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Prof. Dr.-Ing. Gebhard Wulfhorst

Technische Universität München

MASTER'S THESIS

M.Sc. in Transportation Systems

Assessment of the Perceptions and Behaviors Towards Bicycle Integration to the BRT System TransMilenio in Bogotá, Colombia

Author,

María Alejandra Pabón Renjifo

Matriculation Number: 03646633

Supervisors:

Montserrat Miramontes, M.Sc.

Carlos Felipe Pardo, M.Sc.

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Abstract

Understanding and solving transportation issues is a pressing need for governments in Latin America and the Caribbean region. An increasing number of private vehicles, chronically deficient public transport systems, and a lack of infrastructure that guarantees the safety of non-motorized transport users characterize most of the major urban centers in this region, including Bogotá – capital of Colombia –, the city in which the present study is focused. As a result, there is the emergence of economic, social and environmental problems including congestion, loss of time, informality, inequality, growing greenhouse gas emissions and pollution, public health problems, etc.

An approach that can greatly contribute to solving Bogotá's dire transport situation is the combination of bicycle and public transport use. This approach can have a substantial impact in people's mobility, motivate a shift in mindset that can potentially lead to a car-free lifestyle, and improve the overall system's sustainability. These outcomes have been evidenced not only in developed cities like Munich but also in other cities within Colombia like Medellín.

The overarching goal of the present study is to reveal the attitude of Bogotá residents towards cycle-transit integration, gather insights from existing cycle-transit users, and formulate strategies to address the system's structural deficiencies.

The study includes an extensive review of existing literature on accessibility to public transport and the concept of cycle-transit integration, commonly known as bike-and-ride, as well as a description of the current mobility situation in Bogotá. This is combined with face-to-face and online surveys to determine cycle-transit users' demographic profile and trip characteristics, understand their perception of the current system's performance and issues, and identify how they prioritize measures aimed at improving the whole cycle-transit integration.

The combination of a deep-dive in cycle-transit integration theory and first-hand verification and understanding of the reality faced by cycle-transit users in Bogotá leads to the development of a set of specific recommendations organized in a three-step course of action: i) incentives, ii) soft measures and iii) physical infrastructure enhancements. The study finalizes with an outline of the actions that should follow this thesis.

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1. Introduction

1.1 Problem Definition

Urbanization is occurring all over the world (Nkurunziza, 2013) and "cities in developing countries and emerging economies are growing by the hour. Developments in their transport systems, however, are not keeping pace" (GIZ, 2015, p. 23). The role of transport in urban areas is crucial to accommodate the increasing levels of travel demand. Solving transportation problems has become a major task that governments in developing countries have to confront.

According to Khisty (2003), all through the last century transportation planning and the implementation of transportation facilities in the developing world have been heavily weighted towards motorized individual transport (MIT), despite the fact that non-motorized transport (NMT) and public transport (PT) constitute a significant proportion of all trips in urban areas, and provide viable alternatives to most motorized trips (Nkurunziza, 2013). Cities in Latin America and the Caribbean (LAC) are some of the many examples and most of them encounter rather similar problems in relation to urban transport and urban daily mobility.

The region is characterized by a significant percentage of urban population, and an accelerated urbanization process (Jirón, 2013). Additionally, an increasing number of private vehicles that dominate the roads and keep on oversaturating them, and a lack of accessible and affordable PT services and safe infrastructure for NMT (UN, 2011). As a result, LAC cities face economic, social and environmental issues including congestion, loss of time, informality, inequity (Jirón, 2013), growing Greenhouse Gas (GHG) emissions, air pollution, noise, public health problems and traffic injuries and fatalities (UN, 2011); all of which play an important role affecting their sustainable development.

Colombia is not exempt from this fact, around 78% of the people live in urban areas, and it is expected to have a five-year average urbanization rate equal to 1.2% (Wessels, Pardo, & Bocarejo, 2012). The capital of the country, Bogotá, has more than 7.8 million inhabitants (DANE, 2011), and deals with a large affluence of people leaving rural areas and other cities because of the current armed conflict or seeking better opportunities in the capital (El Tiempo, 2008).

Nevertheless, since the year 2000 when the Bus Rapid Transit (BRT) system *TransMilenio* (TM) was implemented, Bogotá has been accomplishing meaningful progress in terms of sustainable urban development. Local authorities have established a new vision of the city with high-quality public spaces, promotion of NMT, provision of bikeways throughout the city, and improvement of the PT (Wessels et al., 2012). Moreover, the use of TM has increased by 35% in the last five years (Cómo Vamos, 2015), the collective bus system is currently being reorganized and restructured into a new scheme called Integrated Public Transport System (SITP, for its name in Spanish), the bicycle network – known as *Ciclorrutas* (CR) – has today more than 350 km of built lanes, and 17 of the TM stations have free of charge bicycle parking facilities – known *Cicloparqueaderos* (CP) (CCB & Uniandes, 2015).

All the same, Bogotá is today one of the most congested cities in LAC and faces serious problems in terms of mobility, accessibility, and equity, among others. Less than 40% of the people feel satisfied with the transport mode they use (Red Cómo Vamos, 2013), and citizens with an increasing spending power are deciding to buy private vehicles and motorcycles, bringing, as a result, a growth of the motorcycle and automobile fleet of 104% and 36%, respectively, over the last five years (Cómo Vamos, 2015). Thus, there is a great need for new ways of sustainable mobility that not only offer solutions to these problems, but also give attractive, comfortable and easy to use transportation alternatives to all citizens.

One interesting approach to the creation of new forms of mobility is the combination of the already existing transport modes. For example, the combined use of bicycle and PT may improve the mobility conditions of people and also enable car-free lifestyles (Martens, 2004), i.e. cease the growth of the private vehicle fleet and increase the share of other transport modes. In fact, cycle-transit (CT) integration – also known as bike-and-ride – is mutually helpful enhancing the benefits of both modes and encouraging more bicycling as well as more PT use (Hegger, 2007). On the one hand, bicycling supports PT by extending the catchment area of transit stops beyond the walking range, and at lower costs than feeder buses and park-and-ride facilities. On the other hand, adequate access to PT for bicycle users helps them to achieve longer distances than possible by bike (Pucher & Buehler, 2009).

Introducing a comprehensive package of measures for successfully integrating bicycling and the mass transit system in Bogotá has the possibility of becoming one of the most cost-effective alternatives towards the city's objective of Sustainable Transport Oriented Development (STOD) (Pardo & Calderón, 2014). But, most of the transportation decisions joint on the understanding of the behavior of trip makers and interpreting their perceptions, preferences, and choices (Nkurunziza, 2013). Therefore, an assessment of people's perceptions and behaviors towards bike-and-ride in the case of Bogotá is necessary to identify its potential and thus, design a better-targeted implementation.

1.2 Research Motivations

For Khisty (2003), it is ironical that although NMT holds many advantages over MIT, the community, and the city in general, from the perspective of different factors as energy conservation, environmental impact, social equity, and economy, these attributes have rarely been exploited to their fullest extent by developing countries. Furthermore, until not so long ago, the majority of transportation policymakers in the developing world believed that a higher proportion of MIT, often at the expense of NMT and PT, was vital for economic development, carrying, as a result, problems as severe traffic congestion, widespread air and noise pollution, increased fuel consumption, steeper infrastructure costs, and higher accident rates (Nkurunziza, 2013).

Bogotá is not different from most cities with the above-mentioned characteristics. The city needs to change the direction of its urban transport development to a more sustainable future, through the development of affordable, economically viable, people-oriented and environment-friendly transport systems (UN, 2011). Specifically speaking, there is a great need to stop the growth of the private vehicle fleet and to improve the mobility conditions of the people who live in the city. So far, improvements of the PT services and the promotion of bicycling have brought important changes to the city's mobility, however, it is now important to think about the integration of these modes of transport and study the impact it would have in terms of accessibility and travel behavior.

Introducing the concept of CT integration to the specific case of Bogotá has the potential of becoming one of the most cost-effective alternatives to help to solve the issue of mobility, and with positive results shown already in the short term. By understanding attitudes, perceptions and preferences towards the combined use of NMT and PT, better-targeted policies in this field can be developed and a more efficient and effective deployment of scarce transport resources can be made.

1.3 Objectives

Sustainable transport policy can alleviate poverty while stimulating economic growth and climate change mitigation, by providing socially equitable and environmentally sound transport alternatives to the people (Nkurunziza, 2013). In order to have effective, efficient and equitable policy development, it is necessary to understand the key behavioral factors and motivators for people to choose one transport mode over the other. This understanding can result very helpful to policy makers to effectively and efficiently do an implementation of CT integration.

The overarching goal of this master thesis is, therefore, to investigate and explain people's attitudes towards CT integration in the context of Bogotá, and use the knowledge generated to suggest better-targeted recommendations to successfully achieve such integration.

The following objectives are defined to achieve the above-mentioned goal:

i. To identify the specific benefits of integrating bicycling and public transit according to research and case study examples.

ii. To characterize and describe the use of the bicycle in Bogotá as a PT feeder mode.

iii. To assess the potential of bicycle integration to TM by understanding user's perceptions.

1.4 Thesis Outline

The document is divided into 6 parts. The first part entails the literature review performed for the study, containing information about CT integration concepts and study cases, as well as a theoretical background on surveying. Then, the city of Bogotá is described in the second part, using mobility numbers and figures to define how *“Bogotanos”* move within the city and to characterize bicycle use in recent years. Additionally, a summary of a previous study done on the subject of cycle transit integration is presented in this chapter. The third part explains the methodology developed and implemented for the empirical part of the study, followed by the fourth part which shows the obtained results and their analysis. The fifth part focuses on the recommendations for achieving a successful integration of both bicycling and PT use in Bogotá, and the last part closes the document with the conclusions.

2. Literature Review

The current chapter is divided into two parts: the first part focuses on giving a theoretical background about the concept of CT integration along with some case studies; the second part explains the different data collection methods to carry out the empirical research required for the study.

2.1 State of the Art

2.1.1 Accessibility to Public Transport

Since long ago, PT has gained attention as a sustainable and environmentally sensitive transport mode that serves the travel needs of those without access to cars or motorcycles, thus benefiting social equity principles. However, despite all the attempts of convincing an increasingly mobile, affluent and demanding society to make use of this mode, its share has been declining around the world. There are numerous and diverse reasons for this trend. The accessibility to PT – i.e. distance from origins or destinations – and the inconvenience – i.e. disutility – of having several stages and connections have a big share of the responsibility (Krygsman, Dijst, & Arentze, 2004).

When performing a trip by PT, much of the effort is associated with reaching the system at the beginning of the trip, and the final destination at the end of it. Access and egress stages – together with wait and transfer times – are the weakest links in the PT chain, and an increase in access and/or egress times or distance is directly associated with a decrease in PT use (Krygsman et al., 2004). If access and egress exceed an absolute maximum threshold, users will not use the PT system. Accordingly, if the access and egress trip components are acceptable, users will be more inclined to use the system (Krygsman et al., 2004). In this sense, the potential share of PT is determined to a considerable extent by the quality of commuting from home to the place of activity (Rietveld, 2000b).

The further away people live from a PT stop or station, the less they are inclined to travel by this mode (Rietveld, 2000b). A clear example of this can be found in The Netherlands, where the frequency of railway use tends to decline as the distance between the residence and the railway station increases – see Table 2.1.

Table 2.1 Frequency of railway use versus distance between residence and nearest railway station (The Netherlands, 1994). Source: (Rietveld, 2000b)

Distance (km)	Frequency of railway use (index)
0.0–<0.5	1.00
0.5–<1.0	0.82
1.0–<3.5	0.71
3.5–<5.0	0.53

The distance decay between the residence and the PT stop or station is a function of the different access and egress modes, with certain modes being more sensitive to distance than others (Krygsman et al., 2004). The shares of the access modes chosen by PT users depend strongly on distance, and each mode has its own catchment area. For short distances most people prefer to walk or take the bicycle, whereas for long distance access trips they take PT or MIT (Keijer & Rietveld, 2000). In The Netherlands, for example, at the home-end, Rietveld (2000b) found that walking is the most important access mode for distances up to about 1.2 km while bicycling is dominant between 1.2 and 3.7 km. For distances longer than 3.5 km, Keijer & Rietveld (2000) found that most travelers chose PT. Figure 2.1 shows that, when reaching a railway station, walking and the bicycle are the preferred access modes.

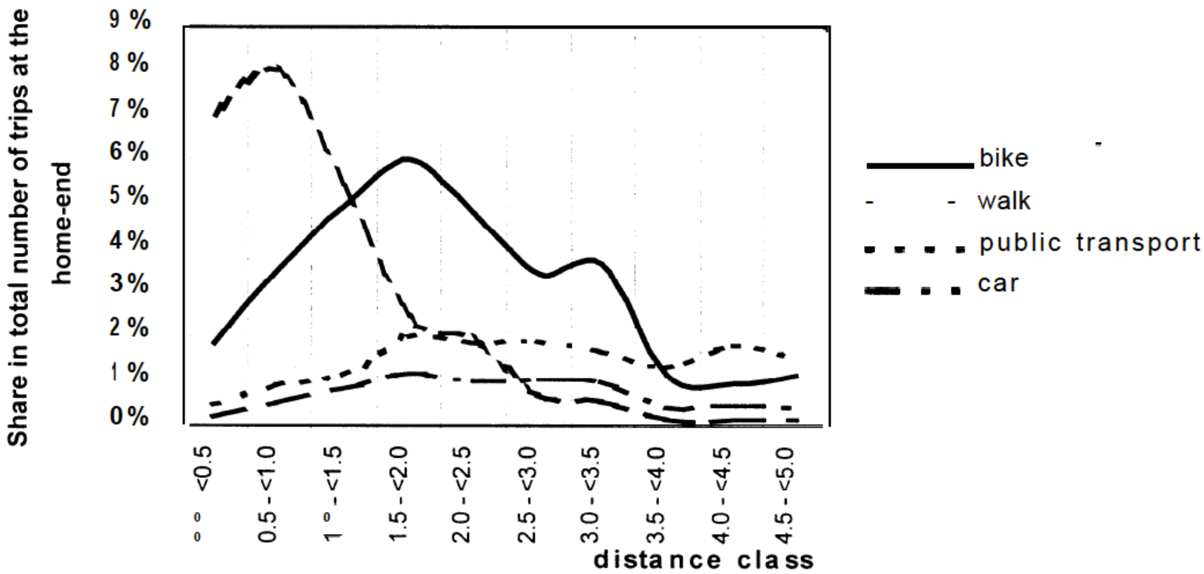

Figure 2.1 Importance of transport modes in relation to the distance at the home end. Source: (Keijer & Rietveld, 2000)

Catchment areas, used to describe the geographic area within which most transit users are comfortable traveling to or from a PT stop or station (Flamm & Rivasplata, 2014b), can be defined based on a number of factors including distance, travel time and/or geographic boundaries to the facility. According to Krygsman et al. (2004), access and egress modes determine the catchment of PT stops or stations and the intensity of use within catchments, but distance to or from transfer locations is the most important factor in access and egress mode choice, and is probably the ultimate disincentive to the use of PT. The bicycle helps to expand catchment areas by permitting areas more distant from transit stops and stations to be accessible via a faster-than-walking NMT mode (Flamm & Rivasplata, 2014a). Nonetheless, the degree to which the environment leading to the station is bicycle-friendly, and the quality of the bicycle parking provided are crucial factors that define its accessibility, and therefore, its use (Flamm & Rivasplata, 2014b).

Accessibility to PT is about people's ability to get to and from different places to a station or stop, i.e. enabling access to this mode. An accessible PT systems not only includes concepts of availability, affordability, and usability of services, but also considers the connectivity of various modes and the ease of use, which in the end contribute to the desirability of PT as a transportation choice (Public Transport Victoria, 2013). For this, access modes – mainly walking and bicycling, but also feeder bus lines – need to be considered as complements to PT, and adequate infrastructure both at the station or stop and on access routes should be provided (Rietveld, 2000a).

If access and egress are the weakest links in a PT chain that determine not only the availability, but also the convenience of PT use, initiatives of multimodality such as bicycle and PT integration hold the potential to significantly attract more users, and are inexpensive options compared to infrastructure and vehicle enhancement alternatives (Krygsman et al., 2004). Compared to other access modes, the bicycle is substantially faster than walking and more flexible than feeder bus lines (Martens, 2004), leads to shorter access times (Krygsman et al., 2004), is cheap, environmentally friendly, and requires only modest parking space near the transit station (Rietveld, 2000b).

For all the foregoing, the combined use of bicycle and PT, better known as CT integration – or bike-and-ride –, has recently gained attention as part of the wider search for multimodal alternatives to MIT. Next section makes a short review of the literature available on the topic to better understand the concept and to clearly identify the benefits it brings towards a sustainable development, such as the one intended for Bogotá.

2.1.2 Cycle-transit Integration

According to Bachand-Marleau et al. (2011), the combination of modes allows for more flexibility and increases travel options, making multimodal and intermodal transport more appealing.

Bicycling and PT integrate well (Victoria Transport Policy Institute, 2014). The coordination of these two modes is mutually helpful, enhances the benefits of them both, and encourages their use (Pucher & Buehler, 2009). While PT is most effective for moderate- and long-distance trips on busy corridors, bicycling is effective for short-distance trips with multiple stops (Victoria Transport Policy Institute, 2014). Moreover, whereas cycling supports PT by extending the catchment area of transit stops beyond walking range and at a lower cost than neighborhood feeder buses and park-and-ride facilities, PT services allow cyclists to make longer trips than possible only by bike (Pucher & Buehler, 2009). In general, combining PT and bicycling can provide a high level of mobility comparable to MIT travel (Victoria Transport Policy Institute, 2014).

Bike-and-ride offers a number of environmental, economic and societal benefits over the use of the private car. According to Martens (2004), the environmental benefits include reductions in energy use, and air and noise pollution – the magnitude of these benefits will depend on the number and length of the car trips being replaced by bike-and-ride. The economic benefits comprise the reduction of congestion levels on specific corridors due to the replacement of car trips by bike-and-ride, and the strengthening of the economic performance of specific types and lines of PT, as it attracts an additional group of consumers (Martens, 2004). Finally, societal benefits comprehend improving people's mobility by overcoming distance, topographical, weather, safety, and infrastructure barriers (Wang & Liu, 2013). All of these benefits help communities reduce their reliance on single-occupant vehicle travel and make their transportation systems work more efficiently (Schneider, 2005).

For Martens (2004), the combined use of bicycle and PT has the potential of enabling car-free lifestyles considering that it provides a relatively competitive alternative to this transport mode for medium- and long-distance trips. In addition, bike-and-ride is important from a perspective of "social justice" as it offers high-quality service for people who cannot drive a car – or even afford it. Finally, CT integration attracts an additional group of consumers, therefore, strengthening the economic performance of specific types and lines of PT (Martens, 2004). For (Bachand-Marleau et al., 2011), a successful marriage between bicycling and PT will likely result in increasing:

i. The catchment area and subsequent benefaction of PT,
ii. The efficiency of PT by reducing the need for feeder bus services, and
iii. The overall demand for bicycling.

Now, the combination of bicycle and PT can take different forms: trip-makers can use the bicycle as a feeder mode for access trips – at the home-end of a trip –, for egress trips – at the activity-end of a trip –, or for both (Martens, 2004). The attractiveness of bike-and-ride lies in its potential to solve the accessibility problem of PT stations and stops, but the degree to which this problem is solved is affected by the quality of system integration, that is the ease of transferring between modes, the infrastructure characteristics of stations and terminals, and the parking convenience (Litman, 2012). Moreover, the share of bike-and-ride is influenced by the popularity of the bicycle, the bicycle infrastructure, and the bicycle policies. At large, high levels of bicycle ridership, well-developed bicycle networks, and dedicated bike-and-ride facilities will most likely go hand in hand with higher levels of bike-and-ride (Martens, 2004).

In general terms, for having an effective integration of bicycling and PT, it is required to analyze a broad range of alternatives, and such alternatives must fully consider the travel patterns and needs of individuals and key characteristics of the built environment – e.g., density, bicycle facilities (Krizek & Stonebraker, 2010). Concretely, the following measures can be implemented for having a successful CT integration (Bachand-Marleau et al., 2011; Schneider, 2005):

- Enabling bicycles to be brought on transit vehicles,
- Improving the availability of parking near transit stops,
- Providing staffed racks and lockers at major transit hubs,
- Connecting transit stations to an existing network of bicycle paths and lanes,
- Offering other bicycle services at parking facilities, and
- Providing bicycle-sharing systems near transit stations and major destinations.

Next section provides case studies on bike-and-ride in order to clearly understand how this integration can be executed, and to highlight the positive changes in people's travel behavior it may bring. These case studies could then be used as examples to follow for the specific case of Bogotá.

2.1.3 Case Studies on CT Integration

According to Martens (2004), the importance of bike-and-ride may be expected to differ between countries depending on the general levels of bicycle ridership – i.e. cycling culture –, the infrastructure available to cyclists, and the specific facilities offered to potential CT users. This section describes two different case studies with the objective of evidencing characteristics, problems, and best practices to be considered in the analysis of Bogotá's case. Results from other CT integration cases are provided to give evidence of the resulting changes in people's travel behavior after implementation.

Munich, Germany

Germany has been characterized by moderate levels of bicycle ridership in the 1970's and 1980's and a substantial rise in more recent years. Many German cities show higher bicycle shares than the national average, with a substantial number of cities reporting figures between 15% and 25% (Martens, 2004).

According to Martens (2004), the first systematic investments in cycling facilities in Germany date from the late 1970's and early 1980's, when the federal government decided to financially support the realization of bicycle paths along roads of national importance and launched a program to promote cycling inside towns. Martens (2004) highlights that the first initiative resulted in a tripling of the bicycle network along non-urban roads and the implementation of the program stimulated a substantial number of towns and cities to invest in bicycle facilities. Today, most of these localities now have well-developed bicycle networks and relatively high percentages of bicycle ridership.

Special initiatives to promote the combined use of bicycle and PT were first introduced in German cities in the late 1980's. During the second half of the 1990's, a widespread recognition was given to the potential of bike-and-ride leading to an increased attention at all levels of government for policy making and having reached political agenda (Martens, 2004). Munich was one of the first cities to invest substantially in bike-and-ride facilities. Since the second half of the 1980s, such facilities have been created at many stops along metro, suburban and long distance trains.

The city of Munich had in 2013 1.4 million inhabitants, plus 500,000 daily commuters (Landeshauptstadt München, 2013). It was one of the first cities to invest substantially in bicycle lanes and bike-and-ride facilities (Martens, 2004), and by 2013 it had a bicycle network of nearly 1,200 km that reached into virtually all areas of the city (Landeshauptstadt München, 2013), and has today more than 50,000 parking spaces (MVV, n.d.) – see Figure 2.2.

Figure 2.2 Bike-and-ride parking spaces in Ubahn and Sbahn stations in Munich. Source: (MVV, n.d.)

In addition, since 1998, the Deutsche Bahn offers a public bike-sharing system (BSS) – a short-time bicycle rental program – named *"Call a bike"*, where people can easily register online and download a mobile application for finding and unlocking bicycles situated all over the city. Although this system is meant for performing complete trips by bicycle, it can also be used for reaching PT stations. Complementarily, the Munich Transportation Corporation (MVG, for its name in German) recently launched a new BSS called *"MVG Rad"*, with 125 planned stations near PT stations, stops and central spots (Radlhauptstadt, 2015), and 1,200 bikes (MVG, 2015). Moreover, cyclists are also allowed to take their own bicycles inside trains just by paying an extra ticket before boarding them.

Martens (2004) found that the number of bicycle parking spaces in Munich and the adjacent localities rose from about 19,000 in 1986 to more than 41,000 in 1998, giving evidence of the growing use of bike-and-ride in the city. Furthermore, even though it is too soon to have quantitative data on the use of *"MVG Rad"*, according to Nitschke (2015), this new BSS should be seen as an additional way to increase the use of sustainable transport modes and an additional advertisement for PT, that eventually will lead to a reduction of trips made with private vehicles in Munich.

Medellín, Colombia

Medellín, located in the middle of the Aburrá Valley, is the capital of the department of Antioquia and is the second largest city in Colombia with a population of more than 2.6 million inhabitants in 2015 (Vamos, 2015). Currently, the city counts with an integrated PT system composed of two metro lines, cable car, tram and a BRT system, all which connect to the different municipalities within the Aburrá Valley (Rios Tiusabá, 2015) – see Figure 2.3.

Medellín has given great importance to NMT modes and introduced in 2011 a BSS called *"EnCicla"* with the clear objective of presenting the bicycle as an integrated and complementary alternative to the use of PT in the city and metropolitan area. *"EnCicla"* is framed on the principle of inter-modality, and is presented as a non-conventional mode of transport integrated to the existing ones providing a component that improves mobility and quality of life to citizens (EnCicla, 2015).

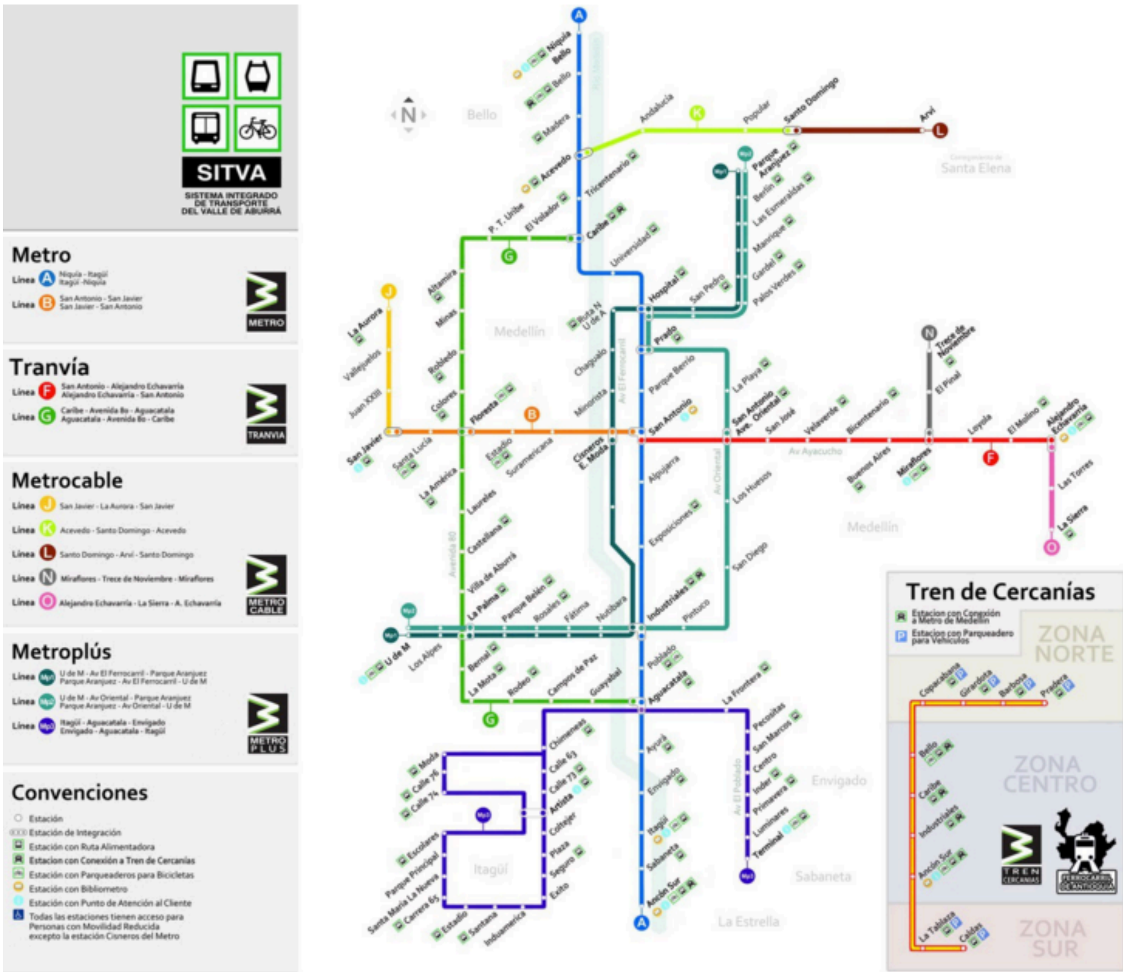

Figure 2.3 Integrated PT System in the Aburrá Valley. Source: (Secretaría de Movilidad de Medellín, 2015)

In 2011, the system began with 105 bicycles and 6 stations as a complementary service to the metro, and in 2012, it had already turned out to be an important part of the city's planning. As a result, 13 new stations were opened and 325 bicycles were introduced in 2013, and by 2014, the system had already consolidated itself with 44 stations and 430 bikes. For the coming years, it is projected to have more than 80 stations and a total of 1,420 bicycles available across the city (Rios Tiusabá, 2015).

The BSS is founded on four specific strategies that seek to position the bicycle as a mode of transport that articulates correctly with the Integrated Transport System of the Aburrá Valley (SITVA, for its name in Spanish) (Rios Tiusabá, 2015):

- Build a bicycle network that covers the whole city.
- Generate the Bicycle Metropolitan Master Plan, published in December 2015.
- Implement bicycle parking facilities near PT stops and/or stations.
- Promote the bicycle for commuting

According to Rios Tiusabá (2015), the BSS has in total 9,600 users from which 28% are women and 72% are men. From the total, 73% of the users have ages ranging from 18 to 24 years old, followed by a 15% of people between 25 and 31 years old. Trips originated at metro stations represent almost 20% of the total trips performed using *“EnCicla”* (Rios Tiusabá, 2015).

Other Case Studies

- In Greater Helsinki, Jäppinen et al. (2013) concluded that CT integration through the implementation of a BSS would save about six minutes between origins and destinations compared to PT alone, which would lead to an average reduction of 10% in travel times throughout the entire region.
- Ma, Liu, & Erdoğan (2014) found that in Washington D.C., *“Capital Bikeshare”* is significantly associated with *“Metrorail”* ridership. The study’s results show that a 10% increase in bicycle sharing ridership would lead to a 2.8% increase in transit ridership.
- In Santiago, a study by Ortúzar et al. (2000) determined that the incorporation of a dense network of cycle ways and the inclusion of adequate bicycle shelter facilities at metro, suburban train, and BRT stations would result in the use of bicycles for medium and long distance trips, and an increase of up to 10% of bike use in some sectors of the city. Moreover, bike-and-ride could also help broadening the use of bicycles to the higher income sectors.

In summary, the case studies mentioned above show that CT integration increases the cycling and PT ridership shares, reduces total travel time, and helps to shift MIT trips to more sustainable modes. Moreover, theses examples give evidence that different cities, each one with different socioeconomic backgrounds and cultural characteristics, can have very similar results in terms of use of bike-and-ride.

Even though it is expected to have a higher share of bike-and-ride in cities that have a very strong cycling culture with policies and infrastructure that support and protect this mode – like the case of Munich –, examples like Medellín demonstrate that these characteristics are not a prerequisite for having a successful CT integration. It is rather more important to have adequate bicycle parking facilities near TP stations or stops, and even a BSS to attract those without a bicycle and give more flexibility to users.

2.2 Transport Data Collection Methods

Data collection is the process of gathering and measuring information on variables of interest in a systematic way in order to answer stated research questions and evaluate outcomes. The quality of the collected data is very important in any type of research; inaccurate data will affect the results of the study leading to invalid results and mistaken conclusions. The following sections describe the transport data collection methods used to gather information on CT users, and the different variables to be considered before being able to do a valid statistical analysis.

2.2.1 Transportation Survey Methods

According to Richardson et al. (1995), all people involved in planning will be involved with data collection at some point. For transport and land-use planning, surveys are of particular help and relevance. Usually, they play a major role in specifying the location, characteristics, and performance of transportation systems, describing users' demographic and socioeconomic characteristics, understanding their travel patterns and behaviors, and comprehending their perceptions and attitudes toward specific matters (Richardson et al., 1995).

Intercept Surveys

According to Schaller (2005), intercept surveys are highly valuable as a mean of obtaining important information and opinions from a cross section of customer – in this case, people that do bike-and-ride in Bogotá. They are used to collect data on users' trip characteristics, travel behavior, demographic characteristics, and attitudes about service. Intercept surveys may be the only cost-effective way to gather information, and are highly useful to specific user segments. They often provide higher response rates than alternative methodologies such as telephone, mail, and on-line surveys, and at lower cost (Schaller, 2005).

Intercept surveys take place at sites outside the household – where people are intercepted in the course of carrying out an activity, in this case in the process of using a mode of transport. They include surveys on board PT vehicles, at stops or stations, at cordon points on roads, and at other activity sites such as shopping centers, workplaces or transport nodes (Richardson et al., 1995). They can be either personal interviews or self-administered surveys, distinct from telephone interviews, mail surveys, and on-line surveys, as they involve personal interaction between surveyors and respondents (Richardson et al., 1995; Schaller, 2005).

Online Surveys

Online surveys have advantages such as speed and easiness of data collection, low resource intensity in terms of budget, time and personnel, and automation of data input and handling, among others (Duffy, Smith, Terhanian, & Bremer, 2005). However, some disadvantages include the problem of skewed data given the fact that they are only available to people who have access to the internet, and incomplete or incorrect answers given the lack of an interviewer (Mae Sincero, 2012).

2.2.2 Sample Size

According to Richardson et al., (1995), a sample is defined as a collection of units, which is part of a larger population and is specially selected to represent the whole population. From this, four aspects are of particular importance:

- What the units, which comprise the sample, are – usually individuals
- What the target population, which the sample seeks to represent
- How large should the sample be
- How is the sample to be selected

Surveys aim to obtain representative data on a population. The information gathered from surveys is used to generalize findings from a drawn sample back to a population, within the limits of random error (Bartlett, Kotrlik, & Higgins, 2001). Defining a sample is a fundamental stage of surveying; the sample size is chosen to increase the possibility of uncovering a definite mean difference, which would also be statistically significant. In general, larger sample sizes increase the significance of survey results because they reflect the population's mean in a more reliable way (Puszczak, Fronczyk, & Urbański, 2013). Nonetheless, the sample size should be in accordance with the size of the population, and the availability of workforce to conduct the surveys. Therefore, the sample size should try to cover a maximum number of respondents in the available resources to get more accurate results from the survey (EMBARQ, n.d.).

In addition to the above, it is necessary to specify three criteria in order to determine the sample size:

I. The sampling error – or the level of precision –, which expresses the difference between the true, but unknown, value and the observed ones, if the survey were repeated numerous times (Schaller, 2005).
II. The confidence level, which refers to how often the average value of the observed attribute is within the chosen sampling error, if the survey were repeatedly done (Puszczak et al., 2013; Schaller, 2005).
III. The degree of variability in the main measured attributes, which applies to the distribution of attributes in the population. The more heterogeneous a population, the larger the sample size in order to reach an acceptable sampling error. Consequently, the more homogeneous a population, the smaller the sample size (Puszczak et al., 2013).

Based on the variables mentioned above, a confidence level of 95% is acceptable for most research (Bartlett et al., 2001), a proportion of 50% is often used when determining more conservative sample sizes as it indicates the maximum variability in a population (Puszczak et al., 2013); and a sampling error between ±3% to 10% is usually adequate considering the available resources in terms of budget, time, and personnel.

There are different ways to determine exact sample sizes. Some of these include using or conducting a census survey, referring to a sample size from a similar survey, relying on published tables, which provide sample sizes for a given combination of sampling error, confidence level and variability, or applying formulas to calculate sample sizes for different combinations of the variables described previously (Puszczak et al., 2013). For the present study, the use of formulas is the best option to find the correct sample size of the studied population – i.e. the total number of CP users. As the universe is unknown, a very large or infinite size is considered in order to obtain a conservative sample size.

Now, for estimating a proportion in large or infinite populations – e.g. the proportion of CT users that used to travel by car to their final destination before they decided to use the bicycle –, Cochran (1963) developed Equation 2.1:

$$n_0 = \frac{z^2 * p * (1 - p)}{e^2}$$

Equation 2.1 Cochran's formula for sample size for proportions. Source: (Puszczak et al., 2013)

Where,

- n_0 is the sample size
- Z is the abscissa of the normal curve that cuts off an area σ at the tails
- e is the acceptable sampling error
- p is the estimated proportion of an attribute[1] that is present in the population

However, sometimes the examined attributes are measured on an interval scale, where the mean represents a central tendency for an attribute – e.g. average distance traveled by bike to reach the transit station. In this case, Equation 2.1 is transformed into Equation 2.2:

$$n_0 = \frac{z^2 * \sigma^2}{e^2}$$

Equation 2.2 Cochran's formula for sample size for the mean. Source: (Puszczak et al., 2013)

Where,

- n_0 is the sample size
- Z is the abscissa of the normal curve that cuts off an area σ at the tails
- e is the acceptable sampling error

[1] Attribute can be understood as the indicator to be studied with the question to be asked.

- σ^2 is the variance of the attribute in the population

According to Puszczak et al. (2013), one important disadvantage of using Equation 2.2 is that a "good" estimate of the population variance is needed, but it is often not available – being the case of the current study. Moreover, when analyzing several attributes – also the case of the present study –, the sample size can vary widely from one attribute to another given the fact that each one is likely to have a different variance. Therefore, Equation 2.1 is frequently preferred.

Table 2.2 is an application of Cochran's Equation 2.1 and provides the sample sizes needed for different levels of precision at a 95% confidence level for various population sizes.

Table 2.2 Sample sizes needed for various populations at various levels of precision (with p equal to 50%). Source: (Forsyth, Agrawal, & Krizek, 2012)

	Margin of Error			
Population	±3%	±4%	±5%	±10%
2,000	696	462	323	92
5,000	880	536	357	95
10,000	965	566	370	96
20,000	1,014	583	377	96
50,000	1,045	593	382	96
100,000	1,058	597	383	96
500,000	1,065	600	384	96
1,000,000	1,066	600	384	96
5,000,000	1,067	600	384	96

On the other hand, for cases where the population size is small and known – e.g. CP users per station –, the following formula applies:

$$n_0 = \frac{N * z^2 * p * (1-p)}{e^2 * (N-1) + z^2 * p * (1-p)}$$

Equation 2.3 Formula for sample size for finite populations. Source: (Torres, Paz, & Salazar, 2006)

Where,

- n_0 is the sample size
- Z is the abscissa of the normal curve that cuts off an area σ at the tails
- e is the acceptable sampling error
- p is the estimated proportion of an attribute that is present in the population
- N is the size of the population

2.2.3 Sampling Methods

Since the objective of sampling is to obtain a small sample representative of the entire population, it is important to ensure that the sample is drawn with care to ensure that it is indeed representative. The accuracy of the estimation of parameters is dependent on the sampling being performed in an acceptable way. Usually, the only acceptable sampling methods are based on some form of random sampling, which entails the selection of units from a population by chance methods (Richardson et al., 1995).

There are many types of sampling methods, some of the most frequently encountered are:

- Simple random sampling, where each item in the population has the same probability of being selected as part of the sample as any other item (Barreiro & Puerto, 2001).
- Stratified random sampling, where, first, the population is broken into "strata," or groups, such people living in different socioeconomic neighborhoods, and second, a random sample is selected from each group (Richardson et al., 1995). Here, the population is divided into subgroups based on mutually exclusive criteria (Westfall, 2009).
- Cluster sampling, where the population being sampled is divided into clusters, and then a random sample is then taken from within one or more selected clusters. Here, instead of having homogeneous subgroups as in the stratified random sampling, a cluster is as heterogeneous as possible to match the population (Westfall, 2009).

Sampling Error and Bias Error

There are two distinct types of error, which occur in survey sampling and contribute to the measurement of error in sampled data when combined. The first of these errors is the already described sampling error, which arises simply because of dealing with a sample and not the total population. This error will always be present due to chance occurrences, however, it can be minimized by increasing the sample size, and it should not affect the expected values of parameter averages, but the variability around these averages (Richardson et al., 1995).

The second type of error is called sampling bias, it arises because of mistakes made in the selection of the sample, and it means that the data collected may not be accurate or represent the group (Taylor-Powell, 2009). This error is a systematic deviation of the value of a parameter obtained from a sample survey to its true population value. These differences include demographics, persons and trip characteristics, and are determined from comparison to supplement data, predominantly the census data (Nilufar, 2003).

While the concept of sampling error is based on obtaining differences in the value of survey statistics over replications when having different units of the sample and the same survey design, biases do not change over all possible replications; unlike sampling errors, bias is non-random in character (Nilufar, 2003). While sampling error only affects the variability of the average of the estimated parameter, sampling bias affects the value of the average itself and, therefore, is a more severe distortion of the sample survey results. Small sampling error results in precise estimates while small sampling bias results in accurate estimates (Richardson et al., 1995) – see Figure 2.4.

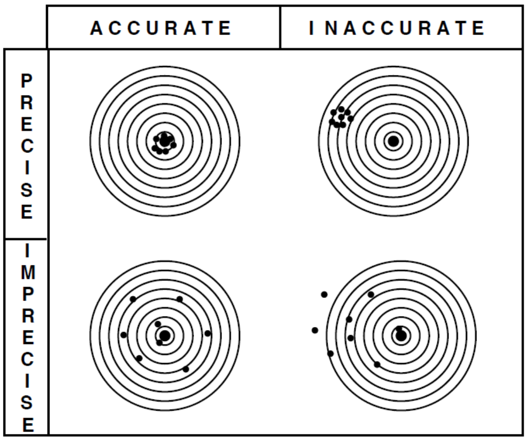

Figure 2.4 The distinction between Accuracy and Precision. Source: (Richardson et al., 1995)

The presence of 'bias' affects the quality of survey data. Unfortunately, this bias can be hard to detect, and its size – unlike that of random error – cannot be estimated (Nilufar, 2003). However, it can be virtually eliminated by careful attention to various aspects of sample survey design (Richardson et al., 1995), and by using weighting and expansion techniques.

Next chapter focuses on Bogotá and gives an overview of the mobility situation providing numbers and figures, as well as a characterization of the bicycle use in the city.

3. Bogotá

Bogotá D.C., the capital of Colombia, is one of the major metropolises of LAC and is the prime urban, political, administrative, commercial, industrial, and cultural center of the country (Wessels et al., 2012). In 2015, the city had approximately 7.9 million inhabitants according to projections from the census made in the year 2005 (DANE, 2011). It was home to 19% of the Colombian population (Wessels et al., 2012), and had a density equal to 16,600 inhabitants per square kilometer, making it one of the top ten most dense cities in the world (Carlosfelipe Pardo & Calderón, 2014). By the year 2050, the city and its metropolitan region[2] – see Figure 3.1– are expected to grow to a megacity – defined by the UN as large cities with a population of above 10 million – with an estimated population of more than 13 million inhabitants (Wessels et al., 2012).

Figure 3.1 Greater Bogotá: capital city and surrounding municipalities. Source: (Wessels et al., 2012)

[2] The metropolitan region includes the following municipalities: Bojacá, Cajicá, Chía, Cota, La Calera, Facatativá, Funza, Gachancipá, Madrid, Mosquera, Sibaté, Soacha, Sopó, Tabio, Tenjo, Tocancipá and Zipaquirá.

Figure 3.2 shows the evolution of Bogotá's urban expansion over the years and evidences its rapid expansion.

Figure 3.2 Urban expansion of Bogotá. Source: (Wessels et al., 2012)

Consequently, the vehicle fleet and motorization rate have also been increasing over the years (Gómez & Obando, 2014; Wessels et al., 2012). Even though compared to other LAC cities, Bogotá still has a low motorization rate – 100 automobiles and 50 motorcycles per one thousand inhabitants in 2007 (CAF, 2010; Wessels et al., 2012) –, it has had an important rise and is expected to increase even more in the following years – see Figure 3.3.

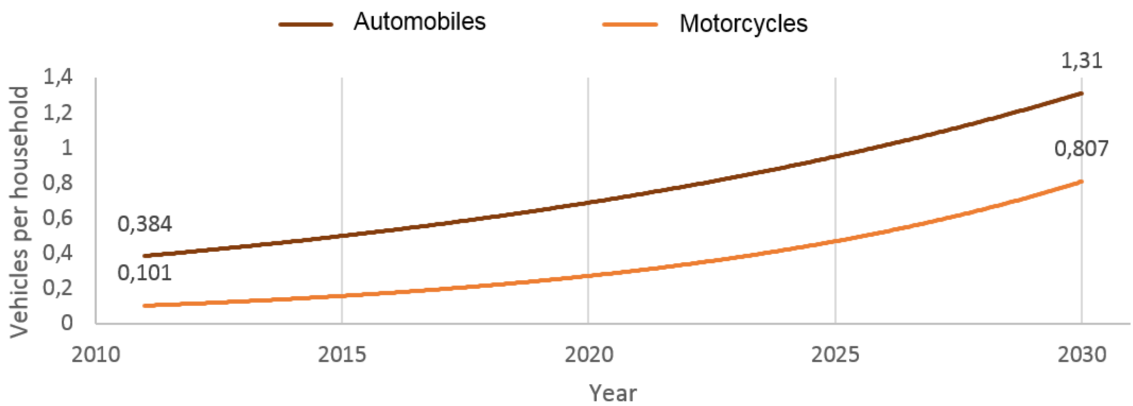

Figure 3.3 Projected number of vehicles per household in Bogotá. Source: (Gómez & Obando, 2014)

During the last decades, Bogotá's local authorities have established a more sustainable vision of the city, based on providing high-quality public space, promoting the use of NMT and PT, and building bicycle-friendly infrastructure throughout the city (Wessels et al., 2012). Nonetheless, a lot more is yet to be done in order to achieve Wessels et al. (2012)'s envisioned city for the year 2050, in which Bogotá becomes a "role model for sustainable urban development grounded on compact growth and polycentric, transit-oriented development" (Wessels et al., 2012, p. 12).

The following sections provide information about Bogotá's current situation in terms of its transportation systems and mobility statistics, as well as figures regarding CT integration so far in the city, and previous studies on the subject. This will help as a starting point from which improvements can be performed.

3.1 Mobility in Numbers and Figures

Since 1995 and approximately every 4-5 years, the District Department of Transportation (SDM for its name in Spanish) realizes a mobility survey to collect statistical information about the travel behavior of citizens – older than 5 years of age – of Bogotá and its metropolitan region. Furthermore, this survey is used to characterize and evaluate mobility in Greater Bogotá by building Origin-Destiny matrices of all the transport modes. These matrices consider the different times of the day and trip purposes, as well as the demographic characteristic of travelers.

This survey has become an important tool for planning, evaluating and defining policies, as well as for developing and implementing projects that seek to improve the citizen's quality of life (SDM, 2015). The survey's latest update was performed between March and August 2015. Two types of surveys were performed: household and intercept, for a total of 28,212 valid surveys, a 95% confidence interval, and a margin error of 0.73% for all the study area. The survey results are shown in this section.

By 2015, the population of Bogotá Metropolitan Region – from now on denoted as Greater Bogotá – is estimated in 9.1 million, where Bogotá city holds 7.9 million inhabitants. For the same year, 17.1 million trips were performed on a daily basis in Greater Bogotá. Table 3.1 shows the trip rate for the precedent years.

Table 3.1 Total trips per day in Greater Bogotá. Source: Own elaboration based on (SDM, 2015)

Year	Trips per day
1995	9.3 million
2005	9.5 million
2011	17.6 million
2015	17.1 million

Overall 36% of the population is younger than 25 years old and 10% is older than 65; whilst 53% are women and 47% men. 30% of the population have technical or professional education, 53% make part of the working force and 22% are studying (SDM, 2015).

In Colombia, the population is officially divided into six socioeconomic strata – *"estratos"* – to determine household utility costs and subsidies. These are:

1. Lowest
2. Low
3. Middle-low
4. Middle
5. Middle-high
6. High

According to the National Department of Statistics (DANE for its name in Spanish), the stratification is the mechanism with which it is possible to group people under similar social and economical characteristics, through an evaluation of the physical aspect of their place of residence, their immediate surroundings, and their urban or rural context (SDP, n.d.). It does not focus on the characteristics of the people nor the households, but on the external characteristics of the residences and the level of development of their environs. The stratification methodology is applied through the use of a software, however, the steps and calculation within the methodology are not available to the public.

Based on the mobility survey, Figure 3.4 shows the population distribution according to the socioeconomic strata:

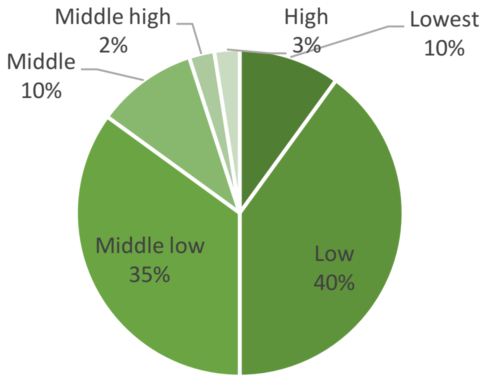

Figure 3.4 Socioeconomic strata distribution in Greater Bogotá. Source: Own elaboration based on (SDM, 2015). Note: Percentages are an approximation

3.1.1 Vehicle Fleet and Motorization Rate

Private, public and official service vehicles compose the vehicle fleet. By 2014, the total fleet had more than 2 million vehicles registered, from which 94% of the total corresponded to private vehicles (SDM, 2014d).

Figure 3.5 shows that registered vehicle fleet has been growing historically by more than 100,000 new vehicles year over year. This increase is especially notorious in the last five years, where factors such as population growth, higher spending power, and new job opportunities show evidence of being quite strong. This could bring as a result the migration of PT use to private transport (SDM, 2014d).

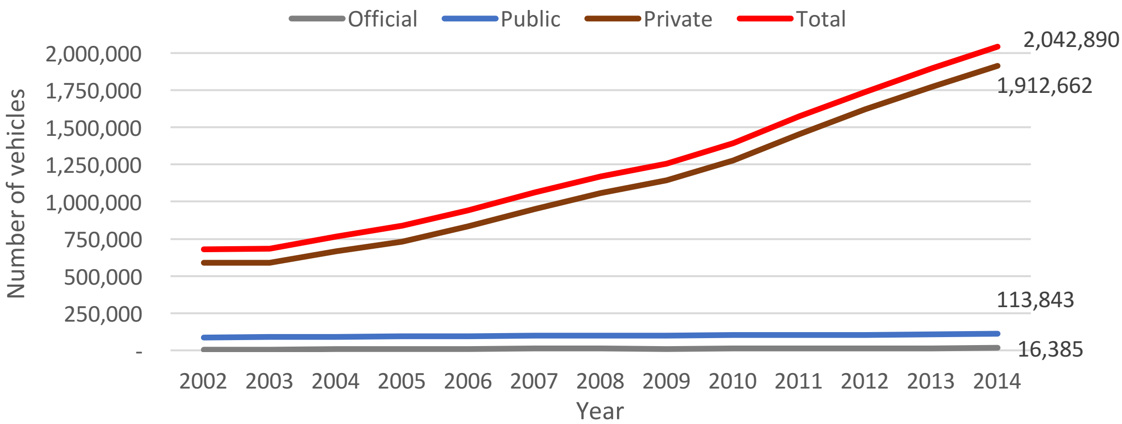

Figure 3.5 Historical growth of vehicle fleet in Bogotá. Source: Own elaboration based on (SDM, 2014d)

3.1.2 Mass Public Transport

The mass PT in Bogotá is composed by TM and the new bus zonal scheme called SITP. Additionally, it is still possible to find buses belonging to the old collective bus system (TPC for its name in Spanish), but it is expected to be extinguished and totally replaced by the SITP in the following years.

TransMilenio

The BRT system TM is composed of 11 trunk lines – 113 km – with segregated traffic (Transmilenio, 2014a), 125 regular stations, nine terminal stations with integration to feeder bus lines – *Portal 80*, *Portal Norte*, *Portal Usme*, *Portal Tunal*, *Portal Américas*, *Portal Suba*, *Portal Sur*, *Portal 20 de Julio*, *Portal Eldorado* –, and seven intermediate stations also with integration to feeder bus lines – *Granja-Cra 77*, *Avenida Cali*, B*anderas*, *Molinos*, *Calle 40 Sur*, *General Santander*, *Bicentenario*. In addition, the system has four stations in the municipality of Soacha, and a public transit preferential lane – with no physical segregation from other traffic – on the *Carrera 7* with TM buses. Figure 3.6 shows the system's map including the connections to other types of PT services – e.g. feeder lines, SITP, inter-municipal buses, etc. (SDM, 2015).

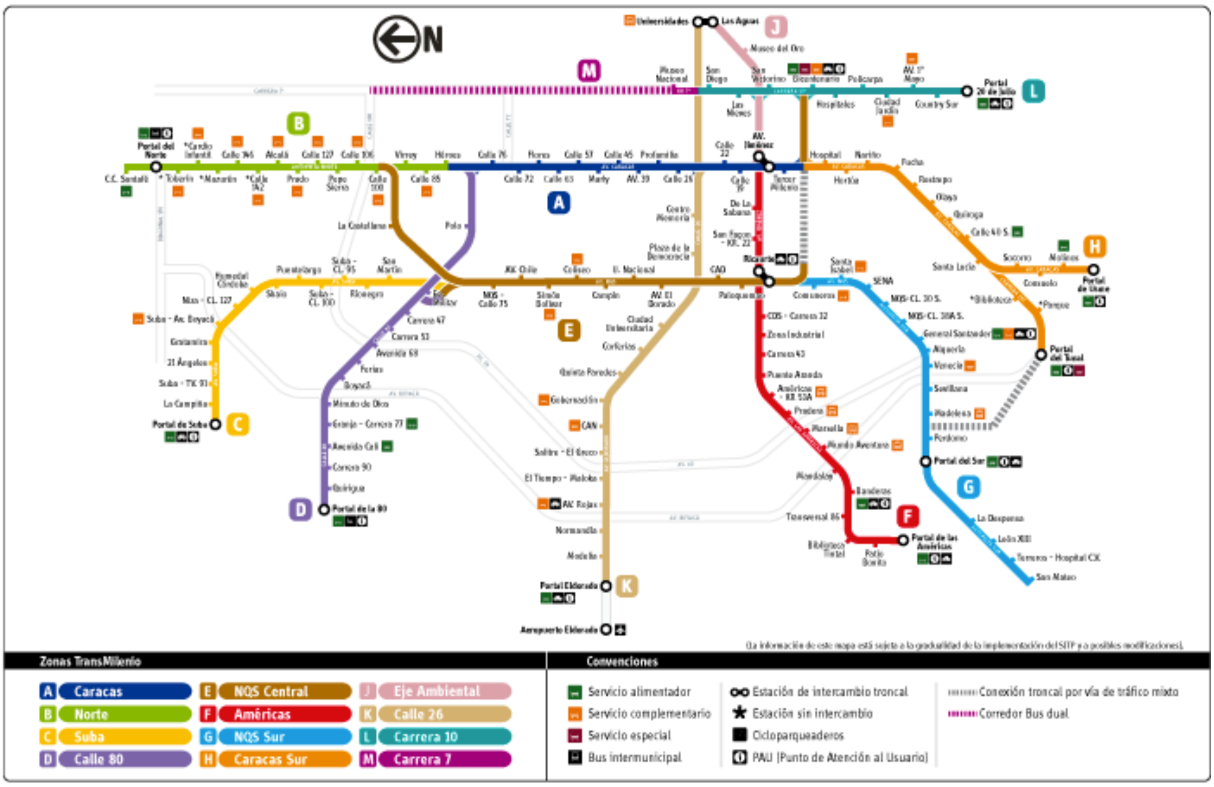

Figure 3.6 Map of TM system. Source: (Transmilenio, 2015b)

Since its beginning in 2000, the system has been implemented in Phases. Phase I started in 2000, then in 2003 Phase II was executed, and in 2012 Phase III was opened to the public.

Phase IV is expected to start construction in 2016. Table 3.2 shows the different phases and the trunk lines that belong to each phase.

Table 3.2 TM Phases and trunk lines. Source: Own elaboration based on (Transmilenio, 2014a)

Phase I	**Phase II**	**Phase III**
(2000)	(2003)	(2012)
Calle 80	*Avenida Americas*	*Calle 26*
Avenida Caracas	*NQS Central*	*Carrera 10a*
Avenida Caracas Sur	*NQS Sur*	
Autopista Norte	*Avenida Suba*	
	Eje Ambiental	

Integrated Public Transport System – SITP

The SITP is the new PT structure in Bogotá; it was designed to optimize the service level and guarantee a better quality of transportation in the city. The local government and the citizenship are working together to gradually implement and learn new behavioral mechanisms to achieve a more organized, safe, efficient, economic and accessible transport system (SITP, 2016).

The main objectives of the SITP are:

- Have a 100% coverage of the PT service supply in the city.
- Integrate the operation and fare among the different types of PT services.
- Improve road safety and accessibility by technologically adjusting the bus fleet.

The system is a transformation of the old collective PT scheme into a new arrangement composed by:

- TM: red buses
- Feeder lines: green buses
- Urban: blue buses
- Complementary: orange buses
- Special services: red buses

Figure 3.7 shows the different existing buses, fleet size, the number of trips per day and average speed.

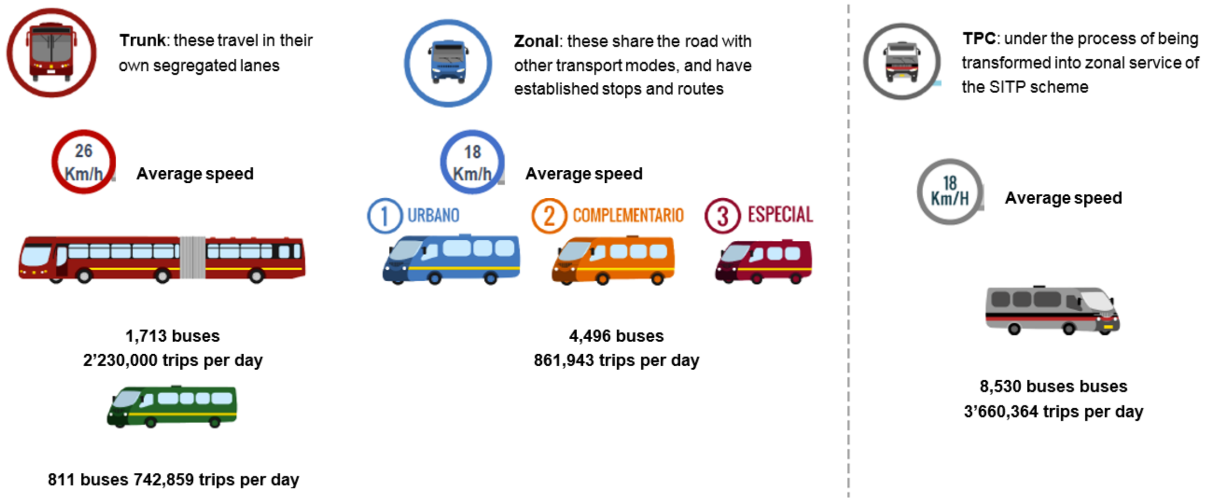

Figure 3.7 SITP scheme. Source: (CCB, 2015). Note: Data from August 2013

3.1.3 Transport Demand Management

The city has already applied some Transport Demand Management (TDM) strategies to improve mobility in Bogotá and is planning to implement new measures to encourage citizens to shift from MIT towards other modes such as PT and NMT. This section describes each of these measures giving an overview on how the local government is planning the city of tomorrow.

License Plate Restriction

Due to traffic congestion and the number of cars in the city, the city implemented in 1998 a License Plate Restriction scheme – better known as *"Pico y Placa"* – as a transport demand management measure to mitigate traffic congestion during weekdays' peak hours. This measure restricts the circulation of 50% of the private vehicle fleet during peak hours – 6:00 to 8:30 and 15:00 to 19:30 – depending on the vehicle's plate last digit and the day of the month. Therefore, if the last plate number is even, the vehicle is restricted on all even days of the month and if it is odd the vehicle is restricted on all odd days. (SDM, 2015).

The driving restriction also applies to taxis, but under a different organization. The restriction reduces the available fleet by approximately 20% every day and it is applied from Monday to Saturday from 5:30 to 21:00 (SDM, 2015).

Congestion Charging

The capital district administration has presented the to the Council different proposals to implement a Congestion Charging Scheme in high congested areas within Bogotá city (SDM, 2014a).

This area would initially cover 9 km^2 – 2.1% – of the city's urban area going from East to West from *Carrera 7ma* to *Autopista Norte*, and from North to South from *Calle 116* to *Calle 72* – see Figure 3.8. The fare for entering the area was established in COP 6,500 – approximately EUR 1.75[3].

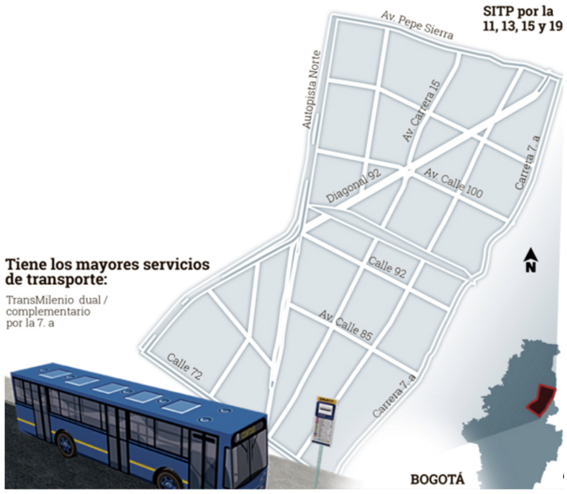

Figure 3.8 Charging congestion area. Source: (El Tiempo, 2015)

The measure seeks to improve the city's mobility conditions whilst generating financial resources that will be invested in other projects to recover the environment. Moreover, it poses the possibility of improving PT circulation by restricting the traffic of MIT and urban freight transport, among others (SDM, 2014a).

The expected results include a 14% decrease in car use in an area where 80% of the vehicles have only one passenger, and economic resources of approximately EUR 24,300 that will contribute to the enhancement of the PT, bicycle supply, and the environment (El Tiempo, 2015).

Car-free Days

In 2000, the city of Bogotá voted by popular consultation for the creation of a Car-free day once a year. Ever since this day is celebrated in February and all private vehicles are restricted to transit Bogotá's roads.

This day has the objective of making *"Bogotanos"* think about their excessive use of MIT, and showing the advantages of using sustainable transport modes, such as PT and NMT in terms of air quality, public health and road safety (El Espectador, 2015a).

[3] Exchange rate: EUR 1 = COP 3,700. February 3rd, 2015.

The day starts at 05:00 and finishes at 19:30; additional bike lanes are enabled around the city, the whole PT fleet runs the streets, and bicycle activists organize leisure activities. In 2000 approximately 600,000 private vehicles were kept out of the roads, today this number has gone up to 1.5 million vehicles (El Espectador, 2015a). In 2016, the Car-free day was celebrated on February 4th; this time, motorcycles were also included in the restriction.

3.1.4 Modal Split

When considering the modal share, it is important to acknowledge that a person may use different transport modes to perform one trip, reason why the survey considers two types of indicators:

i. The number of times one specific transport mode is used in one trip – referred to as stages.
ii. The predominant transport mode in which the trip is done.

In this sense, if a person walks more than 3 minutes to access a feeder bus to reach a TM station and then takes a taxi to finish the trip, the trip will be counted as performed by TM, but the stages will consider walking, feeder bus lines, TM and taxi (SDM, 2015).

When comparing 2015 with 2011, the number of stages have increased 12%, which means that people have become more intermodal; however, during the same period, the number of trips has declined 3% – see Table 3.3. The greatest variation is seen in motorcycle trips that have greatly increased both in the number of trips and stages. Walking has plummeted in the number of trips, but has kept a similar performance in the number of stages. Car trips show a low increase in the number of stages and trips while mass PT – considered as the sum of TM, TPC-SITP, feeder bus lines, and inter-municipal services – and the bicycle have shown important boosts in both aspects.

Table 3.3 Number of stages and trips by mode of transport in Greater Bogotá and variations between the years 2011 and 2015. Source: Own elaboration based on (SDM, 2015)

Transport Mode	***Stages***			***Trips***		
	2011	***2015***	***Change (%)***	***2011***	***2015***	***Change (%)***
Walking	16,784,121	15,392,058	**-8%**	8,136,778	5,554,810	**-32%**
TPC/SITP	3,890,558	4,934,092	**27%**	3,602,986	3,820,451	**6%**
TM	1,682,840	3,049,395	**81%**	1,494,082	2,289,893	**53%**
Car	1,848,111	2,130,601	**15%**	1,818,499	1,851,479	**2%**
Feeder bus	863,782	1,325,592	**53%**	90,669	221,646	**144%**

Inter-municipal	254,841	355,088	**39%**	109,104	185,482	**70%**
Motorcycle	412,674	1,021,982	**148%**	410,613	819,135	**99%**
Bicycle	614,713	908,768	**48%**	611,343	784,502	**28%**
Taxi	674,932	900,831	**33%**	610,243	719,202	**18%**
Special	482,078	800,062	**66%**	467,236	663,196	**42%**
Informal	222,534	182,251	**-18%**	153,357	97,310	**-37%**
Other	136,508	124,138	**-9%**	106,151	95,164	**-10%**
Total	27,867,692	31,124,858	**12%**	17,611,061	17,102,270	**-3%**

While in 2011 79% of the trips by mass PT were performed at one stage, in 2015 this value decreased to 67%. More than 90% of the MIT – car, taxi, and motorcycle – trips were performed at one stage in 2011, but in 2015, these percentages decreased more than 10%. The same trend is observed with NMT modes, where the average trip in one stage decreased from 50% in 2011 to 39% in 2015. These results confirm the evidence that people are becoming more intermodal and are now combining different transport modes to travel.

Figure 3.9 shows the transport mode share in Greater Bogotá in 2015. The most popular transport mode is mass PT with a 38% share, followed by NMT with 37%; MIT with 20% of the share.

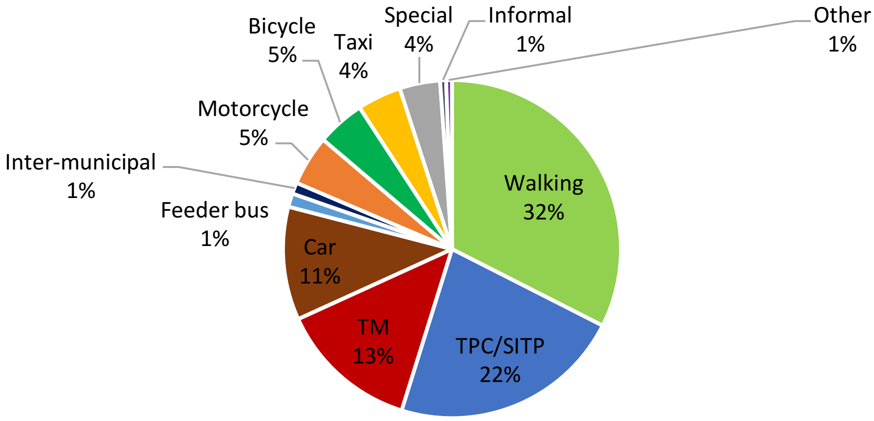

Figure 3.9 Mode share in Greater Bogotá. Source: Own elaboration based on (SDM, 2015)

Table 3.4 shows the transport mode distribution in Greater Bogotá in 2015 considering only walking trips equal or longer than 15 min. In 2015 the total number of trips was 14,625,180, whereas in 2011 it was 12,207,947 (SDM, 2015), showing that the total number of trips performed in the city and metropolitan region have actually increased. Compared to the percentages from above, results show that the number of walking trips shorter than 15 minutes has plummeted in more than 50% while those longer or equal to 15 minutes have risen in a 13%.

Table 3.4 Mode share in Greater Bogotá in the years 2015 and 2011, only considering walking trips equal or longer than 15 minutes. Source: Own elaboration based on (SDM, 2015)

Transport Mode	***Trips***		
	2011	***2015***	***Change (%)***
Walking	2,733,664	3,077,720	**13%**
TPC/SITP	3,602,986	3,820,451	**6%**
TM	1,494,082	2,289,893	**53%**
Car	1,818,499	1,851,479	**2%**
Feeder bus	90,669	221,646	**144%**
Inter-municipal	109,104	185,482	**70%**
Motorcycle	410,613	819,135	**99%**
Bicycle	611,343	784,502	**28%**
Taxi	610,243	719,202	**18%**
Special	467,236	663,196	**42%**
Informal	153,357	97,310	**-37%**
Other	106,151	95,164	**-10%**
Total	12,207,947	14,625,180	**20%**

The shares of mass PT and private MIT have increased to 45% and 23%, respectively, whilst the share of NMT have decreased to 26% – see Figure 3.10

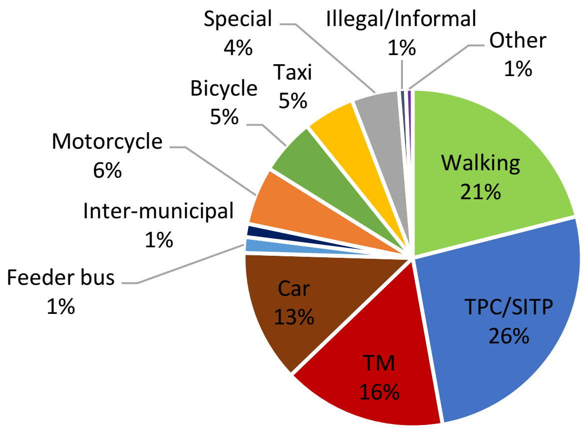

Figure 3.10 Mode share in Greater Bogotá only considering walking trips equal or longer than 15 minutes. Source: Own elaboration based on (SDM, 2015)

By socioeconomic strata, PT plays a very important role in the lower classes – Lowest, Low, and Middle-low –; while in the higher groups – Middle, Middle-high, and High – the car and the taxi take the lead. Unlike 2011 where NMT represented an important share for the lower strata, in 2015, there is no longer a big differentiation by socioeconomic group (SDM, 2015).

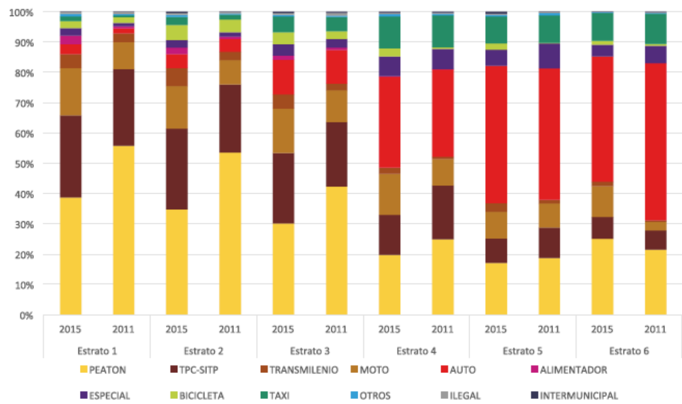

Figure 3.11 Mode share in Greater Bogotá by socioeconomic strata for the years 2015 and 2011. Source: (SDM, 2015). Note: The lowest socioeconomic group corresponds to 1 and the highest to 6

3.1.5 Travel Time

In terms of travel time per trip, Greater Bogotá has an average of 53 minutes and Bogotá city of 56 minutes. The largest travel times are registered on transport modes that involve walking and vehicle change or transfers, whereas the lowest travel times are related to the use of NMT modes most probably because they include shorter trips compared to motorized trips (SDM, 2015).

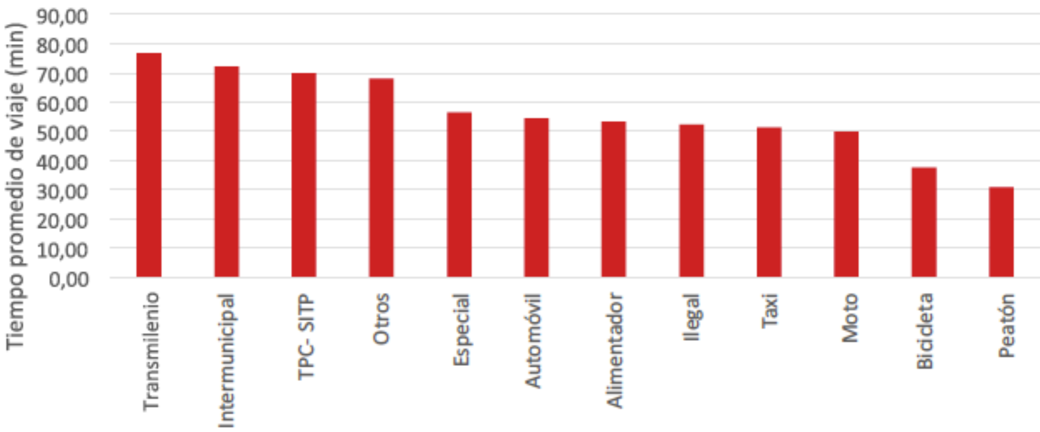

Figure 3.12 Average travel time by transport mode in Grater Bogotá. Source: (SDM, 2015)

3.2 Characterization of Bicycle Use in Bogotá

This section is divided into four parts that attempt to characterize the bicycle as a transport mode in Bogotá. The first part is the historical background of bicycle use in the city, the second shows how the different governmental institutions are involved in the management of bicycles in the city, the third describes the infrastructure and complimentary services supply currently found in the city, and the fourth part depicts the demand for the bicycle use.

3.2.1 Historical Background

"Bogotá is often considered a bike-friendly city due to its extensive network of bikeways, which has grown since the late 1990s, and the recreational *"Ciclovía"* on Sundays and holidays in existence since 1974" (Verma, López, & Pardo, 2015, p. 16).

Table 3.5 shows how user groups and their motivations have used bicycles in Bogotá since the late 1800s.

Table 3.5 Historical Summary of main phases of bicycle use. Source: Own elaboration based on (Verma et al., 2015)

Historical Moment	Bicycle Users	Bicycle Uses	Perception of Bicycles
1800's arrival of the bicycle	High-income men and women	Transport, recreation	High status
1903 arrival of the automobile	High-class children primarily	Recreation for children	Bicycles are for children
1950 *"Vuelta a Colombia"*	Low-income people	Sport	Vehicle of the poor (upper-class perception)

1974 implementation of *"Cliclovía"*	Everyone	Sport, recreation	Vehicles for everyone's recreation
1998 first mass bikeway construction	Mostly low-income people, but increasingly high-income as well	Transport	Increasingly positive as a mode of transport
2000 first Car-free Day	Everyone	Transport	Increasingly positive as a mode of transport

The city's bicycle-friendly reputation had its boost during the mayoral administrations of Enrique Peñalosa (1998-2000) and Antanas Mockus (1995-1997, 2001-2003). By this time of history, the city was already well known for inventing the Sunday *"Ciclovía"*, in which 121 kilometers of the city's primary roads are closed to motorized traffic for the exclusive use of people on foot, bikes, skateboards, rollerblades, etc. for recreational purposes. It was until this late 1990's boom period, that the governments of Peñalosa and, to a lesser extent, Mockus built more than three hundred kilometers of bicycle lanes, developed alongside TM and other public space interventions, with the main objective of promoting bicycles as a daily mode of transportation (Verma et al., 2015). Today, the current mayor of the city, Peñalosa, seeks to duplicate the percentage of bicycle ridership not only with infrastructure, but rather with the execution of comprehensive cycle-inclusion policies.

3.2.2 Institutional Scheme and Arrangement

There are different stakeholders involved in the formulation, implementation and follow-up of all the policies related to the use of the bicycle as a mode of transport. These stakeholders can be categorized into three groups according to their tasks: policy generation, infrastructure management, and demand management.

The policy making group are all the entities involved in the formulation and evaluation of policies in general, which are translated into plans that establish objectives and strategic lines of action to address each sector's needs. Policies related to the use of the bicycle as a transport mode are geared to improve the infrastructure supply, properly manage the existing demand and promote the use of this mode. The main entities involved in the formulation of such policies are the District Department of Planning (SDP for its name in Spanish), the Secretariat of Government and the SDM (SDG, 2013).

The infrastructure management group includes entities that are aligned with the overall objectives of the government and are responsible for implementing the policies through specific programs and projects aimed at building and managing the supply of infrastructure. The most important entities involved in this group are the Urban Development Institute (IDU for its name in Spanish), Transmilenio SA, and the SDM. Some other stakeholders involved to a lesser extent are the Administrative Department of Public Space Defense (DADEP for its name in Spanish), Bogotá's Water and Sewer Company (EAAB for its name in Spanish) and the Institute for Social Economy (IPES for its name in Spanish) (SDG, 2013).

Finally, the demand management group includes those entities in charge of implementing demand management policies. The programs and projects of this group of actors are directed primarily at ensuring adequate mechanisms for regulation, control, security, participation and training of bicycle users. Within these entities are the SDM, the District Institute of Recreation and Sport (IDRD for its name in Spanish), the Bogotá's Metropolitan Police (MEBOG) and the Road Safety Fund Corporation (CFPV for its name in Spanish) (SDG, 2013).

Table 3.6 shows a scheme of all the governmental institutions involved in the use of the bicycle as a transport mode, and another group of actors that participate in the different tasks of the three groups previously described including citizens, activists, suppliers and the private sector. According to SDG (2013), one of the major problems faced by all these stakeholders is the lack of coordination amongst them. Even though each entity has the faculties to perform the activities they were entitled to, the decentralization of some initiatives generates synchronization and coordination problems. Additionally, the communication channel between the transversal stakeholders and the three groups is currently very weak and diffuse making it very difficult to have a unified image of what is needed and wanted for the bicycle (SDG, 2013).

Table 3.6 Stakeholders involved in the use of the bicycle as a transport mode in Bogotá. Source: Own elaboration based on (SDG, 2013)

Policy Making	Infrastructure Management	Demand Management
SDP	IDU	IDRD
SDM	Transmilenio SA	SDM
Secretariat of Government	SDM	CFPV
	DADEP	MEBOG
	EAAB	
	IPES	
Transversal Actors		
Citizen associations and Activists	Suppliers and Commerce	Private investors

3.2.3 Characterization of the Supply

For this section, mainly one source of information was used apart from the 2015 mobility survey performed by the SMD. This source is a survey conducted to 1,110 people via web during one month by the consulting firm Steer Davis Gleave (SDG) in 2013 with the support of Despacio.

Now, the supply is described as follows in terms of provision of bicycle lanes – roads and intersections –, parking facilities – urban furniture, at mass transport, and private facilities –, and user information – road signals and means of user communication.

Bicycle Lanes

By the end of 2014, Bogotá had 392 km of bicycle lanes (CCB & Uniandes, 2015). These lanes can be classified according to their location on the road: 62% are located on sidewalks, 21% along canals or inside parks, 11% on street separators, 4% on boardwalks, and 2% on streets (Verma et al., 2015). The whole network is accessible – distance within 500 m from every home to a bikeway – to 57% of the city's total area. Figure 3.13 depicts the current network map and the road enabled for Sunday's *"Ciclovía"*.

Figure 3.13 Bicycle network in Bogotá. Source: (Alcaldía Mayor de Bogotá, 2015)

According to SDG (2013), more than 80% of the infrastructure is in very good and good conditions, and only 4% is in not so good and bad conditions. Figure 3.14 shows how the bikeway infrastructure in Bogotá is classified according to their actual condition.

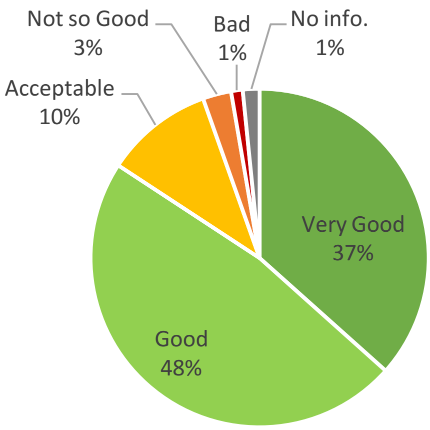

Figure 3.14 Current conditions of bicycle lane infrastructure in Bogotá. Source: (SDG, 2013)

The bicycle network has approximately 1,066 intersections (SDG, 2013) between bicycle lanes and motorized transport. In terms of road safety, most of the incidents between bicycle users and motorized traffic occur right at intersections (SDG, 2013) due to the lack of an adequate design that protects pedestrians and cyclists. SDG (2013) identified risk factors at the intersections with the highest number of incidents. Some of the factors were the no segregation of modes at intersections, invasion of the public space by street vendors and automobiles, no clear priority road signals, interrupted bike lanes near the intersection and unattractive and insecure flyovers amongst others (SDG, 2013).

Bicycle Parking Facilities

In Bogotá, three kinds of bicycle parking facilities can be found: urban furniture, at mass transport, and private facilities.

Urban Furniture

First, urban furniture refers to those parking facilities located in the public space accessible to everyone. The two structures mostly used are the *Wave* and the *Toast* – Figure 3.15 –, both options are not recommended due to security and capacity reasons according to Despacio & ITDP (2013); SDG (2013). According to SDG (2013), the city has currently a very low coverage of this type of parking spaces with only one-fourth of the local authorities, district hospitals and other district entities having them. The lack of urban furniture in the city is a big disincentive for people to use the bicycle as a transport mode (SDG, 2013).

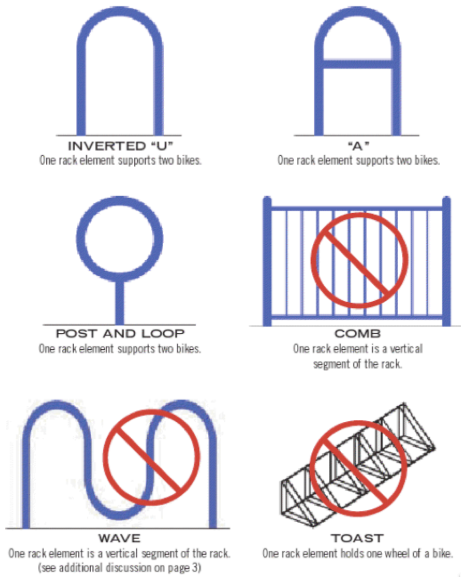

Figure 3.15 Types of urban furniture bicycle parking facilities. Source: (SDG, 2013)

Facilities at PT Stations

Second, there are bicycle parking facilities integrated to the BRT system TM. These parking facilities are known as *"Puntos de Encuentro"* (PEs)[4] and *"Cicloparqueaderos"* (CPs). Currently, there are four PEs and 13 CPs around the city – see Figure 3.16.

On the one hand, PEs were built by the IDU and the IPES is the service supplier; they are free of charge, have surveillance and are opened every day from 6:00 to 20:00. On the other hand, CPs are operated by TM, are also free of charge, have surveillance and have the same opening hours as the BRT system: Monday to Saturday from 5:00 to 23:00 and Sundays and Public holidays from 6:00 to 22:00. Most CPs have an access system where users have to register with an ID card, a photograph, and the bicycle's characteristics in order to get a barcode printed out for the bike. This barcode records every access and egress the user makes to the CP. PEs have no automatic access system, therefore, the information about the user, bicycle, and access/egress times must be written down every time in a notebook.

[4] For the purposes of the present study, no distinction between PEs and CPs it to be done, therefore all bicycle parking facilities found in Figure 3.16 are to be referred to as CPs. Distinctions between the two types will only be done according to the service supplier: IPES or TM.

Figure 3.16 Bicycle parking facilities integrated to the TM network. Source: (CCB & Uniandes, 2015)

Today, the 17 parking facilities found next to TM stations have a total capacity of 2,532 bicycles. The first four facilities managed by IPES were opened in the year 2000, then the decision to build a bicycle parking area in *Portal Américas* during TM's Phase II was primarily made to reduce the use of feeder buses – which are generally overcrowded and are expensive to operate (Verma et al., 2015). Figure 3.17 shows the capacity of each CP according to their opening year.

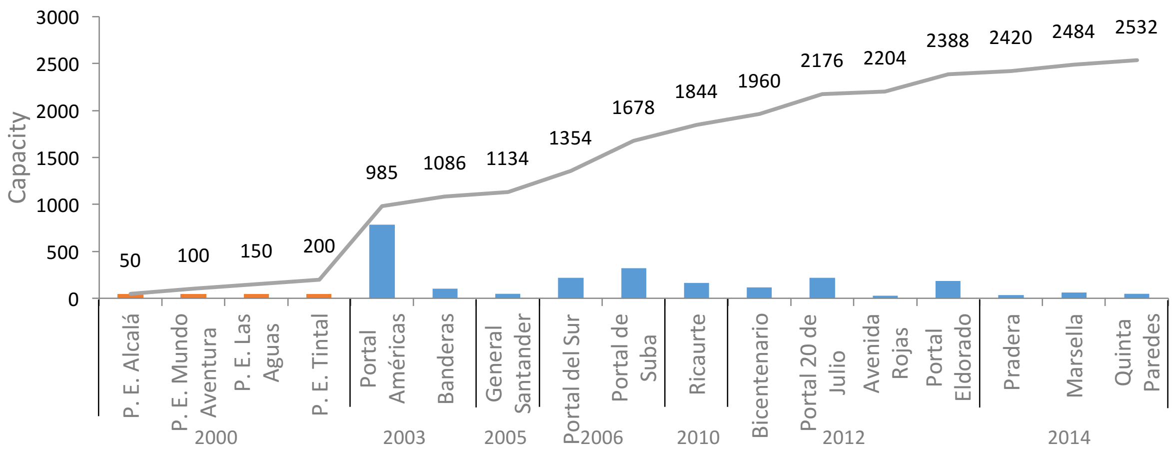

Figure 3.17 Capacity and cumulative capacity of CPs. Source: Own elaboration based on (Verma et al., 2015)

Figure 3.18 shows the average occupancy rate of the CPs; in some areas, there is evidence of oversaturation while others barely have some users. According to Despacio (2014), this is because bicycle parking spaces in stations are allotted based on available space as opposed to demand. Besides, no demand studies have been performed before the construction of these parking facilities (Verma et al., 2015).

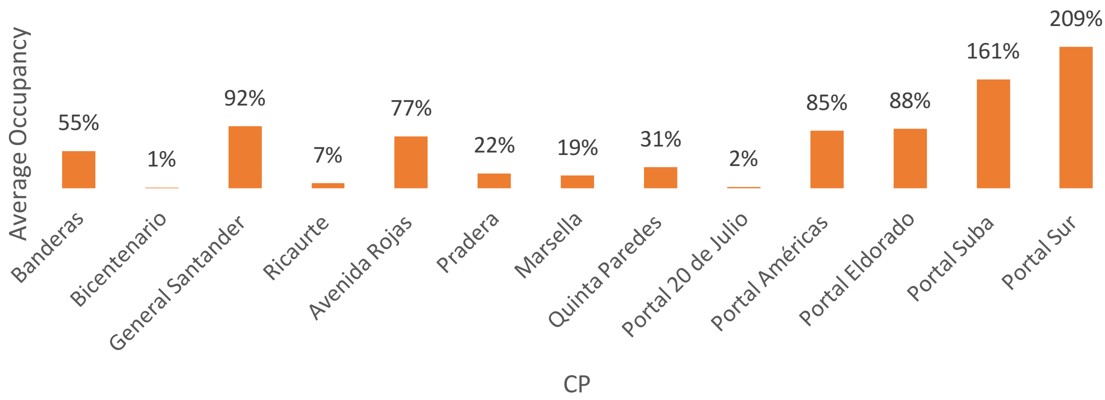

Figure 3.18 Average occupancy of TM's CPs. Source: (Transmilenio, 2014b). Note: Data from 2015

Nowadays, it is also possible to carry folding bicycles – see Figure 3.19 – inside the Zonal and TM buses. However, since this measure is very recent, there is no data available about this.

Figure 3.19 Folding bicycle. Source: (Transmilenio, 2015a)

Private Facilities

Third and last, there are bicycle parking facilities in private areas such as universities, malls, companies, governmental institutions, supermarkets, libraries and private car parking lots. This type of facilities conform the biggest part of the supply in Bogotá (SDG, 2013) and are found almost around the whole city thanks to two normative documents – Decree 034 of 2006 and Decree 236 of 2006 – that state the requirement of a minimum number of bicycle parking spaces for every car parking space.

User Information

The user information scheme enables an interface for communicating rules and availability of the supply so that the infrastructure is properly utilized. With such an information scheme, current users can plan their trip and make decisions, whilst potential users are informed on how to use the bicycle as a mode of transport.

On the one hand, horizontal and vertical road signals indicate the infrastructure operation rules and give users information that assists them throughout the trip. In Bogotá, road signals on bike lanes are taken from the Manual for Road Signals regulated by the Ministry of Transport. There are also normative and technical documents that describe the requirements for road signals' design and depict behavioral norms for each road actor. These include the Bicycle Lane Design Manual, Master Bicycle Lane Plan, National Code of Road Transport, Road Signals Manual, and Practical Guide for Urban Pedestrian Mobility (SDG, 2013).

Figure 3.20 shows the conditions in which the horizontal and vertical road signals on bike lanes are in Bogotá. According to SDG (2013), only 44% of the horizontal and 38% of the vertical road signals are in excellent and good conditions, whereas more than 50% of the road signals are in acceptable, bad and very bad conditions.

Figure 3.20 Classification of the horizontal and vertical bicycle lane signals in Bogotá by their condition. Source: (SDG, 2013)

On the other side, there are educational and outreach mechanisms that not only seek to inform cyclists about their expected behavior when using the bicycle, but also promote the mode and attract potential users. First, there are analog and digital communication media, and then there are campaigns to promote the use of the bicycle and to educate on road safety.

In Bogotá, there are to some extent posters, flyers, manuals, guides, and maps at PT stations or stops; most of this information can also be found online. The SDM has displayed several strategies, projects and campaigns for promoting the bicycle and educating on road safety through analog and digital media (SDM, 2014d). According to SDG (2013), the lack of analog information jeopardizes road safety because, for example, people have to make decisions about which mode to use and which route to take without having full knowledge of all their options with the bicycle. The inconvenience with online information is that people not always have access to the internet and also sometimes the user doesn't know this information is even available online (SDG, 2013).

One example of a pro-bicycle campaign is *"Pedalea por Bogotá"*, which has generated optimism that "Bogotá will continue its trajectory as a bicycle-friendly city" (Verma et al., 2015, p. 21). There are also other promotion and awareness campaigns led by the SDM that intend to achieve the following (SDM, 2015):

- Create a bicycle use trend
- Incentivize cycling to work and to school
- Encourage bicycle users to wear and use road safety elements
- Consolidate a sense of belonging, tolerance, responsibility and solidarity values among different modes.

Figure 3.21 Bicycle promotion and awareness campaigns. Source: (SDM, 2015)

Moreover, two programs have been developed to encourage young people to go by bike to school: *"Al colegio en bici"* and *"Semilleros de la bici"*. With these programs, more than 4,800 students in more 50 public schools have been benefited and now go to school by bike every day (CCB & Uniandes, 2015).

Regarding the bicycle parking facilities and bike integration to TM, during the fieldwork, there was found only one poster proving information of which TM stations have bicycle parking facilities exist and their capacity – see Figure 3.22.

Figure 3.22 Poster of the CPs at TM stations. Source: Own photo

3.2.4 Characterization of the Demand

Bicycle Trip Attributes

Figure 3.23 shows users' motivations when mobilizing by bicycle. More than 50% of the trips are commuting trips for going to work or to study, followed by other reasons that include shopping, leisure, visiting someone and running errands with almost a 30% of participation, and picking up or leaving someone with a 13%. These results do not include the option "going back home", which corresponds to 45% of the total.

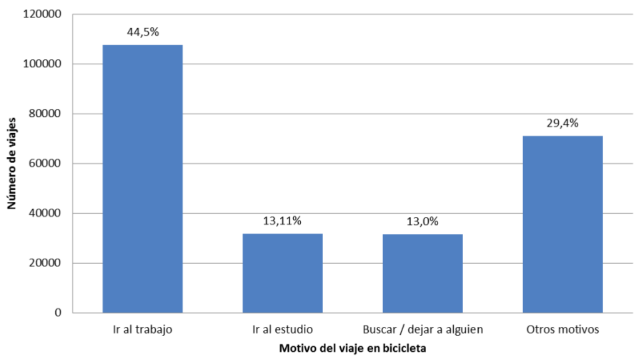

Figure 3.23 Number of bicycle trips by purpose excluding "going back home". Source: (SDG, 2013)

Figure 3.24 shows trip duration; results show that 80% of the trips last 30 minutes or less. Assuming an average speed by bike of 15 km/h, it is possible to calculate a probable distance of 7.5 km (SDG, 2013).

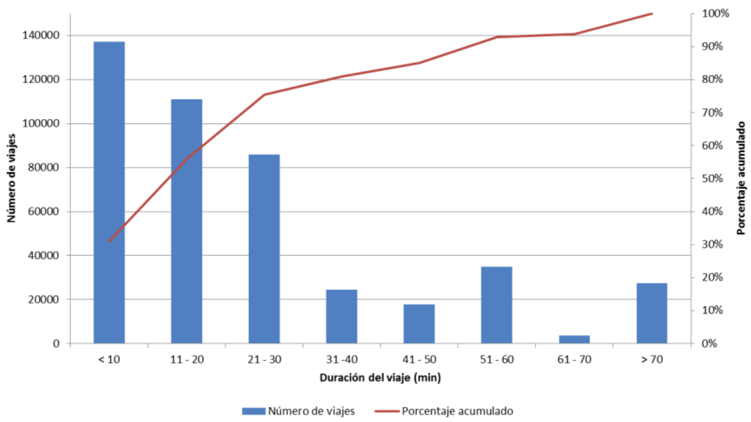

Figure 3.24 Bicycle trip duration. Source: (SDG, 2013)

Attributes of Bicycle Users

Only about one-fourth of the trips by bike are performed by women while the rest are performed by men (Verma et al., 2015). Figure 3.25 shows the bicycle trip distribution by age. Results indicate that the age groups with the highest level of bicycle use are the ones between 25 and

44 years old, comprising around 57% of all bicycle trips. People under 44 years old account for 85% of all trips.

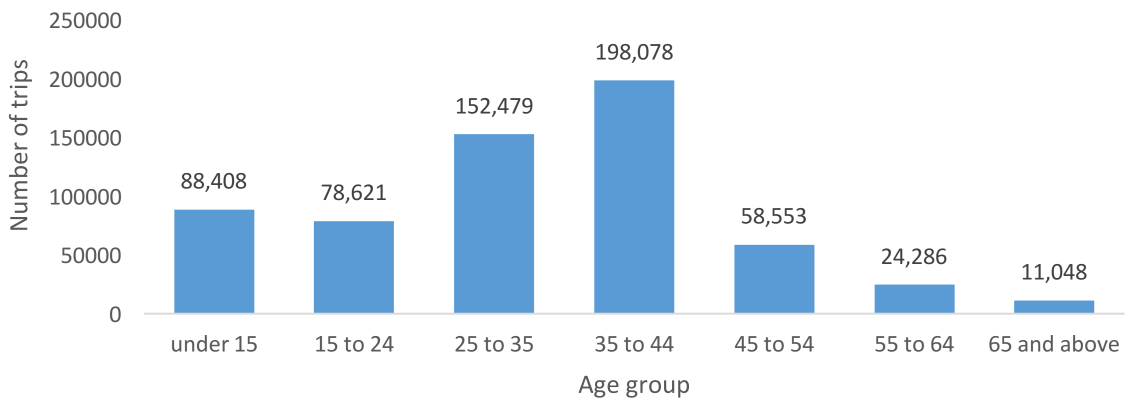

Figure 3.25 Bicycle trips distribution by age group. Source: Own elaboration based on (Verma et al., 2015)

Per capita, the three lowest socioeconomic groups make the most bicycle trips and comprise around 80% of all bicycle trips in the city. The majority are in the low-middle and lower groups, as seen in Figure 3.26. According to Despacio (2014), there are several possible explanations for the differences across socioeconomic strata: cycling's relatively low cost makes it an attractive transport mode within the low-income communities. However, bicycle use in the lowest socioeconomic group is not as high as the other because the poorest neighborhoods are located on the southern edge of Bogotá, and bicycle trips to jobs, for example, are longer than for the other classes.

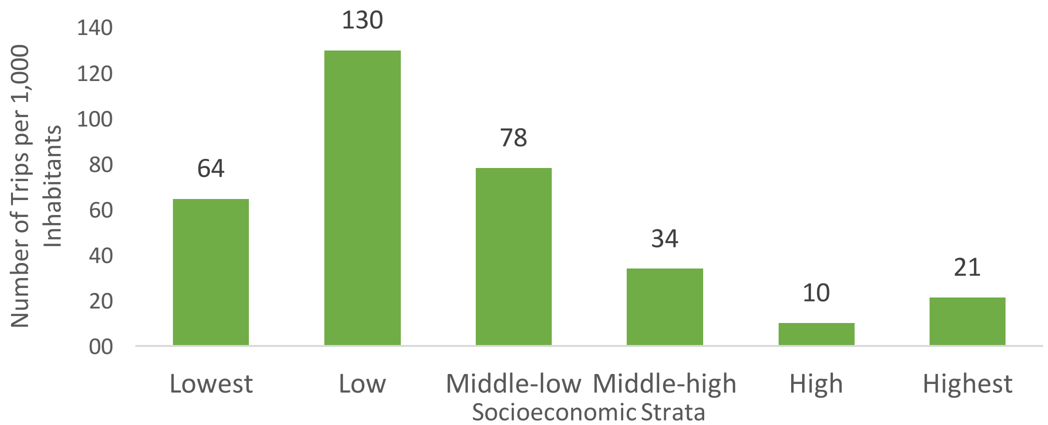

Figure 3.26 Bicycle trips distribution by socioeconomic strata. Source: Own elaboration based on (Verma et al., 2015)

Perceptions of Bicycle Users

In order to understand why *"Bogotanos"* choose to use – or not to use – bicycles for recreation and transport purposes, Despacio (2014) conducted a survey to 229 people; 25% in five different locations at the *"Ciclovía"* and the rest via web. The results of this survey were used as exploratory information rather than statistically valid conclusions because of the small sample (Verma et al., 2015).

The main positive perception of cycling in Bogotá has to do with the possibility of doing exercise while riding a bicycle, followed by trip duration. The ranking of positive factors of cycling is shown in Table 3.7.

Table 3.7 Perceived positive factors of using the bicycle. Source: Own elaboration based on (Verma et al., 2015)

Rank	Positive Factor
1	Fitness
2	Health
3	Trip duration
4	Environment
5	Reliability
6	Trip cost

In the 2015 mobility survey, non-bicycle users were asked to mention the reason why they do not use bikes as a mode of transport. The most popular reason was not having a bicycle. For women, the second most important reason was the fear of being assaulted while riding a bicycle, whereas for men it is the long distances they would need to cover to their destination. Only 7% of the people are not interested in cycling, indicating that there is a big potential for the share of bicycle use to increase. It is important to mention that only 1.5% of the people have inconveniences with the weather (SDM, 2015) – see Figure 3.27.

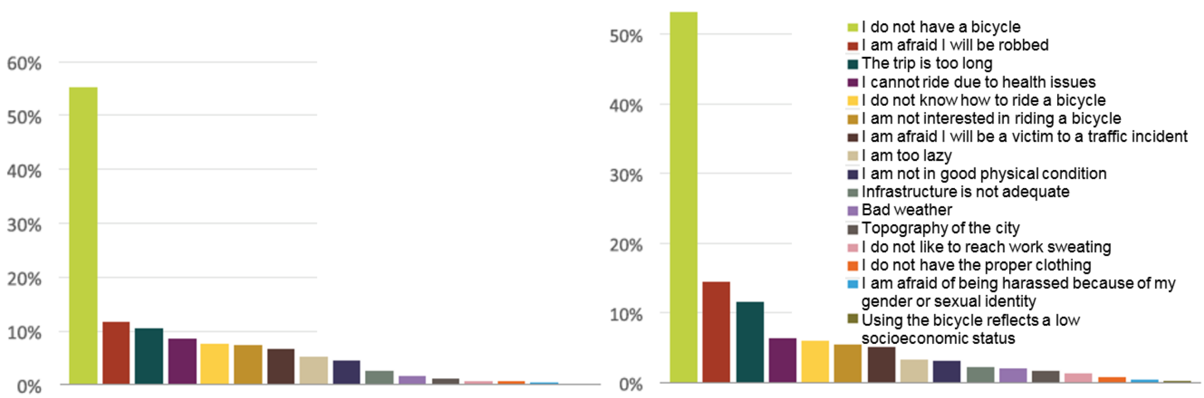

Figure 3.27 Women (left) and men's (right) reasons for not using the bicycle. Source: (SDM, 2015)

According to (Verma et al., 2015), to make cycling a mainstream transport mode – i.e., with a modal share of above 10% – several issues need to be addressed. Figure 3.28 presents some factors that might lead to increased rates of cycling according to respondents. An expanded bike network is key to raise bicycle use in the city, followed by a public bicycle system and free bicycle parking at TM stations. Improving and integrating infrastructure and transport modes should, therefore, be a central element of bicycle planning.

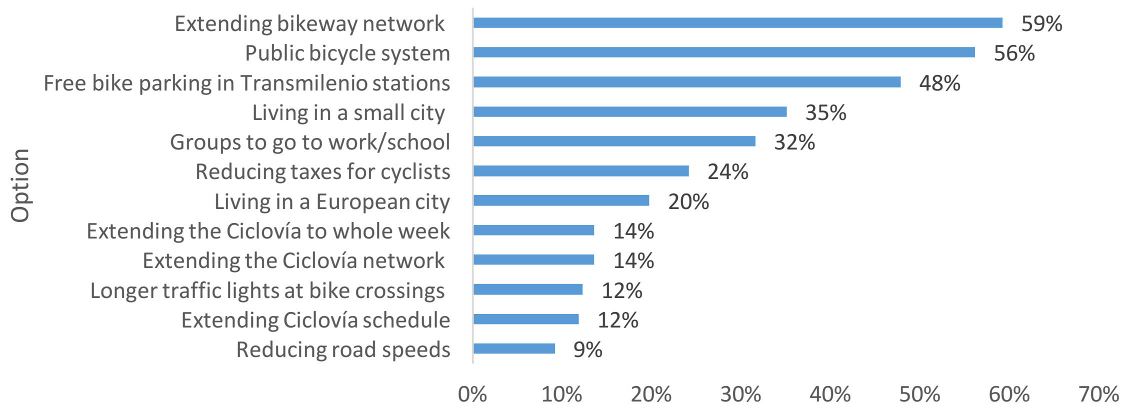

Figure 3.28 What would make you more likely to ride a bike? Source: Own elaboration based on (Verma et al., 2015)

3.3 Bike-sharing System

In March 2015, the contract for the implementation of the first BSS in Bogotá was given to a Chinese-Colombian consortium (El Espectador, 2015b). The objectives of the system are (SDM, 2014c):

- To generate an inter-modality system among the different transport modes in the city.
- To promote sustainable means of transport.
- To expand transport coverage in the city through NMT modes.

Eleven zones with the most bicycle demand and adequate urban environment were identified as potential implementation zones. Then, two zones were selected for the implementation of Phase I, and six additional zones were chosen for Phase II as an expansion stage – see Figure 3.29. Zone 1 will be implemented in 18 months and Zone 2 in 24 months after Zone 1 is finished (SDM, 2014b).

Figure 3.29 Phase I and II of the BSS implementation. Source: (El Espectador, 2015b)

Until today, the consortium in charge of implementing the BSS in Bogotá has had problems with the initiation of the project and has failed to comply with the deadlines and deliverables.

3.4 Previous Studies on CT Integration in Bogotá

Very little has been done so far in terms of studies on CT integration in Bogotá. The level of integration so far – discussed in the previous section – is a product of TM's opportunity to take advantage of the available space at or close to stations. Nonetheless, in 2013, an exploratory study with intercept surveys to CT users was carried out at two stations of the TM system. This section is an overview of the study results and findings and gives evidence of the starting point from which the present study was elaborated.

According to Elsner (2015), the objective of the study was to improve the little knowledge about the connectivity between the bicycle and TM. The study attempted to describe the current situation and identify problems and relevant topics to have a better CT integration.

The study focused on generating specific knowledge about the following topics:

- The number of daily users of the TM bicycle parking facilities and the distance they cover.
- The different motivations people have for using the bicycle to reach TM stations.
- The CPs usage patterns.
- CP users' perceptions of the current situation.
- Measures to improve bike-and-ride.

The study's fieldwork was executed in two TM: *Portal Américas* and *Avenida Rojas*, and the surveys were asked for two weeks during June 2015. At the beginning, a 36-question questionnaire was designed, and then it was shortened to make it faster to answer – see

Appendix 13.1. In total 57 people in *Portal de las Américas* and 12 people in *Avenida Rojas* were surveyed. Results and conclusions were withdrawn in an exploratory manner[5] (Elsner, 2015), these include:

- More than two-thirds of the people have been using CPs for more than one year.
- The big majority use the facility every day.
- The main motivation for using the bicycle as a feeder mode is that it is fast, especially when compared to the feeder bus lines, which have very low frequencies and are always very busy.
- People use feeder bus lines as an alternate mode when not using the bicycle.
- The average travel distance by bike to a CP is 2.7 km.
- The majority of people have a very positive perception of the bicycle parking service provided and the design of the facility.
- Only one-third of the people is satisfied with the current bicycle infrastructure and traffic calming zones.
- People rate as very important to improve the infrastructure conditions to reach TM stations.
- Efficiency problems during peak hours, security aspects of the CPs, and additional services inside the bicycle parking facility are the most important factors to improve.

The survey conducted by Elsner (2015) was used as a starting point for deciding which questions to use in the survey here performed. Moreover, the information about the origins of the 57 surveyed people was included in the average travel distance calculations performed in the present study. Therefore, the sample size for the estimation of this later parameter is larger and, thus, the sampling error is smaller – see Section 4 for further explanations.

The following chapter presents the methodology for the elaboration of the empirical part of the study.

[5] No bias corrections nor expansion factors were applied to the answers before doing calculations.

4. Methodology

In order to understand the concepts behind CT integration, to assess the current bike-and-ride situation in Bogotá, and evidence the potential of improvement, both a theoretical and an empirical investigation were carried out.

The theoretical investigation was based on research and literature review on the concept of CT integration, case studies of cities with a successful implementation, and a summary of the collection methods used for gathering information about CT users. Moreover, an overview of the current situation in Bogotá considering not only the level of CT integration existing today in the city, but also previous studies performed on the subject was also made.

The empirical investigation was based mainly on the elaboration of intercept surveys in different TM stations with bicycle parking facilities. An online survey was performed as well to complement the results from the intercept surveys and to consider other not-visited TM stations.

The main purpose of the survey was to characterize and describe the use of the bicycle in Bogotá as a PT feeder mode and analyze findings in qualitative and quantitative ways. The main aspects to be analyzed with the survey are the following:

- Average distance people travel by bicycle to the TM stations
- Modal shift from other modes to the integrated use of bicycle and TM
- Time savings due to modal shift from other modes to the use of bicycle and TM
- People's perception about the current level of CT integration
- People's rating of the different options for improvement of the current level of CT integration

The population studied in this empirical investigation are CT users in Bogotá who bike with a certain frequency – at least once a week – to a TM station, park their bicycles in the CP and continue their journey by TM to their destination. For the intercept surveys, this requisite was controlled by asking only people entering or leaving the CPs at the TM stations and asking them how often they used the facility – see Figure 4.1 –; for the online surveys by having a first question asking if the person was a frequent CP user – at least once per week.

Figure 4.1 Entrance to bicycle parking facilities. Source: (Transmilenio, 2015a)

The following sections focus on describing the process for obtaining the sample size and error, selecting the CPs to survey, and other aspects related to the surveying process and correction of bias.

4.1 Sample Size and Error

Given that the population size is unknown and in order to be conservative, a very large or infinite population was assumed and a 95% confidence level was taken. Now, to determine which margin of error or level of precision to use, it was considered the fact that the larger the sample size, the higher the precision to make conclusions about a population. However, Figure 4.2 evidences that the improvement in accuracy is minimal for larger sample sizes, i.e. the gains of precision of estimates are not directly proportional to the increases in sample size, therefore, gaining more accuracy is relatively slower when the sample size increases (Puszczak et al., 2013).

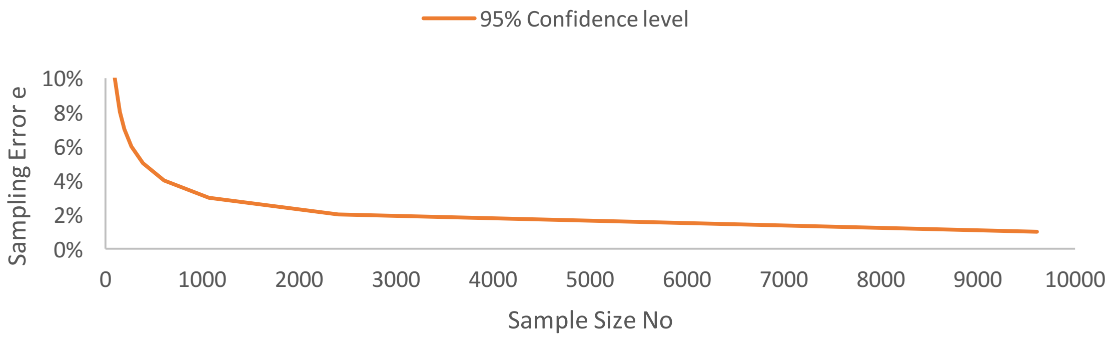

Figure 4.2 Dependence of sampling error on sample size with a margin of sampling error calculated for infinite populations. Source: Own elaboration based on (Puszczak et al., 2013)

In practice, the most relevant factor that limits a sample size is the cost of the study or the marginal cost of precision (Puszczak et al., 2013). According to Table 2.2, in order to have a ±5% sampling error and a 95% confidence level, it would have been necessary to have a sample size equal to 384. However, given the time, budget and personnel restrictions of the study as well as the nonresponses of people, it was possible to perform 205 surveys, which translates in the end to a sampling error equal to ±6.8% under the same 95% confidence interval.

In addition, since the data obtained form Elsner's (2015) study summarized in Section 3.4 was taken into account for the average travel distance calculations, the sample size for the estimation of this specific parameter was expanded to 274, the sampling error was reduced to ±5.9%, and the geographical bias was reduced – bias error and expansion factors are further discussed in Section 4.5.

4.2 Selection of CPs for the Intercept Surveys

Bogotá city was selected as the study area. However, given the limited resources, it was necessary to select only a few TM stations with bicycle parking facilities to perform the survey and then apply expansion factors to analyze the whole area of study.

For the selection of the CPs to be surveyed, the map of Bogotá was divided according to its predominant socioeconomic strata and all the bicycle parking facilities at the TM stations were geographically located – see Figure 4.3.

From Figure 4.3 it is was possible to have an initial idea of the possible CPs to be selected – e.g., *Alcalá* as it is the only station with access to Middle-high and High socioeconomic strata. However, additional information about the amount of users of the CP and the type of TM station was also considered to make the final decision. From Figure 4.3 it was also possible to identify that there are no CPs covering the lowest socioeconomic strata, therefore, it is expected to have missing information from this group.

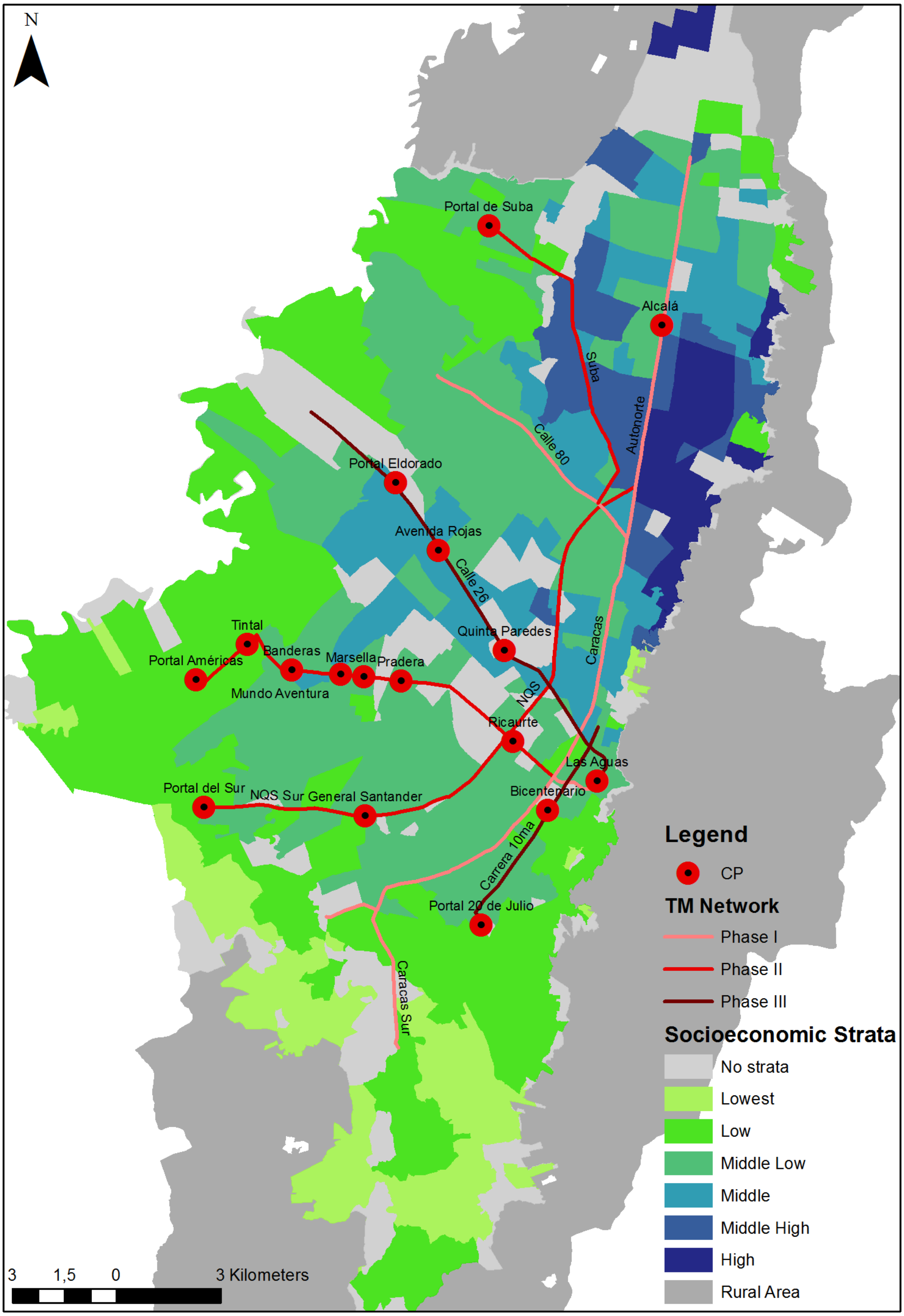

Figure 4.3 Map of Bogotá by socioeconomic strata and localization of CP at TM stations. Source: Own elaboration based on data provided by Despacio (2015). Note: The areas without any strata classification belong to industrial areas.

The following characteristics were used as criteria for selecting the bicycle parking to be surveyed and Table 4.1 summarizes them:

- CP average occupancy rate with data from 2015
- TM phase
- Type of TM station: simple, intermediate, of transference, or terminal
- Bicycle parking service supplier: TM or IPES

Table 4.1 Bicycle Parking Characteristics. Source: Own elaboration based on (Transmilenio, 2014b) and (CCB & Uniandes, 2015). *Estimation based on visits and interviews with personnel

Bicycle Parking Facility	Capacity	Average CP users/day	Occupancy Rate	TM Phase	Type of Station	Service Supplier
Alcalá	70	Over 70	Over 100%*	I	Simple	IPES
Avenida Rojas	104	80	77%	III	Intermediate	TM
Banderas	101	56	55%	II	Intermediate	TM
Tintal	50	No info.	No info.	II	Simple	IPES
Bicentenario	116	2	1%	III	Intermediate	TM
General Santander	48	44	92%	II	Intermediate	TM
Las Aguas	50	No info.	No info.	I	Transference	IPES
Marsella	64	12	19%	II	Simple	TM
Mundo Aventura	50	No info.	No info.	II	Simple	IPES
Portal 20 de Julio	216	5	2%	III	Terminal	TM
Portal Américas	785	670	85%	II	Terminal	TM
Portal de Suba	324	521	161%	II	Terminal	TM

Portal del Sur	220	460	209%	II	Terminal	TM
Portal Eldorado	332	293	88%	III	Terminal	TM
Pradera	32	7	22%	II	Simple	TM
Quinta Paredes	48	15	31%	III	Simple	TM
Ricaurte	165	12	7%	II	Transference	TM

After studying the attributes mentioned above, three stations were finally chosen as study area: *Alcalá*, *Avenida Rojas*, and *Portal de Suba*. *Alcalá* was chosen due to its high occupation rate; for the fact that it is managed by IPES and because it has access to Middle-high and High socioeconomic strata. *Avenida Rojas* was selected due to its high occupation rate and because it makes part of Phase III of TM. Finally, *Portal de Suba* was selected because of its high occupation rate and for being a terminal station. *Portal del Sur* and *General Santander* were also considered as potential stations for the study area, but for logistic reasons they were not included in the end.

4.2.1 Alcalá

Figure 4.4 Alcalá TM station. Source: (Transmilenio, 2015a)

The TM station of *Alcalá* is part of the *Troncal Autonorte* from TM's Phase I. The CP is located on the northeast side of the station outside the system's paid zone to also allow cyclists that are not traveling then by TM to use the facility. The socioeconomic groups surrounding the station are Middle-low, Middle, Middle-high and High. The CP has a total capacity of 70 bicycles, is equipped with hooks and racks for securing the bikes with a lock, and has a few lockers for users to leave their helmets and other gear inside.

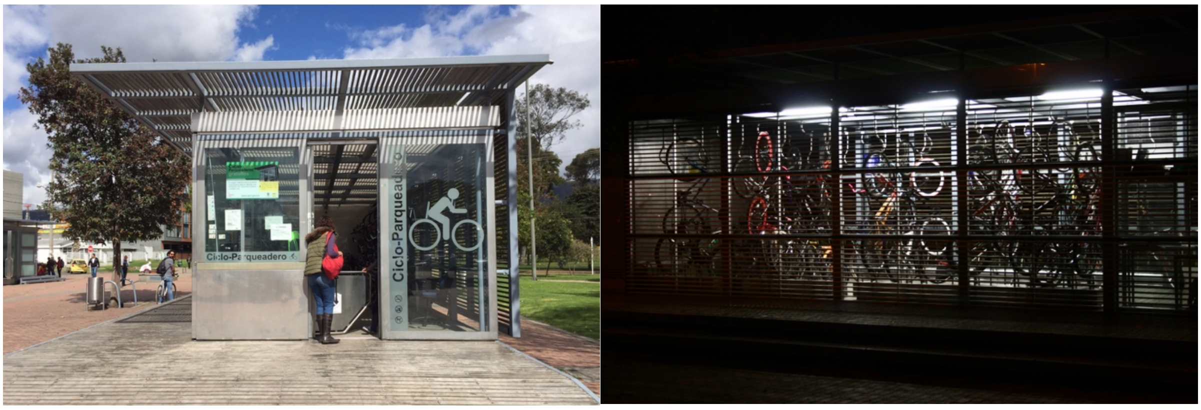

Figure 4.5 Bicycle parking facility at Alcalá

There are no extra services provided inside the CP. Nonetheless, as shown in Figure 4.6, just outside the facility people have toilets, small convenience stores, and an information point from the police.

Figure 4.6 Additional services at Alcalá

From several visits performed and a small interview with the CP's security personnel, it was possible to estimate an average occupancy rate of over 100%. The facility is opened every day from 6:00 to 20:00 and it is usually fully occupied by 9:00. This has become an important issue for CP users coming after 9:00 because, if they do not find available spaces for their bicycles, they must drive back home as there are no other facilities nearby. Moreover, people complain that the CP closes too early, sometimes they are not able to arrive on time and are forced to leave the bicycle overnight.

The access/egress door is not automatic and the registration process is done manually using the user's ID card and identifying the bicycle by color. People must bring their own lock for securing the bicycle, and the facility is not responsible if the accessories left attached to the bicycle – e.g. lights, bells, helmet, etc. – are lost or stolen. For picking up the bicycle the user must show again the ID card, the color of the bicycle is checked, and the owner must give a signature as a prove of having picked up the bicycle.

According to the guards, there are always between 10 and 20 bicycle left overnight affecting the overall capacity of the CP – see Figure 4.5. Lately, in order to partially solve the capacity problem and to prevent people from leaving their bicycles indefinitely in the CP, it is mandatory to pick up the bicycle the same day it is left in the CP. If the bicycle is left overnight, the owners has to bring a letter from the IPES authorizing the collection of the bicycle. This new policy has become a problem for those who use the bicycle for the last mile part of the trip and it is also a disincentive for using the CP as sometimes people change their routine and are not able to pick up their bicycle the same day.

When considering the infrastructure surrounding the CP, there are bicycle lanes that connect with the station, although there is not enough information and road signals showing where the bicycle parking is found. Street lighting is decent and there are always security guards walking around the area. According to the guards' reports, no bicycle has ever been stolen so far, but sometimes bicycle accessories have been lost.

Figure 4.7 Alcalá's surrounding areas

4.2.2 Avenida Rojas

Figure 4.8 Avenida Rojas TM station. Source: (Transmilenio, 2015a)

The TM station of *Avenida Rojas* is part of the *Troncal Calle 26* from TM's Phase III and has a CP located inside the system's paid zone with the same opening hours as TM: from 4:30 to 23:00. The socioeconomic groups surrounding the station are Middle-low and Middle. The CP has a total capacity of 104 bicycles, an average occupancy rate equal to 77% (Transmilenio, 2014b), and is equipped with hooks and racks for securing the bikes with a lock. When the facility is more than 50% full, it can be quite challenging for users to park their bikes because of the reduced available space – see Figure 4.9. No additional services are offered inside the facility nor in its surrounding areas. Furthermore, the CP has no roof to protect the bicycles against the weather.

Figure 4.9 Bicycle parking facility in Avenida Rojas

The access/egress door is automatic and it is only possible to enter by paying TM's ticket; the registration and collection procedures are performed in the same manner as in *Alcalá* station. People must bring their own lock for securing the bicycle and the facility is not responsible for the loss of accessories. In this facility, it is possible to leave bicycles overnight, however, the security guards are told to recommend users to collect the bicycles the same day in order to always have available space. Nevertheless, according to the security personnel, there are always between 20 and 30 bicycles left overnight affecting the overall capacity of the CP.

In terms of the surrounding infrastructure, there is a bicycle lane with adequate road signals on the *Avenida Eldorado* that connects with the station – see Figure 4.8. The bike lane also has sufficient lighting along the way, except for the tunnels that can still be too dark for cyclists at night.

4.2.3 Portal de Suba

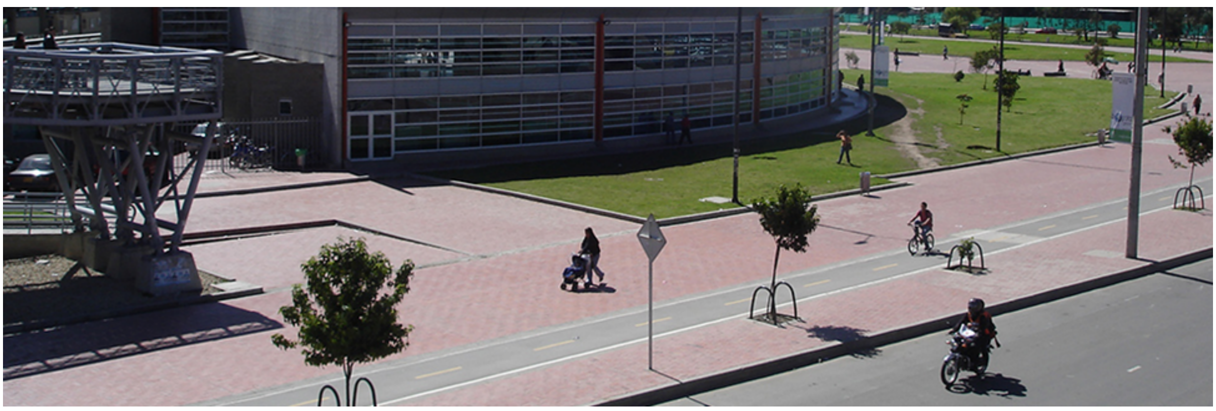

Figure 4.10 Portal de Suba TM station. Source: (Transmilenio, 2015a)

The TM station of *Portal de Suba* is part of the *Troncal Suba* from TM's Phase II and has a CP located inside the system's paid zone as in *Avenida Rojas* station. The socioeconomic groups surrounding the station are Low and Middle-low. The CP is equipped with racks for securing the bikes with a lock and has a total capacity of 324 bicycles. The occupation rate of this CP is 161% (Transmilenio, 2014b) making it diccicult for CP users to park their bikes.

The facility does not offer any additional services, however, inside the TM station, toilets can be found and, as in *Alcalá*, it is possible to find small food and drinks stands just outside the station – see Figure 4.12.

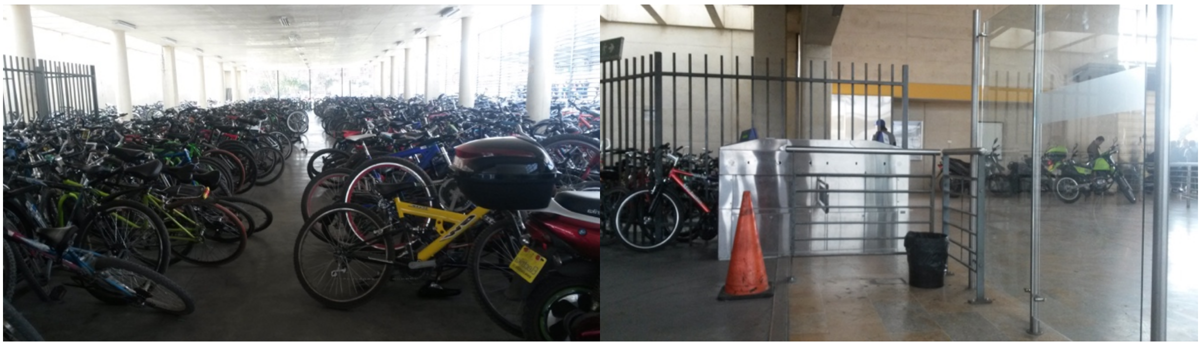

Figure 4.11 Bicycle parking facility in Portal de Suba

As in *Avenida Rojas*, the access/egress door is automatic and it is only possible to enter by paying TM's ticket – see Figure 4.11. Given the high volume of people using the facility, long queues are formed during peak hours generating important losses of time. This issue has become a major disincentive for doing bike-and-ride, CP users have already complained about this matter, but TM has not given any response.

In this facility a machine[6] and software are used for registering CP users and their bicycles and for dropping off and picking up the bicycles every time. The first time a person brings a bicycle, an ID must be presented, the color of the bicycle is noted and a picture of both the person and the bicycle is taken. All this information is entered into the server and a barcode is printed and placed on the bicycle. Every entry and exit are registered using this barcode and only the person appearing in the picture is authorized to collect the bicycle.

According to the guards, there are always between 50 and 70 bicycles left overnight every day, issue that has become a major problem for the CP's capacity. Lately, bicycles are parked without any order and sometimes it is not possible to lock them to the racks, so people place them wherever there is free space. There are no cases of stolen bikes so far, but sometimes users complain because accessories are lost, but, as in the other CPs, the facility does not respond for any loss.

[6] No picture of the machine is shown as it was forbidden.

Regarding the infrastructure surrounding the CP, there is not enough information nor road signals showing where the facility is located. Moreover, there are only a few kilometers of bicycle lanes connecting to the station and street lighting is very poor. With respect to security, there are always guards watching the area.

Figure 4.12 Portal de Suba's surrounding areas

4.3 Sampling

For the present study, as the population in the city of Bogotá is geographically distributed according to their socioeconomic strata, and the CPs are located in different zones within this distribution, it was necessary to use the stratified random sampling method for selecting the units that would represent the entire population as explained in Section 2.2.3.

After choosing the CPs that would form the study area, the random sampling method was applied in order to select the bicycle parking users to intercept and survey.

4.4 Surveying

The survey was designed based on previous knowledge and the work performed by Elsner (2015). Questions were selected according to the following sections:

i. Demographic characteristics
ii. Trip characteristics
iii. Rating of the current situation
iv. Rating of the improvement options

In the end, the questionnaire consisted of 19 questions – Appendix 13.2 –, and it was designed to last approximately 5 minutes. There were no open questions, most of them were multiple choice, and a few were rating and ranking questions. In the last part of the questionnaire people were given some minutes to express their concerns or additional comments with respect to the bicycle parking facility.

An internet-based survey was considered as a second method for asking CT users. It did not only allow to expand the sample size, but also helped to reach people who use other CPs different from the ones visited and, thus, reduce the geographical bias. The questionnaire was the same used in the intercept survey and was developed using a free online survey software called *SurveyMonkey*. The link to it was distributed to different bicycle activist groups in Bogotá, who answered and helped to share the questionnaire. Social media such as Facebook and Twitter were also used for sharing the survey.

4.5 Bias

Weighting and expansion techniques are measures to reduce bias in survey samples. In order to identify the weighting or expansion factors to be used, Transmilenio (2015) was asked to provide information about the gender, age and socioeconomic strata of all the CPs users ever registered in their system – not all of the CPs have registration systems, therefore, some of this information is lost.

After making this request, it was only possible to obtain information about the socioeconomic strata distribution of the CP users. Even though the socioeconomic distribution of all the registered users does not necessarily correspond to the distribution of the actual frequent users, it was the only information available to make a comparison between the surveyed sample and the population. Table 4.2 shows the socioeconomic distribution of the sample and the population.

Table 4.2 Distribution of the socioeconomic strata of the surveyed sample and population. Source: Own elaboration based on (Transmilenio, 2014b). Note: 7% of the registries had no information about the socioeconomic stratum, therefore it was not considered for the expansion factor calculations.

Socioeconomic Strata	Surveyed Sample	(%)	Population*	(%)
Lowest	0	0%	2,060	8%
Low	69	34%	18,517	72%
Middle-low	81	40%	4,615	18%
Middle	47	23%	323	1%
Middle-high	8	4%	35	0%
High	0	0%	45	0%
Total	**205**	**100%**	**25,595**	**100%**

Given that the surveyed sample had no elements describing the Lowest and High socioeconomic groups, these were grouped into classes according to their similarity with other social classes. The calculated expansion factors are shown in table Table 4.3; with these, the survey results were expanded to the whole population and the problem of bias error was reduced.

Table 4.3 Expansion factors. Source: Own elaboration based on data form (Transmilenio, 2014b)

Socioeconomic Strata	Surveyed Sample	Population	Expansion Factor
Lowest and Low	69	20,577	298
Middle-low	81	4,615	57
Middle	47	323	7
Middle-high and High	8	80	10

For the calculations of average travel distance, other expansion factors had to be calculated due to the data addition from Elsner's (2015) study to the data collected in the present one. Table 4.4 shows the distribution of the newly surveyed sample and the expansion factors to be used for the estimation of the average travel distance parameter.

Table 4.4 Expansion factors for average travel distance calculations. Source: Own elaboration based on information from (Transmilenio, 2014b)

Socioeconomic Strata	Travel Distance Surveyed Sample	Population	Expansion Factor
Lowest and Low	126	20,577	163
Middle-low	90	4,615	51
Middle	50	323	6
Middle-high and High	8	80	10

4.6 Fieldwork and Data Collection

During the process of performing the intercept surveys, there was one person standing in front of the bicycle parking facility for approaching users after they had parked their bicycles, or after they had collected them. Generally, it was difficult to survey people during morning hours because they usually stated that they were in a hurry, therefore most of the surveys were performed during the afternoon hours to catch users in a more willing-to-answer attitude.

The TM stations of *Alcalá*, *Avenida Rojas* and *Portal Suba* were visited four times each during weekdays from 11:00 until 15:00 and from 17:00 until 20:00. Most of the CP users were willing to answer the survey, except for those who were in a hurry. There were no major inconveniences during the surveying process, questions were easily understood by the respondents, and in average less than 5 minutes were needed to complete the questionnaire.

In total 188 people were surveyed face to face, and 17 people completed the online survey – out of the 42 that started it, but did not finish it. Figure 4.13 shows how the respondents are distributed according to the bicycle parking facility they use.

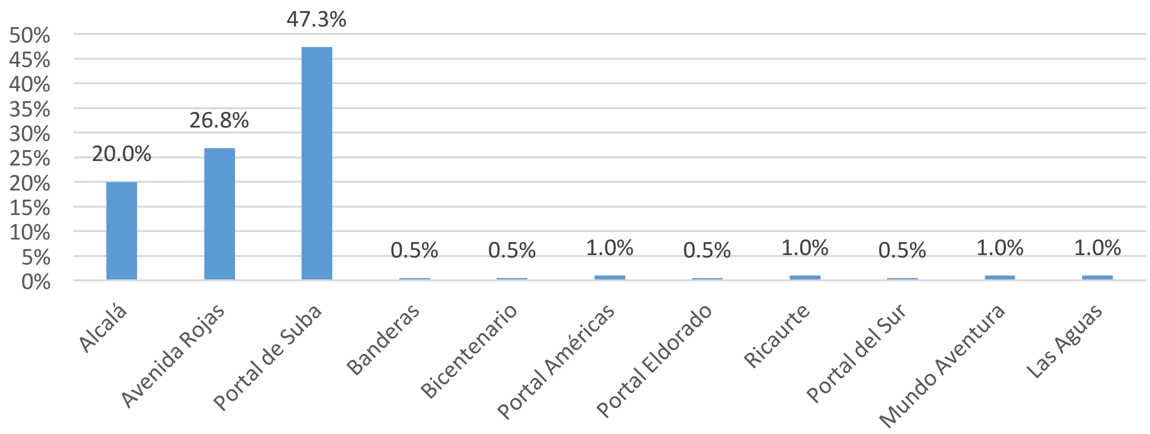

Figure 4.13 Surveyed stations by percentage of respondents

Two main challenges were presented during the surveying process:

i. It would have been very useful to have at least two people approaching CP users while performing the intercept surveys, as there were periods in which several CP users would come at the same time to pick up their bicycles; and
ii. It would have been necessary to have more than one distribution channel for communicating the online survey since the use of social media only showed to be inefficient.

Once the fieldwork was finalized and the needed information was collected, it was typed and organized in a comprehensive database. After having the database, the answers were tabulated and the application of expansion factors was carried out. Finally, different tables and charts were generated allowing the characterization of the CP users and achieving the objectives of the study. The next chapter describes the survey's results and its analysis.

5. Survey Results and Analysis

This chapter presents the results of the empirical investigation described in the previous section. A detailed explanation of the survey outcomes is provided, as well as their qualitative and quantitative analysis.

This chapter is divided into the same segments of the survey, as presented in Table 5.1.

Table 5.1 Structure of the chapter and number of questions per section

	Section	Number of questions
i.	Demographic characteristics	4
ii.	Average travel distance	1
iii.	Trip characteristics	8
iv.	Modal shift	2
v.	Rating of the current situation	2
vi.	Rating of the possible improvement measures	1

Every descriptive statistic here presented was first corrected by the expansion factors calculated in Section 4.5.

5.1 Demographic Characteristics

The objective of this first section is to characterize CP users according to their gender, age, socioeconomic strata, and occupation in order to cluster them in segments – see Figure 5.1 and Figure 5.2. Understanding user's characteristics allow the formulation of strategies addressing their specific needs and motivations. It also lets the creation of effective marketing campaigns as the communication and activations will be relevant for the targeted user.

It is very important to highlight that during the surveying process none of the survey respondents belonged to the lowest and highest socioeconomic groups, therefore no information about these segments was collected. Results related to the socioeconomic strata only show the Low, Middle-low, Middle and Middle-high classes.

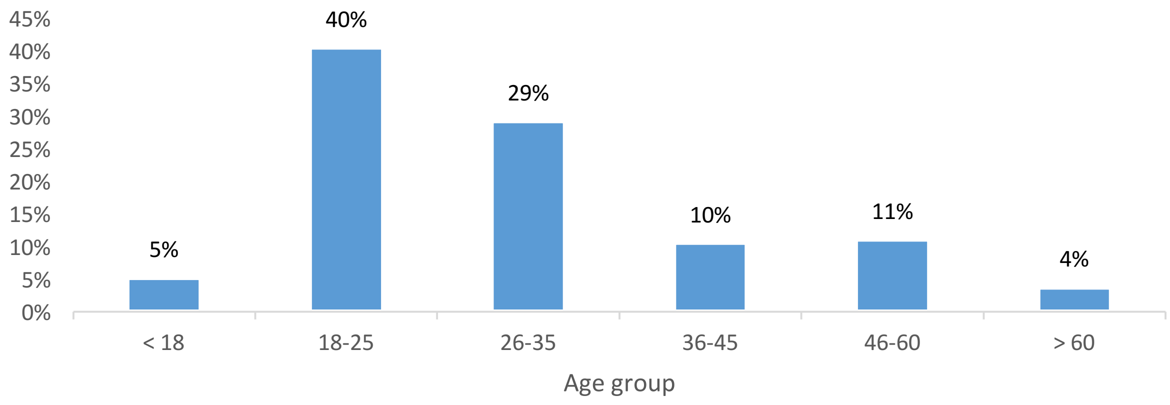

Figure 5.1 CP users' distribution by age

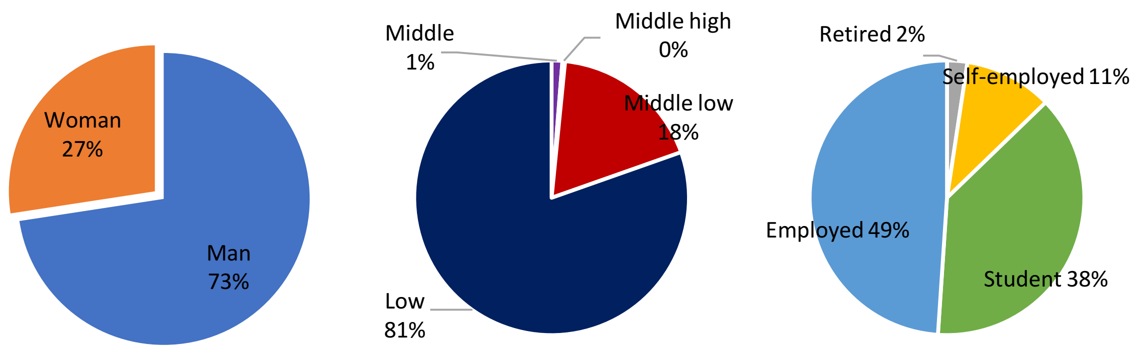

Figure 5.2 CP users' distribution by gender, socioeconomic strata, and occupation

Figure 5.1 and Figure 5.2 show that the majority of CT users are employed men, between the ages of 18 and 25 from the Low socioeconomic stratum. This would fit the description of a young male adult, from a lower income family, who just finished studying and/or has recently started working. This is the first evidence that helps to characterize the current CP users and it allows to preliminary identify the strongest segment of CP users, as well as the population groups that could be potential users, but still need to be attracted.

When combining the age groups and gender, it can be seen that the age distribution between men and women is very similar except for the age group between 26 to 35, where women have 15% more participation than men – see Figure 5.3.

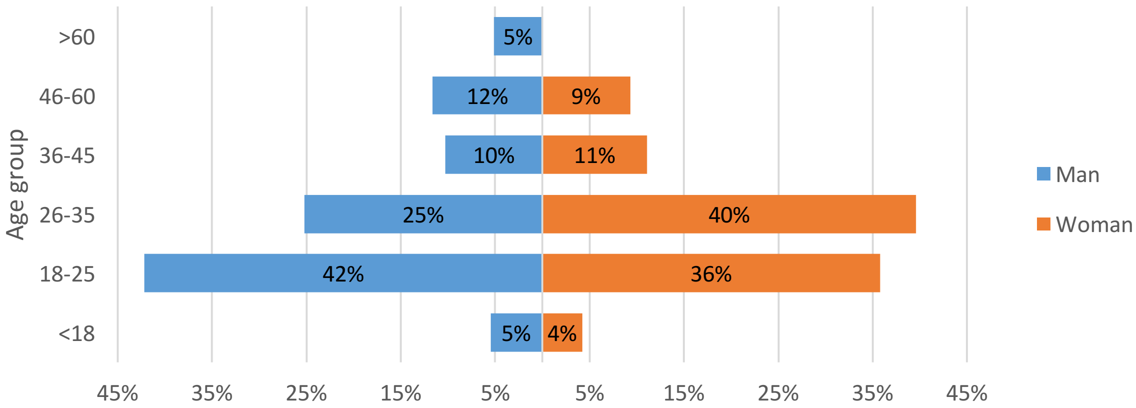

Figure 5.3 CP users' distribution by age and gender

For both genders, more than 60% of the CP users have ages that range between 18 and 35, evidencing that the attractiveness of the CPs needs to be improved in order to incentive people from ages different than 26-35 to use the facilities. Great importance has to be given to the ages below 18 and above 60, which have very low participation in the use of CPs.

Figure 5.4 shows a clear relationship between age group and occupation of the CP users.

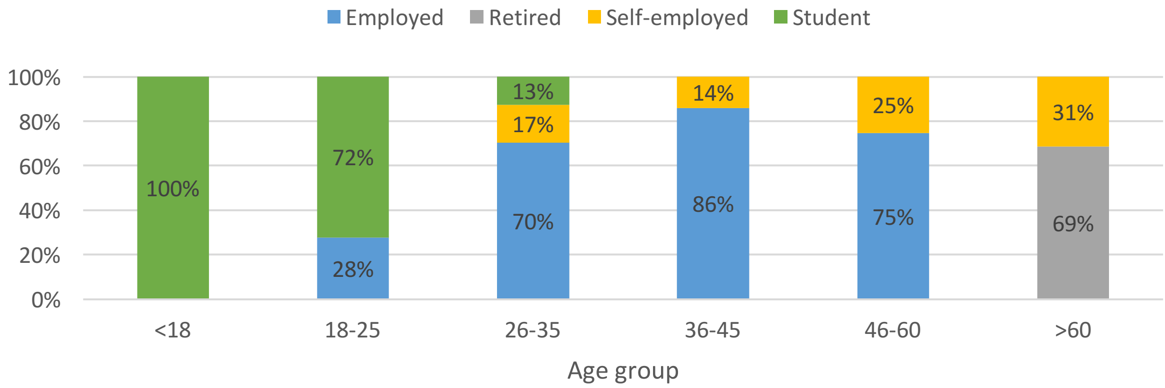

Figure 5.4 CP users' distribution by age and occupation

Most of the students are 25 years old or younger, employees have ages that range mostly between 26 and 60, self-employed people have a wider age range covering ages from 26 up to over 60, finally, more than half of the people older than 60 are retired.

From Figure 5.5 there can be distinguished different predominant occupation groups by socioeconomic strata.

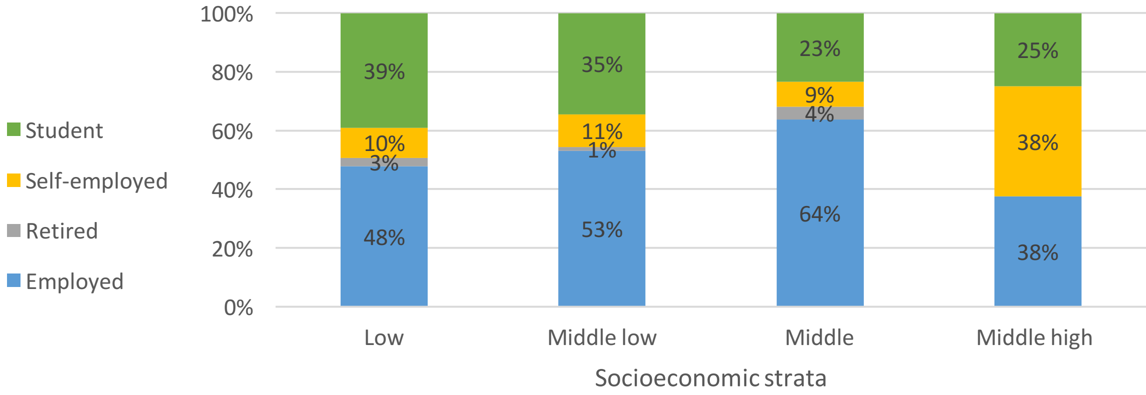

Figure 5.5 CP users' distribution by socioeconomic strata and occupation

Low and Middle-low socioeconomic strata have a similar behavior and show that approximately half of the people are employed, followed by students that sum up one-third of the total. The Middle class has the same distribution, but in this case, the percentage of employed people is larger, and students have a smaller participation. Regarding the Middle-high socioeconomic group, it can be seen that the population is almost homogeneously divided into students, employed and self-employed people.

Reviewing the demographical characteristics considering the three main surveyed stations – *Alcalá*, *Avenida Rojas*, and *Portal de Suba* –, Figure 5.6 shows how CP users are distributed in each CP by their socioeconomic strata.

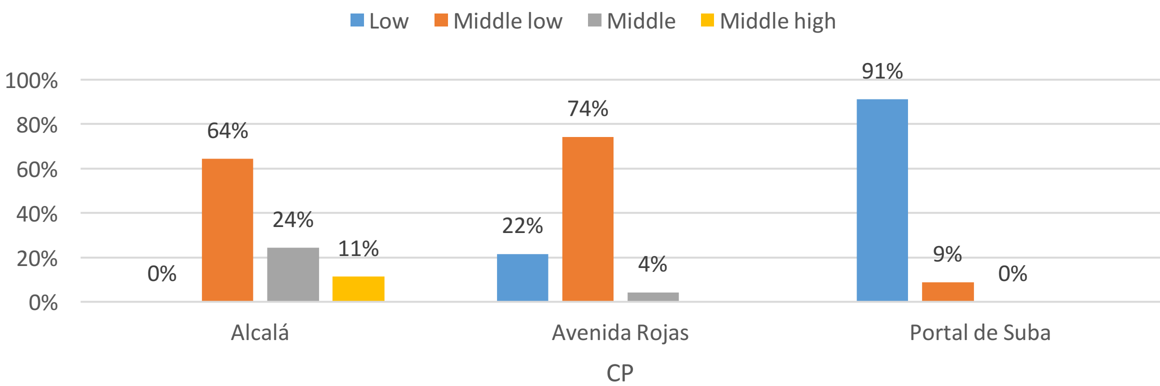

Figure 5.6 CP users' distribution in surveyed CPs by socioeconomic strata

Alcalá has CP users from Middle-low, Middle and Middle-high socioeconomic groups, *Avenida Rojas* from Low, Middle-low and Middle classes, and *Portal de Suba* mostly from the Low group with a few from Middle-low. These results were expected due to the location of the facilities as evidenced in Figure 4.3.

Even though it was intended to consider all socioeconomic groups with the selection of the stations, it was not possible to obtain information from the lowest and the highest socioeconomic strata. To be able to have users from the highest group, it would be necessary to have more CPs in the northern part of the city, and to have people from the lowest category *Portal del Sur* could be considered as a potential option in a further study.

Figure 5.7 evidences the age group distribution of CP users by TM station.

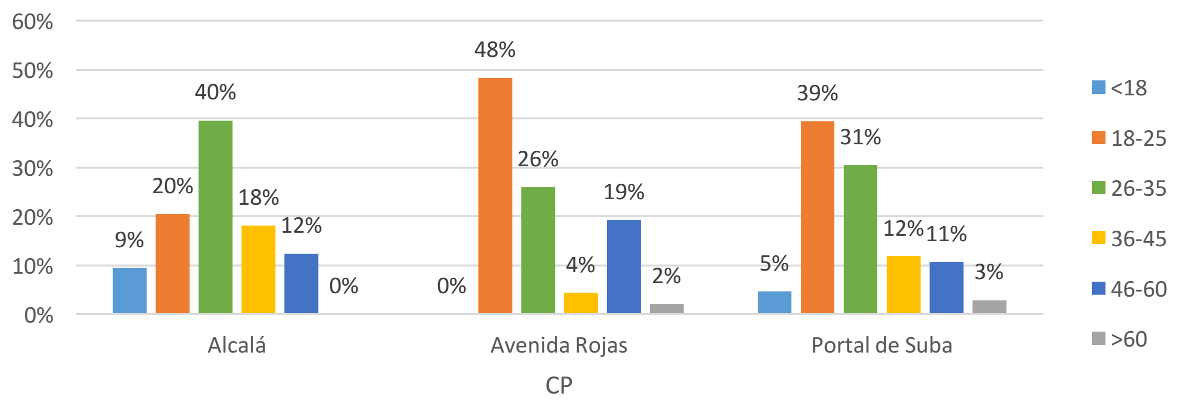

Figure 5.7 CP users' distribution by CP and age

Figure 5.7 shows that in *Alcalá* almost half of the CP users have ages between 26 and 35, while in *Avenida Rojas* and *Portal de Suba* the majority of users have ages between 18 and 25. If the age distribution is related to the occupation as evidenced in Figure 5.4, then it can be said that most of the CP users in *Alcalá* are employed while in *Avenida Rojas* and *Portal de Suba* most users are students and a smaller proportion are employees.

5.2 Average Travel Distance

This section focuses on finding the average distance CP users bike to reach TM stations and its categorization by socioeconomic strata, age, and gender. Additionally, with the average travel distance, it is possible to find the catchment areas of all the CPs at TM stations, as well as identify those areas of Bogotá with no bike-and-ride coverage.

As explained before, all the calculations carried out in this section took into account Elsner's (2015) data in addition to the data collected in the present study. Moreover, the expansion factors used are the ones calculated in Table 4.4.

The average distance people cycle to a TM station was calculated using the location where CP users start their trips[7] and then applying two different methods:

[7] In order to have the origin information of respondents, they were told to provide the address of their trip's starting point. The geographic coordinates from the addresses were found using Google Maps,

i. The Euclidean distance multiplied by a correction factor for traveling through an orthogonal network.
ii. The travel distance through Bogotá's real road and bicycle networks.

For the first method, the Excel software was used. The correction factor was calculated by finding an average ratio between the sum of the two legs of a triangle rectangle and its hypotenuse – see Figure 5.8 – and after doing this exercise for one thousand triangles, the average corrector factor found was 1.3.

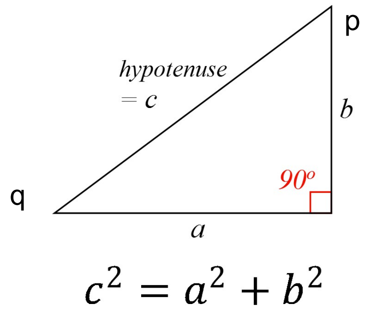

Figure 5.8 Pythagorean Theorem. Source: Own elaboration based on (Mc Closkey, n.d.)

The Euclidean distance was then calculated with Equation 5.1. It determines the length of the line segment connecting two points – e.g. p and q in Figure 5.8 – with regards to their Cartesian coordinates.

$$\boldsymbol{d}(\overline{\mathbf{pq}}) = \sqrt{(\mathbf{q_y} - \mathbf{p_y})^2 - (\mathbf{q_x} - \mathbf{p_x})^2}$$

Equation 5.1 Euclidean distance. Source: Own elaboration based on the Pythagorean Theorem

For the second method, the software ArcGIS was used for calculating the same distance between CP users starting point and the TM station, but, this time, considering Bogotá's existing road and bike networks. The origins of the CP users were located in Bogotá's map – as evidenced in Figure 5.9 –, and the distances between these origins and each CP were found by using the Network Analyst tool.

From Figure 5.9, it identified that not all CP users choose to bike to the closest CP they have, possibly because sometimes the destination is not well connected to the TM network, so It is easier to use the bicycle for longer distances and then ride the TM for shorter segments.

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and then this coordinates were turned to Cartesian coordinates using this information: 1° in latitude equals 113.3 km, and 1° in altitude equals 111.11 km.

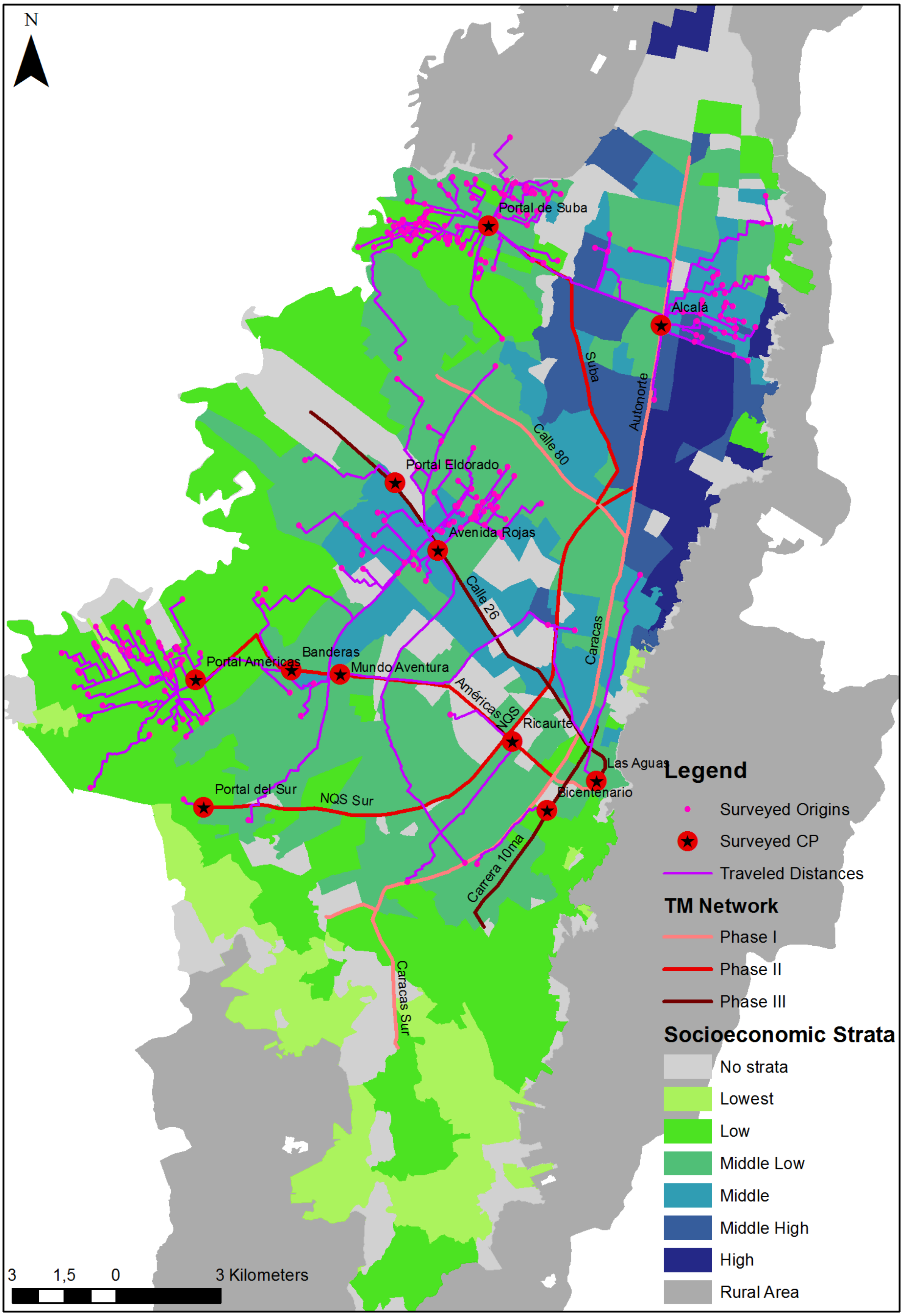

Figure 5.9 Traveled distances by bicycle to CPs at TM stations.

The results found with each method are presented in Table 5.2. Although the values found with both methods are very similar, it was expected to have a larger average travel distance with the Excel method, than with the ArcGIS method. The Excel method can overestimate the distances found due to the 1.3 factor used to converting the Euclidean distance into a distance through an orthogonal network while the ArcGIS method calculates always the shortest distance between an origin and a destination.

In order to understand how Excel could overestimate a distance, an example with a straight line will be used. In this case, while ArcGIS will effectively find the distance between the two points of the straight line, Excel will also find it, but then it will expand it with the 1.3 factor giving as a result a longer distance. In this sense, it can be said that the Excel method is a good approximation when not having the real road and bicycle network of a city, but it shall always incur in this overestimation issue whenever the distance to be found is a straight line.

In conclusion, ArcGIS is a better tool for this type of exercises. However, it is important to keep in mind that, even though the tool finds distances through a network, the distances found are always the shortest possible, but it may happen that in real conditions cyclists do not always know the shortest route to their destination. Moreover, the precision of the distance found with ArcGIS method will be entirely dependent on the quality of the geographical information available and on how updated it is with respect to reality.

Table 5.2 Average distance people bike to CPs

Method	Corrected Euclidean Distance	Distance Through Bogotá's Network
Software	Excel	ArcGIS
Average	2.8 km	2.7 km
Standard Deviation	1.3 km	1.3 km
Confidence Interval (95%)	[2.6 km, 2.9 km]	[2.5 km, 2.6 km]

Figure 5.10 shows the distribution of al travel distances using ArcGIS' data.

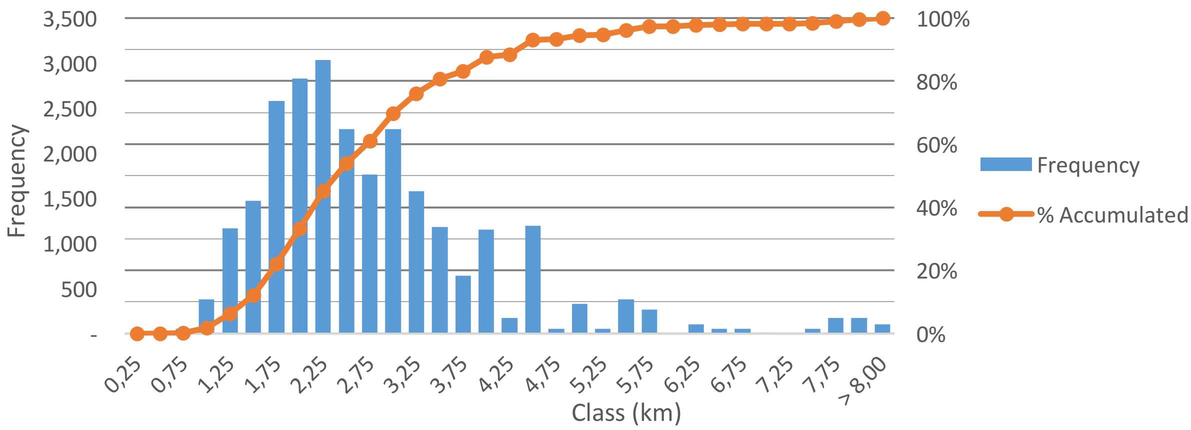

Figure 5.10 Histogram of travel distances

From the histogram, it can be seen that 80% of the people travel between 1.0 km to 3.5 km to reach a TM station, and only 5% travel more than 5km. Additionally, 50% of the people cycle less than 2.5 km to a CP, and the most common distances CP users cycle to a station are between 2.0 km to 2.25 km.

Now, after estimating the average travel distance CP users bike to the facilities, it is possible to identify the service areas of all the CPs in the city at TM stations, and clearly distinguish those uncovered areas where more facilities should be implemented. For this, the radius of 2.7 km calculated with ArcGIS was used – see Figure 5.11.

At a first glance, Figure 5.11 evidences that the city is well served by CPs towards the southwest side, but that the northwest side has very little coverage. Moreover, the northern, southern and north-central regions serviced with TM have no bicycle parking facilities available.

As mentioned before, it was not until 2003 with TM's Phase II that CPs started being implemented regularly at a few TM stations; their location was always dependent on the available space, rather than of the actual demand (Verma et al., 2015). Before that, only four bicycle parking facilities were randomly built in the year 2000: *Alcalá*, *Mundo Aventura*, *Las Aguas* and *Tintal*, and all of them were operated by the IPES. This is clearly evidenced in Figure 5.11, and it explains why there are so few – or none – CPs at Phase I trunk lines, i.e. *Calle 80*, *Av. Caracas*, *Autonorte* and *Calle 13*.

At TM's Phase II *Av. Américas* and *NQS Sur* trunk lines there is a good CP coverage, however, *NQS* and *Avenida Suba* trunk lines still have a very low coverage. Moreover, TM's Phase III trunk lines – *Calle 26* and *Cra. 10ma* – are well covered by CPs, although more facilities along the trunk lines connecting to the city center would still be useful.

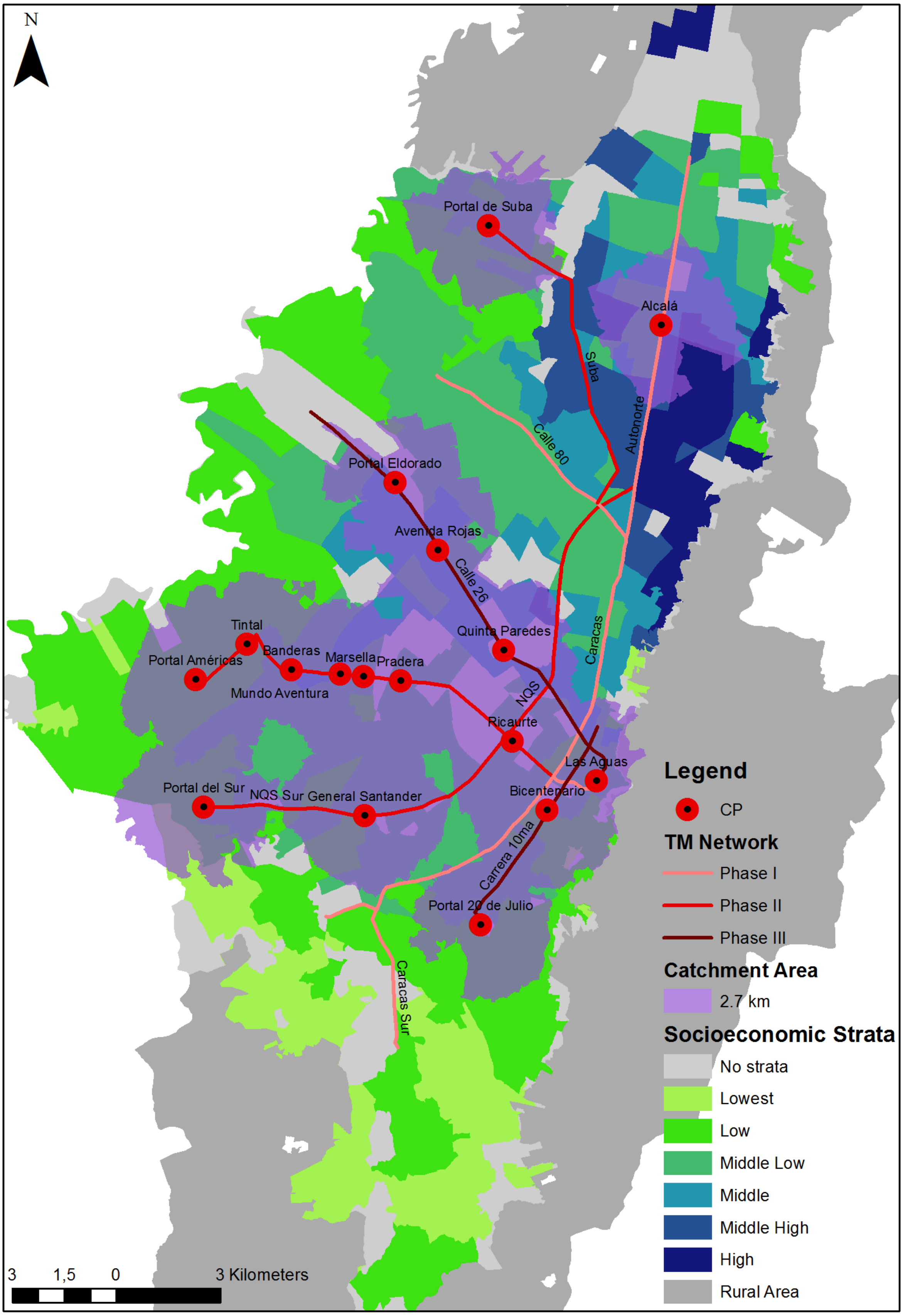

Figure 5.11 Catchment areas of CPs at TM stations.

It is interesting to see that, even though Figure 5.11 shows that *Alcalá* partially covers areas of the highest socioeconomic group, during the surveying process none of the respondents was from this class. The two most possible reasons for this are:

- There is not sufficient information regarding the existence of the CP and potential users simply do not know it yet.
- People from this stratum rather use other modes than combine the bicycle with TM. Since it is the group with the highest spending power, it is most likely that they prefer to use MIT modes.

Additionally, when going more into detail, it is possible to see that the city's southern side – where most of the lowest socioeconomic class are found – is also lacking CPs. Actually, the only CP with a service area covering this group is *Portal del Sur* and, yet, it serves only a small portion of the total area.

Figure 5.12 shows that the average travel distance is correlated with the socioeconomic strata of CP users.

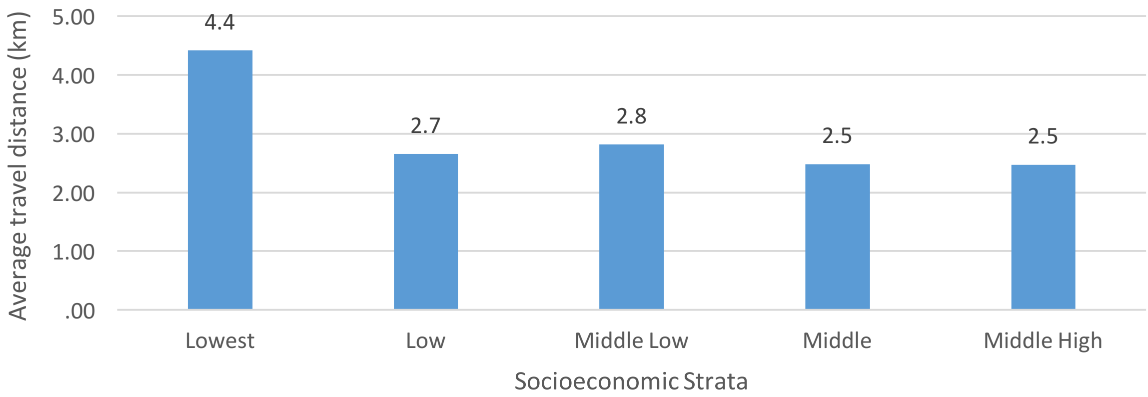

Figure 5.12 Average distance CP users cycle to TM stations by socioeconomic strata

The lower the socioeconomic group the longer the distance CP users travel to reach a TM station. This data lacks information from the highest class, however with the available results, it can be seen that the lowest class almost travels double the distance than the Middle-high stratum.

These results evidence the importance that must be given to the bicycle network extension and density in the lowest socioeconomic, whilst the highest groups need more bicycle parking facilities to attract them. In this sense, by having a good network supply towards the city's south side, which has already a good CP coverage, and having more CPs towards the north side, it would be possible to attract more people from the different strata and incentive potential users to shift to bike-and-ride.

Figure 5.13 shows the average travel distance by group age and gender.

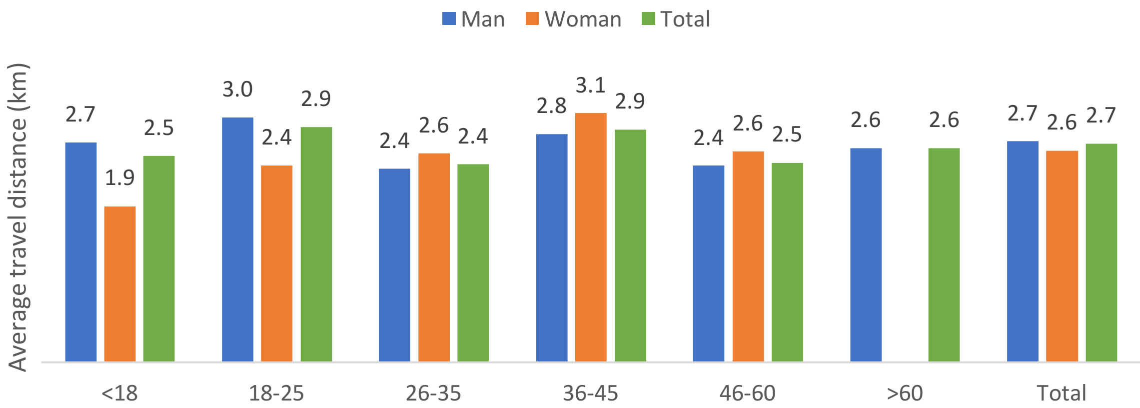

Figure 5.13 Average distance CP users cycle to TM stations by age and gender

It can be seen that there are no trends in the average travel distance when breaking down the data by group ages. The CP user groups biking the most are between 18 to 25 and 36 to 45 years old; interestingly those who bike the less are the group age ranging from 26 to 35.

Important differences may be identified by gender. Among women, a correlation between age and travel distance can be evidenced, where the older groups travel more than the youngest ones. Contrarily, it seems that there is no relationship between age and travel distance among men. In average, men travel distances a bit longer than women, but men older than 26 bike less than women of the same age group.

It was not possible to gather information about women older than 60 bicycling to TM stations. However, given that only about 25% of the bicycle users are women, and that less than 10% are over 45 years old, it is likely that very few women over 60 feel incentivized to combine the bicycle and TM. In this sense, improvements on CT integration should be made considering this particular group in order to attract them.

5.3 Trip Characteristics

This section seeks to typify the trips performed by CP users to reach TM stations. It considers different trip characteristics, such as: frequency of TM ridership and bicycle use to reach a TM station, bike travel time to a TM station, infrastructure used when cycling to the CP, how long have CP users been cycling to TM stations, and using the CPs, and main motivations for biking to TM stations. Additionally, CP users' gender, age, and socioeconomic strata further characterize these trip features.

Figure 5.14 shows the frequency with which CP users travel by TM to their destination broken down by socioeconomic strata.

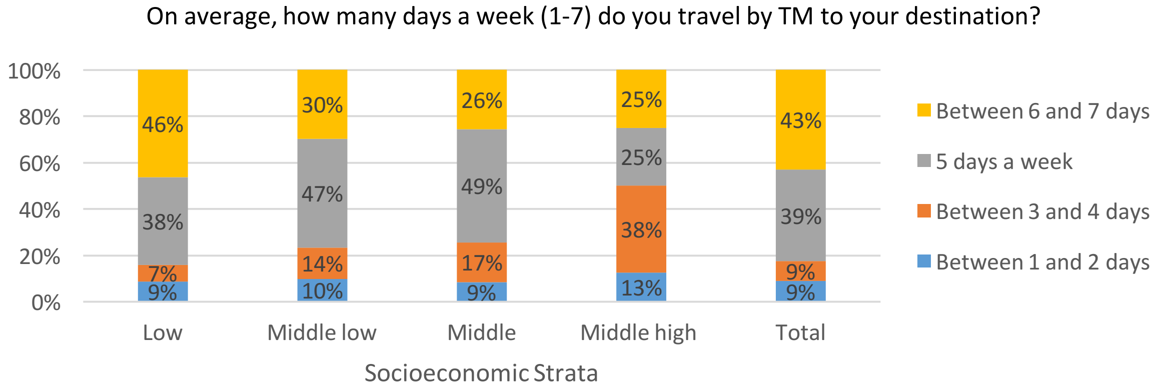

Figure 5.14 Frequency of TM ridership to reach destination by socioeconomic strata

From Figure 5.14 it can be seen that the Low socioeconomic class is the most frequent TM user with a share of 46% using TM between 6 to 7 days a week. Almost 50% the Middle and Middle-low socioeconomic groups use TM 5 days a week, and the majority of the Middle-high socioeconomic stratum travels by TM between 3 to 4 days a week. This distribution is possibly due to the income level of the different socioeconomic classes and the access they have to alternate modes of transportation; lower classes have less access to – i.e. cannot afford – other transport modes, whereas higher classes are rather more multimodal, can afford and have more access to other alternatives of transportation.

Moreover, from the results in Figure 5.14 it could be inferred that TM stations at lower strata locations can have more potential for frequent CP users, than TM station at higher socioeconomic level locations. Nevertheless, when observing the absolute values, it can be seen that more than 80% of the CP users are frequent TM passengers and use this mode at least 5 times per week.

The following Figure 5.15 shows how often CP users travel by TM to their destination by occupation.

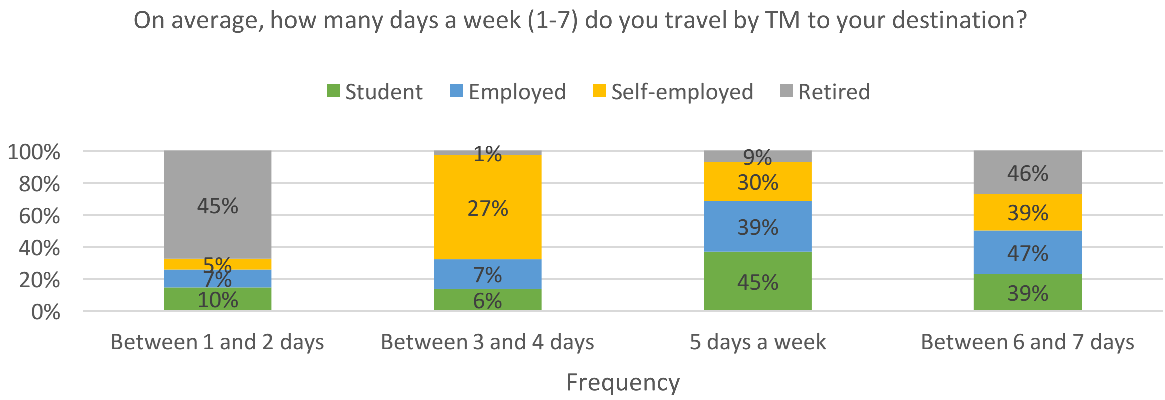

Figure 5.15 Frequency of TM ridership to reach destination by occupation

As it was expected, Figure 5.15 shows that the retired and self-employed CP users are the ones who use TM less regularly, possibly because they have more flexible schedules and do not always have to travel. On the other hand, almost 50% of the students commute 5 times per week by TM, followed by approximately 40% of the employed CP users; and around 40% and 50% of the students and employees use TM almost every day, respectively.

Now, Figure 5.16 shows the frequency of bicycle use to reach TM stations according to the socioeconomic strata of CP users.

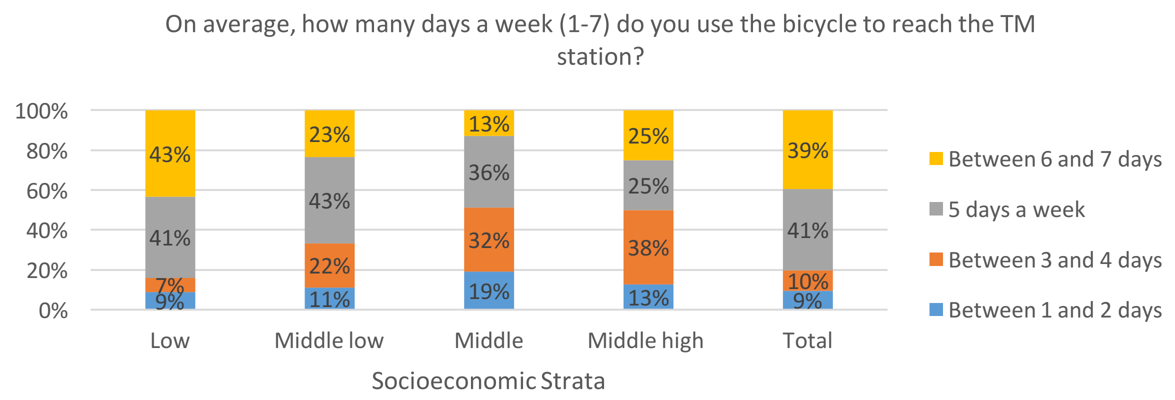

Figure 5.16 Frequency of bicycle use to reach a TM station

In general, Figure 5.16 shows a very similar trend as the one found in Figure 5.14, where the higher the socioeconomic group, the less frequent the use of the bicycle to reach the TM station. The reason for this trend could be the fact that higher classes use more regularly other transport modes and therefore, do not use that often the bicycle as a feeder mode. However, it is important to highlight that, in average, the great majority – i.e. 80% – of the CP users use the bicycle as a feeder mode to TM at least 5 days a week. Thus, CP users are not only frequent TM users as revealed in Figure 5.14, but they are also frequent users of the bicycle and the parking facilities.

In order to verify if CP users reach TM stations by bike with the same frequency they travel by TM, answers from each respondent to both questions were compared to determine its correction. The analysis shows that 94% of the CP users always bike to the TM station whenever they travel by TM and 5% still use the bicycle as a feeder mode more than half of the times, whilst only 1% do it less than half of the times. This result confirms that in fact, CP users use the bicycle almost every time to get to TM stations.

Regarding average travel time, Figure 5.17 shows the histogram of the perceived travel time by bicycle to TM stations.

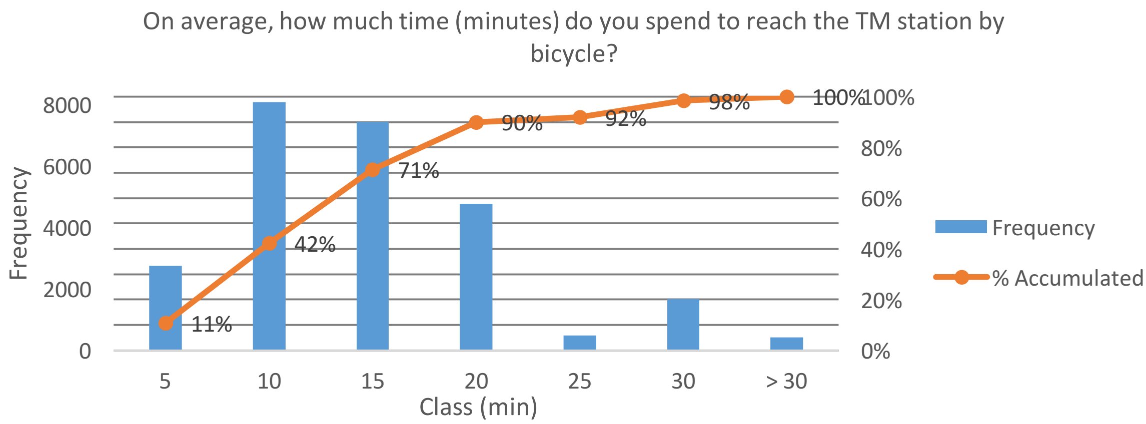

Figure 5.17 Histogram of the perceived travel time by bicycle to TM stations

From the histogram, it can be seen that 71% of the CP users travel maximum 15 minutes to reach a TM station, while 27% need between 15 to 30 minutes and only 2% travel more than 30 minutes to reach a TM station. Additionally, 50% of the people bicycle less than 2.5 km to a CP and the most common distances CP users bike to a station are between 2.0 km to 2.25 km.

Figure 5.18 shows the perceived travel time by bicycle to TM stations by socioeconomic strata.

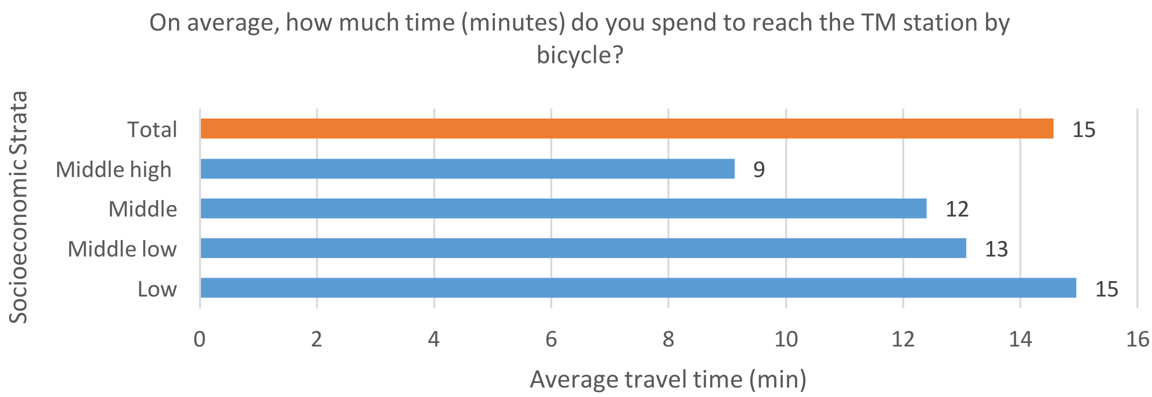

Figure 5.18 Average of the perceived travel time by bicycle to TM stations by socioeconomic strata

It can be evidenced in Figure 5.18 that on average CP users spend 15 minutes to reach a TM station. Furthermore, CP users from lower socioeconomic groups cycle for longer periods than CP users from higher groups. This trend supports the previous findings from Figure 5.12, in which lower classes cover longer distances than higher classes. It also highlights the fact that, when compared to the higher strata, the lower strata not only have less access to multimodal transport – as inferred from Figure 5.14 –, but also have major disadvantages due to the larger distances they have to cover to reach TM.

Figure 5.19 displays the perceived travel time by bicycle to TM stations by gender and age group.

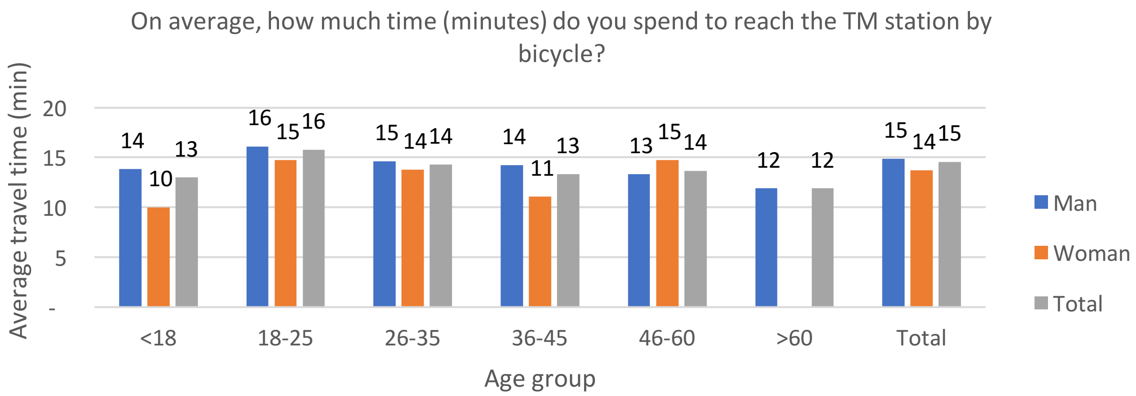

Figure 5.19 Average of the perceived travel time by bicycle to TM stations by age group

By gender, the results from Figure 5.19 support the previous discovery from Figure 5.13, where men bike longer distances compared to women, although the difference between both genders is relatively small: one minute in average. By age groups, it is evidenced that the ages that bike for the longest periods are between 18 to 25 though, in general, the differences between age groups are not very large. When comparing the results by gender and age, the distribution of both variables is reasonably homogenous.

Figure 5.20 displays the distribution of CP users regarding the infrastructure they habitually use to reach TM stations and whether they would still use the bicycle as a feeder mode if there were no bicycle lanes – i.e. CRs.

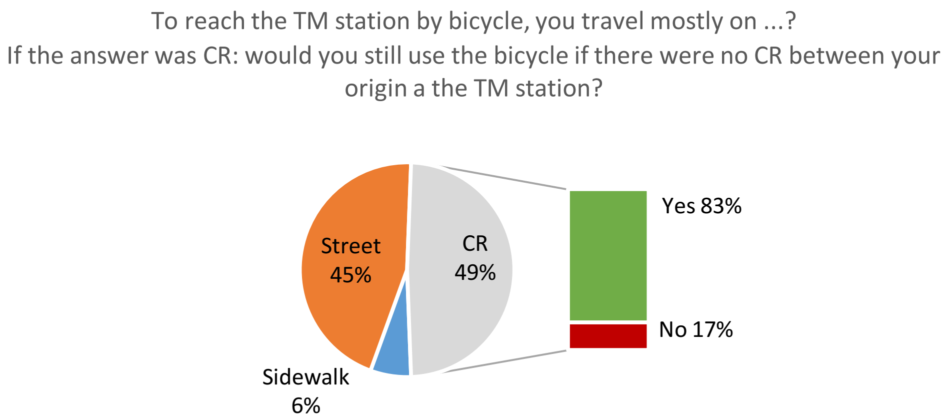

Figure 5.20 Infrastructure used to reach TM stations by bicycle

In general, almost 50% of the CP users use the available bicycle lanes to reach TM stations, 45% cycle on the streets and only 5% use the sidewalks. Moreover, from those who usually use the bicycle network, 83% would still go by bicycle to TM stations even if there were no bicycle lanes they could use; the other 17% would stop using the bicycle as a feeder mode and possibly shift to other transport modes. This evidences that, even though half of CP users do use the available infrastructure when they have access to it, the lack of a network would not be a breaking point for the use of the bicycle.

Figure 5.21 shows the distribution of CP users regarding the infrastructure they habitually use to reach TM stations broken down by the three main surveyed CPs.

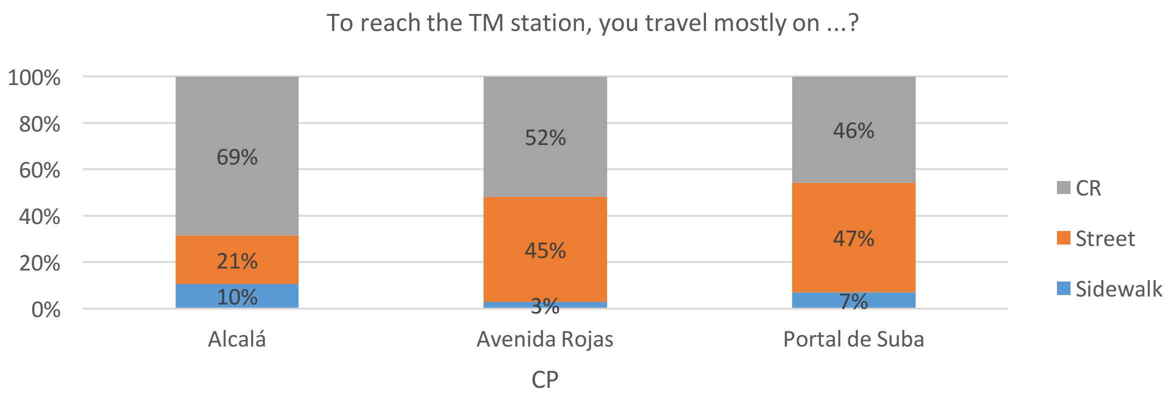

Figure 5.21 Infrastructure used to reach TM stations by bicycle

Numbers in Figure 5.21 match with the descriptions of the CPs' surrounding areas in section 4.2. In this sense, the more kilometers of bicycle lanes near CPs, the more people use the infrastructure to reach TM stations. Here, the CP where the bicycle network is used the most is *Alcalá* with almost 70% of the share, followed by *Avenida Rojas* with more than 50%, and *Portal de Suba* with less than 50%. Furthermore, there is evidence that the less CP users use the bicycle lanes, the more they use the street to travel by bike; only very low percentages use the sidewalks.

Now, if there were no bicycle parking facilities at TM stations, the majority of CP users would stop using the bicycle. From the total, 84% would stop using the bicycle, and only 16% would keep using it. Compared to Figure 5.20, it could be said that having a dedicated place where to leave the bicycle is more important than having a dedicated bicycle network.

Moreover, it is interesting to see that the previous results demonstrate that CP users do not know and/or consider other types of bicycle parking facilities, such as urban furniture and private parking spaces as alternate options to CPs. The main reason for this could be the absence of information about these other forms of bicycle parking; however, it would also be possible that people do not use these facilities due to security and price reasons. On the one hand, urban furniture facilities could be perceived as insecure as no one is taking care of the bicycle park there and, on the other hand, most private parking facilities charge a parking fee.

Regarding how long CP users have been doing bike-and-ride, Figure 5.22 describes how long they have been using the bicycle as a feeder mode to TM, and how long they have been using the CPs.

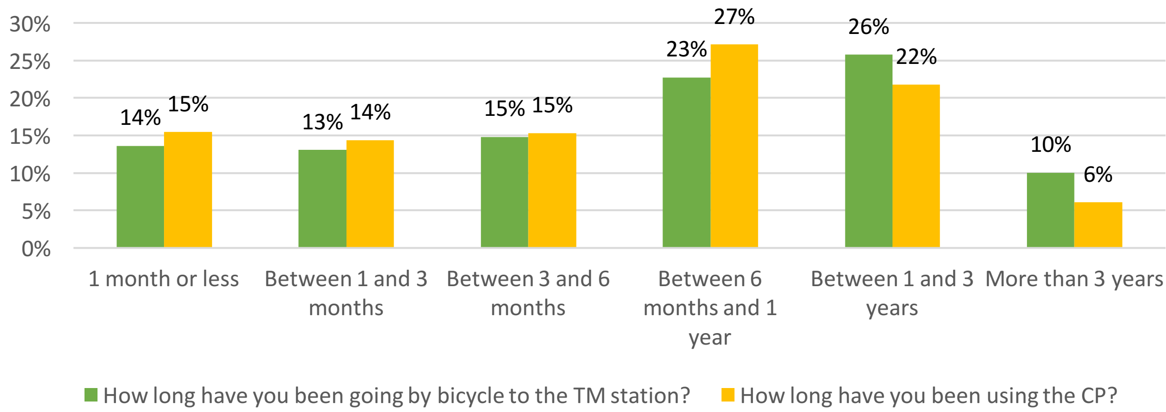

Figure 5.22 How long have CP users been using the bicycle as a feeder mode to TM, and how long have they been using the CPs

Before withdrawing conclusions from Figure 5.22, the answers from each respondent to both questions were compared to see if they would be related to each other. As a result, it was found that 82% of the CP users started using the bicycle and the CPs at the same time, and the other 18% started using the CPs sometime after they started biking to the TM station. This could mean that having a CP is a decisive driver to make people start using the bicycle as a feeder mode to TM, which also supports the conclusion revealing that the lack of a CP near TM stations would make people stop using the bicycle to reach TM.

Figure 5.22 evidences that both questions have similar distributions, meaning that most of the times CP users start using the bicycle and the CP at the same time. In terms of how long CP users have been using both, around 40% started using it 6 months ago or less, about 50% between 6 months to 3 years ago, and only 10% approximately for more than 3 years.

The last part of this section focuses on CP users' main motivations for using the bicycle as a feeder mode to TM segregated by their demographic characteristics. These results are very useful for the design of better-targeted CT integration strategies to maintain current users and to attract new ones. First, Figure 5.23 displays these motivations by gender.

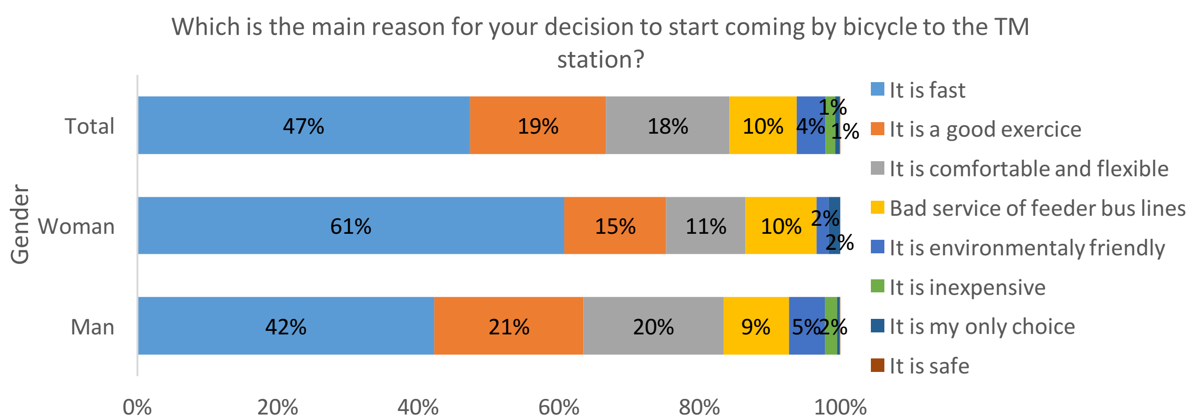

Figure 5.23 Main motivations for using the bicycle as a feeder mode to TM

From the total, 47% of the CP users use the bicycle because it is fast and saves time when compared to other feeder modes, 19% due to its exercising features, and 18% because it is comfortable and flexible to use. It is important to mention that 10% of the CP users that prefer the bicycle due to the low frequency and overcrowdings of feeder bus lines.

Figure 5.23 reveals that there are no significant differences between genders, both men and women have the same main reasons for using the bicycle – speed, exercise, comfort, and flexibility –, but with some differences in the shares. For example, for women trip duration is more important than for men, while men give a bit more importance to exercise, and comfort and flexibility.

Figure 5.24 shows the main motivations for CP users' decision to use the bicycle over other transport modes by age group.

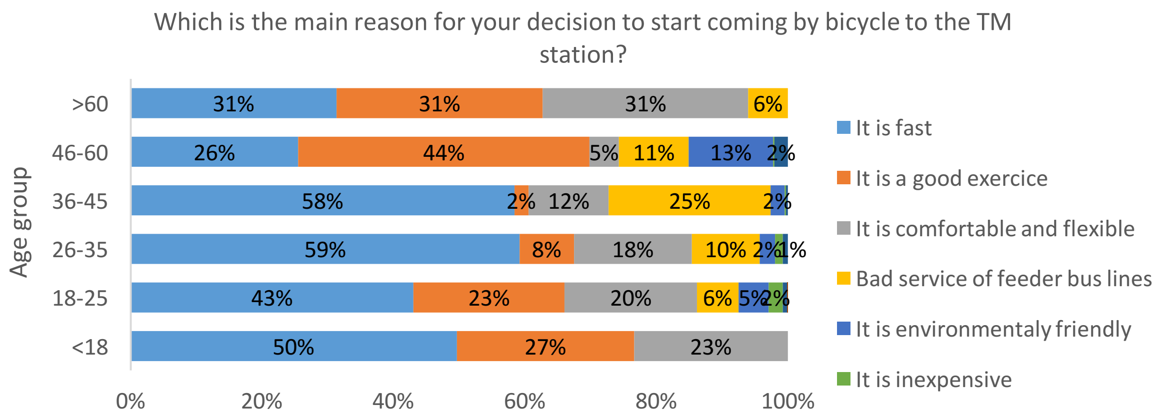

Figure 5.24 Main motivations for using the bicycle as a feeder mode to TM by age

For CP users younger than 25 and older than 60, the main motivations are still trip duration, exercise, comfort and flexibility. Conversely, reasons such as the environment and the bad service of feeder bus lines play an important role for ages between 26 and 60.

The youngest age group does not worry about the bicycle being environmentally friendly, whilst the age group between 46 and 60 even considers this factor more important than comfort and flexibility, and the bad service of feeder bus lines. For the age group 36-45 the bad service of feeder bus lines is more important than for any other age group, whereas exercise is the most important motivation for the age range 46-60.

Figure 5.25 displays the main motivations for CP users' decision to use the bicycle over other modes segregated by socioeconomic strata.

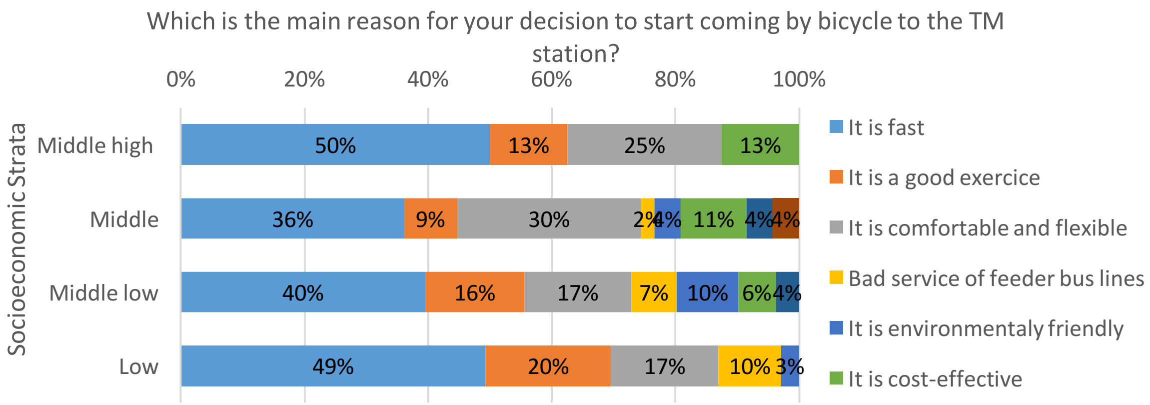

Figure 5.25 Main motivations for using the bicycle as a feeder mode to TM by socioeconomic strata

Figure 5.25, evidences again that people consider trip duration, exercise, comfort and flexibility as the main motivations for using the bike. It is interesting to see that, while lower socioeconomic groups criticize the bad service of feeder bus lines, higher groups consider more the cost-effectiveness of the bicycle. This can be explained once more with the fact that lower classes have less access to other transport modes when compared to higher classes. In this sense, it is possible that lower classes shifted from feeder lines – which are free of charge –, whereas higher classes shifted from other modes, in which they had to pay – modal shift is further discussed in Section 5.4.

Finally, Figure 5.26 shows the main motivations for CP users' decision to use the bicycle over other modes segregated by occupation.

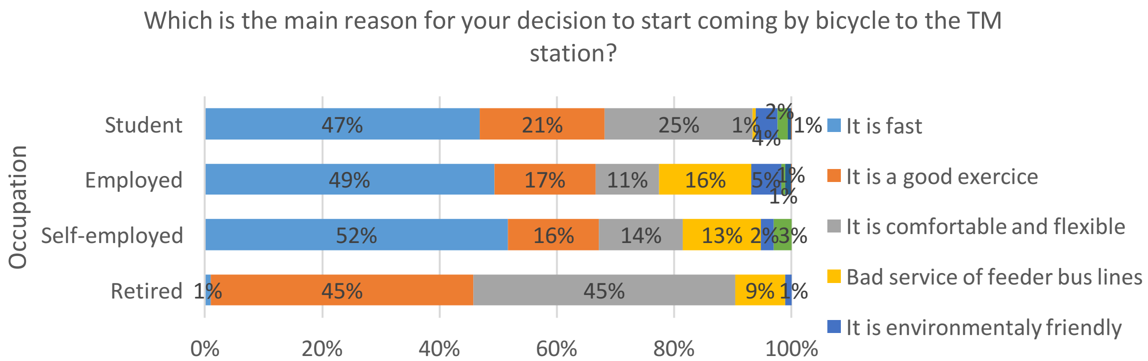

Figure 5.26 Main motivations for using the bicycle as a feeder mode to TM by occupation

Students have as main motivations speed, comfort, flexibility, and exercise; the working groups have as main motivations speed, exercise and bad service of the feeder bus lines, and finally retired people only consider exercise and comfort and flexibility as the most important motivations.

These answers can be directly related to the available time CP users have when commuting, people studying and working consider time more important, whereas retired people consider other facts such as exercise to be more relevant.

5.4 Modal Shift

The objective of this section is to give evidence CP users' modal shift at two different moments:

i. The transport mode used when they had not started doing bike-and-ride.

ii. The transport mode used at times when they do not bike-and-ride.

This characterization allows discovering from which transport modes CP users shift and measure the travel time, costs, and ease with which the trip was performed as well as the competitor transport modes to the bicycle.

5.4.1 Pre-Bike-and-Ride Transport Mode

Figure 5.27 displays which transport modes were used by CP users before they started doing bike-and-ride.

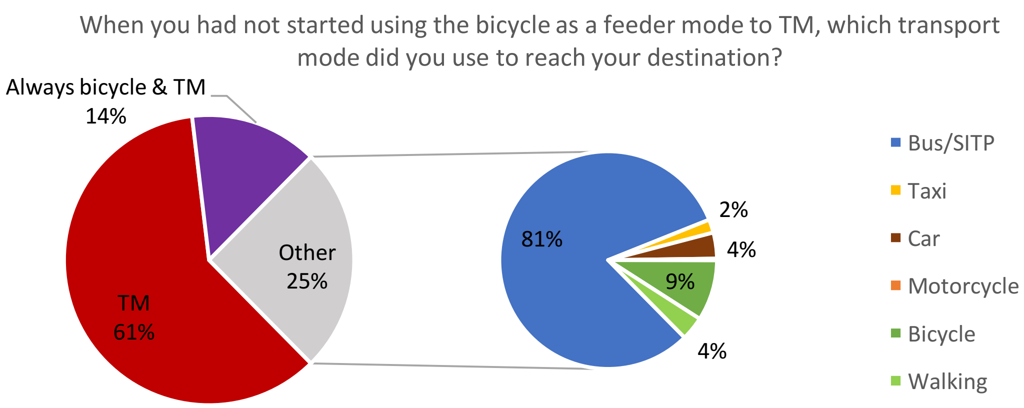

Figure 5.27 Modes of transport used before CP users started doing bike-and-ride

Figure 5.27 shows that 14% of the people have always done bike-and-ride, 61% have always traveled by TM – yet using other feeder modes –, and, most importantly, 25% used to travel by other means of transport and have shifted to CT integration as a result of the installation of CPs at TM stations. From this 25%, 81% used to travel by bus/SITP, 9% used to perform the entire trip by bicycle, 4% by car, 4% walking, and 2% by taxi.

These numbers evidence that CT integration not only helps to decongest bus/SITP lines, but also aids to reduce the use of MIT. Figure 5.27 shows how much has been achieved so far with the current supply – lanes, parking facilities and user information – and gives evidence of the potential to have better results. In this sense, a better-targeted integration of the bicycle and TM would attract potential users achieving higher shares of modal shift from MIT modes to PT.

The figures that follow consider only the 25% of the CT users that used to travel by other transport modes different than TM. Figure 5.28 displays the average of the perceived travel from home to the destination by each of these other modes used.

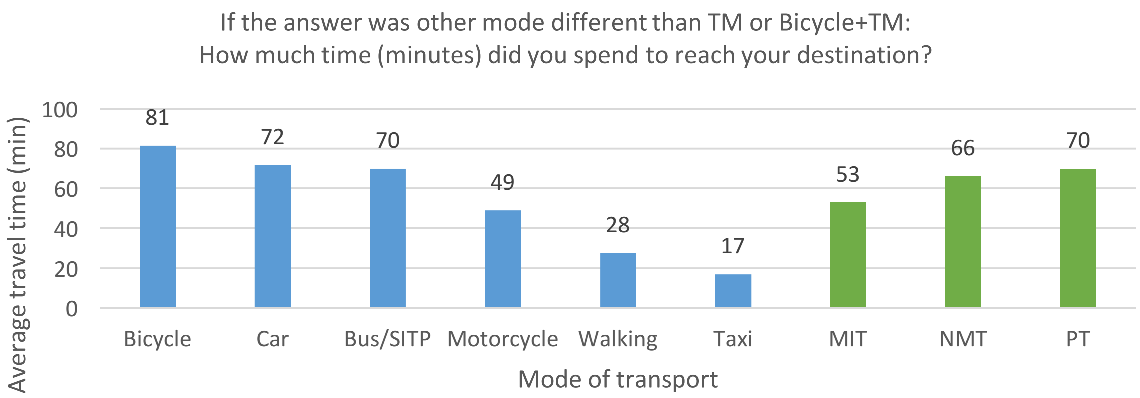

Figure 5.28 Average of the perceived travel time by other modes before CP users started doing bike-and-ride

It is interesting to see that while the bicycle is the slowest mode, walking is the second fastest option. Moreover, whereas the taxi is the fastest option, the car is the second slowest mode. One possible explanation would be the distances people travel to their destinations. For example, it would be expected that people travel shorter distances by foot than by bicycle, and longer distances by car than by taxi because of trip costs reason.

Overall, MIT modes – including car, motorcycle and taxi – are the fastest with an average travel time of 53 minutes, followed by NMT with 66 minutes, and PT – bus and SITP – with an average of 70 minutes. Thus, in terms of travel time, the less attractive option for traveling is PT, whereas the best one is IMT.

Figure 5.29 shows the average travel cost per trip by mode – figures are shown in Colombian Pesos (COP).

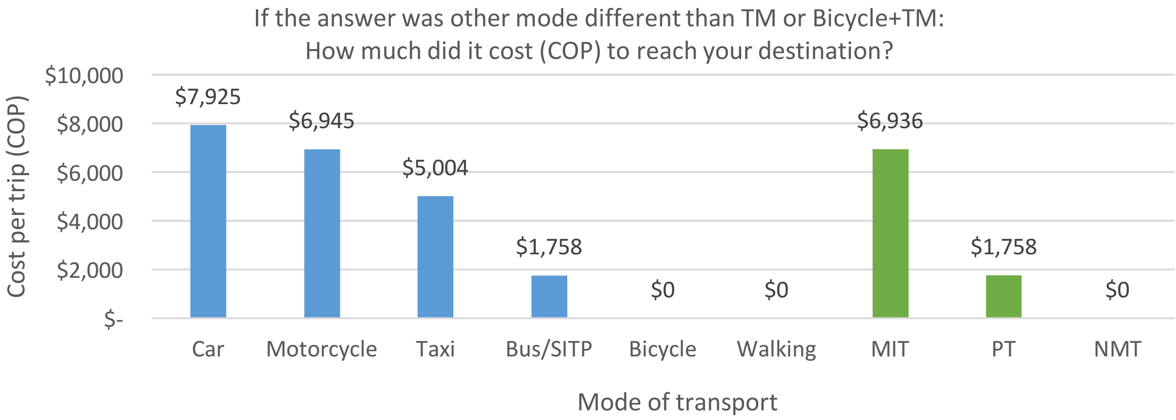

Figure 5.29 Average travel cost by other modes before CP users started doing bike-and-ride

MIT modes are the most expensive ones with a cost per trip up to five times more expensive than PT. Nevertheless, it is important to keep in mind that the MIT modes' cost per trip were self-estimations from respondents and, therefore, the cost can actually be higher or lower to these estimations.

Figure 5.30 shows the perceived ease with which CP users traveled by other modes to their destinations – results are shown in terms of PT, NMT and MIT, for detailed information by mode refer to Figure 13.1 in the Appendices.

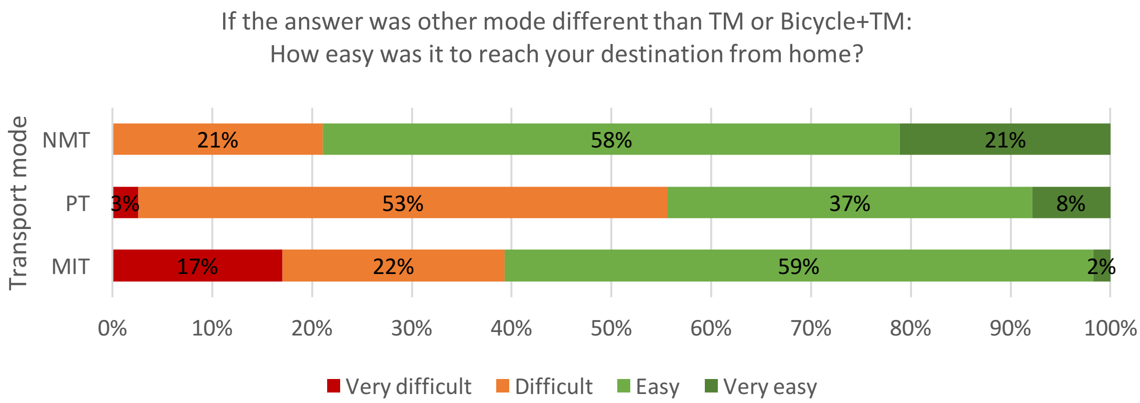

Figure 5.30 Ease with which CP users traveled by other modes to their destination before they started doing bike-and-ride

From Figure 5.30 it can be seen that more than 50% and almost 40% of the CP users that used to travel by PT and MIT, respectively, considered them difficult or very difficult to travel by, whilst NMT modes were the best-rated modes. The reason for the difficulties with PT modes could be the waiting times and the overcrowding of buses; the difficulties with MIT modes could be the time spent searching for parking places. Overall, the most important cause adding to the difficulty when traveling by motorized modes could be the heavy traffic conditions that characterize Bogotá.

Almost 80% find it easy or very easy to travel by NMT however, there is a 20% that still find it difficult, which means that there is an opportunity to improve the performance of these modes.

Now, the figures that follow consider the other 61% of CT users that have always traveled by TM, but used other feeder modes. Figure 5.31 displays which feeder modes were used.

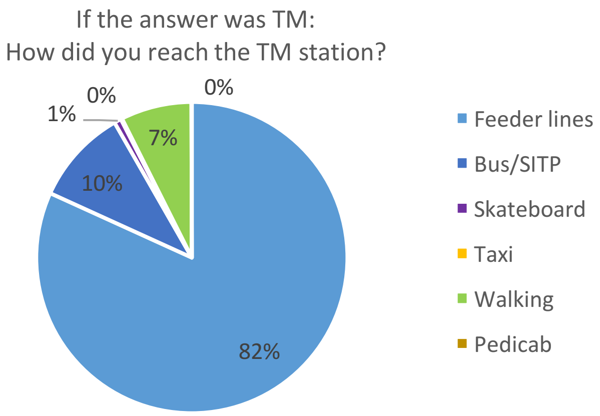

Figure 5.31 Other feeder modes to TM used before CP users started doing bike-and-ride

From the total, 82% used feeder bus lines, 10% bus/SITP and 7% walked. This is an evidence that bike-and-ride helps to reduce the need for feeder bus lines expensive to operate and alleviates the use of regular bus/SITP. Moreover, CT integration could help to alleviate the overcrowding problem in feeder bus lines, regular buses and SITP, thus, it would not be necessary to increase their capacity by adding more buses and shortening frequencies.

Figure 5.32 displays the average of the perceived travel by the different feeder modes versus the average travel time by bicycle.

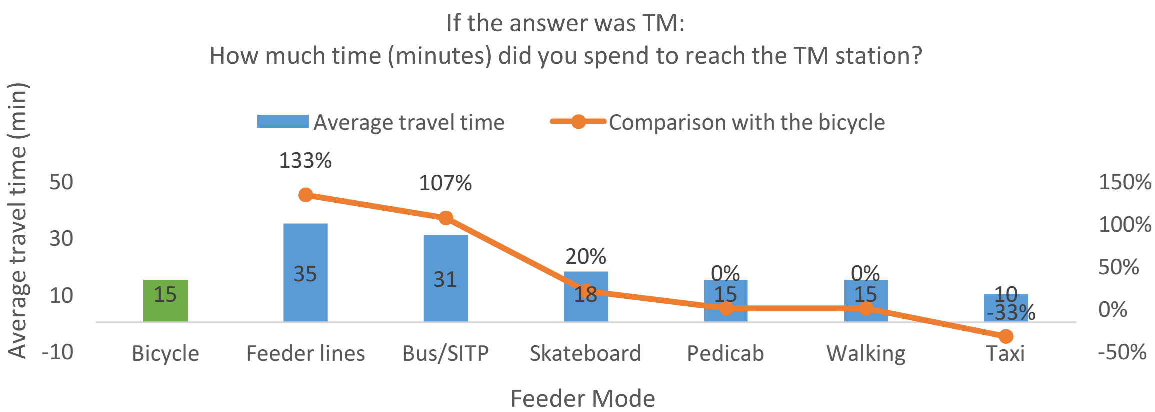

Figure 5.32 Average of the perceived travel time by other feeder modes before CP users started doing bike-and-ride and comparison with the current average travel time to CPs by bicycle

PT modes are the slowest ones to reach TM stations with more than double the time spent by bicycle, whereas the taxi is the fastest mode being 33% faster than the bicycle. It can also be identified that walking and pedicabs are competing modes to the bicycle in terms of travel time.

Figure 5.33 presents the average travel cost per trip by each feeder mode – figures are shown in Colombian Pesos (COP).

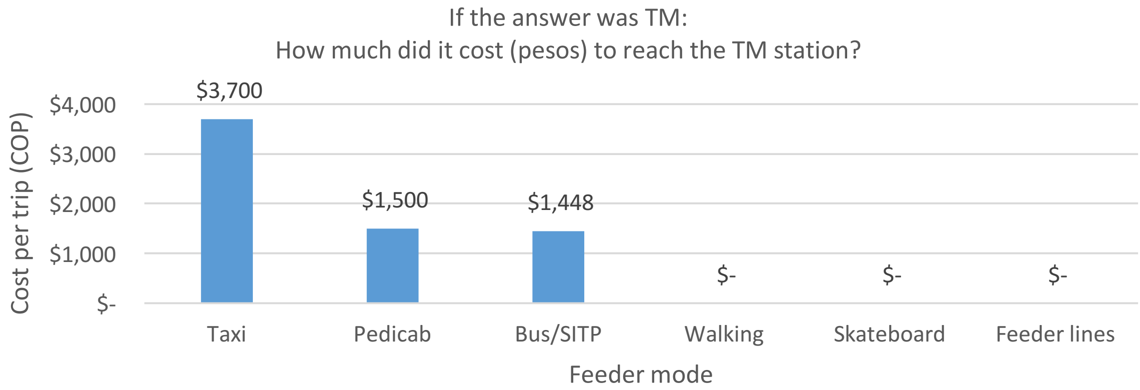

Figure 5.33 Average travel cost by other feeder modes before CP users started using the bicycle.

The taxi is the most expensive mode, followed by pedicabs and the bus/SITP. With regard to trip cost, walking, feeder lines and other NMT modes are competitive to the bicycle.

Figure 5.34 shows the perceived ease with which CP users traveled by other feeder modes to TM – results are shown in terms of PT, NMT and MIT. Refer to Figure 13.2 in the Appendices for detailed information by mode.

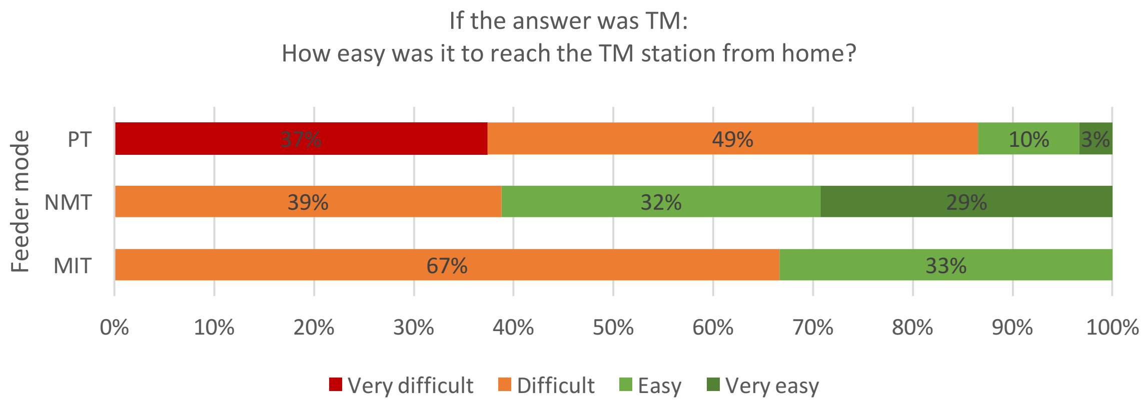

Figure 5.34 Ease with which CP users traveled by other feeder modes to TM before they started doing bike-and-ride

In general, NMT modes were the best-rated modes although there is a 39% that considered them difficult to travel by. On the other hand, 67% of the CP users that traveled by MIT modes stated that it was difficult to travel with them, and 86% of the CP users that traveled by PT thought it was difficult or very difficult to reach TM stations by PT. This can be explained by the city's traffic conditions, and the waiting times and overcrowding of PT.

5.4.2 Alternative Transport Mode to Bike-and-Ride

At times when CP users do not cycle to TM stations, they have the possibility of using other feeder modes to reach them or they can use other transport modes for performing the entire trip. Figure 5.35 shows the transport modes CP users travel by when not doing bike-and-ride.

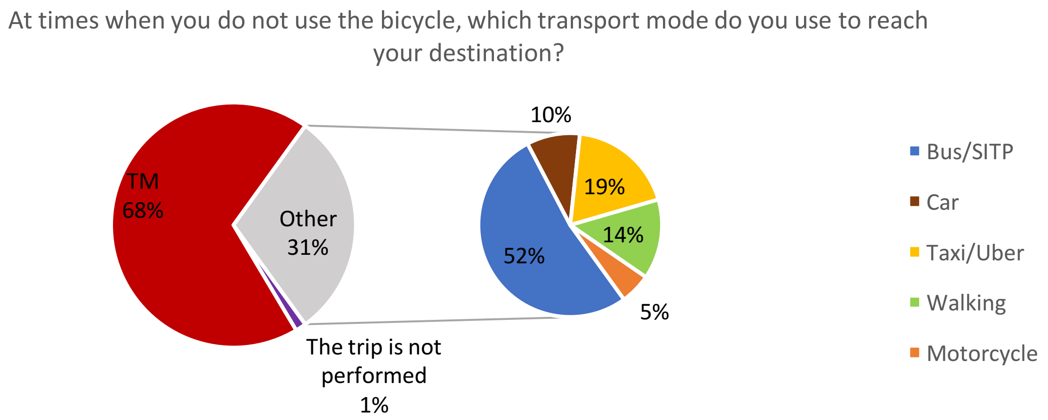

Figure 5.35 Modes of transport used at times when CP users do not bike-and-ride

From the total, 68% of the CP users continue traveling by TM, while 31% uses other modes and only 1% does not perform the trip at all. Figure 5.35 shows that, from the 31% that performs the entire trip by other modes, 52% continue traveling by PT, 34% shift to MIT modes and the rest walks.

Figure 5.36 shows the distribution by gender of the 31% of CP users that travel by other transport modes.

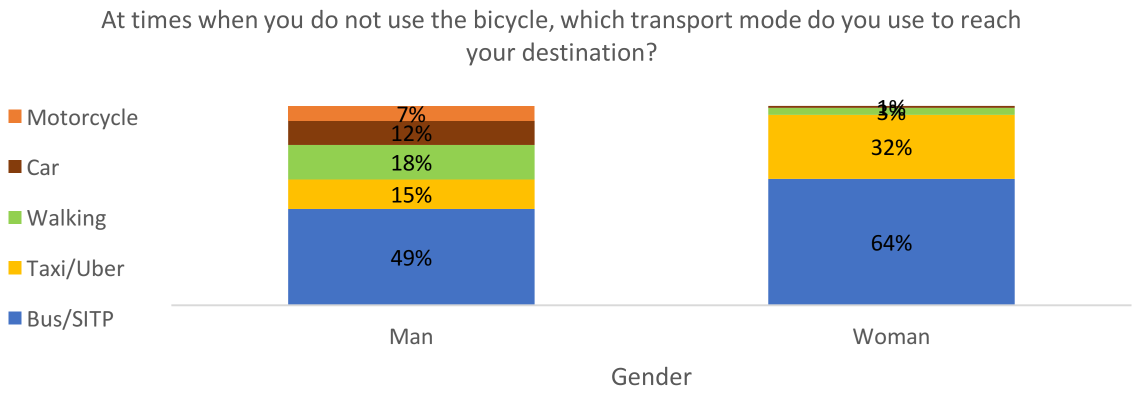

Figure 5.36 Modes of transport used at times when CP users do not bike-and-ride by gender

From Figure 5.36 it can be seen that men are more multimodal than women. Women mainly use bus/SITP and taxi/Uber, while men also walk and use the car and motorcycle. In general, less than 1% of women shift to private MIT, whilst about 20% of men use to these modes. Nonetheless, whereas only 3% of women travel by foot, 18% of men shift to this option.

The figures that follow consider the other 68% of CP users that always travel by TM, but use other feeder modes. Figure 5.37 displays the distribution of the feeder modes they use.

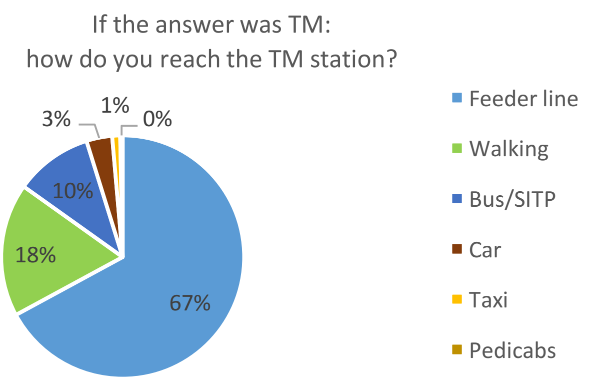

Figure 5.37 Other feeder modes to TM used at times when CP users do not bike-and-ride

Most of the CP users travel by PT with a total share of 77% followed by NMT with an 18%, and MIT modes with a 4%. It is interesting to see that, even though most of the surveyed stations have pedicabs – a type of tricycle designed to carry passengers on a hire basis –, less than 1% of the people use this mode to reach the station.

Figure 5.38 shows the distribution by gender of the CP users that travel by other feeder modes.

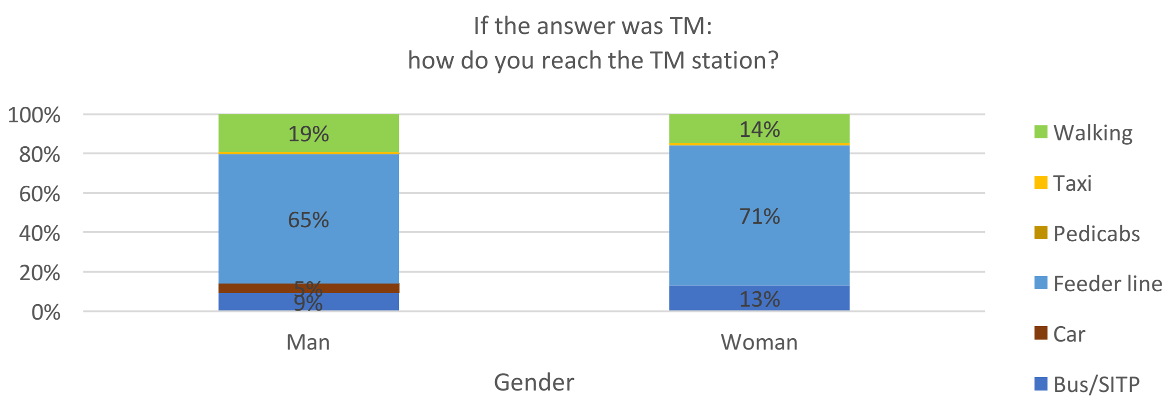

Figure 5.38 Other feeder modes used at times when CP users do not bike-and-ride by gender

Results do not show a great difference except for the fact that 5% of the men use the car, whereas women do not.

The way in which the survey was designed did not have more question regarding the mode choice at times when CP users do not bike-and-ride. Therefore, a new study would be necessary to reveal more detailed information about this.

5.5 Rating of Current Situation

This section explores CP users' rating regarding the current situation. The objective is to understand their perceptions and make a diagnosis of how TM and bicycles have been integrated until now. Based on a Likert-type scale in terms of the level of agreement (Vagias, 2006), CP users were asked to rate the bicycle network, the areas surrounding the CPs, and the parking facilities – in terms of design, operation and capacity. Figure 5.39 presents the results.

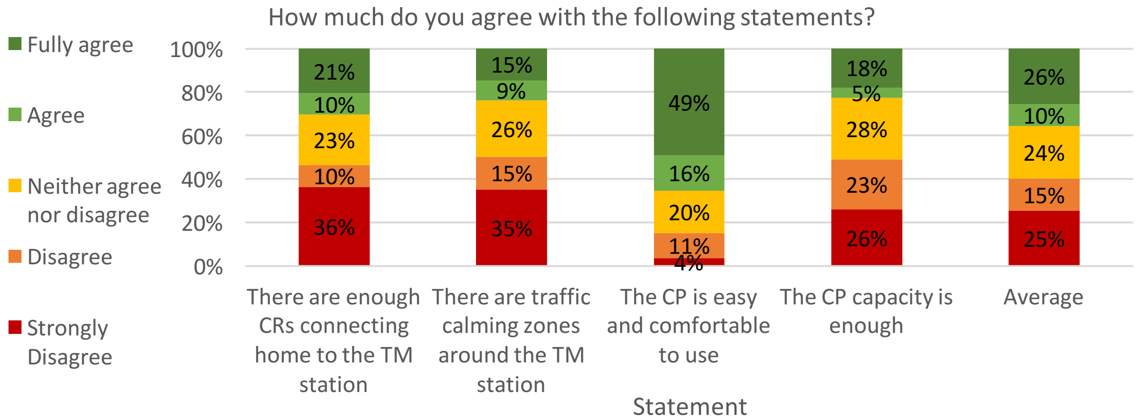

Figure 5.39 CP users' rating of the current situation

On average, 36% of the CP users agree and fully agree with the statements, 24% are neutral, and 35% disagree and strongly disagree reflecting a general division of opinions.

From Figure 5.39, it can be seen that the opinions regarding the bicycle network and the CPs' surrounding areas have a similar behavior. In both cases, nearly half of the CP users disagree that there are enough bicycle lanes and areas with low vehicle speeds and only one third thinks otherwise.

In terms of the ease and comfort with which people can use the bicycle parking facilities, 65% of the CP users agree and fully agree that they are easy and comfortable to use. A 20% is neutral about it and only 14% disagree and strongly disagree with the statement.

With respect to the CPs' capacity, 49% of the users think that there is not enough space for all the bicycles left at the stations whilst 23% think otherwise. These results support the capacity and occupancy numbers of the CPs shown in Section 4.2 where it is presented that some facilities are oversaturated whereas others barely have some users.

During the surveying process, it was perceived that many CP users like having bicycle parking facilities at TM stations. Moreover, using the bicycle as a feeder mode to TM has become a very good option to save time, do some exercise, and have more flexibility and comfort – see Figure 5.23. However, the results from Figure 5.39 indicate that there is an important level of discomfort with how CT integration has been implemented so far showing the great opportunity for improvement. The current flaws must be fixed and the positive aspects need to be reinforced in order not only to attract potential users, but also to keep the current ones.

In a future study about bike-and-ride in the city, it would be useful to ask people about the user information aspects. It is important to know their perceptions regarding road signals and, more importantly, about the educational and outreach mechanisms used to promote and inform the people. It is necessary to identify is the communication media and campaigns are reaching people and modifying their transport behaviors.

Now, given that each bicycle parking facility has different characteristics, it is important to evaluate them separately. Additionally, in order to have a quantitative estimation of users' ratings, each Likert item was assigned a value – see Table 5.3 – and each statement was given a score based on the average of CP user's answers. The system used goes from 1.0 to 5.0 where 1.0 is the lowest score and 5.0 the highest; 3.0 is considered acceptable.

Table 5.3 Scoring system for the rating of the current situation aspects

Likert Item	Score
Strongly disagree	1
Disagree	2
Neither agree nor disagree – Neutral	3
Agree	4
Fully agree	5

Figure 5.40 depicts how people scored each parameter asked breaking down the data by the three main surveyed stations: *Alcalá*, *Avenida Rojas* and *Portal de Suba*.

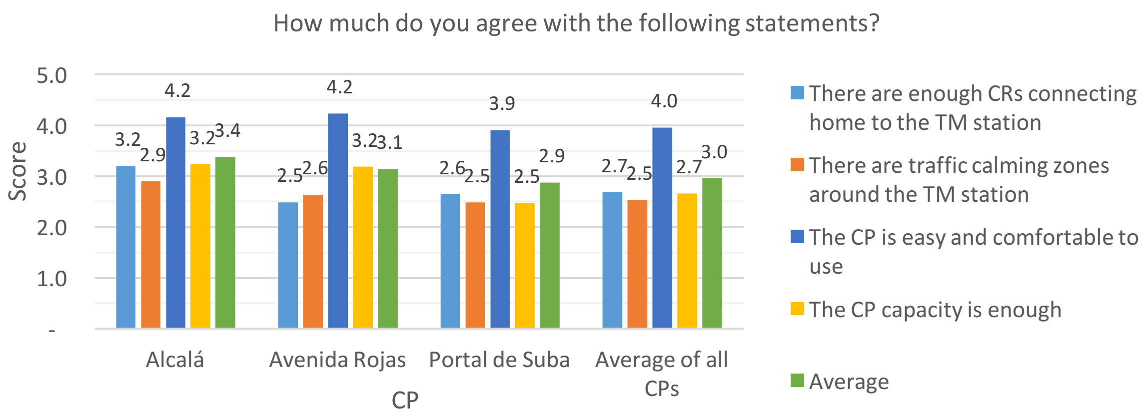

Figure 5.40 CP users' rating of CPs by parameter

At a first sight, the parameter with the highest score is the one that refers to the design and operation of the CPs with a total scoring of 4.0, whereas the parameter with the lowest score refers to the traffic calming zones in the stations' surroundings with 2.5. *Alcalá* is the CP with the highest mark in all parameters, with results even higher than the average of all surveyed stations. *Avenida Rojas* has negative rates in terms of the bicycle network and traffic calming zones, but positive marks concerning the CP's design, operation and capacity. *Portal de Suba* is the worst scored station, with almost every score below 3.0, except for the parameter regarding the design and operation of the CP.

Overall, al CPs got in average a score of 3.0 evidencing the general acceptance on how CT integration has been implemented so far, nevertheless, it certainly could be improved. As mentioned before, *Alcalá* is the CP with the highest mark, followed by *Avenida Rojas* and *Portal de Suba*, which in fact has a negative score.

Figure 5.41 shows CP users rating of CPs's opening hours.

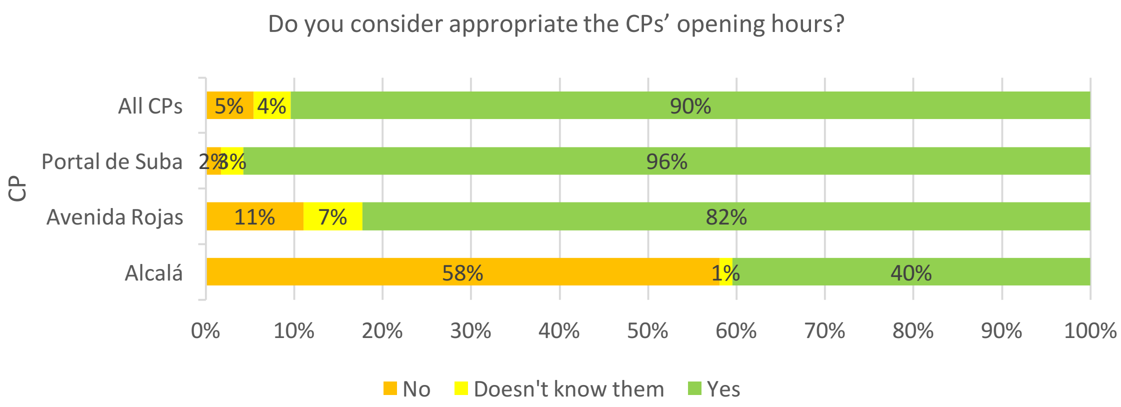

Figure 5.41 Rating of the CPs' opening hours

From the total, 90% of the CP users agree that the opening hours are appropriate, 4% do not know them, and 6% think that they should be extended. By CP, it can be seen that in *Alcalá* almost 60% do not agree with the CP's opening hours, possibly because it does not have the same schedule as TM, and it opens after and closes before TM. Nevertheless, other CPs in average show positive results.

From the total people that would like to extend CPs' opening hours, 88% said that they would prefer that they close later and 12% said that they should open earlier and close later.

5.6 Rating of Improvement Measures

This last section of the survey results has as main objective to evaluate how important it is for CP users to implement measures for a better CT integration. Based on the literature review, CP users' rating of the current situation and the fieldwork performed for the present study, ten improvement measures were chosen to be rated. The list is shown bellow:

i. A denser CR network in the city
ii. Implement traffic calming zones near TM stations
iii. More bike-and-ride promotion and awareness campaigns
iv. More information about CPs and better road signals
v. Improve lighting of CRs
vi. Improve surveillance of areas surrounding CPs
vii. Improve design of CPs
viii. Increase capacity of CPs
ix. Extend CPs' opening hours
x. Offer additional services (e.g. lockers, tools, hydration points, etc.)

All the suggested measures are related to the improvement of the bike network, user information, safety and security conditions, and characteristics of the facilities. Based on the Likert-type scale on the level of importance (Vagias, 2006), Figure 5.42 shows how relevant these measures are.

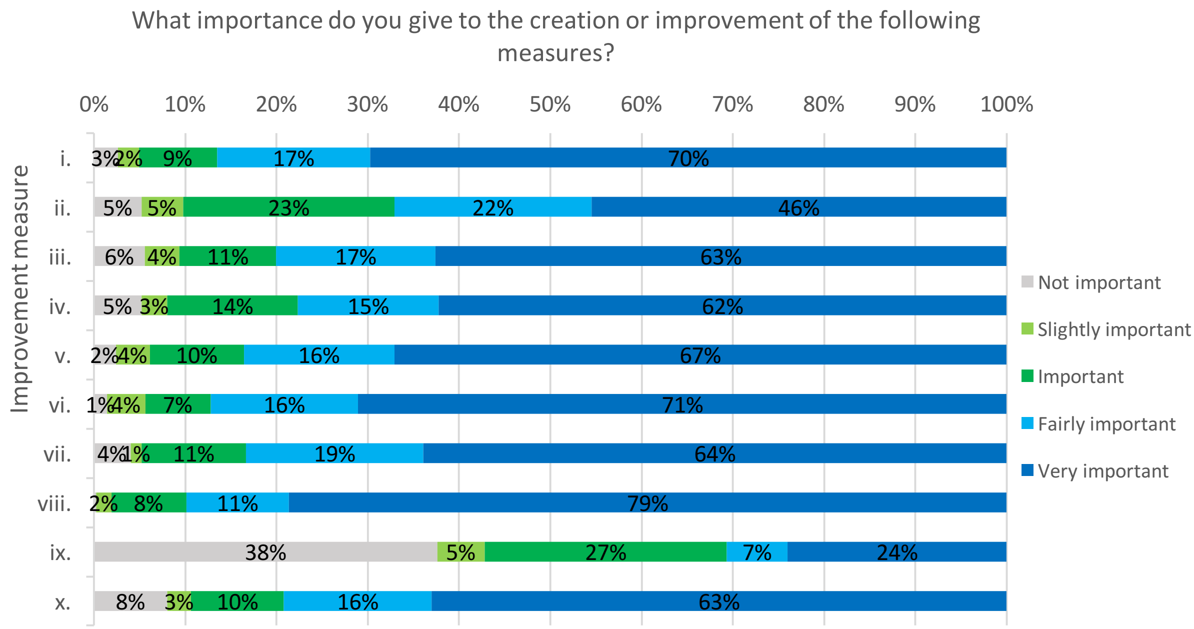

Figure 5.42 CP users' rating on improvement measures

Broadly speaking, according to CP users, all measures should be implemented or improved, except for the one related to the facilities' opening hours. However, in order to have a quantitative estimation and be able to prioritize measures, a similar scoring system to the one used in Section 5.5 was utilized –Table 5.4 shows the scores assigned to each Likert item. Once again, the system used goes from 1.0 to 5.0, where 1.0 is the lowest score meaning that the given measure has no importance at all, and 5.0 the most importance. The score 3.0 is considered neutral, meaning that the measure is a nice to have, but not fundamental.

Table 5.4 Scoring system for the ranking of the improvement measures

Likert Item	Score
Not important	1
Slightly important	2
Neutral	3
Important	4
Very important	5

Figure 2.1 presents the ranking of each measure according to the answers of the CP users. The presented results are an average of all the CPs, however, detailed information about CP users' ranking by station can be found in Figure 13.3 in the Appendices.

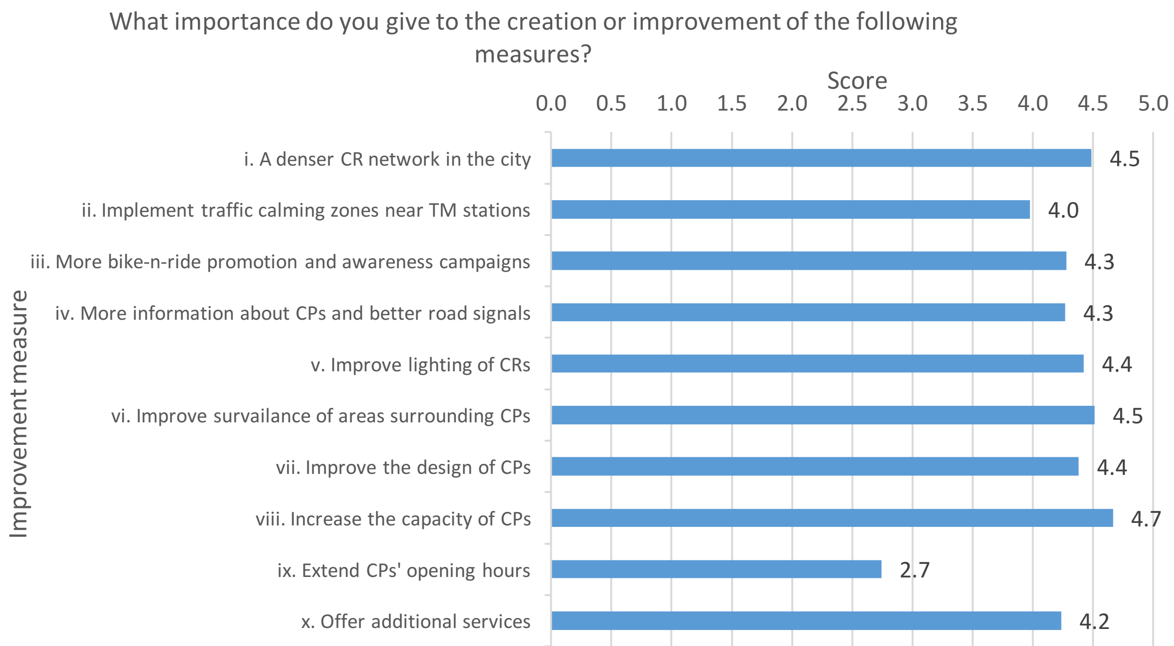

Figure 5.43 CP users' ranking of the improvement measures

The most important improvement measure is to increase the capacity of CPs, followed by improving surveillance of the CPs' surrounding areas, and a denser bicycle network in the city. These high scores show that CP users perceive that the integration between TM and bicycles can be enhanced, therefore, if these were to be implemented, not only the current CP users would be kept, but also potential users would be attracted to do bike-and-ride.

After having presented the survey results and having analyzed the different outcomes, recommendations will be presented in the next section with the objective of having a better and successful CT integration in Bogotá.

6. Recommendations

From the literature review it was learned that a successful integration of bicycle use with PT ridership could be achieved by implementing the following measures in a comprehensive manner:

- Enabling bicycles to be brought on transit vehicles,
- Improving the availability of parking near transit stops,
- Providing staffed racks and lockers at major transit hubs,
- Connecting transit stations to an existing network of bicycle paths and lanes,
- Offering other bicycle services at parking facilities, and
- Providing BSS near transit stations and major destinations.

Additionally, apart from the actions mentioned above that seek the improvement of the bicycle infrastructure and supply, bike-and-ride needs to be promoted and incentivized through different user information tactics and strategies. The options go from having better road signals and print and online user information on all relevant topics, to marketing campaigns aiming to raise awareness and persuade people to change their mobility behavior. The combined effort will not only allow current CT users to make well-informed decisions when planning their trips, but will also attract potential users.

Nevertheless, several aspects must be considered before implementing any of these tactics or strategies in the specific case of Bogotá. This section gives recommendations on how to approach and execute each measure starting by recognizing what the city has already achieved in terms of CT integration, and then by taking into account the conclusions and out-takes as well as the lessons learned from the research and empirical work performed for present study.

To start with, it is necessary to keep incentivizing the use of the bicycle by generating proper environments that enhance the accessibility to non-motorized and public transportation and, most importantly, to improve the safety and security perception when riding a bicycle. A bicycle culture has already been created in Bogotá, yet it must be strengthened so it can be expanded to the whole population and become a more powerful transport mode.

By supporting public and private initiatives that seek the prioritization of the bicycle – such as the marketing and awareness campaigns led by the SDM and the different bicycle activities promoted by citizens and activists –, it will be possible to have higher investment in bicycle lanes, parking facilities and user information. Once the accessibility to bike-and-ride is enhanced, new users will be attracted to the system increasing the demand and, thus, incentivizing additional investments to keep improving the whole CT integration supply. Figure 6.1 presents how this virtuous cycle between supply and demand functions.

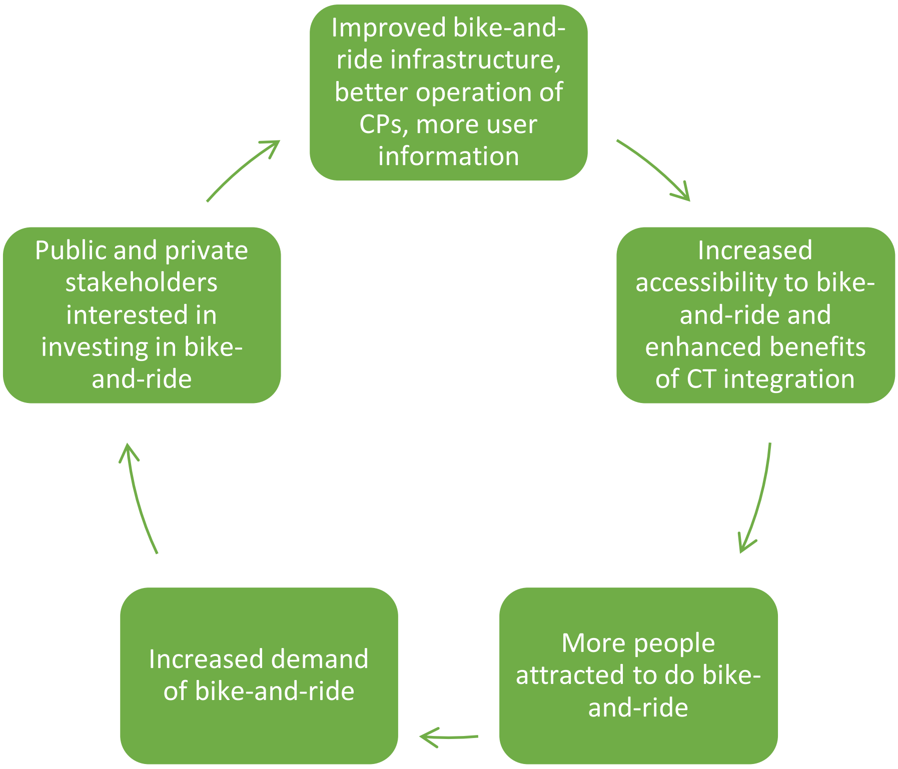

Figure 6.1 Virtuous cycle between bike-and-ride's supply and demand. Source: Own elaboration based on (Wulfhorst, 2003)

As a second step, before investing in new infrastructure and building more bike lanes and parking facilities at PT stops and stations, soft measures should be implemented in order to maximize and optimize the use of the current infrastructure and system. In this sense, based on the occupancy level of the 17 existing CPs at TM stations two complementary actions should be carried out:

i. Expand the communication and available information regarding the possibility of doing bike-and-ride in Bogotá. Highlight all its benefits – time savings, no cost, health, and exercise, etc. – through several campaigns and strategies looking to drive awareness and promotion of the system, along with print and online communication.
ii. Enhance the current design and optimize the operation of the existing CPs. Based on the results, increasing the capacity of the CPs is the most important measure to implement, however, it is not the only one to consider, other improvements such as more surveillance and lighting in the surrounding areas are also very important and of easy execution.

Regarding the information availability and promotion, Bogotá already counts with a few campaigns that promote the use of bicycles, as well as different communication tools that inform citizens on the mobility options available in the city. Nonetheless, during the execution of the study very few information about CPs was found. It is important to develop communication tools to inform in a clear and convenient way current and potential users all the relevant information regarding bike-and-ride, such as CPs location, access routes, service hours, the capacity of the facilities, etc. With the appropriate outreach mechanisms, these tools will allow current and potential users to program their trips and make informed decisions.

In addition, information points around the city would be very useful for locals and users to be able to get information about cycling, bicycle parking and use of PT in an integrated manner. Moreover, information about other types of bicycle parking facilities is also required, so that people can consider other parking options at those TM stations without any CP coverage, or where the current capacity has been surpassed.

Regarding the design and operation of CPs, since "*being fast*" is the most popular reason for people to start using the bicycle as a feeder mode, it is very important to ensure that this feature remains very strong when compared to other modes. Therefore, the design and operation of the CPs must aim at achieving time savings from the moment the person plans the trip up to the point where the bicycle is left at the parking facility.

Regular maintenance to the existing CPs and bicycle network is also important, as well as the installation of road signals. Overall, the design of all parking facilities should be standardized and should focus on providing a high-quality service. For this, it is necessary to visit, assess and give a diagnosis of the flaws and improvements needed in the existing facilities and surrounding areas.

As a third step, it is necessary to make investments in new bicycle supply i.e. new bicycle lanes for a denser bicycle network and, most importantly, new bicycle parking facilities in those areas without any CP coverage – see Figure 5.11. To be more precise, these new facilities are required at TM's Phase I stations, where it was observed that very few CPs were found. Consequently, with these new bicycle parking facilities, it would be possible to attract users from the highest and lowest socioeconomic strata, which currently have a very low share.

In order to decide in which specific TM stations to build the new CPs, a demand study should be carried out instead of choosing the stations based simply on space availability– as it is currently happening. It would also aid to properly determine the number of potential users and, therefore, design facilities with the adequate capacity. Complementarily, this study allows the classification of users into homogeneous segments to then develop strategies consistent with the segments' needs and motivations. By segmenting the population, major user groups can be identified and specific incentives and marketing action can be undertaken.

The design of the new bicycle parking facilities must seek to provide comfort and convenience to users. They should be equipped with the required hardware and software that allow the automation of user's registration and the tracking of the facility's occupancy. Offering additional services like lockers, tools for quick reparations and hydration points are also required to attract more users to the system. However, before rolling out this kind of initiatives across CPs a pilot should be developed in order to determine people's reaction and if they give a correct use to the services provided.

Based on the three categories of recommendations described above, Table 6.1 summarizes the different specific improvements required for upgrading the current CT integration system in Bogotá.

Table 6.1 Specific CT integration improvement measures to be implemented in Bogotá

Category	Specific Measure	Priority
I. Incentives	Cooperate with public and private initiatives that seek to prioritize the use of the bicycle among other motorized modes.	High
	User information on where to find other types of bicycle parking facilities i.e. urban furniture and private parking.	Medium
	Give more flexibility to CP users by allowing them to collect their bicycle after returning to the station by other modes and by allowing them to leave their bikes overnight for short periods e.g. three days.	Medium
	Offer additional services inside CPs.	Low
	Extend the opening hours in CPs managed by IPES so they match TM's schedules.	Low
II. Soft Measures	Launch campaigns to communicate relevant information about CT integration and use appropriate outreach mechanisms.	High
	Increase capacity of the existing CPs according to the demand.	High
	Improve lighting on bike lanes to enhance the sense of security.	High
	Provide a standardized CP user registration system across CPs.	High
	Implement more efficient access/exit systems to minimize queuing and waiting times at the entrances.	High
	Install information kiosks or road signals near TM stations for cyclists to know where CPs are found and how to reach them.	Medium
	Provide strict control over the minimum speed limit for vehicles – maximum 30 km/h – near TM stations to improve pedestrians and cyclists' road safety conditions.	Low
	Prioritize the transit of bicycles in residential streets where there is not enough space for having segregated bike lanes.	Low

	Implement bicycle traffic lights at intersections with other motorized modes.	Low
	Inspect existing bicycle supply and perform the required maintenance activities.	Medium
III. Infrastructure	Introduce more CPs at TM's Phase I stations	High
	Increase the supply of private parking facilities and urban furniture – in the form of *Inverted U* for example – around the city.	High
	Provide all CPs with a roof in order to protect bicycles against weather conditions.	Medium
	Continue building a denser bicycle network that connects with the different types of bicycle parking facilities.	Medium

As it can be observed, most of the specific improvements are soft measures, which usually require less investment than new infrastructure. Moreover, these measures need less time to be implemented meaning that it would be possible to achieve positive results in terms of new CT users in a short term.

A successful CT integration is grounded not only in providing the necessary supply, but also in encouraging users to take care of the system and persuading others to do the same. Therefore, complementing the initiatives described above, it is important to educate and sensitize road users to drive a sense of belonging and respect for the bicycle infrastructure and bike-and-ride service to help the overall preservation of the system. This can be accomplished by displaying information on how use the system correctly and on people's rights and duties.

From an institutional point of view, it is fundamental that the actions and initiatives of all stakeholders are synchronized and oriented towards the same common objective: to strengthen the use of sustainable modes around the city.

Finally, it is recommended to incorporate CT integration to a BSS systems and other TDM strategies implemented in the city. This way, people will be incentivized to use NMT and PT and moved away from MIT modes. As a result, improvements in Bogotá's current mobility conditions will be seen, as well as enhancement on the pollution and emissions levels, public health and in general, a better quality of life for the *"Bogotanos"* will be reached.

7. Conclusions

As it was shown in the present study, since the late 1970's until today, Bogotá has been internationally recognized as a pro-bicycle city. This is not just because of its Sunday's *"Ciclovía"* and extension of its bicycle lanes, but because today it is one of the capital cities that realizes the most number of bicycle trips in the LAC region. However, the city's development and the increasing spending power of citizens have brought as a result important problems in terms of mobility, congestion, accessibility, equity, etc. that need to be addressed urgently.

Throughout this thesis, it was studied how CT integration is able to generate car-free travel behaviors, improve the mobility conditions of *"Bogotan*os", and enhance the performance of sustainable transport modes by encouraging more bicycling as well as more PT. For cyclists, bike-and-ride is an efficient way of making longer trips, whereas, for PT use, it increases the catchment areas of stops and stations at a much lower cost than with feeder lines. Furthermore, with the combination of these two transport modes, the mobility of non-car users is enhanced and car-only trips meet a sustainable, cheaper and healthier competitor. As a result, the use of MIT is discouraged and even car ownership is reduced.

Nevertheless, for all this to happen it is determinant to create adequate interchange conditions to allow a smooth transition between both modes and incentivize people to shift to this modality. In other words, the system requires high-quality parking options that are safe and accessible, as well as adequate information tools, bicycle lanes, and surrounding areas.

The main objective of this master thesis was to understand people's attitudes towards CT integration in Bogotá's context and use this knowledge to formulate recommendations that support the successful achievement of this integration. For this, intercept and online surveys were carried out along with an extensive research and analysis of citizens' mobility behaviors and bicycle use.

The surveys were very effective to characterize and understand current CT users and learn about their motivations and perceptions about the status quo, as well as the opportunities to have a better CT integration. Furthermore, CT user's demographic characteristics were established, the average distance they travel to TM stations was found, and the alternate modes they use when not using the bicycle were identified and outlined.

The analysis and results of this research allowed to conclude that CT integration in Bogotá had a relatively good start with 17 CPs at TM stations, over 2,500 bicycle parking spaces and the possibility to carry folding bicycles inside buses. There are still general improvements that are required like the improvement of capacity in oversaturated facilities and better surveillance and user information. However, it is more important to start with a unified and holistic approach of all the recommendations provided and have clear strategies that contribute to the achievement of one and a common goal: having a successful and integrated CT system that serves the needs of Bogotá's users.

Even though the whole exercise of surveying CP users could be considered successful, some shortcomings were present at the time of the data collection and analysis. These are:

- Small sample size due to the scarce time and resources.
- No data collection for CP users of the lowest and highest socioeconomic strata, which increased bias error and affected the expansion factors.
- Little information about CT users from ages bellow 18 and above 60.
- Lack of questions related to the quality and availability of user information.
- No data collection with regards to trip characteristics by TM – duration, ease of travel, etc. – in order to make comparisons against the other transport modes used.

In order to solve these shortcomings and improve statistical reliability of the findings, it is necessary to expand the sample and survey more CP users from different TM stations. Additionally, to completely understand the modal shift resulted from CT integration it is necessary to have questions related to the trip duration, costs and ease of travel by TM. Only this way it would be possible to make a valid comparison between bike-and-ride and other transport modes.

The analysis on the case studies showed that it is possible to achieve a successful CT integration regardless of the the city where it is implemented. Different options for PT and cycling can be available and even distinct bicycle cultures can characterize people's mobility, however, as long as there are adequate facilities allowing a smooth transition between transport modes, a sufficient bicycle network and enough user information, people will be encouraged to be more intermodal.

Naturally, the more the bicycle is prioritized with respect to other modes of transport in a city – without competing with pedestrians, who should always have the highest priority –, the easier it will be to attract people to do bike-and-ride. CT integration could act as a starting point from which the bicycle starts gaining a relevant position in the daily mobility of people until it reaches the point where its mode share is even comparable to the share of most bicycle-oriented cities.

Bogotá's mobility problems are just beginning and the expectation is for these to worsen. As evidenced already, the city's motorization rate is still very low compared to other LAC cities and the majority of its citizens travel by mass PT modes. Nevertheless, people can perceive already the everyday heavy congestion and the other economic, social and environmental problems that come along. It is for this reason that the city needs to seek for measures aimed at alleviating the city's transportation situation, and therefore, prioritize, invest and strengthen the use of sustainable modes at the same time that it disruptions MIT users' paradigms on the use of other modes.

Finally, when looking forward to the next steps of the research initiated in this thesis, it is determinant to start with a demand estimation study in order to determine the potential of a comprehensive CT integration in Bogotá and also considering the implementation of the projected BSS. Moreover, within this study it would be important to segment CT users in order to develop more effective strategies and communication campaigns. The outcomes of the proposed study could attract the local government and private sector to invest in bike-and-ride allowing *"Bogotanos"* to have more and better mobility options and overall, a better quality of life.

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9. List of Abbreviations

BRT	Bus Rapid Transit
BSS	Bike-Sharing System
CFPV	Road Safety Fund Corporation
COP	Colombian Peso
CP	CicloParqueadero
CR	CicloRuta
CT	Cycle-Transit
DADEP	Administrative Department of Public Space Defense
DANE	National Department of Statistics
EAAB	Bogotá’s Water and Sewer Company
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IDRD	District Institute of Recreation and Sport
IDU	Urban Development Institute
IPES	Institute for Social Economy
LAC	Latin America and the Caribbean
MEBOG	Bogotá's Metropolitan Police
MIT	Motorized Individual Transport
NMT	Non-Motorized Transport
PE	Punto de Encuentro
PT	Public Transport
SDG	Steer Davos Gleave
SDM	District Department of Transportation
SDP	District Department of Planning
SITP	Integrated Public Transport System
SITVA	Integrated Transport System of the Aburrá Valley

STOD Sustainable Transport-Oriented Development

TDM Transport Demand Management

TM TransMilenio

TPC Collective Public Transport

10. List of Figures

11. List of Tables

12. List of Equations

13. Appendices

13.1 Survey by Elsner (2015)

Day: Hour: CP:

The person is:

a. Dropping off the bicycle at the CP
b. Picking up the bicycle at the CP

Trip characteristics:

1. Where is the origin/destiny of your trip by bike (address)?
2. How much time does the trip to the CP take?
3. How many days a week do you come to the TM station?
4. How many days a week do you use the bicycle to come to the TM station
5. Why did you decide to start using the bicycle to come to the TM station?
   a. It's inexpensive
   b. It's fast
   c. It's comfortable
   d. Distance is too long to walk
   e. Only option
   f. It's flexible
   g. I like it
   h. I do exercise
   i. Other: _____
6. How long have you been using this CP?
7. If there were a bike-sharing system, would you use it instead of using your own bike?

Demographic characteristics:

8. Age (years):
   a. < 15
   b. 16 to 20
   c. 21 to 25
   d. 25 to 35
   e. 35 to 50
   f. > 50
9. Gender
10. Main occupation:
    a. Employee
    b. Retired
    c. Self-employed
    d. Unemployed
    e. Student
    f. Other: _____
11. Education level:
    a. None
    b. Primary school
    c. High school
    d. Technician
    e. Graduate
    f. Postgraduate
    g. No Information

13.2 CT Integration Survey

Survey No. __ Date: ___/___/___ Hour: ___:___ CP: ________

Demographic Characteristics:

1. Gender: Woman ______, Man ______.
2. Age: a. < 18 ____, 18-25 ____, 26-35 ____, 36-45 ____, 46-60 ____, > 60 ____.
3. Socioeconomic strata: 0 ____, 1 ____, 2 ____, 3 ____, 4 ____, 5 ____, 6 ____.
4. Origin of the trip to the TM station (address): ____________________________.
5. Occupation: a. Student __, b. Employee __, c. Self-employed __, d. Unemployed __, e. Retired __.

Trip characteristics:

6. On average, how many days a week (1-7) do you travel by TM to your destination? _____.
7. On average, how many days a week (1-7) do you use the bicycle to reach the TM station? ______.
8. On average, how much time (minutes) do you spend to reach the TM station by bicycle? ________.
9. To reach the TM station by bicycle, you travel mostly on: a. CR __, b. Sidewalk __, c. Road __.
   9.1. If the answer was CR: would you still use the bicycle if there were no CR between your origin and the TM station? Yes ______, No ______.
10. How long (months/years) have you been coming by bicycle to the TM station? ___.
11. How long (months/years) have you been using this CP? _____.
12. If there were no CP, would you still come by bicycle to the TM station? Yes _, No _.
13. Which is the main reason for your decision to start coming by bicycle to the TM station? a. It is inexpensive ___, b. It is fast __, c. It is comfortable and flexible ___, d. I do exercise ___, e. It is environmentally-friendly ___, f. Other: ____.
14. At times when you do not use the bicycle, which transport mode do you use to reach your destination? a. TM __, b. Walking__, c. Motorcycle___, d. Pedicab __, e. Taxi__, f. Bus/SITP__, g. Car __, h. Other: _____.
    14.1. If the answer was TM: how do you reach the TM station? a. Walking ___, b. Motorcycle ___, c. Pedicab ___, d. Taxi ___, e. Feeder bus ___, f. Bus/SITP ___, g. Car ___, h. Other: ___________.
15. When you had not started using the bicycle as a feeder mode to TM, which transport mode did you use to reach your destination? a. Bicycle+TM ___, b. TM ___, c. Walking ___, d. Motorcycle ___, e. Pedicab ___, f. Taxi ___, g. Bus/SITP ___, h. Car ___, i. Other: ___.
    15.1. If the answer was other mode different than TM or Bicycle+TM:
        15.1.1. How much time (minutes) did you spend to reach your destination? _____.
        15.1.2. How much did it cost (COP) to reach your destination? _____________.

15.1.3. How easy was it to reach your destination from home? a. Very easy ____, b. Easy ____, c. Difficult ____, d. Very difficult ____.

15.2. If the answer was TM:

15.2.1. How did you reach the TM station? a. Walking ___, b. Motorcycle ___, c. Pedicab ___, d. Taxi ___, e. Feeder bus ___, f. Bus/SITP ___, g. Car ___, h. Other: __________.

15.2.2. How much time (minutes) did you spend to reach the TM station? _____.

15.2.3. How much did it cost (pesos) to reach the TM station? _____________.

15.2.4. How easy was it to reach the TM station from home? a. Very easy ____, b. Easy ____, c. Difficult ____, d. Very difficult ____.

<u>Rating of current situation:</u>

16. Do you consider appropriate the CPs' opening hours? Yes ______, No ______, I do not know them ______.

16.1. If not, what do you suggest? ___________________.

17. How much do you agree with the following statements? Considering a scale from 1 to 5, where: (5) Totally agree, (4) Agree, (3) Neither agree not disagree (Neutral), (2) Disagree, (1) Fully disagree.

		5	4	3	2	1
17.1	There are enough CRs connecting home to the TM station					
17.2	There are traffic calming zones around the TM station					
17.3	The CP is comfortable and easy to use					
17.4	The capacity of the CP is sufficient					

<u>Rating of the improvement measures:</u>

18. What importance do you give to the creation or improvement of the following factors? Considering a scale from 1 to 5, where: (5) Very important, (4) Important, (3) Neutral, (2) Slightly important (1) Not important at all.

		5	4	3	2	1
18.1	A denser bicycle lane network in the city					
18.2	Implement traffic calming zones near TM stations					

18.3	More bike-and-ride promotion and awareness campaigns					
18.4	More information about CPs and better road signals					
18.5	Improve lighting of CRs					
18.6	Improve surveillance of areas surrounding CPs					
18.7	Improve design of CPs					
18.8	Increase capacity of CPs					
18.9	Extend CPs' opening hours					
18.10	Offer additional services inside the CPs (e.g. lockers, tools, hydration points, etc.)					

Additional comments: ____.

13.3 Extra Figures

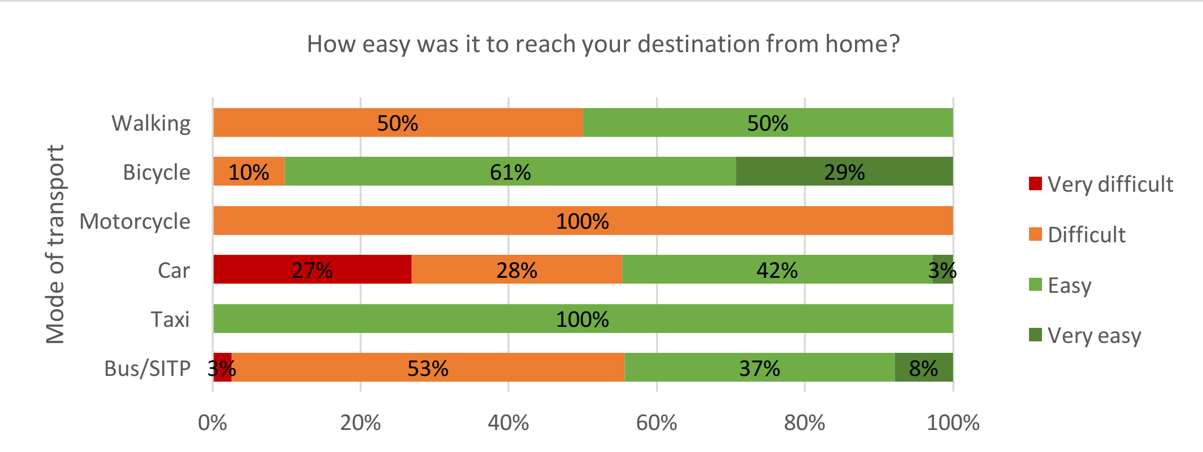

Figure 13.1 **Question 15.1.3 How easy was it to reach your destination from home?**

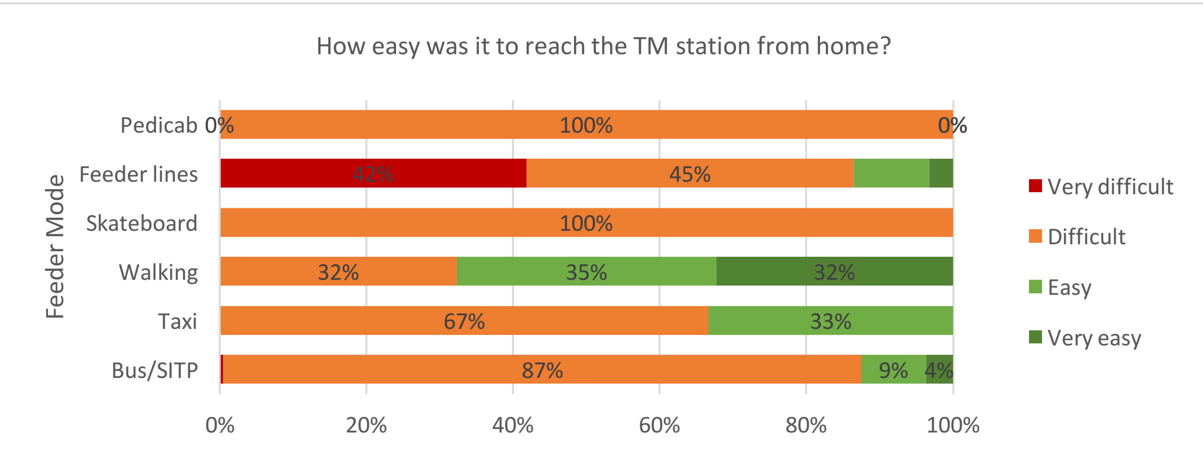

Figure 13.2 **Question 15.2.4 How easy was it to reach the TM station from home?**

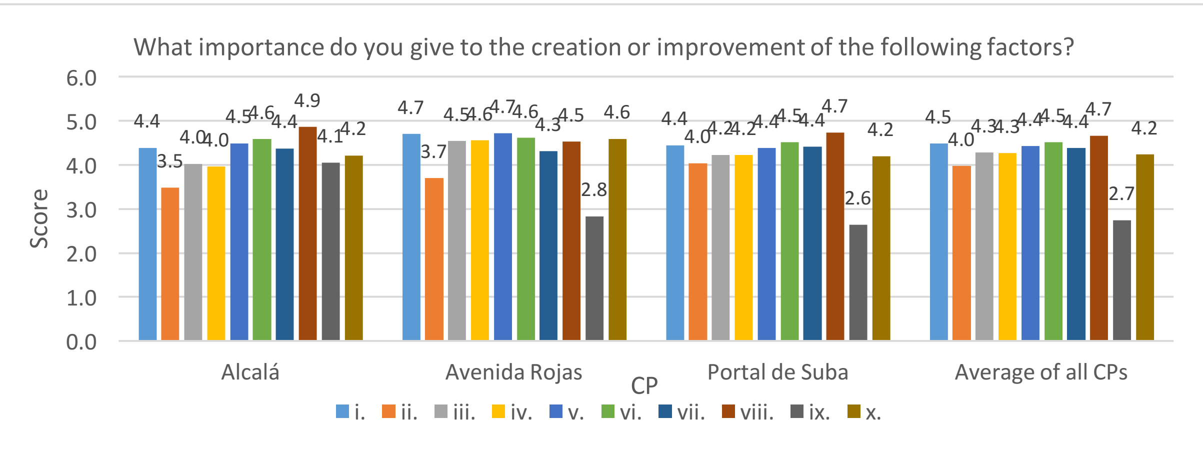

Figure 13.3 **CP users' ranking of the improvement measures by CP**

14. Declaration Concerning the Master's Thesis

I hereby confirm that the presented thesis work has been done independently and using only the sources and resources as are listed. This thesis has not previously been submitted elsewhere for purposes of assessment.

Munich, March 31^{st}, 2016

Alejandra Pabón