a BSP program in Porto only in the downtown area and along the Douro river, mainly in the neighborhood of Foz and Matosinhos, because these areas already have existing bike infrastructure. Therefore, the hilliness and topography of Porto was not considered as a major barrier when it comes to BSP in the spreadsheet scenarios. However, the topography and hilliness will be later considered in comparisons to other cities as an additional comparative analysis. In addition, it would be beneficial to have a BSP in these areas because they are not serviced by the Metro, despite being often visited by tourists. Historically, the area of Matosinhos has been difficult to get to and is serviced only by a handful of buses that are often delayed. As a result, tourists often use taxi or Uber in
order to access these areas – with BSP installed visitors can utilize bicycles as a mode of transportation to explore the area at their own leisure.

The number of bikes was set at 200 at the beginning of the study because anything under 250 bikes is considered to be more manageable for a small to medium sized city such as that of Porto. Each station should have 10 bikes and they should be equally distributed along the pathway. From there, I compared the costs to the number of potential riders as a source of revenue for the city of Porto. Once the baseline model was established, I quantified the results and compared various factors which could impact the potential outcome and profitability for of various scenarios.

According to the Institute for Transportation & Development Policy (ITDP), “the potential for bike theft or vandalism should be taken into account when planning a bike-share” and most cities should “have a plan in place to deal with it as soon as possible after it occurs” (Institute for Transportation & Development Policy, 2014). As a result, I began modeling the bike implementation phase with the potential for theft and vandalism in mind. From there I entered the number of bikes per station along with expansion of bikes in year 5 and year 10 in order to expand and to cover potential damaged bikes due to theft, vandalism, or general wear and tear. I entered the number of stations and used that number to multiply with the number of bikes per stations in order to get the total bikes available for users.

Other line items variables in the spreadsheet model were:

- Percentage of Fleet Remaining After Theft/Vandalism: “In many bike shares, the theft and vandalism experienced is due to users not docking the bikes correctly and locking them down. Having better education for first time users and having
better directions on the kiosk or docking points for the bikes can prevent this” (Bush, 2012). While BSP does have a risk factor of vandalism, from academic research and published materials, the percentage of damaged bikes at the end of the year is usually around 1% for bikes with docking stations (Heda, 2012). For the 3rd generation of bicycles, “advancements in credit card transaction capabilities and RFIC (radio-frequency identification) chips have allowed operators to introduce accountability and reduce theft and vandalism” (Institute for Transportation & Development Policy, 2014). When bike share “is first introduced, the theft rate is high because of user error; however, as the system evolves and users become more knowledgeable about the system the theft rate decreases” (Bush, 2012).

- **Number of Bikes Per Station:** ITDP recommends that “the station size will then be the number of bikes per station multiplied by the docking-space-per-bike ratio to determine the number of docking spaces at each station” (Institute for Transportation & Development Policy, 2014). This number usually amounts to 10 to 15 bicycles per station according to the size and location of the station. In order to avoid overcrowding, a conservative approach of 10 bikes per station was used for this model to provide more space.

- **Replacement Bikes:** While in the case of theft of damage, the user might be charged for replacement bikes; however, it usually falls on the operator to replace the damaged bikes. As a result, beginning in year 2 and after that, a steady number of bikes are expected to be replaced and the cost will be accounted for in the model. It is projected that on average five bikes will be added to the system,
except for 2025 and 2030, when 100 bikes will be added to the system in order to meet the potential for growth.

- Number of Stations: Each station contains multiple docks and are usually located close to an area with heavy foot traffic in order to maximize the potential of usage. It’s important to identify a coverage area— in this case within the downtown area and along the Douro river leading to the Atlantic Ocean. The bike stations were equally distributed to ensure that the system will have high number of ridership from tourists and local citizens.

- Total Bikes Available: At the end of the year, after considering potential losses such as theft and vandalism as well as the number of replacement bikes, the total bikes available is the amount that is remaining within the system and available for users such as tourists, citizens and other system members.

Baseline Costs

“Capital costs are often expressed in terms of the cost per bike,” defined as the total cost of the system—including stations, bikes, redistribution equipment, the control center, and other equipment—divided by the total number of bikes in the system” (Institute for Transportation & Development Policy, 2014). While there are various factors that need to be considered when it comes to launching a bike sharing scheme, one of the most important considerations is the total capital cost of the program. Some capital costs included in the initial launch phrase could include equipment, operation, maintenance, marketing, insurance, and more. Since bicycles within a shared system need to be equally distributed and maintained in order to assure that users can benefit from the program as well as to optimize the overall performance of the system, often a third-party
contractor is brought it to distribute the bikes throughout the day/week/month. While an important part of a bike sharing scheme is redistribution, research shows that for a small BSP of less than 250 bikes or less, redistribution only takes place once or twice a season (Buckley, Card, Norris, & Hinkle, 2014). In addition, cities with lower urban densities have less need for rebalancing and lower operational costs. Therefore, in an effort to lower the cost of maintenance and to make the initial launch phase more manageable for the city of Porto, the initial launch for the baseline scenario will consist of 200 bikes with the cost of $3,800/bike based on historical data from published materials (Midgley, 2011). The initial capital cost is in line with the implemented costs from other similar cities such as Montreal where the cost was $3,000/bike and Lyon where the cost was $4,500/bike (Midgley, 2011).

These components will be considered in the costs section of the model and will be explain in more details in the next section. Per station capital costs vary depending on the vendors, features, and station size. They often range from $30,000 (low end at $3,300/bike) to $55,000 (high end at $6,000/bike) per station (Great Rivers Greenway, 2014). The price per bike from this study is derived from the averages from published materials as well as other prominent bike sharing case studies.

For this particular model, the 3rd generation of BSP will be used as a baseline model. Even though we are currently in the 4th generation of BSP implementation and even dockless BSP - in Portugal, there has not been a lot of verified success surrounding dockless bikes in order to use it as a baseline. The reason, for this assessment is due to the fact that in Portugal, there are legal barriers when it comes to doing business and as a result multiple companies with dockless bicycles and 4th generation bicycles such as OFO
and oBike recently failed to launch (Bush, 2012). According to the European Cyclists’ Federation (ECF), dockless bicycles have not been very successful in the past mainly due to lack of distribution efforts, lack of regulation, lack of maintenance which leaves discarded bikes piling up in public spaces, lack of coordination and cooperation which local authorities (Association of Public Transport & European Cyclists’ Federation, 2017). In order to solve these problems, it is necessary to consider where users can park the bikes and return them even if they are dockless. Despite these issues, it is possible to consider dockless bikes in Porto as long as regulations are met during the first stage of assessment and if there are designated areas with visible indications so users know where to park the bikes at the end of their trips. Costs of purchasing and maintaining bikes and stations are outlined below:

- 3rd Generation Traditional Bicycles with Docking Stations ($3,800/bike): While the price is higher for bikes with docking stations, they are easier to manage as users often have more awareness of where to park the bikes. As outlined in Table 6, each bike can range anywhere from $1,800 to $5,000. For the purpose of the baseline model scenario, the amount of $3,800/bike was used since it is in line with other costs per bike for similar cities such as Porto (Institute for Transportation & Development Policy, 2014).

- Maintenance Cost: Annual maintenance is estimated at about $1,000/bike for various U.S systems while, German system operators estimate their annual maintenance costs at $868/bike (Institute for Transportation & Development Policy, 2014). Since maintenance such as checking gears, tire pressure, and performance of the bikes are very important, the amount of $1,000/month should
be in line with the maintenance cost across other systems in both North America and Europe.

- **Operating Cost:** Operating costs can vary depending on the service agreement between the operator and the municipality. As a result, the amount per bike can drastically change depending on the amount of labor, mechanisms, and resources needed to perform this task. “A bikeshare system’s operating costs reflect its size and sophistication. The city will need to estimate (and work to minimize) operating costs if it plans to manage the system through a public-private partnership that includes some cost-sharing. Otherwise, operating costs fall completely to the operator(s), and the level of transparency around those costs will vary” (Institute for Transportation & Development Policy, 2018). This cost can vary from system to system and can have an estimate range from $1,200 (Montreal) to $1,944/bike (New York) (Midgley 2011). The higher range of estimates include maintenance costs to cover bike mechanics, contractor, bicycle parts, replacement bikes, station batteries, communications and more. However, since there is a separator bucket for maintenance cost, administrative and replacement bikes, the operating cost amount for this model was inputted as $1,500.

- **Insurance Cost:** Accident and anti-theft insurance is important for the success of the program. General liability coverage can pay anywhere from $1 million to $5 million per claim (Shaheen, Cohen, & Martin, 2012). Some operators insure the whole fleet while others smaller operators have the option to insure single bikes. While public information and other financial data regarding insurance of BSP are
limited, through several interviews from key members of the GIRA bike sharing system in Lisbon as well as other members of the cycling community in Porto, the insurance per bike was estimated at $1,000/bike through current estimates in Portugal as well as published material (Shaheen, Cohen, & Martin, 2012).

• Docking Station Costs: One of the biggest obstacles for many BSP is costs associated with docking stations. The docking stations bring with it several other factors such as equipment for docking stations, construction, license, computer system to operate the equipment, member access cards, installation and more. Docking station costs can vary depending on the number of bikes available at that particular station. While the costs can vary, for the purpose of this study, the amount will be set at $50,000/station in order to accommodate the entire costs as well as to cover other possible extra fees that come with building these stations. However, this cost would be a one-time investment during the initial launch until more stations are needed to be built to accommodate the system.

• Docking Station Maintenance Cost: In addition to the costs associated with building the docking stations, other costs include maintaining the infrastructure of these stations. According to Toole Design, maintenance costs for a docking station range from $12,000 to $28,000 for a docking station that could accommodate 11 to 19 bikes (Shaheen, Cohen, & Martin, 2012) (Table 2). Even though some stations can be manual or automated, they do need maintenance throughout the year. As a result, the amount of $20,000 was set aside to maintain these stations.
Table 2. Docking station costs (Buckley, Card, Norris, & Hinkle, 2014).

<table>
<thead>
<tr>
<th>Station Size (Docks)</th>
<th>Bikes</th>
<th>Equipment and Installation (includes bikes)</th>
<th>Approximate Annual Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>6</td>
<td>$35,000 to $40,000</td>
<td>$12,000 to $15,000</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>$45,000 to $48,000</td>
<td>$18,000 to $21,000</td>
</tr>
<tr>
<td>19</td>
<td>10</td>
<td>$53,000 to $58,000</td>
<td>$24,000 to $28,000</td>
</tr>
</tbody>
</table>

- Administrative Cost: Based on research from other similar cities and bike sharing systems, the administrative labor cost was set at $500,000/year for consistency. Since the cost of living and salary in Portugal is much lower in comparison to the neighboring countries such as Spain and France, $500,000 would be more than enough to hire a team of at least 10 administrative members to manage the system as well as to cover extra labor costs from third party contractors. Therefore all the human labor costs associated with BSP are accounted in one group. This amount is based on a study conducted by Toole Design Group and the Mineta Study where a range between $420,000 and $540,000 were suggested for administrative costs in order to operate 100 bikes and 10 stations (Buckley, Card, Norris, & Hinkle, 2014).

- Marketing Cost: In order to promote the BSP, the city of Porto will need to develop a communication and marketing plan, including marketing campaigns, print media, Internet, and more. The amount of $10,000/year was set aside for the marketing strategy in the model.
Baseline Revenues

Variables and other line items to forecast revenue streams in the model were:

- Advertising Revenue ($50,000/station): Advertising is one of the biggest factors of revenue when it comes to bike sharing. While there is a cost associated with having docking stations, one of the benefits is that the city of Porto can use it for advertising purposes. Advertising boards that can be rented as a source of revenue for the system along with bikes that originated from that particular station. It is uncertain how much revenue could the city of Porto bring in based on advertising; however, based on results from other cities around the world the amount of $50,000/station is a good estimate. Based on data from the coastal city of Fort Lauderdale, where 200 bikes and 20 stations were implemented, the revenue the city received from advertising equate to $800,000, which is about $40,000/station (Alta Planning and Design, 2012). Since the city of Porto is much larger with a metro population of nearly 2 million people, the advertising revenue will be more; however, for this study I used a conservative estimate of $50,000/bike station. This amount could also be higher depending on the fluctuation of tourism. For example, New York City Bike’s arrangement with Citi Bank resulted in revenues of $68,000/station (Alta Planning and Design, 2012).

- Sponsorship Revenue ($1,000/bike): In some cities, it is possible to advertise on a single bike instead of renting out a large billboard. “Bike-share is known for bundling bikeshare and outdoor advertising contracts by contracting companies like JCDecaux or Clear Channel. These firms operate public bikeshare systems in exchange for exclusive (or near-exclusive) rights to the city’s outdoor advertising
space” (Institute for Transportation & Development Policy, 2014). Based on data from Hirebike in Lincolnshire, U.K., sponsorships can be purchased on a single share bike. Sponsorship of five bikes for a duration of 12 months will cost the private company or organization about 942 Euros (Hirebike, 2016). As result, the city of Porto would be justified to charge sponsors $1,000/bike.

Membership Revenues

Membership revenue streams were based on these considerations:

- **Population Estimates**: Porto currently has a greater urban population of 2.4 million people; however, the core area including adjacent municipalities such as Foz and Matosinhos comprise of roughly 1.3 million people (United Nations, 2017). Based on data from 2016, the population is 55% female and 45% male (United Nations, 2017). Since we are looking at implementing bike sharing just in downtown Porto as well as the neighborhoods of Foz and Matosinhos which are located near the core of Porto, I considered 1.3 million as the population of Porto.

- **Population Growth Rate**: According to UN projections, Porto is set to grow at a rate of 0.21% on average per year. According to UN estimates, the growth rate for 2019 is set to be 0.21%, 2020 at 0.24%, 2025 at 0.32%, 2030 at 0.33%. The estimates used in the spreadsheet are these United Nations projections (United Nations, 2017).

- **Single Trip**: Most cities have free single trips for users under 30 minutes; however, in order to avoid the risk of theft and vandalism, users should pay close to one Euro for a single trip under 60 minutes. This strategy is in line with the Washington D.C. Capital Bikeshare which charges $3 per single trip as well as
Toronto Bixi bikes which charges user $2 per single trip. In addition, bike sharing fees are much lower in Europe in comparison to North America, for example, a single trip is $0.50 in Barcelona, $0.66 in Manchester, and $1.20 in Cologne (Institute for Transportation & Development Policy, 2014). For this study the single trip fee was set at $1.

- Daily Trip: The average daily membership fee range anywhere from $2 to $5 in Europe; therefore, an estimate amount of $3 is within this range (Institute for Transportation & Development Policy, 2014).

- Monthly Trip: Is the membership fee which can rage anywhere from $10 to $30 (Institute for Transportation & Development Policy, 2014). The amount is much higher in North America; however, in Europe they are much lower at an average of $15/month.

- Annual Trip: In North America, the price of an annual membership is much higher at $65 (Madison) - $163 (New York City) depending on the system and the location (Institute for Transportation & Development Policy, 2014). In Europe, perhaps through subsidization from the European Union, prices for an annual membership is consistent across multiple countries and they usually range from $29 (Dublin) - $56 (Cologne); however, in most cities the price is set at around $30/year (Institute for Transportation & Development Policy, 2014).

- Casual Subscribers: Casual members often consist of tourists and those who would like to try out BSP but are not committed to a year-long membership. Research shows that often there are more casual members than year-long members. The number of casual members often correspond to various factors
such as the location of the city, size of the city and the type of BSP. Projections were made based on case studies from cities with similar size, climate and BSP infrastructure to that of Porto (Heda, 2012).

- Annual Subscribers: Annual subscribers often consist of individuals who are living in the city. They are committed to a year-long membership and often use cycling as a form of commute and leisure. Research shows that often there are fewer year-long members versus casual members. This projection was based on data from published materials as well as a case study from Cincinnati where the population is similar to that of Porto (Alta Planning and Design, 2012). In addition, the statistic projections from Cincinnati were based on metrics from Washington D.C., Minneapolis, Montreal, Denver, and Paris.

- Total Annual Subscribers: This is the combined number of casual subscribers and annual subscribers.

- Revenue from Casual Memberships: Since this is a hypothetical project, it would be difficult to calculate revenue from single rides as well as monthly rides. The best estimate to calculate revenue from casual members would be the daily rides. Using the same methods of calculating revenue from casual memberships through the bike share business plan from the city of Sacramento, I multiplied the daily user fee by the number of annual members.

- Revenue from Annual Memberships: Using the same methods from above, we can calculate the total revenue from annual memberships by multiple the number of annual user fee with the number of annual members.
Alternative Scenarios

The values for many of the parameter values in the future scenarios spreadsheet are intrinsically the same as those for the baseline model. There are various differences when it comes to the generation of bike sharing being implemented, such as scenarios with docking stations or without docking stations. While electric bikes often have a higher rate of theft and vandalism, research shows that by implementing electric bikes, we can reduce barriers to cycling by making it more affordable, convenient and accessible for those who are unable to use regular bikes. To avoid redundancy, below are some lines of input which vary from the baseline scenarios:

- 3rd Generation Electric Bicycles with Docking Stations: The estimate price per bike of $1,500 is based on data from past case studies in Denmark, Spain as well as other similar cities to Porto (Matasyan, 2015). While the cost of electric bikes with docking stations is estimated to be $1,500/bike they often have a higher maintenance cost due to the electrical circuit and power supply designed to charge the docking stations (Matasyan, 2015).

- 4th Generation Traditional Dockless Bicycles (300/bike): According to published materials, dockless bike sharing companies often do not release public data because most of them are private companies. As a result, it can be difficult to figure out costs and revenues when it comes to dockless bikes. Based on several published materials, dockless bikes can range anywhere from $100 to $300/bike (Institute for Transportation & Development Policy, 2018) (Recode, 2017). The lower quality bikes in the $100 price range are often made in China and might not be suitable for all roads, while Lime Bike officially quoted its price as $300;
therefore, for the purpose of this study we will use $300/bike as the cost for dockless bikes.

- **4th Generation Bicycles with Docking Stations (1,000/bike):** According to a study by Alta Planning, the latest bike would cost approximately $1,600/bike; however, that includes maintenance and installation costs. Since there is a separate bucket for maintenance costs, the price for the 4th generation bikes in this scenario will be set at $1,000/bike (Alta Planning and Design, 2012). In addition, other research which includes only the cost of the bikes also have the price range closer to $1,000/bike (City of Santa Monica, 2012).

- **4th Generation Dockless Electric Bicycles with Designated Parking Space ($1,500/bike):** Research shows that electric bikes with docking stations such as San Francisco Ford GoBike and New York Citi Bike have similar price point to the traditional bikes with docking station. Since technology has vastly improved over the last few years, electric bikes can now range anywhere from $1,000 to $2,000/bike. In this scenario, the price will be set at $1,500 (Institute for Transportation & Development Policy, 2014).

- **Docking Stations Cost:** As a result of previous studies on electric bikes using docking stations, an estimate of capital cost of $70,000 was projected to cover the initial cost for electric docking stations (Matasyan, 2015). However, for dockless bikes which do not require docking stations, the cost was set to $0.

- **Maintenance Cost:** Since data for dockless bikes are often not available for the public, it is uncertain how much maintenance for dockless bikes really cost. For dockless bikes, maintenance cost is presumed to be lower in comparison to
traditional bikes because dockless bikes are lighter and have no attachment maintenance costs related to docking stations. As a result, for the purpose of this study the maintenance cost was presumed to be $500/bike.

- Single Trip Tariff: Data was collected according to published materials such as The Bikeshare Planning Guide (Institute for Transportation & Development Policy, 2018), as well as other publicly available case studies data such as Bixi, B-Cycle, Ford GoBike, New York Citibike and more. The tariff was adjusted according to the specific type of BSP.

- Daily Trip Tariff: Data was collected using the same methods as above.

- Monthly Trip Tariff: Data was collected using the same methods as above.

- Casual Subscribers: The number of annual subscribers is estimated to increase by 20% for electric bikes based on the belief that more individuals are willing to enroll into the system in comparison to more traditional BSP. The concept of electric bike sharing is more accessible to individuals with health problems or those who were unable to cycle due to some sort of physical limitations (Matasyan, 2015).

- Annual Subscribers: For consistency, the number of annual subscribers for electric bikes was also increased by 20%.

The cost and revenue for five different options were calculated using the same methods. The primary differences in these options were the costs relating to the type of bikes, and maintenance and operating costs. In addition, the membership fees were adjusted to reflect the type of BSP that would be implemented. The scenarios focused more on the annual membership fees that would derive from the usage from the citizens.
of Porto who are more likely to support and subscribe to the scheme. This method of measuring the success of a BSP by looking at the annual membership revenues is often used by other BSPs around the world. By adjusting the membership rate accordingly, we can project the membership revenues and how that would affect the entire scheme.
Chapter III

Results

The aim of my analysis was to determine whether or not bike sharing would be financially feasible in Porto. Once establishing a baseline net present value (NPV), I examined various factors relating to which scenario would be suitable for Porto. In addition to calculating the feasibility of the program, I also observed various influencing factors that could affect the success of bike sharing disregarding the specific model being implemented in that city. The two spreadsheets analyzed were 1) the predictive model scenarios spreadsheet, and 2) the comparison analysis spreadsheet which provides an all-encompassing view of different BSP around the world. A regression analysis of these various influencing factors used to build the spreadsheets was performed in order to make a judgement to whether or not a city should adopt bike sharing.

Regression Analysis

The results from multiple regression indicated that there were no variables that significantly predicted success of BSP (ANOVA, p= 0.645, (Table 3). Bike sharing success was not predicted by a city’s climate, economic situation, topography, cost of living, weather, or other factors. An individual willing to bike will not be more or less persuaded to use bike sharing. In addition, cyclists who are more inclined to bike will also bike in any type of weather conditions, topography, infrastructure, and conditions.
(Table 3) shows an ANOVA table which indicates the significance as 0.645 which is over 0.05; therefore, the model is not significant.

Table 3. ANOVA table of regression results for variables predicting bike sharing.

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>3829937.32</td>
<td>10</td>
<td>382993.732</td>
<td>0.787</td>
<td>0.645</td>
</tr>
<tr>
<td>Residual</td>
<td>3891410.24</td>
<td>8</td>
<td>486426.280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7721347.55</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictive Model Scenarios Spreadsheet

For the scenarios spreadsheet, the NPV for the baseline model was -$4,989,621, which represents the overall loss for the city of Porto over 15 years (Table 4). This factors in a discount rate of 3% to account for the change in monetary value over time.

The predictive model scenarios spreadsheet comparisons showed that the only profitable scenario after 15 years was the 4th Generation Dockless Electric Bikes with Parking Stalls. All the remaining scenarios failed to make any profit or break even even after 15 years. These projections are in line with other past problematic BSP such as London, Paris and Montreal. Despite being world class cities, they have all failed to maintain bike sharing successful within their city, largely due to a combination of misfortunate issues such as financial mismanagement, lack of interest and simply being early adopters. A decade ago when bike sharing technology was more expensive, it required more capital
|                | 2019  | 2020  | 2021  | 2022  | 2023  | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  | 2031  | 2032  | 2033  | 2034  | Total  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| **Year**       | 2019  | 2020  | 2021  | 2022  | 2023  | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  | 2031  | 2032  | 2033  | 2034  |       |
| **CapEx**      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Table 4**    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Baseline Model.** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Discount Rate** | 0.18  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Bike Share** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Implementation** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Number of Vehicles per Station** | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  |       |
| **Replacement Bikes** | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    | 5    |       |
| **Number of Stations** | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   |       |
| **Total Vehicles Available** | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  | 200  |       |
| **Capital Costs** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **3rd Generation Traditional Bicycles with Locking Stations (500)** | $190,000 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **4th Generation Electric Bicycles with Charging Stations (250 per)** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **5th Generation Traditional Dockless Bicycles (500 per)** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **6th Generation Dockless Electric Bicycles w/ Designated Parking** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Administration** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Operating Cost (2/500 per)** | $200,000 | $190,000 | $180,000 | $170,000 | $160,000 | $150,000 | $140,000 | $130,000 | $120,000 | $110,000 | $100,000 | $90,000 | $80,000 | $70,000 | $60,000 | $50,000 |       |
| **Total Costs** | $1,500,000 | $1,420,000 | $1,340,000 | $1,260,000 | $1,180,000 | $1,100,000 | $1,020,000 | $940,000 | $860,000 | $780,000 | $700,000 | $620,000 | $540,000 | $460,000 | $380,000 | $300,000 |       |
| **Revenues** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Advertising Revenues** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Sponsorship Revenues** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Total Revenues** | $1,300,000 | $1,210,000 | $1,120,000 | $1,030,000 | $940,000 | $850,000 | $760,000 | $670,000 | $580,000 | $490,000 | $400,000 | $310,000 | $220,000 | $130,000 | $40,000 | $40,000 |       |
| **Membership Revenues** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Population Estimates** | 1,800,000 | 1,700,000 | 1,600,000 | 1,500,000 | 1,400,000 | 1,300,000 | 1,200,000 | 1,100,000 | 1,000,000 | 900,000 | 800,000 | 700,000 | 600,000 | 500,000 | 400,000 | 300,000 |       |
| **Subscription** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Annual Subscriptions** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Total Subscription** | $120,000,000 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Revenue from Creative Commercial** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Revenue from Sponsorship** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Total Revenue** | $1,300,000 | $1,210,000 | $1,120,000 | $1,030,000 | $940,000 | $850,000 | $760,000 | $670,000 | $580,000 | $490,000 | $400,000 | $310,000 | $220,000 | $130,000 | $40,000 | $40,000 |       |
| **Profitability** |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| **Revenue Costs** | ($120,000,000) | ($118,000,000) | ($116,000,000) | ($114,000,000) | ($112,000,000) | ($110,000,000) | ($108,000,000) | ($106,000,000) | ($104,000,000) | ($102,000,000) | ($100,000,000) | ($98,000,000) | ($96,000,000) | ($94,000,000) | ($92,000,000) | ($90,000,000) |       |
| **Net Present Value** | ($44,072,289) |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
and investments in order to keep BSP in operation. On top of that, users were not interested in using 2nd and 3rd generation BSP because the bikes were heavy, bulky and prone to accidents and vandalism. As a result, there were a lack of foresight and research when BSP were launched in these cities which resulted in much wasted time and money.

After looking at several cities in North America and Europe that implemented BSP, and compiling similar methods for all the scenarios, the results indicate that in the past, BSPs have not been financially feasible due to a lack of balance between bike technology as it relates to costs (Capital, Maintenance, Operating). In addition, there was a low number of memberships due technical barriers as well as a lack of revenue from partnerships or advertisements income. At the time that BSP were launched in cities such as London, Paris, and Montreal, often a third-party vendor comes into the city to pitch an idea of implementing BSP. Their pitches often gather a lot of attention and soon afterwards, bike sharing is implemented in that particular city. The problem that comes with this business model is that the third-party vendor often does not understand the working infrastructure, political climate, or any other issues relating to that particular city. As a result, these past BSP have all failed. In the past, some of these BSP program failed largely to a combination of those issues that were previously mentioned as well as a lack of transparency and poor financial management. As a result, since Porto is entering late into the trend, the city could take advantage of more improved bike share technology and avoid past operational mistakes. Through more improvement in technology and lower capital costs, the concept of bike sharing can definitely benefit citizens’ health physically and mentally. Despite potential positive outlooks, bike sharing implementation
should be looked at as an incentive instead of a financial benefit from a public policy perspective due to a lack of financially successful cases in past implementations. Below is a revenue breakdown of all the scenarios including the most successful 4\textsuperscript{th} Generation Dockless Bikes with Designated Parking Stalls.

Table 5. Production variations spreadsheet yearly profit breakdown.

<table>
<thead>
<tr>
<th>Type of Bike Share</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd Gen Traditional</td>
<td>(4,989,621)</td>
</tr>
<tr>
<td>3rd Gen E-Bikes w/ Docks</td>
<td>(2,804,865)</td>
</tr>
<tr>
<td>4th Gen Traditional Dockless</td>
<td>(3,804,873)</td>
</tr>
<tr>
<td>4th Gen w/ Docks</td>
<td>(5,390,432)</td>
</tr>
<tr>
<td>4th Gen Dockless E-Bikes w/ Parking</td>
<td>5,193,803</td>
</tr>
</tbody>
</table>

The most profitable scenario was the 4th Generation Dockless Electric Bikes with Designated Parking (NPV=$5,193,803) (Table 5). The rest of the scenarios were not profitable at all. By looking at the baseline, we can clearly see that it is not enough to sustain BSP based on memberships revenues alone; therefore, many BSP need a large number of advertising revenues in order to compensate for the high costs. Since many BSP are often run by the municipal government of that city, it is often difficult to find an advertising partner that is going to abide by all the rules and regulations set out by the government while at the same time willing to fund a major portion of the project. As a result, unfortunately many BSP are doomed to fail before they even begin - despite having raised billions of dollars (The Economist, 2017). This result is aligned with other case studies which showcase more recent failure in bike sharing across North America,
Europe, and Asia. In Europe, unprofitable BSP such as Paris Velib has already shut down while London Santander Cycles and Dublinbikes are operating at a loss.

In Asia and North America, dockless bikes have created more problems as a result of oversupply, low demand and a lack of prior research. Many dockless bikes can be found abandoned in various places and have become a major environmental disaster. Unfortunately, Lime bikes have been the poster child for problematic dockless bikes as many of their bikes have been abandoned, vandalized, and archived throughout social media such as in the cases of Dallas, Boston, Seattle and more (Lindeman, 2018).

Other similar regression analysis outputs were also performed which all pointed to a lack of significance between the various factors. After the regression analysis, further measurements were calculated to look into the financial feasibility of past case studies which also show that most of the past and current BSP are not financially feasible. After inputting various data, it seems that most programs that are currently operating are doing so at a loss. Due to several failures in managing previous BSP, many cities have opted not to disclose any financial data since it could result in a backlash from public citizens.

Comparison Analysis Spreadsheet

The comparison analysis pulled together data from 23 countries in order to compare and analyze similarities and differences between historical BSP. When it comes to bike sharing, there is a lack of financial transparency which makes it difficult to measure the feasibility of BSP as a public member. The only city that has transparency and has been successful with its BSP is New York City (Figure 8). Even though Paris is indicated as profitable, the program is no longer in business due to the high costs of
maintenance. New York City on the other hand has a lower cost in comparison to the revenues that it brings in.

Figure 8. Cost vs. revenue comparison of cities with BSP.

Some factors that could have made New York City successful when it comes to bike sharing are possibly the following attributes: high number of tourists, high membership fees which result in the highest membership revenues, and major sponsorships from private corporations. Since the city is home to some of the world’s major companies, such as Citi Group, Goldman Sachs and more, it is often not difficult for the municipal government to find a major sponsorship deal. When looking at scenarios based on a 12-years lifespan of BSP, New York City was the only system that has the potential to last another 7 years based on its current financial situation (Table 6). The other cities that are currently operating BSPs are most likely doing so at a significant financial loss as previously noted.
<table>
<thead>
<tr>
<th>City</th>
<th>Total Revenue Funding Based on a 12 Years Life Span</th>
<th>Remaining Years for the System Based on a 12 Years Life Span</th>
<th>Additional Costs</th>
<th>Total Capital Cost ($000)</th>
<th>Operating Cost for Year Operating Cost to Date</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>$82,748,654.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$548,662,000.0</td>
<td>$5,509,000.0</td>
<td>$5,509,000.0</td>
</tr>
<tr>
<td>Paris</td>
<td>$600,000,000.0</td>
<td>30,000,000</td>
<td>N/A</td>
<td>$1,200,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Lyon</td>
<td>50.0</td>
<td>(145,133,333)</td>
<td>N/A</td>
<td>$55,000,000.00</td>
<td>$5,100,000.0</td>
<td>$5,100,000.0</td>
</tr>
<tr>
<td>Barcelona</td>
<td>$136,406,000.0</td>
<td>(137,000,000)</td>
<td>N/A</td>
<td>$17,600,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Milan</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Dublin</td>
<td>$18,590,000.0</td>
<td>(28,344,750)</td>
<td>N/A</td>
<td>$30,000,000.00</td>
<td>$2,250,000.0</td>
<td>$2,250,000.0</td>
</tr>
<tr>
<td>Oslo</td>
<td>$600,000,000.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Madrid</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Porto</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Lisbon</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$6,000,000.00</td>
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<td>N/A</td>
</tr>
<tr>
<td>Boston</td>
<td>$4,500,000.0</td>
<td>(28,800,000)</td>
<td>N/A</td>
<td>$4,800,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>New York City</td>
<td>$252,000,000.0</td>
<td>87,000,000</td>
<td>N/A</td>
<td>$5,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>San Francisco</td>
<td>$25,356,000.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$1,200,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Seattle</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$30,000.000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Denver</td>
<td>$900,000.00</td>
<td>(3,887,824)</td>
<td>N/A</td>
<td>$2,262,824</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Portland</td>
<td>$2,000,000.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$2,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Boulder</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$500,000.000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Madison</td>
<td>50.0</td>
<td>N/A</td>
<td>N/A</td>
<td>$500,000.000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Washington D.C.</td>
<td>$36,000,000.0</td>
<td>(39,000,000)</td>
<td>N/A</td>
<td>$9,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Chicago</td>
<td>$73,000,000.0</td>
<td>(400,000)</td>
<td>N/A</td>
<td>$18,000,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Montreal</td>
<td>$53,600,000.0</td>
<td>(45,283,333)</td>
<td>N/A</td>
<td>$39,250,000.00</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Toronto</td>
<td>$43,000,000.0</td>
<td>(4,600,000)</td>
<td>N/A</td>
<td>$66,666,807</td>
<td>5,000,000.0</td>
<td>5,000,000.0</td>
</tr>
</tbody>
</table>

Table 6. Analysis based on a 12 Years Life Span of a BSP.
In order to continue its successful operation, New York City has made the controversial decision to further increase its membership cost even though currently the city already has the highest membership cost in the country (Figure 9). This decision is still heavily debated; however, an increase in pricing will create a barrier for low to middle income individuals that cannot afford to have access to the system.

Figure 9. Annual membership costs of various bike sharing programs around the world.
Chapter IV

Discussion

The combination of the predictive model scenarios and the comparison analysis calculations show that it is not feasible for a city to invest in BSP if there is no major grants or corporate sponsorships. As a result, prior to implementing a BSP of any size, it would be best for Porto to secure a financially stable partner in order to receive an adequate amount of advertisement revenue to keep the project going for the long run. In addition, it is important for Porto to have full transparency when it comes to dealing with a corporate partner or an operator in order to avoid the potential of financial mismanagement similar to Bixi Montreal, where the city was unable to recuperate the $37 million loan to Bixi, its BSP operator (Montreal Gazette, 2019). Since bike sharing is a costly investment, it is important for the city to take time and investigate possible issues and potential setbacks relating to bike sharing. While the future of bike sharing might have been questionable in the past, the city Porto now has the potential to create a successful bike sharing scheme due to the advancement of technology, more data, and knowledge.

Furthermore, even though the future for bike sharing might not look as bright as researchers have previously thought, it does not mean that a municipality should not invest in cycling. Active users who often have their own bikes will be more likely to bike if the infrastructure is available, no matter what the weather condition is. While the expansion of bike sharing would have a positive impact in helping Portugal to meet its
goals of becoming a sustainable city and attracting entrepreneurs and tourists – not every BSP can be financially feasible to implement. As previously indicated, the best performing scenario model is the 4th generation electric bikes with docking stations (Table 5); therefore, the city of Porto should use this technology or wait for an even better technology.

By looking at factors such as temperature, precipitation, costs, funding, sponsorships, and overall revenues, I came to a conclusion that generally bike sharing is not profitable; however, with a large grant or sponsorship deal, it could be profitable. Even if a city has great infrastructure such as Paris or London, bike sharing often fails due to mismanagement of funds, lack of interest and overall high costs to run the program. The only profitable bike sharing city is New York; however, this is largely due to a large amount of funding from banks and the private sector that are willing to pay for maintaining the program. Since not every city in the world is structured the way the same way as New York City, it will be difficult to implement any kind of successful BSP. However, since Porto is currently receiving a lot of tourists, by reducing costs and implementing strategic methods used by New York City, the city could also be successful in implementing BSP.

One of the major problems pointed out by other research as well as this analysis is the lack of revenue from membership fees. Unless the city can successfully increase the number of participants or increase the membership fees, it would be difficult for any city to succeed in implementing BSP.

While the future for BSP seems challenging, the 4th generation of dockless electric bikes with designated parking stalls would allow a municipal government to also
gain revenue from advertisements spaces at the same time reduce the capital costs. This scenario is based on San Francisco Ford GoBike and Santa Monica Breeze Bike Share. Since both cities are located close to major tech companies, they rely heavily on corporate advertising revenue and sponsorships rather than revenue from members. In order to succeed, Porto should identify a key partner for the purpose of corporate sponsorship prior to launching the program. If the city fails to do so, this particular scenario might not succeed.

Conclusions

While change may come slowly in Portugal, it is finally beginning to take place. This is because there is both strong interest from the local population regarding cycling and adequate financing from the E.U. for the advancement of technology and sustainability. With the improvement in technology and lower capital costs, soon Portugal will be able to implement a successful BSP through careful research and consultation. If bike sharing is implemented correctly, the citizens of Porto will benefit from a green mode of transportation that helps to reduce GHG emissions as well as to increase the quality of life for its citizens. These findings are not only important in helping Porto to meet its sustainable and economic goals but they also have the potential to improve Portugal as a whole. Prior to BSP implementation, Portugal will need to make significant improvements in infrastructure, public policy, research, and bicycle safety education. As shown in the past, there is a tremendous amount of interest as well as funding from the E.U. in order to make bike sharing happen in the city of Porto. By using this analysis, policy makers and stakeholders could develop better policy and
infrastructure to de (Woodcock et al., 2009; Ferreira, 2015). The spreadsheet analysis could also be used as a scientific supplement and decision aid tool for stakeholders.

By using the previous methods to examine historical data and applying it to the case of Porto, I evaluated the possible financial feasibility of bike sharing in the city. If implemented successfully using the 4th Generation Electric Dockless Bikes with Parking Stalls, and mirroring past success from New York City, the result of bike sharing can have a tremendous positive economic impact for the city of Porto. The potential for success will be driven by an increase in tourism, low cost of production, low percentage of crime, as well as a strong commitment to mitigate the effects of climate change from the municipality and the people of Porto.

In conclusion, upon reviewing several case studies and analyzing various data, my analysis concluded that bike sharing has the potential to emerge in the city of Porto only through the implementation of the scenario of where 4th Generation Electric Dockless Bikes with Parking Stalls are being used. Due to the current state of technology, this scenario would be the best option; however, in the future if there is going to be a similar scenario where there is low capital cost and a high potential for revenues, then the City of Porto should consider that option as well. By using designated bike parking areas for advertisement, this particular scenario would enable to city to lower the costs of implementation through more improved and inexpensive technology while at the same increase revenues from memberships and advertisements. One of the key measures of success is for the city of Porto to identify a strong advertising partner because based of past case studies, the city will not be able to thrive based on membership revenues alone.

While ensuring the success of a BSP can be challenging, by implementing bike sharing
later than other cities, Porto can model after the best scenario and choose the factors that are most suitable for the city in order for Porto succeed where other cities have failed in the past when it comes to bike sharing implementation.
## Appendix

### Ancillary Bikeshare Information

Table 7. Comparing bike share operator scenarios (ITDP, 2018).

<table>
<thead>
<tr>
<th>Financing</th>
<th>Coordination with city</th>
<th>Service delivery</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SINGLE OPERATOR (PPP)</strong>&lt;br&gt;Barcelona, London, Manchester, New York City, Rio de Janeiro</td>
<td>Long-term contract between a private operator and the city establishes a long-term commitment to financial sustainability. Goals of both parties align through revenue-sharing agreements.</td>
<td>Often responding to an RFP, operator understands and agrees to meet city demands to secure a contract. City has significant involvement in major decisions, i.e., station locations, data sharing.</td>
<td>A contracted operator is expected to meet service levels for maintenance, rebalancing, marketing, customer service, etc. set by the city. Failure to do so results in penalties. Thus, operators are financially incentivized to provide quality service.</td>
</tr>
<tr>
<td><strong>MULTIPLE PRIVATE OPERATORS</strong>&lt;br&gt;Seattle, Singapore, Tianjin</td>
<td>Requiring no upfront costs to the city for bikeshare assets reduces the time needed for planning and implementation, and can be more politically palatable than the city providing funding to start a bikeshare program.</td>
<td>Cities that demand certain operating standards using a regulatory framework (permit, MOU, code of conduct, etc.) can achieve optimal outcomes including public space management, equitable access to bikeshare, data sharing and transit integration, etc.</td>
<td>Competition between operators for rides encourages constant improvement on and responsiveness to the user experience.</td>
</tr>
<tr>
<td><strong>SINGLE (PPP) OPERATOR &amp; PRIVATE OPERATORS</strong>&lt;br&gt;Guangzhou, Washington, DC</td>
<td>Service area expansion becomes fiscally viable if private operators are able to &quot;fill in the gaps,&quot; providing service in areas where the PPP operator could not afford to expand into.</td>
<td>City staff and processes already in place to coordinate with an existing bikeshare operator will likely provide capacity and support when drafting and implementing new policies that allow for a multi-operator system.</td>
<td>Different systems (i.e., station-based, dockless) and bike types (i.e., e-bikes, lightweight models) can be provided, offering a range of choices to riders that may encourage more trips made by bike.</td>
</tr>
</tbody>
</table>
Table 8. Bike share fee in North America (ITDP, 2018).

<table>
<thead>
<tr>
<th>City</th>
<th>Operator(s)</th>
<th>Usage Fees</th>
<th>Other</th>
<th>Time Included (minutes)</th>
<th>Deposit/ Hold Amount</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Annual</td>
<td>Monthly</td>
<td>Daily</td>
<td>Per Trip</td>
<td>(minutes)</td>
</tr>
<tr>
<td>New York City</td>
<td>Motivate</td>
<td>$103.00</td>
<td>$14.95</td>
<td>$12.00</td>
<td>--</td>
<td>45 (Annual/Monthly)</td>
</tr>
<tr>
<td>Portland</td>
<td>Motivate</td>
<td>$114.04</td>
<td>$12.00</td>
<td>$12.00</td>
<td>$2.50</td>
<td>--</td>
</tr>
<tr>
<td>Vancouver</td>
<td>CycleHop</td>
<td>$121.69/</td>
<td>$770</td>
<td>--</td>
<td>--</td>
<td>59.25 (1-3-month pass)</td>
</tr>
<tr>
<td>Atlanta</td>
<td>CycleHop</td>
<td>$120.00</td>
<td>$15.00</td>
<td>$26.00</td>
<td>$3.50</td>
<td>--</td>
</tr>
<tr>
<td>Seattle</td>
<td>LimeBike, ofo, Spin</td>
<td>$99.00</td>
<td>$25.00</td>
<td>--</td>
<td>$1.10</td>
<td>--</td>
</tr>
<tr>
<td>Dallas</td>
<td>LimeBike, ofo, Spin, VBikes</td>
<td>$99.00</td>
<td>$25.00</td>
<td>--</td>
<td>$1.00</td>
<td>--</td>
</tr>
<tr>
<td>Chicago</td>
<td>Motivate</td>
<td>$99.00</td>
<td>--</td>
<td>$15.00</td>
<td>$3.00</td>
<td>--</td>
</tr>
<tr>
<td>Boston</td>
<td>Motivate</td>
<td>$99.00</td>
<td>$20.00</td>
<td>$8.00</td>
<td>--</td>
<td>$15.00</td>
</tr>
<tr>
<td>Washington, DC</td>
<td>Motivate/Multiple dockless operators</td>
<td>$85.00</td>
<td>--</td>
<td>$8.00</td>
<td>$2.00 Capital Bikes, LimeBike, Ofo, Spin</td>
<td>28.00 (10-day pass)</td>
</tr>
<tr>
<td>Boulder</td>
<td>Bcycle</td>
<td>$80.00</td>
<td>$11.00</td>
<td>$6.00</td>
<td>$2.00</td>
<td>--</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>CycleHop</td>
<td>$75.00</td>
<td>$16.00</td>
<td>$6.00</td>
<td>$3.00</td>
<td>--</td>
</tr>
<tr>
<td>Montreal</td>
<td>BIXI Montreal</td>
<td>$70.00</td>
<td>$23.75</td>
<td>$3.95</td>
<td>$2.30</td>
<td>$43.50 (30-day pass)</td>
</tr>
<tr>
<td>Madison</td>
<td>Bcycle</td>
<td>$65.00</td>
<td>$15.00</td>
<td>$6.00</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mexico City</td>
<td>Clear Channel</td>
<td>$21.80</td>
<td>--</td>
<td>$5.00</td>
<td>--</td>
<td>$16.50 (3-day pass)</td>
</tr>
</tbody>
</table>
Table 9. Bike share fee in Europe (ITDP, 2018).

<table>
<thead>
<tr>
<th>City</th>
<th>Operator(s)</th>
<th>Usage fees</th>
<th>Time included (minutes)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>Serco</td>
<td>$19.00</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Cologníc</td>
<td>mobike</td>
<td>$14.90</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Barcelona</td>
<td>Clear Channel</td>
<td>$14.95</td>
<td>30</td>
<td>Annual membership allows for unlimited 30 minute trips and annual e-bike access for a base price plus $10.50 per trip</td>
</tr>
<tr>
<td>Paris</td>
<td>Smobengo</td>
<td>$44.00</td>
<td>45 (Annual Plus) 30 (Annual/Weekly/Daily)</td>
<td>Two annual membership types: annual, and annual plus, which allows for 45 minutes of included ride time per trip instead of 30</td>
</tr>
<tr>
<td>Milan</td>
<td>Clear Channel</td>
<td>$42.00</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Dublin</td>
<td>JC Decaux</td>
<td>$39.00</td>
<td>30</td>
<td>$174.00</td>
</tr>
<tr>
<td>Manchester</td>
<td>Mobike</td>
<td>--</td>
<td>30</td>
<td>$60.00</td>
</tr>
</tbody>
</table>

Table 10. Components and relevant technologies in bike sharing (Civitas Initiative, 2017).

<table>
<thead>
<tr>
<th>Component</th>
<th>Relevant technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycles</td>
<td>Real-time on-bike information on navigation, public transport schedules, local events, information about the bicycle (such as remaining battery charge) and the availability and location of nearby docking stations</td>
</tr>
<tr>
<td></td>
<td>GPS tracking to aid positioning and navigation systems, reduce risk of bicycle being lost or stolen, or reduce the need for docking stations</td>
</tr>
<tr>
<td></td>
<td>Solar panels fitted to bicycles to power electronic components</td>
</tr>
<tr>
<td></td>
<td>Pedal generators applied to electric bicycles and cargo bikes and reducing the need for batteries and charging infrastructure</td>
</tr>
<tr>
<td></td>
<td>Accelerometers to detect a bicycle being moved or interfered with without authorisation</td>
</tr>
<tr>
<td></td>
<td>Sensors to detect attempts to tamper with or break locks</td>
</tr>
<tr>
<td></td>
<td>Better design and use of more advanced materials to make bicycles robust but lightweight</td>
</tr>
<tr>
<td></td>
<td>‘Smart’ bike locks that fit to standard bicycles and connected with smartphone apps, allowing small-scale bike-sharing schemes where individual owners can offer their own bicycles for hire</td>
</tr>
<tr>
<td>Docking stations</td>
<td>Mobile stations that can be relocated by the operator to match demand at short notice</td>
</tr>
<tr>
<td></td>
<td>Stations that collect energy generated by cyclists to feed it back to the grid</td>
</tr>
<tr>
<td></td>
<td>Free-roaming, GPS-tracked bicycles that do not need stations, improving convenience and reducing installation costs</td>
</tr>
<tr>
<td></td>
<td>Designation of areas where users are encouraged to return their bicycles in schemes without fixed stations as a means of reducing unpredictable distribution</td>
</tr>
<tr>
<td>User payment and access systems</td>
<td>Ticketing systems integrated with wider public transport network so that users with smartcards for other modes do not need a separate key or smartcard to access bike-sharing</td>
</tr>
<tr>
<td></td>
<td>Payment through use of saved account details for other online purchases</td>
</tr>
<tr>
<td>ITS Technology</td>
<td>Integration of data into online journey planners so that details of bike-sharing options appear alongside alternative options for travel by default</td>
</tr>
<tr>
<td></td>
<td>Integration of bike-sharing with wider fares system so that multimodal tickets can be purchased which cover bike-sharing schemes</td>
</tr>
<tr>
<td></td>
<td>Use of smartphone applications for journey planning and real-time information on the availability of bicycles and stations</td>
</tr>
<tr>
<td></td>
<td>Use of smartphone applications to connect individual bicycles owners and users in a peer-to-peer bike-sharing system – negating the need for a single public provider</td>
</tr>
<tr>
<td>Bicycle distribution system</td>
<td>Locking technology fitted to bicycles as an alternative to stations, which have limited capacity</td>
</tr>
<tr>
<td>Peer-to-peer</td>
<td>Integration with existing bike-sharing schemes or bike rental</td>
</tr>
<tr>
<td></td>
<td>Integration with car sharing or other peer-to-peer services</td>
</tr>
</tbody>
</table>
Table 11. Bike share system costs (Institute for Transportation & Development Policy, 2014).

<table>
<thead>
<tr>
<th>City</th>
<th>Country</th>
<th>System Name</th>
<th>Capital Cost (Per Bike)</th>
<th>Replacement Cost of Bike</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>U.K.</td>
<td>Barclays Cycle Hire</td>
<td>$4,000</td>
<td>$1,435</td>
</tr>
<tr>
<td>Paris</td>
<td>France</td>
<td>Vélib'</td>
<td>n/a</td>
<td>$809</td>
</tr>
<tr>
<td>Barcelona</td>
<td>Spain</td>
<td>Bicing</td>
<td>$3,150</td>
<td>n/a</td>
</tr>
<tr>
<td>Montreal</td>
<td>Canada</td>
<td>Bixi</td>
<td>$4,000</td>
<td>$1,270</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>USA</td>
<td>Capital Bikeshare</td>
<td>n/a</td>
<td>$1,000</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>China</td>
<td>Guangzhou Public Bicycle</td>
<td>n/a</td>
<td>$69</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>China</td>
<td>Hangzhou Public Bicycle</td>
<td>n/a</td>
<td>$74</td>
</tr>
<tr>
<td>Zhuzhou</td>
<td>China</td>
<td>Zhuzhou Jianning Public Bicycle</td>
<td>n/a</td>
<td>$261</td>
</tr>
<tr>
<td>Mexico City</td>
<td>Mexico</td>
<td>Ecobici</td>
<td>$3,400</td>
<td>n/a</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>Brazil</td>
<td>Bike Rio</td>
<td>$1,810</td>
<td>$550</td>
</tr>
<tr>
<td>New York City</td>
<td>USA</td>
<td>Citi Bike</td>
<td>$4,750</td>
<td>n/a</td>
</tr>
<tr>
<td>Denver</td>
<td>USA</td>
<td>Denver B-Cycle</td>
<td>$4,250</td>
<td>n/a</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>USA</td>
<td>Nice Ride</td>
<td>$4,487</td>
<td>$1,000</td>
</tr>
<tr>
<td>Madison</td>
<td>USA</td>
<td>Madison B-Cycle</td>
<td>$5,000</td>
<td>n/a</td>
</tr>
<tr>
<td>Boston</td>
<td>USA</td>
<td>Hubway</td>
<td>n/a</td>
<td>$950</td>
</tr>
</tbody>
</table>
References


