MEASURING BICYCLE AND PEDESTRIAN ACTIVITY IN SANTIAGO, CHILE

By

MARIO F. REYES GALFAN
School of Geography and Earth Sciences
McMaster University
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MARIO F. REYES GALFAN, B.Sc. (Honors)

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SUPERVISOR	:	Associate Professor Dr. Antonio Páez
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Abstract

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Mario F. Reyes Galfán
Master of Science
School of Geography and Earth Sciences
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This research demonstrates a method of data collection to analyse and compare flows of bicycle (with historic data) and pedestrian activity using automatic counters and manual counts in Santiago, Chile. An outstanding challenges facing planning for non-motorized transportation (bicycle and pedestrian) is the lack of consistent information on usage and demand of these modes. This is probably the single greatest impediment to being able to understand the behaviour of travelers using these modes. Further, without consistent and accurate information on demand and usage, it is difficult to measure the real benefits of public investments on health, travel time, and other relevant indicators, and to compare these modes to alternatives such as public transit or private automobile. For these reasons, this research aims to measure bicycle and pedestrian activity in specific points of Santiago-Chile. This study is divided into two sections: 1. Measuring bicycle activity in behaviour s of Antonio Varas Ave. and Simon Bolivar Ave. (Case study 1) and Pocuro Ave., Antonio Varas Ave. and Andrés Bello Ave. (Case study 2); and 2. Measuring bicycle and pedestrian activity in the Metropolitan Park of Santiago. This research is designed to (a) evaluate existing bicycle and pedestrian data sources, (b) conduct comprehensive counts of bicyclists and pedestrians using automatic and manual counting methods and (c) analyze the growth rate of bicycle users. This research presents materials developed including a literature review, research objectives, data collection methodology, results from the data collection effort, analysis, conclusions and future recommendations.

Preface

This thesis comprises four chapters. All chapters were written with guidance from my supervisor, Dr. Antonio Páez. The content of this thesis has not yet been submitted for publication.

I oversaw all aspects of the research presented in this thesis. Conceptualization and design of the experiment was a collaborative effort between myself, my supervisor and other professionals in Chile.

I was responsible for programming, manage collecting and analyzing data. Data collection was performed by a group of engineers, architects and volunteer assistants belonging to UYT consulting office with the collaboration of Tecnología Sustentable Ltd. and Ciudad Viva Corporation.

I was solely responsible for the initial draft of the thesis. My supervisor provided advice on appropriate analyses and subsequent interpretation of the results.

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This work has been developed with donations of two private Chilean companies UYT Ltd. and Tecnologia Sustentable Ltd. and one Non-Governmental Organization Ciudad Viva Corporation. Additionally, I would extend my thanks to the team of "Ciclorecreovía" and the administration of Metropolitan Park of Santiago, which gave us all the conditions to develop this activity in the best way possible.

Finally, my love and heartfelt thanks go out to my wife Daniela Quintanilla, my daughter Antonella Reyes-Quintanilla, and parents Rosa Galfán and Mario Reyes. Without your love and support none of this would have been possible. Thank you for always believing in me.

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CHAPTER 1. INTRODUCTION

1 Introduction

1.1 Background and Motivation

A major challenge currently facing planning for non-motorized, active transportation (specifically bicycle and pedestrian travel), is the lack of consistent information on usage and demand related to these modes. This is probably the single greatest impediment to being able to understand the behaviour of active travelers (e.g. Schneider, Patten et al. 2005; UNDP 2005-2008; Nordback and Janson 2010; Hankey, Lindsey et al. 2012). This situation presents issues in countries were transport policy focuses on the intensive use of cars instead of non-motorized transportation, such as Chile. Without consistent and accurate information on demand and usage, it is difficult to measure the real benefits of public investments on health, travel time, and other outcomes that are influenced by these modes, or to compare them to modes such as public transit or private automobile.

The latest evidence shows that the principal benefits of non-motorized travel are principally based on health, economic efficiency, social benefits and environmental improvements. For these reasons, researchers, government's ministries, public health and transportation organizations are focused in the promotion of cycling as a way to improve individual health, increasing the levels of physical activities and reducing the obesity rates as well as reduce air pollution, congestion, traffic dangers, noise, and other impacts of car use (Pucher, Dill et al. 2010).

In different countries around the world including Chile, cities are implementing infrastructure, programs, and policies to encourage people to cycle based on the benefits that produce. However, many of these proposals lack reliable information of number of users through the years, which makes it impossible to measure the real benefits or impacts of these programs. In fact, Pucher et al. (2010) noticed that past research suggests that separate cycling facilities are associated with higher cycling levels, but there is evidence that this is not true for all lanes or cycle paths. Therefore, it is even more relevant to measure cycling flows in order to evaluate the benefits and negative impacts. Counting, in fact, is an example of a relatively inexpensive investment that can generate important gains of knowledge to inform the development of bicycle infrastructure.

Nowadays there is increased interest in resolving traffic congestion, building livable communities and streets (McDonald 2007; McNeil 2011), supporting more active and healthy lifestyles (Stronegger, Titze et al. 2010; Rojas-Rueda, de Nazelle et al. 2012), enhancing pedestrian and bicyclist safety (Jones, Ryan et al. 2010), and encouraging safe routes to schools. This has resulted in a desire and need to measure bicycling rates (Ortuzar, Iacobelli et al. 2000; Macbeth 2002; Schneider, Patten et al. 2005; Richardson and Trb 2006; Miranda-Moreno and Nosal 2011), collision rates, and to understand why, when, and where people bicycle (Williams and Larson 1996; Ortuzar and Roman 2003; Brandenburg, Matzarakis et al. 2007; Dill and Voros 2007). Also, standardized bicycle data collection and analysis techniques are important factors for elevating the status of planning and funding for this travel mode.

The genesis of the research reported in this thesis was a realization about the lack of consistent information on non-motorized transportation usage in Chile, and prompted by the interest of organized citizens supported by professionals with sustainability vocation. The main objective is to provide information to help understand the behaviour of cyclists and pedestrian.

Data collection took place at a time when the Office of the President of Chile, through its "Program of Government"[1], included for the first time in the country's history a clear transport policy guideline associated with cycling. This program was structured around five macro areas: open letter, opportunities, assurance, institutions, and values and quality of life. Values and quality of life incorporate the field of "Sport", and a number of related policies, one of which is as follows:

> "Master Plan of Cycle Lanes will be designed and implemented for the principal cities of the country, which will allow doubling the number of bicycle users in the next four years and the construction of parking for bicycles on all public transport stations, in public buildings, university campuses, schools, etc. With this achievement we will be able to get the triple aim of reducing pollution, congestion of cities and put Chile in shape".

Assessing these policies (e.g., doubling the number of bicycle users after 4 years of the current administration) requires access to baseline data describing the initial situation. In other words, to evaluate the success of the policy requires information on the number of users

[1] http://www.gobiernodechile.cl/programa-de-gobierno/

traveling by bicycle before March, 2010, and to compare those to March, 2014. Considering the actual information, we are conscious that there is a dearth of data to provide a baseline, which represents a difficulty to verify compliance with the policy goals.

In this context, the present research provides a baseline to assess compliance with non-motorized transportation policy in the case of the city of Santiago. The components of this study could in the near future be replicated in other cities in the country.

It is important to note that the development of bicycle and pedestrian transport across a city requires multiple components, such as management, information, education, promotion, design standards, safety, etc. where the materialization of specialized infrastructure is only one of them. Therefore, it may be desirable for future governments to consider incorporating these aspects and also considering significant increases in investment in the transportation budget where citizen participation would be an important component.

Finally, it is remarkable that this is the first case study using continuous automatic measurements in Chile even in Latin America, being an example of promotion for non-motorized transportation mode.

1.2 Research Context

This study takes place in the Santiago Metropolitan Region (*Region Metropolitana*), in Chile. The country is located in South America occupying a long, narrow strip of land between the Andes Mountains to the east and the Pacific Ocean to the west. It borders Peru to the north, Bolivia to the northeast, Argentina to the east, and the Drake Passage in the far south. Chilean territory includes 1,250,000 square kilometres of Antarctica and the Pacific islands of Juan Fernández, Salas y Gómez, Desventuradas, and Easter Island.

Figure 1. Chile

1.2.1 City of Study: Santiago

Santiago is the capital of Chile and the largest conurbation in the country. It is located in the country's central valley, at an elevation of 520 m above mean sea level. Chile's steady economic growth has transformed Santiago into modern metropolitan area, with extensive suburban development, dozens of shopping centers, and high-rise architecture. It has modern transportation infrastructure, including the steadily growing Metro of Santiago, a public bus transport system (Transantiago) that is being continually modernized, and a free flow toll-based ring road and inner city highway system.

1.2.1.1 Political Divisions

Santiago includes 37 comunes each one with a communal authority. The highest authority in Santiago is considered to be the Intendant of the Santiago Metropolitan Region. The office holder is a delegate of the president of the nation.

Figure 2. Comunes of Santiago, Chile

1.2.1.2 Geography

Santiago lies in the center of the Santiago basin, a large bowl-shaped valley consisting of broad and fertile lands surrounded by mountains. The city has a varying elevation, with 400 m in the western areas and 540 m in the downtown region.


Figure 3. Santiago, Chile[2]

1.2.1.2.1 Air Pollution

During winter season, air pollution is one of the principal environmental issues in Santiago. This is produced by the heat island effect which is a meteorological singularity whereby a stable layer of warm air holds down colder air close to the ground because the city's location is in an enclosed valley with limited wind and little rain. This inversion causes high levels of smog and air pollution, within the city principally from car emissions according to the National Commission for Protection of the Environment (CONAMA), even exceeding guidelines suggested by the World Health Organization. This problem causes significant health damage, including premature death, respiratory deceases such as chronic bronchitis, pneumonia, and asthma, and other health effects including coughing, snoring and night awakening. Air pollution in Santiago is caused principally by industrial and vehicle emissions. (Rutllant and Garreaud 1994; Margarita,

[2] NASA http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS004&roll=E&frame=6990

Alvarado et al. 2011). The air pollution qualification scale used in Santiago is good (0 -199 ICAP), alert (200-299 ICAP), preemergency (300-499 ICAP) and emergency (500 or higher ICAP)[3]

1.2.1.3 Weather

Santiago has a somewhat cool Mediterranean climate with relatively hot, dry summers (November to March) with temperatures reaching up to 35°C , while winters (June to August) are more humid with typical maximum daily temperatures of 13°C and minimums of a few degrees above zero. Mean rainfall is 360 mm per year and is heavily concentrated in the cooler months[4].

1.2.1.4 Transport Systems

Santiago has one International airport (Comodoro Arturo Merino Benítez International Airport) located 20 minutes from Downtown, and one rail terminal, which connects Santiago to several cities in the south-central part of the country. There are seven inter-urban bus terminals in the city, where bus companies provide passenger transportation from Santiago to most areas of the country, while some also provide parcel shipping and delivery services. Taxis and others services are available throughout the city. Transantiago is the name for the city's public transport system, which was launched on February 10, 2007. Transantiago works by combining local (feeder) bus lines, main bus lines, and the Metro network. It includes an integrated fare system, which allows passengers to make bus-to-bus or bus-to-metro transfers for the price of one ticket, using a contactless smartcard. Metro of Santiago is South America's most extensive metro network with 108 stations and 19 under construction; the system has five operating lines and carries around 2,400,000 passengers per day.

1.2.1.4.1 Cycle Lanes of Santiago

Santiago hosts 162 kilometers of cycle lanes within the city, as shown in Figure 4.

[3] http://sinca.mma.gob.cl/uploads/documentos/73881f634e74a87884b626007d5e585f.pdf
[4] Chilean Meteorological Office http://www.meteochile.gob.cl/

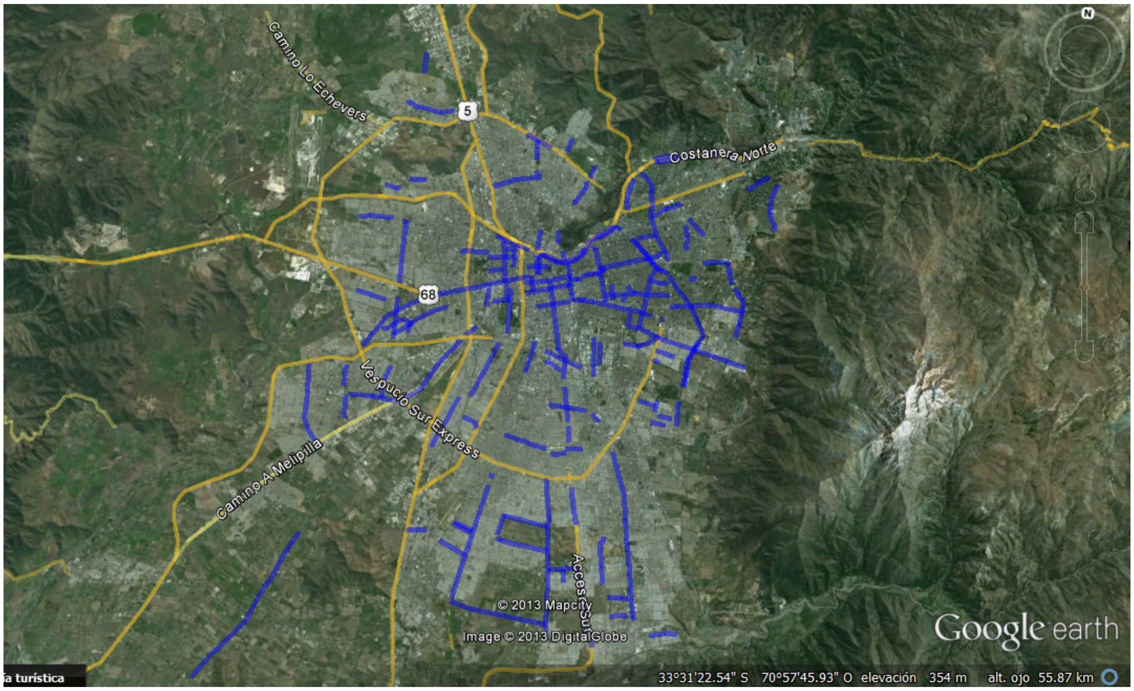


Figure 4. Cycle Lanes of Santiago, developed by Regional Government of Santiago

1.3 Count Methodologies

Bicycle counts are generally conducted either through manual counts or through automated counts and many efforts have been conducted in this sense (Rogers, Papanikolopoulos et al. 2000; Masoud and Papanikolopoulos 2001; Schneider, Patten et al. 2005; UNDP 2005-2008; Richardson and Trb 2006; McCahill and Garrick 2008; Malinovskiy, Zheng et al. 2009; Somasundaram, Morellas et al. 2009; Li, Shao et al. 2010; Nordback and Janson 2010; Larsen and El-Geneidy 2011; Moskovitz and Wheeler 2011; Buehler and Pucher 2012; Schasberger, Raczkowski et al. 2012; Thomas, Jaarsma et al. 2013). Within these two broad classes, the methods to count bicycles vary from limited-time, manual counts to active-infrared overhead imaging sensors. In some cases methods are able to count all modes of vehicles including cyclists and pedestrians being these ones expensive and time-consuming. According to Nordback and Janson (2010, p. 11) *"[vehicle] counts are fundamental to traffic engineering, and quantifying bicycle use is fundamental to understanding bicycle travel. As cycling becomes a more common mode of transportation, better quantification of bicycle use will be required".* This statement is extremely relevant since counting bicycles is helpful to understand bicyclist behaviour, trip patterns, measure changes in bicycle mode share and provide information for planning.

In fact, Miranda-Moreno and Nosal (2011) present a recent approach for using the counting information as a planning tool. In this approach, which is used to analyze the effect of weather on cycling, cyclist count data collection that comes from inductive loop bicycle counters (automatic equipment) is analyzed for the cities of Montreal, Ottawa, Vancouver, Portland and Velo Quebec. This research demonstrates the way weather conditions influence the behaviour of bicycle users in these cities.

Communities have combined manual counts with existing motorized vehicle counts at little or no extra cost. Manual counts are typically conducted by two counters per intersection, though a third person may be needed at busier intersections. Manual counts allow for collection of additional information, including type of users, use of helmets, turning movements and gender (Schneider, Patten et al. 2005). Manual count methods include using a tally sheet, an electronic board, a non-electronic counting board with periodic manual tallying, and using a handheld counter with periodic manual tallying.

Automated technologies are useful in conducting longer-term counts and identifying daily, weekly, or monthly variations in usage. With the exception of video playback systems (Rogers, Papanikolopoulos et al. 2000; Masoud and Papanikolopoulos 2001; Malinovskiy, Zheng et al. 2009; Li, Shao et al. 2010), automated technologies generally require fewer person-hours than manual counts. The most common automated technologies used for non-motorized data collection are:

- Passive infrared (detects a change in thermal contrast)
- Active infrared (detects an obstruction in the beam)
- Ultrasonic (emits ultrasonic wave and listens for an echo)
- Doppler radar (emits radio wave and listens for a change in frequency)
- Video Imagining (either analyzes pixel changes or data are played back in high speed and analyzed by a person)
- Piezometric (senses pressure on a material either tube or underground sensor)
- In-pavement magnetic loop (senses change in magnetic field as metal passes over it)

The decision to use automated or manual count technologies depends on the duration of the count effort, the existence of other ongoing count efforts, the type of data collected, the number of person-hours available for data collection and analysis, and the overall budget of the count effort. Automated count technologies have a higher start-up cost than manual count technologies, though they generally require fewer person-hours than manual counts and can be less expensive in the long-run cost savings. Additionally, Macbeth (Macbeth 2002) evaluated different automatic bicycle counting tecnologies and found them to have a very high accuracy on average, in excess of 96% in these types of systems. On the other hand, manual counts require more person-hours than automated counts, but can collect additional characteristics of bicyclists and pedestrians. A summary of manual and automated counts features is provided in Table 1 (Schneider, Patten et al. 2005)

Table 1. Manual and Automated Count Features

Manual Counts	Automated Counts
• Field observations are labour-intensive, which may limit the number of count locations. • Integrating pedestrian and bicycle counts with existing motor vehicle counts can reduce costs. • Observations have a higher level of accuracy, and can be more complex than automated counting methods (i.e., can include behaviours and other characteristics of users).	• Technologies can significantly reduce labor costs. Settings and positioning of devices must be adjusted to maximize accuracy. • Many technologies allow for remote data download. • Placement should minimize interference with pedestrians and bicyclists and potential for vandalism. • Most technologies work in rain and a wide variety of temperatures. • Most technologies do not count all types of non-motorized users and few can be used to observe behaviours. • Technologies can work in network

The Data collection process used in this research is illustrated in Figure 5 which is based on Jones et al. (2010) :

Figure 5. Typical Data Collection Process

1.4 Bicycles Measurements in Santiago, Chile

Since 2003 the city of Santiago has been conducting some periodic bicycle counts in order to quantify and characterize cyclists. In this sense, the Chilean Government with help from the United Nations Development Programme and World Bank conducted the "Monitoring Plan for the Promotion of bicycle use in comunes of Santiago, Providencia and Ñuñoa. Flow Measurement and Profile of Users and Traffic Safety. Steer Davies Gleave, UNDP" during the years 2005, 2006 2007 and 2008. This provides the possibility of estimating growth rates of demand for the range of years measured, as well as making some projections (UNDP 2005-2008).

This study conducted manual measurements (continuous and periodic) in order to measure the number of bicycles and a travel survey, which identify the behaviour of cyclists, changes in travel patterns and flow volumes. Both tasks were performed twice a year during winter and spring season of 2005 – 2008 for a "normal" weekday and non-working day. It is important to mention that the measuring points were defined with baseline information of 2003 and 2004. Moreover, variables such as use of safety equipment, gender and age were measured too.

The principal results obtained for a weekday is that in winter season the annual growth is 15% since 2004 to 2007 while in spring the annual growth is 8% since 2003 to 2008. On the other hand, for a non-working day, the annual growth is 3% in winter and 5% in spring season for the same periods showed before. In addition, one of the outcomes related to modal change explain that there is a transfer from car users to bicycle from 3% to 6% depending of the season, years and survey.

1.5 Outline of Chapters

Including this introduction, this thesis consists of four chapters. Chapters 2 - 3 show the objective, methodology and results obtained for bicycle and pedestrian activity in Santiago, Chile.

Chapter 2. This chapter shows the objective, methodology and results of measuring bicycle activity in the cycle lanes of Antonio Varas Ave and Simon Bolivar Ave (case study 1) and Pocuro Ave, Antonio Varas Ave. and Andrés Bello Ave (case study 2).

Chapter 3. This chapter shows the objective, methodology and results of Measuring bicycle and pedestrian activity in the Metropolitan Park of Santiago. Additionally, supplementary information relating to gender, age range and cyclists using safety equipment is presented too.

Chapter 4. This chapter presents general conclusions and indications for future research.

CHAPTER 2. MEASURING BICYCLE ACTIVITY IN CYCLE LANES OF PROVIDENCIA AND ÑUÑOA, SANTIAGO - CHILE.

2 Measuring Bicycle Activity in Cycle Lanes of Providencia and Ñuñoa, Santiago – Chile

2.1 Introduction

In this chapter, a project to implement a counting protocol for bicycle traffic is described. As previously noted, Chile, not unlike many other countries around the world, has an interest in increasing the proportion of trips conducted by active modes of travel, and specifically by bicycle. Any plans to develop infrastructure and programs to support travel by bicycle require an informed basis, which is a challenge given the lack of consistent information on usage and demand related to this mode. In particular, consistent and accurate information on demand and usage is required to assess the benefits of public investments on cycling infrastructure, in terms of health, travel time, and other outcomes that are influenced by these modes.

2.2 Context and Objectives

The focus of this Chapter is on two comunes of Santiago, namely Ñuñoa and Providencia.

Ñuñoa is home to a large middle-class population being one of the oldest comunes of the traditional east part of Santiago. As such, this comune enjoys all the benefits of a big city (Metro, hospitals, schools, Universities, banks, shopping malls and so on) while still maintaining its character as a traditional and residential comune. In the last few years, new comune attractions such as parks, infrastructure, metro, and a convenient location have led to an increased desire by young urban professionals to live there in multiple-unit buildings. It is one of the comunes with the highest living standard of Santiago according to the Chilean Association of Comunes. Ñuñoa has good connectivity in terms of transportation, with a public transportation system capable of reaching all parts of the municipality. The core of the comune is localized along the Irarrázaval Ave., which is a 6-km road that cross the entire comune from east to west, and centered in Plaza Ñuñoa where city hall is located. According to the 2002 census of the National Statistics Institute, Ñuñoa area is 16.9 km2 and has 163,511 inhabitants (73,215 men and 90,296 women), making the comune an entirely urban area.

Providencia is home to a large upper middle-class population and it holds the region's highest percentage of population over 60 years old (21.51%). It contains many high-rise apartment buildings as well as a significant portion of Santiago's commerce. It is notable for its large, old and elegant houses inhabited in the past by the Santiago elite and now mostly used as offices. It is one of the comunes with the highest living standard of Santiago according to Chilean Association of comunes. Ñuñoa has good connectivity in terms of transportation, with a public transportation system capable of reaching all parts of the municipality. According to the 2002 census of the National Statistics Institute, Providencia area is 14.4 km^2 and has 120,874 inhabitants (53,082 men and 67,792 women), making the comune an entirely urban area.

Measuring bicycle activity in cycle lanes in comunes of Providencia and Ñuñoa, Santiago - Chile, is based on some counting points reported in 2005, 2006 2007 and 2008 by the United Nations Development Programme and World Bank (UNDP 2005-2008). In order to develop these measures, counting process is divided in 2 case studies that were developed in 2012.

Case study 1 is the first stage of continuous automatic measurements in Santiago in which counting bicycle activity was developed in cycle lanes of Antonio Varas Ave (Comune of Providencia) and Simon Bolivar Ave (Comune of Ñuñoa). The reliability and ease of obtaining these data automatically in the field provides an opportunity to capture additional information relating to cyclists regarding the gender distinction of users and conditions of the use of safety equipment[5].

On the other hand, case study 2 is the second stage of continuous automatic measurements in Santiago in which counting bicycle activity was developed in cycle lanes of Pocuro Ave, Antonio Varas Ave. and Andrés Bello Ave (comune of Providencia). In these measures we do not capture additional information relating to cyclists regarding safety equipment and gender.

To conduct these measurements and ensure the quality of the results, automated counters (pneumatic tubes), which are described in section 2.3.4.1 "Automatic Measurements" developed by Eco-counter, which is a leading French firm specializing in measurement systems in the field of sustainable mobility, are used to count bicycles. These counters are used for the first time in Chile and Latin America as a result of this study. The measuring equipment has an automatic electronic quantification technology, which through Bluetooth or GSM network, sends real-time data to a laptop or to a web server and can synchronize information using specialized software (Eco-visio).

[5] The use of Helmet is Mandatory in Chile according to Law 18.290 of 2007

2.2.1 Objective

The main objective is to measure bicycle activity during 2012 in cycle lanes strategically located in Providencia and Ñuñoa comunes, Santiago - Chile. More specifically, we aim to:

- Quantify the volume of bicycle users circulating by each section of the cycle lanes of Antonio Varas Ave. and Simon Bolivar Ave. (case study 1) AND Antonio Varas Ave., Pocuro Ave. and Andrés Bello Ave. (case study 2) for weekdays and non-working day, using an automated count system.
- Analyze and compare data obtained with information from studies conducted in previous years in the same counting points.
- Characterize the volume of bicycle users by gender using manual observational counting for case study 1.
- Quantify actual use of safety equipment by bicycle users using manual observational counting for case study 1.

2.3 Methods

The method used to measure bicycle flows made by cyclists in 2012 are classified as continuous measurements for case study 1 because it corresponds to a cyclist's record passing through a point during a certain amount of time throughout a day and, as periodic measurements for case study 2, because it corresponds to a cyclist´s record passing through a point during a certain amount of time for a significant number of hours in a day (morning and evening peak).

For case study 1, measurements are recorded for two representative weekdays (Tuesday and Thursday) from 07:00 to 23:00 hrs, and one non-working day (Sunday) from 10:00 to 22:00 hrs. On the other hand, measurements for case study 2 are performed for one representative day of Weekday (Tuesday, Wednesday or Thursday) for morning peak from 07:00 to 10:00 hrs and for evening peak from 18:00 a 21:00 hrs

The flow counts are performed, for both cases of study, using automated counters (pneumatic tubes), which are described, in section 2.3.4.1 “Automatic Measurements”. Additionally, continuous measurement using automated counters is complemented with on-site manual counts, which characterize and quantify the distribution of users by gender and use of safety equipment.

2.3.1 Planning for Measuring Bicycles

To record the volume of bicycle users, an efficient and systematic measurement process was implemented by planning each activity, such as:

- Selection of cycle lanes and specific points to count.
- Determination of days and measurement periods (hours).
- Development of field sheets for manual observational counting.
- Installation of automatic measuring equipment (pneumatic tubes).

2.3.2 Selection of Cycle Lanes and Specific Points to Count

Selection of the measuring sections was informed by a previous study, reported in the document "Final Report 2005-2008, Monitoring Plan for the Promotion of bicycle use in comunes of Santiago, Providencia and Ñuñoa. Flow Measurement and Profile of Users and Traffic Safety" (UNDP 2005-2008) which compiled the continuous flow of cyclists in 12 sections measuring from in 2005 to 2008.

Measuring sections are chosen for the bicycle flow counts. In this case, sections of Antonio Varas Ave, Simon Bolivar Ave, Antonio Varas Ave, Pocuro Ave and Andrés Bello Ave cycle lanes were determined to count bicycles flow. Table 2 shows the location of counting points for case study 1.

Table 2 Measurement Points. Case Study 1

ID	Cycle Lane	Comune	Name of the Section (between streets)	Specific Point
C1	Antonio Varas	Providencia	Arturo Claro - Carlos Wilson	West cycle lane
C2	Simón Bolívar	Ñuñoa	Clorinda Wilshaw - A. Vespucio	South cycle lane

The Figures 6 to 9 show the detail of the above

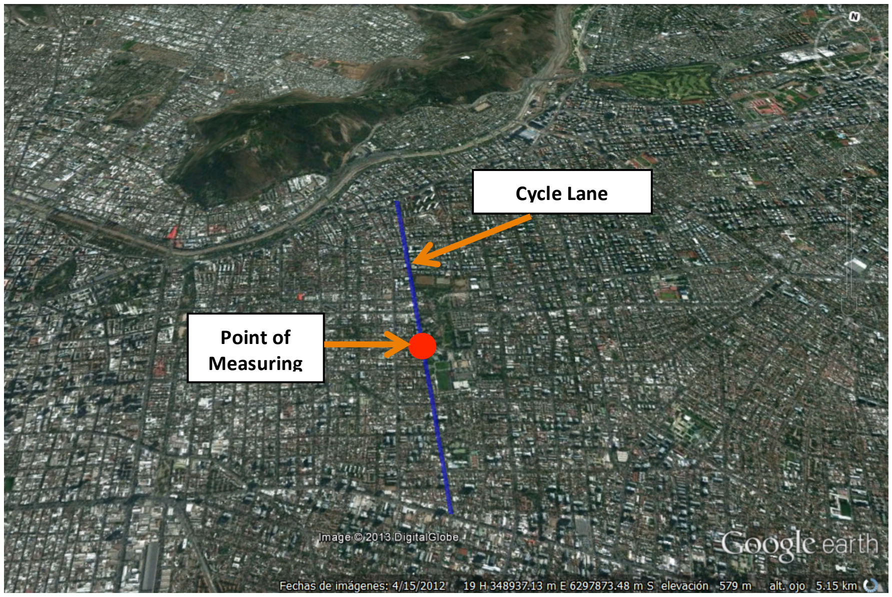
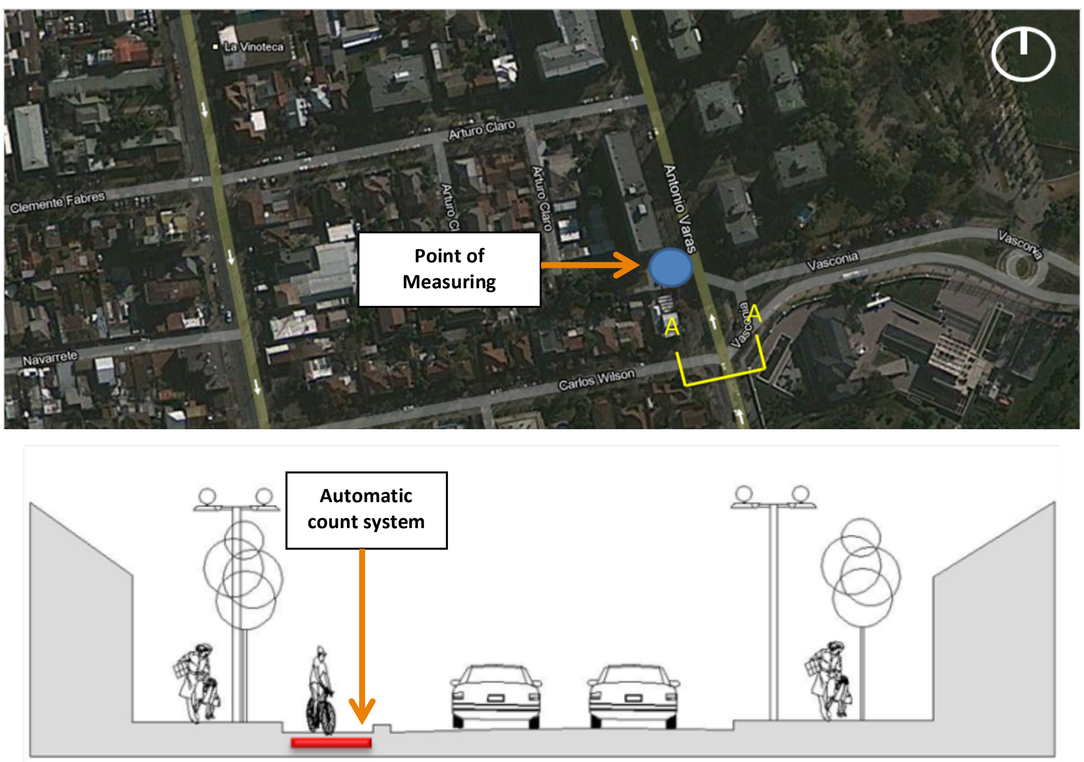


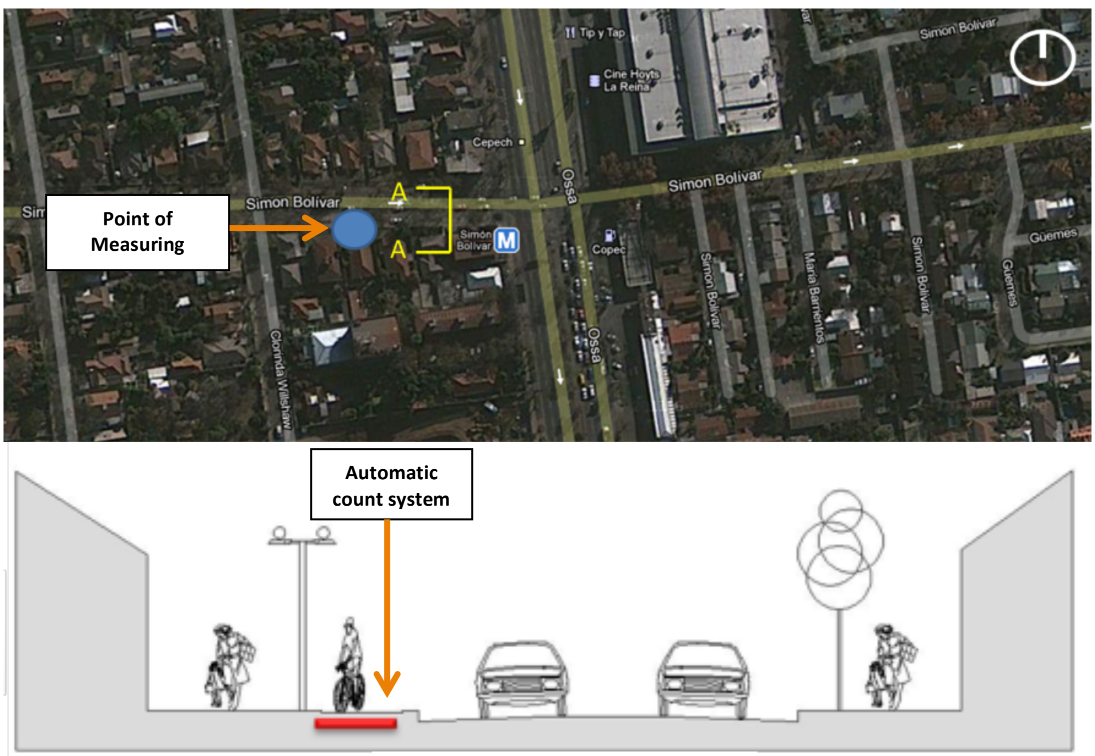
Figure 6. Measuring Point (C1), Antonio Varas Ave. cycle lane



Cut A-A of Section to measure

Figure 7. Characterization of Measuring Point (C1), Antonio Varas Ave. cycle lane between Arturo Claro and Carlos Wilson

Figure 8. Measuring Point (C2), Simon Bolivar Ave. cycle lane



Cut A-A of Section to measure

Figure 9. Characterization of Measuring Point (C2), Simon Bolivar Ave. cycle lane between Clorinda Wilshaw and Americo Vespucio Ave.

The Table 3 shows the location of counting points for case study 2:

Table 3. Measurement Points. Case Study 2

ID	Cycle Lane	Comune	Name of the Section (between streets)	Specific Point
P1	Pocuro	Providencia	Av. Suecia – Ricardo Lyon	North cycle lane
P2	Antonio Varas	Providencia	Arturo Claro - Carlos Wilson	West cycle lane
P3	Andrés Bello	Providencia	C. Calderón – Antonio Bellet	North cycle lane

Figures 10 to 12 show the detail of Table 3.

Figure 10. Measuring Point (P1), Pocuro Ave. cycle lane

Figure 11. Measuring Point (P2), Antonio Varas Ave. cycle lane

Figure 12. Measuring Point (P3), Andrés Bello Ave. cycle lane

2.3.3 Selection of Days and Measurement Periods (hours)

Selection of the days and times to perform continuous measurements for case study 1, was informed by a previous study "Monitoring Plan for the Promotion of bicycle use in comunes of Santiago, Providencia and Ñuñoa. Flow Measurement and Profile of Users and Traffic Safety " (UNDP 2005-2008) which defined as a Weekdays Tuesday and Thursday and Sunday as a non-working day.

The measurement days for point C1 were set for Thursday 26th, Sunday 29th and Tuesday 31st of January, 2012[6]. In the case of point C2 the measurement days were set for Thursday 2nd, Sunday 5th and Tuesday 7th of February 2012[7].

The continuous measurement period was defined from 07:00 to 23:00 hrs for weekdays, and from 10:00 to 22:00 hrs for non-working days. The detail is shown in Table 4:

Table 4. Periods of continuous measurements. Case Study 1

Measurement Periods (hours)	
Weekday	Non-Working Day
07:00 – 23:00 hrs	10:00 – 22:00 hrs

The determinations of the weekday and times to perform periodic measurements for case study 2, are made considering peak hours references obtained from case study 1.

In this sense, the periodic measurement day for point P1 is set for Thursday 18th October, 2012; point P2 the measurement days is set for Thursday 25th October, 2012; and Point P3 is set for Thursday 15th November, 2012[8].

The periodic measurement period was defined from 7:00 to 10:00 hrs and 18:00 to 21:00 hrs. The detail is shown in Table 5:

---

[6] Temperatures: 28°C (sunny) for Thursday 26th, 31°C (sunny) for Sunday 29th and 31°C (partly sunny) for Tuesday 31st

[7] Temperatures: 33°C (sunny) for Thursday 2nd , 31°C (sunny) for Sunday 5th and 31°C (sunny) for Tuesday 7th

[8] Temperatures: 21°C (partly sunny) for Thursday 18th, 24°C (partly sunny) for Thursday 25th and 26°C (sunny) for Thursday 15th

Table 5. Periods of periodic measurements. Case Study 2

Measurement Periods (hours)	
Weekday	
07:00 – 10:00 hrs	18:00 – 21:00 hrs

2.3.4 Automatic and Manual Measurements

As noted above, the methods of data collection were separated into two types, the automatic and manual measurement. The latter is implemented only for case study 1.

2.3.4.1 Technology for Automatic Measurements

To conduct measurements automatically, we used electronic measuring equipment with the brand Eco-counter and model "Pneumatic Tube" which had the technology to capture the passage of cyclists, quantifying the flow and direction.

The Pneumatic Tube is a device developed with advanced technology, capable of measuring bicycle flow circulating in a particular pathway automatically and accurately all day long. Its installation allows the device to be unobtrusive from the perspective of pedestrians. One of its advantages is the energy independence and data transfer via Bluetooth, making it an ideal device for generating periodic or temporary counts. This device comprises a sensor and two modules, with the features described below:

- Sensor: Pneumatic tubes contains two structures which are responsible for capturing the flow of bicycles, by detecting the variation of pressure producing bicycle tires passes over the tubes.
- Processor: it is responsible for processing, storing and sending the data collected by the sensor to the user, via Bluetooth.
- Battery: it is responsible for powering the processor at any time.

Figure 13. Pneumatic Tubes

The installation of the equipment is quite simple and minimally invasive. The process involves fixing over the cycle lane, specifically calibrated tubes for counting the passage of cyclists in different directions.

Figure 14. Installation process of Pneumatic Tubes

When cyclists pass over the tubes the pressure generated is transformed into an electrical signal, which is analyzed by the computer processor. The captured information is then stored in the computer's memory. This process occurs continuously and automatically.

Once stored, the information is extracted and sent to a personal computer via Bluetooth. Then, saved data are sent via internet to a web platform of Eco-counter. The extraction process and data transmission is performed using specialized software developed by the Eco-Counter company called Eco-link. Finally, the information sent through the web platform is analyzed by a software called Eco-visio which is able to process the information computing all the statistics and reporting data in different formats in order to facilitate detailed statistical analysis.

The benefits of using the Eco-counter technology are:

- Automatic collection and data storage.
- Extraction of the data through wireless technology.
- High accuracy (+/- 3%, even in heavy traffic).
- Counts bikes passing side-by-side or closely following each other.
- Specifically designed to monitor bicycles on dedicated bicycle lanes and greenways.
- Ignores motorized vehicles (scooters, motorbikes, cars, buses…)
- Automatic Statistical processing of data.
- Bidirectional count of flows.

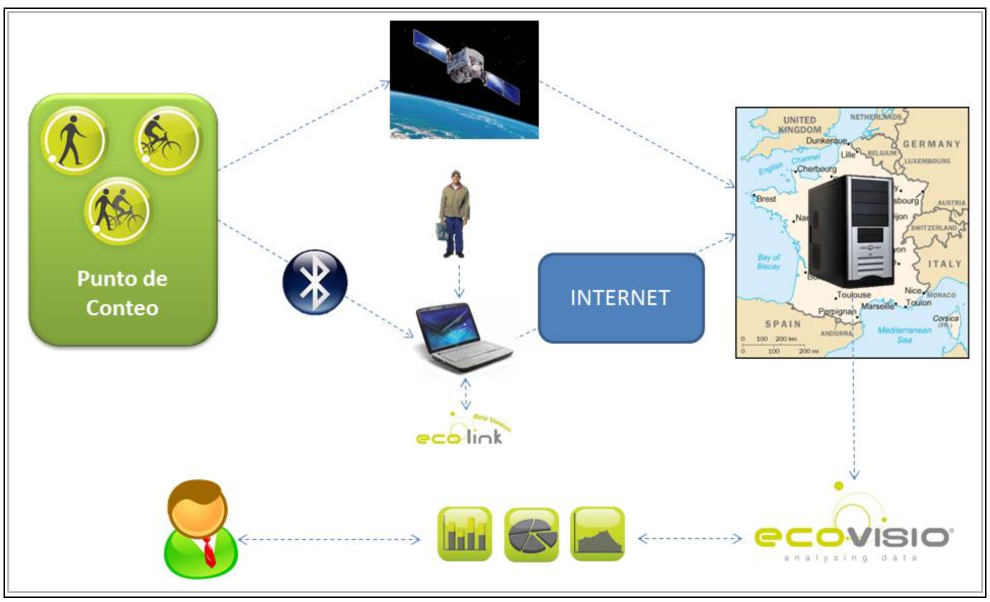


Figure 15. Scheme capture, processing and transmission of count data

2.3.4.2 Manuals Measurements

Manual measurements (case study 1) were supported by registration forms to identify the following characteristics of bicycle users:

- Gender.
- Use of safety equipment. (H: Helmet, L: Lights, H+L: Helmet + Lights, N: Nothing)

- Direction of the flow.

	Direction :								Direction :							
	Man				Woman				Man				Woman			
Hour	H	L	H+L	N	H	L	H+L	N	H	L	H+L	N	H	L	H+L	N
7:00 - 8:00																
8:00 - 9:00																
9:00 - 10:00																
10:00 -11:00																
...																
19:00 - 20:00																
20:00 - 21:00																
21:00 - 22:00																
22:00 - 23:00																
23:00 - 24:00																

Figure 16. Registration Form, Point C1 or C2

Regarding the use of safety equipment, observers could record the use of helmet (H), front and rear lights (L), both helmet and lights (H+L), or neither (N).

In order to fill out the form, the assistant counter needs completing each box with little lines that represent cyclists. Then, it proceeds to count the total number of counts per hour.

2.4 Results. Case Study 1 "Measuring bicycle activity in cycle lanes of Antonio Varas Ave. and Simon Bolivar Ave."

The results obtained are presented in detail with the complete data collection generated both through manual and automated counts for defined points C1 and C2.

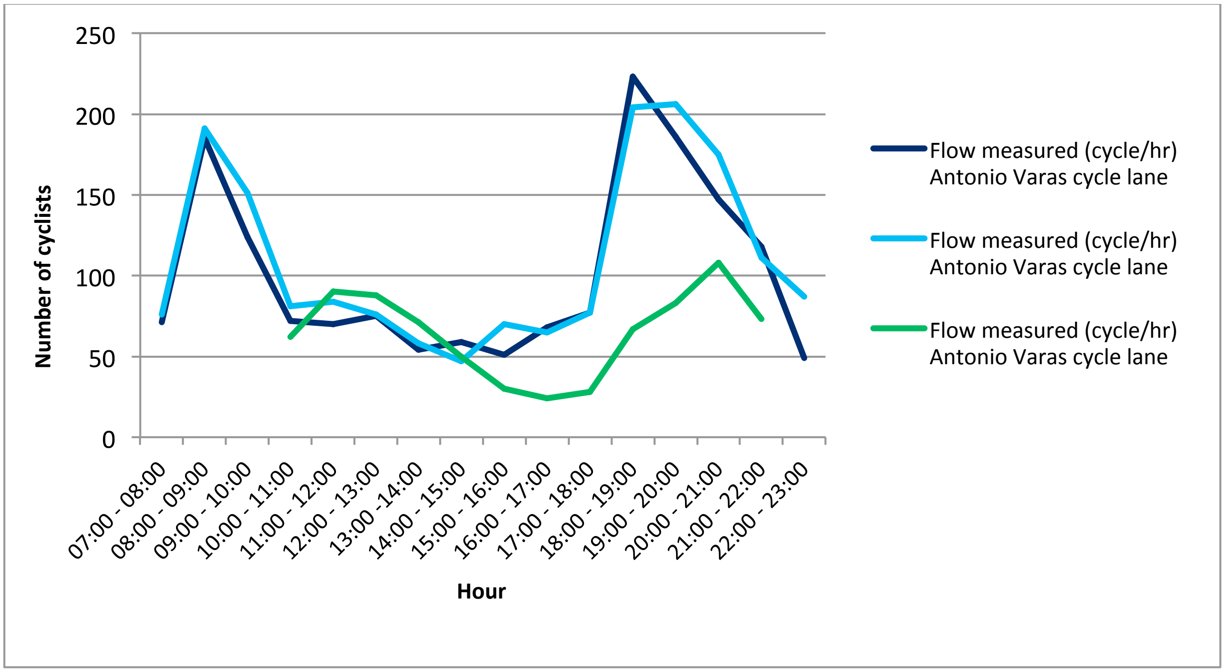
2.4.1 Measuring Point (C1). Antonio Varas Cycle Lane

Table 6 presents the hourly flows detail recorded for different days of measurement for point C1.

Table 6. Flow of bicycles measurements, both directions and Time. Antonio Varas cycle lane (C1)

Hour	Flow measured (cycle / hrs) Antonio Varas cycle lane.		
	Weekday 1	Weekday 2	Non-Working Day
07:00 - 08:00	71	76	-
08:00 - 09:00	185	191	-
09:00 - 10:00	124	151	-
10:00 - 11:00	72	81	62
11:00 - 12:00	70	84	90
12:00 - 13:00	75	76	88
13:00 -14:00	54	58	71
14:00 - 15:00	59	47	50
15:00 - 16:00	51	70	30
16:00 - 17:00	68	65	24
17:00 - 18:00	77	77	28
18:00 - 19:00	223	204	67
19:00 - 20:00	186	206	83
20:00 - 21:00	147	175	108
21:00 - 22:00	118	111	73
22:00 - 23:00	49	87	-
Total	**1,629**	**1,759**	**774**

With the information collected from Table 6, we are able to develop a flow histogram, which is presented in the following graph:



Graph 1. Histogram of flow both directions. Antonio Varas cycle lane (C1)

The following information provides a summary of the overall results obtained by the measurements made in point C1:

- In the weekday 1, the total flow measurement was 1,629 cyclists.
- In the weekday 2, the total flow measurement was 1,759 cyclists.
- In the non-working day, the total flow measurement was 774 cyclists.
- For both weekdays and non-working day it was identified that there are two peak periods, Morning peak and Evening peak.

2.4.1.1 Analysis of the Results for Weekdays and Non-working Day, Antonio Varas Cycle Lane (C1)

2.4.1.1.1 Morning Peak Period

In the morning, it should be noted that for both weekdays 1 and 2, the peak period is set between 08:00 and 9:00 hrs. For weekday 1 the morning peak presents a total flow of 185 cyclists per hour while for weekday 2 morning peak presents 191 cyclists per hour. On the other hand, for non-working day the morning peak period was runs between 11:00 and 12:00 hrs, which presents a total flow of 90 cyclists per hour.

2.4.1.1.2 Evening Peak Period

In the evening, it should be noted that for both weekdays 1 and 2, the peak period is set between 18:00 and 19:00 hrs which presents a total flow of 223 cyclists per hour. For weekday 2 the evening peak period is set between 18:00 and 20:00 hrs which presents an average of 205 cyclists per hour (204 cyclists between 18:00 and 19:00 hrs and 206 cyclists between 19:00 and 20:00 hrs). On the other hand, for non-working day the evening peak period was runs between 20:00 and 21:00 hrs, which presents a total flow of 108 cyclists per hour.

2.4.1.1.3 Flows by Direction. Antonio Varas Cycle Lane (C1)

As we mentioned before, Pneumatic Tube equipment is able to count the number of cyclist and the direction of flows. In this sense, the following is an analysis that considers the information obtained by flows directions for measuring point C1 differentiated by days of count.

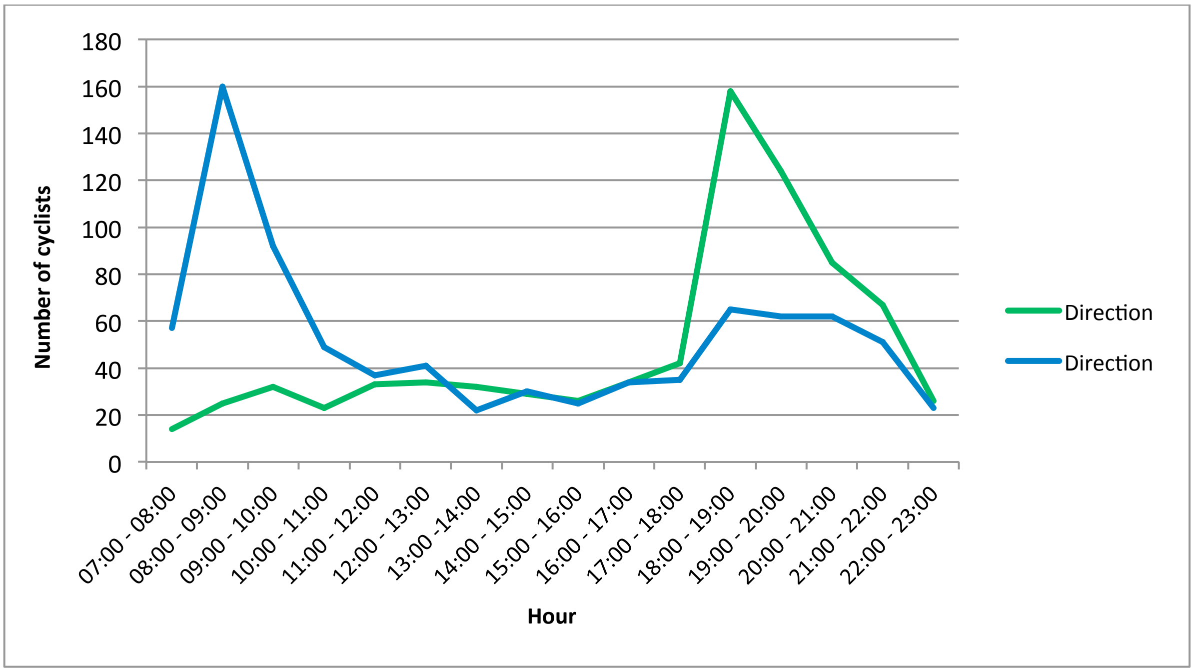
Table 7. Flow Measurements of Cyclists by direction. Antonio Varas Cycle Lane (C1)

Hour	Weekday 1		Weekday 2		Non-Working Day	
	Direction North-South	Direction South-North	Direction North-South	Direction South-North	Direction North-South	Direction South-North
07:00 - 08:00	14	57	8	68	-	-
08:00 - 09:00	25	160	18	173	-	-
09:00 - 10:00	32	92	39	112	-	-
10:00 - 11:00	23	49	30	51	10	52
11:00 - 12:00	33	37	27	57	33	57
12:00 - 13:00	34	41	37	39	56	32
13:00 -14:00	32	22	29	29	48	23
14:00 - 15:00	29	30	28	19	33	17
15:00 - 16:00	26	25	40	30	15	15
16:00 - 17:00	34	34	36	29	8	16
17:00 - 18:00	42	35	37	40	12	16
18:00 - 19:00	158	65	139	65	30	37
19:00 - 20:00	124	62	135	71	47	36
20:00 - 21:00	85	62	112	63	72	36
21:00 - 22:00	67	51	62	49	44	29
22:00 - 23:00	26	23	56	31	-	-
Total	**784**	**845**	**833**	**926**	**408**	**366**

With the information collected from Table 7 we are able to develop a flow histogram and diagram by directions, which are presented below.

2.4.1.1.3.1 Weekday 1. Antonio Varas Cycle Lane (C1)

In weekday 1 it can be appreciated that the direction South-North has a morning peak period set between 08:00 hrs and 09:00 hrs while direction North-South present an evening peak period set between 18:00 hrs and 19:00 hrs.



Graph 2. Flow histogram by direction. Weekday 1, Antonio Varas cycle Lane (C1)

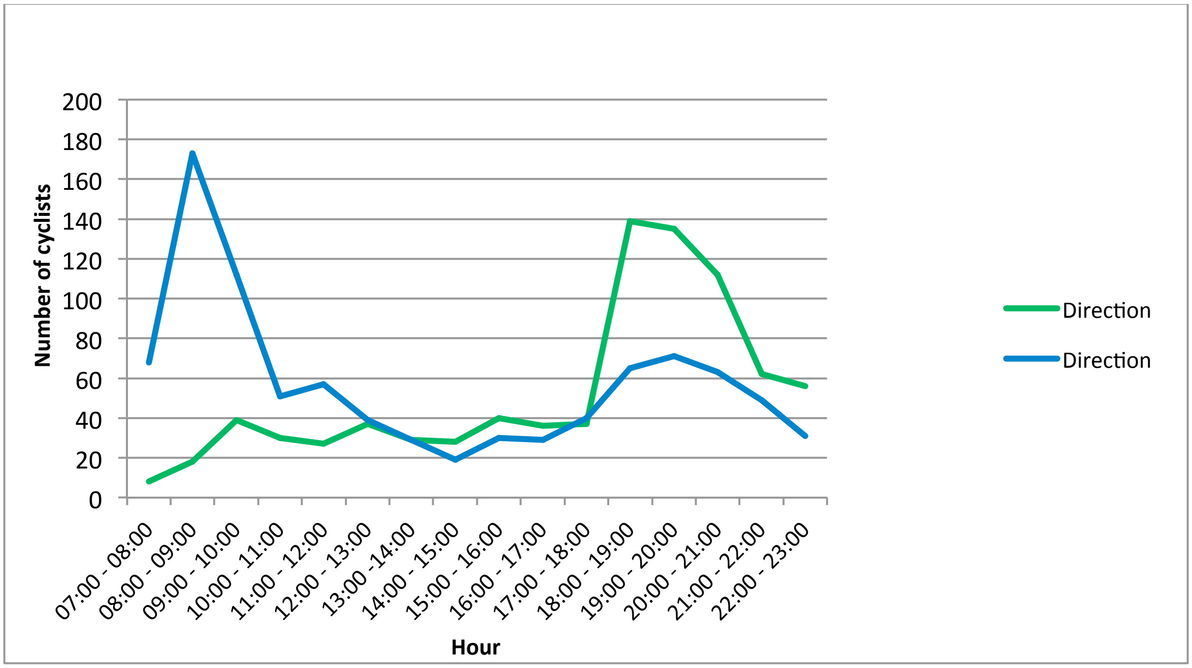
Taking into account the information obtained for weekday 1, we can see that the flow distribution for morning peak period is higher for cyclists who travel South-North direction. The morning peak period for working day 1 is 185 cyclists of which 160 are mobilized South-North and 25 North-South. On the contrary, we can see that the flow distribution for the evening peak period is greater for cyclists traveling from North to South. The evening peak period for working day 1 is 223 cyclists of which 65 are mobilized South-North and 158 North-South. Figure 17 shows the information above-mentioned.

Figure 17. Flow Diagram for peak times. Weekday 1, Antonio Varas cycle lane (C1)

2.4.1.1.3.2 Weekday 2. Antonio Varas (C1)

In weekday 2, it can be appreciated that the direction South-North has a morning peak period set between 08:00 and 09:00 hrs while direction North-South present an evening peak period set between 19:00 and 20:00 hrs.

Taking into account the information obtained for weekday 2, we can see that the flow distribution for morning peak period is higher for cyclists who travel South-North direction. The morning peak period for working day 2 is 191 cyclists of which 173 are mobilized South-North and 18 North-South. On the contrary, we can see that the flow distribution for the evening peak period is greater for cyclists traveling from North to South. The evening peak period for working day 1 is 206 cyclists of which 71 are mobilized South-North and 135 North-South. Figure 18 shows the information above-mentioned.



Graph 3. Flow histogram by direction. Weekday 2, Antonio Varas cycle lane (C1)

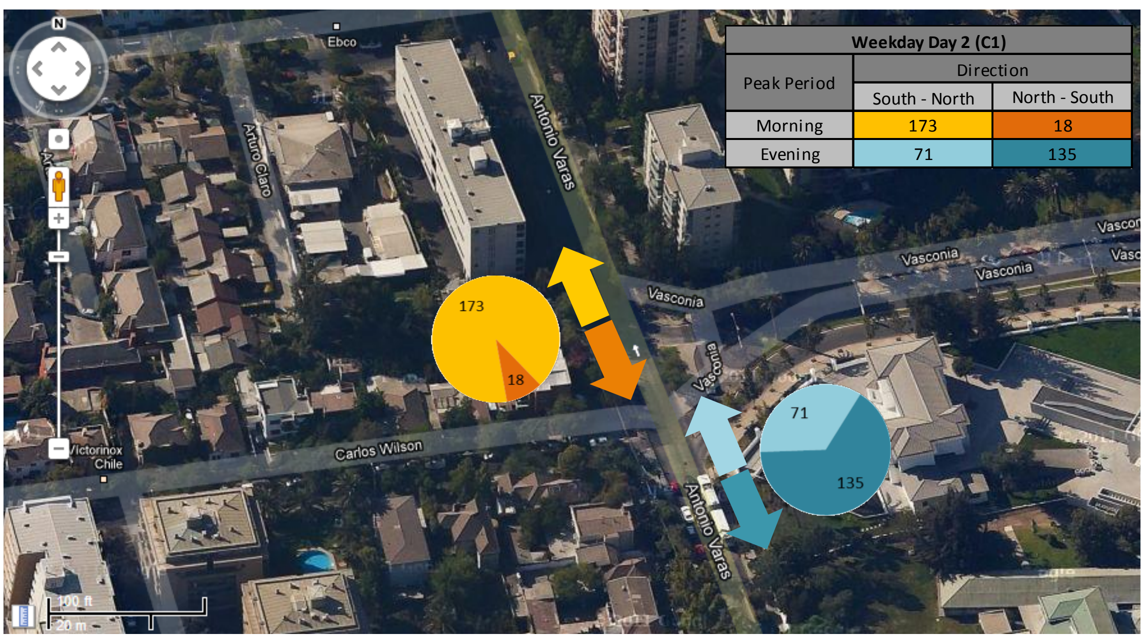
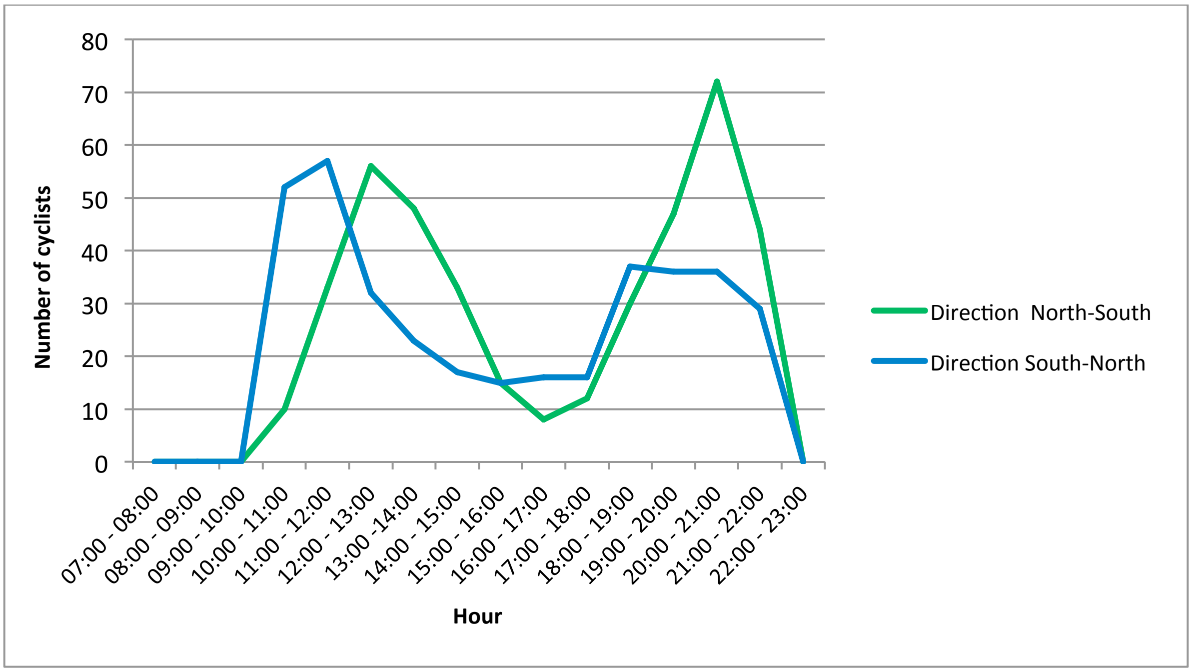


Figure 18. Flow Diagram for peak times. Weekday 2, Antonio Varas cycle lane (C1)

2.4.1.1.3.3 Non-working Day. Antonio Varas Cycle Lane (C1)

In non-working day, it can be appreciated that the direction South-North has a morning peak period set between 11:00 and 12:00 hrs while direction North-South present an evening peak period set between 20:00 and 21:00 hrs.



Graph 4. Flow histogram by direction. Non-working Day, Antonio Varas cycle lane (C1)

Taking into account the information obtained for non-working day, we can see that the flow distribution for morning peak period is higher for cyclists who travel South-North direction. The morning peak period for non-working day is 90 cyclists of which 57 are mobilized South-North and 33 North-South. On the contrary, we can see that the flow distribution for the evening peak period is greater for cyclists traveling from North to South. The evening peak period for non-working day is 108 cyclists of which 36 are mobilized South-North and 72 North-South. Figure 19 shows the aforementioned information.

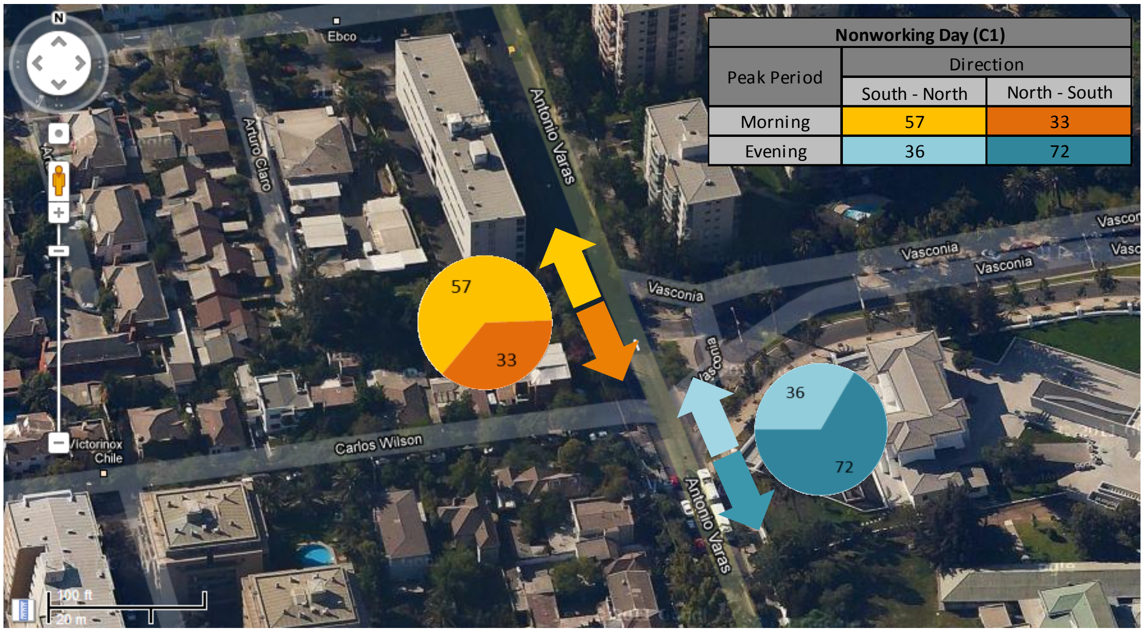


Figure 19. Flow Diagram for peak times. Non-working Day, Antonio Varas cycle lane (C1)

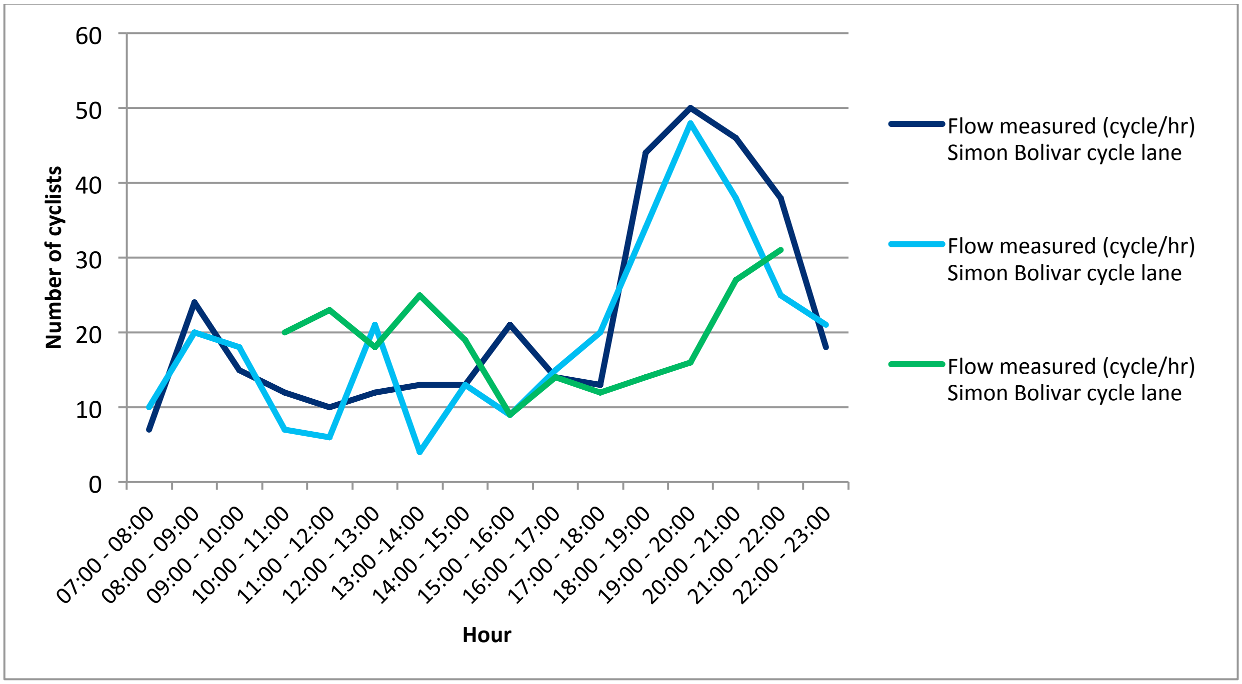
2.4.2 Measuring Point (C2). Simon Bolivar Ave. Cycle Lane

Table 8 presents the hourly flows detail recorded for different days of measurement for point C2.

Table 8. Flow of bicycles measurements, both directions and Time. Simon Bolivar cycle lane (C2)

Hour	Flow measured (cycle/ hrs) Simon Bolivar cycle lane.		
	Weekday 1	Weekday 2	Non-Working Day
07:00 - 08:00	7	10	-
08:00 - 09:00	24	20	-
09:00 - 10:00	15	18	-
10:00 - 11:00	12	7	20
11:00 - 12:00	10	6	23
12:00 - 13:00	12	21	18
13:00 -14:00	13	4	25
14:00 - 15:00	13	13	19
15:00 - 16:00	21	9	9
16:00 - 17:00	14	15	14
17:00 - 18:00	13	20	12
18:00 - 19:00	44	34	14
19:00 - 20:00	50	48	16
20:00 - 21:00	46	38	27
21:00 - 22:00	38	25	31
22:00 - 23:00	18	21	-
Total	**350**	**309**	**228**

With the information collected from Table 8, a flow histogram is developed and presented in graph 5:



Graph 5. Histogram of flow both directions. Simon Bolivar cycle lane (C2)

The following information provides a summary of the overall results obtained by the measurements made in point C2:

- In the weekday 1, the total flow measurement was 350 cyclists.
- In the weekday 2, the total flow measurement was 309 cyclists.
- In the non-working day, the total flow measurement was 228 cyclists.

2.4.2.1 Analysis of the Results for Weekdays and Non-working Day, Simon Bolivar Cycle Lane (C2)

2.4.2.1.1 Morning Peak Period

In the morning, it should be noted that for both weekdays 1 and 2, the peak period is set between 08:00 hrs and 09:00 hrs. For weekday 1 the morning peak presents a total flow of 24 cyclists per hour while for weekday 2 morning peak presents 20 cyclists per hour. On the other hand, for non-working day the morning peak period is run between 11:00 and 12:00 hrs, which presents a total flow of 23 cyclists per hour.

2.4.2.1.2 Evening Peak Period

In the evening, it should be noted that for both weekdays 1 and 2, the peak period is set between 19:00 and 20:00 hrs. For weekday 1 the evening peak period presents total flow of 50 cyclists per hour while for weekday 2 evening peak presents 48 cyclists per hour. On the other hand, for non-working day the evening peak period is run between 21:00 and 22:00 hrs which presents a total flow of 31 cyclists per hour.

2.4.2.1.3 Flows by Direction. Simon Bolivar Cycle Lane (C1)

As previously mentioned, Pneumatic Tube equipment is able to count the number of cyclists and the direction of flows. In this sense, the following is an analysis that considers the information obtained by flow directions for measuring point C2 differentiated by days of count.

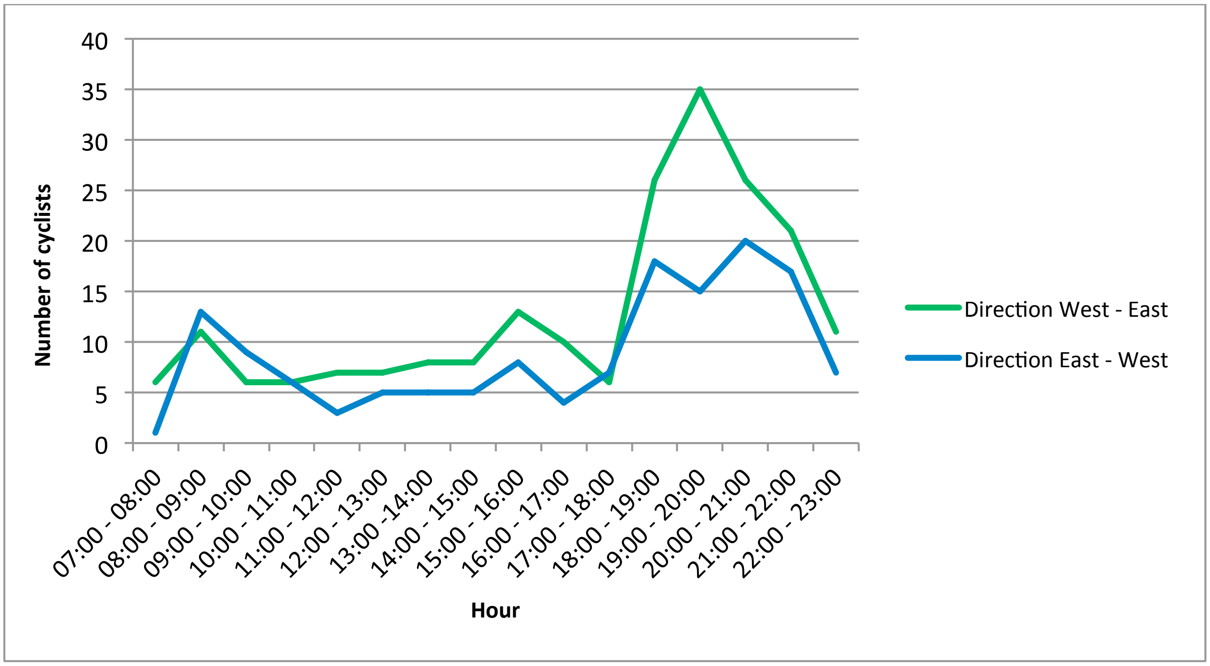
Table 9. Flow Measurements of Cyclists by direction. Simon Bolivar Cycle Lane (C2)

Hour	Weekday 1		Weekday 2		Non-Working Day	
	Direction West - East	Direction East - West	Direction West - East	Direction East - West	Direction West - East	Direction East - West
07:00 - 08:00	6	1	6	4	-	-
08:00 - 09:00	11	13	6	14	-	-
09:00 - 10:00	6	9	8	10	-	-
10:00 - 11:00	6	6	4	3	9	11
11:00 - 12:00	7	3	2	4	10	13
12:00 - 13:00	7	5	12	9	9	9
13:00 -14:00	8	5	4	0	15	10
14:00 - 15:00	8	5	7	6	18	1
15:00 - 16:00	13	8	8	1	7	2
16:00 - 17:00	10	4	9	6	7	7
17:00 - 18:00	6	7	10	10	10	2
18:00 - 19:00	26	18	21	13	8	6
19:00 - 20:00	35	15	36	12	12	4
20:00 - 21:00	26	20	27	11	17	10
21:00 - 22:00	21	17	14	11	18	13
22:00 - 23:00	11	7	16	5	-	-
Total	**207**	**143**	**190**	**119**	**140**	**88**

With the information collected from Table 9, a flow histogram and diagram by directions is presented in graphs 6, 7 and 8.

2.4.2.1.3.1 Weekday 1. Simon Bolivar Cycle Lane (C2)

In weekday 1, it could be appreciate that both directions West - East and East - West present a morning peak period set between 08:00 and 09:00 hrs while direction West - East present a clearly evening peak period set between 19:00 and 20:00 hrs.



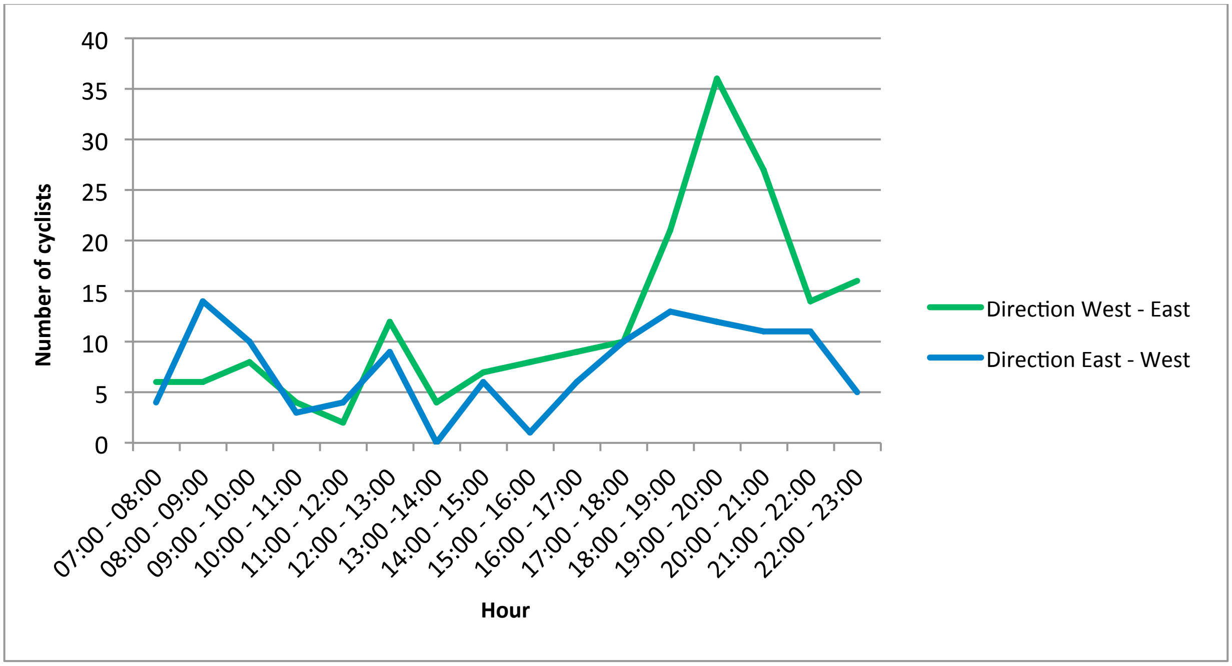
Graph 6. Flow histogram by direction. Weekday 1, Simon Bolivar cycle lane (C2)

Taking into account the information obtained for weekday 1, we can see that the flow distribution for morning peak period is fairly similar for cyclists who travel West - East and East - West directions. The morning peak period for working day 1 present 24 cyclists of which 11 are mobilized West - East and 13 East - West. On the other hand, we can see that the flow distribution for the evening peak period is greater for cyclists traveling from West to East. The evening peak period for working day 1 is 50 cyclists of which 35 are mobilized West - East and 15 East - West. Figure 20 shows the information above-mentioned.

Figure 20. Flow Diagram for peak times. Weekday 1, Simon Bolivar cycle lane (C2)

2.4.2.1.3.2 Weekday 2. Simon Bolivar Cycle Lane (C2)

In weekday 2, it could be appreciate that both directions West - East and East - West present a morning peak period set between 08:00 and 09:00 hrs while direction West - East present a clearly evening peak period set between 19:00 and 20:00 hrs.



Graph 7. Flow histogram by direction. Weekday 2, Simon Bolivar cycle lane (C2)

Taking into account the information obtained for weekday 2, we can see that the flow distribution for morning peak period is fairly similar for cyclists who travel West - East and East - West directions. The morning peak period for working day 2 present 20 cyclists of which 6 are mobilized West - East and 14 East - West. On the other hand, we can see that the flow distribution for the evening peak period is greater for cyclists traveling from West to East. The evening peak period for working day 2 is 48 cyclists of which 36 are mobilized West - East and 12 East - West. Figure 21 shows the information above-mentioned.

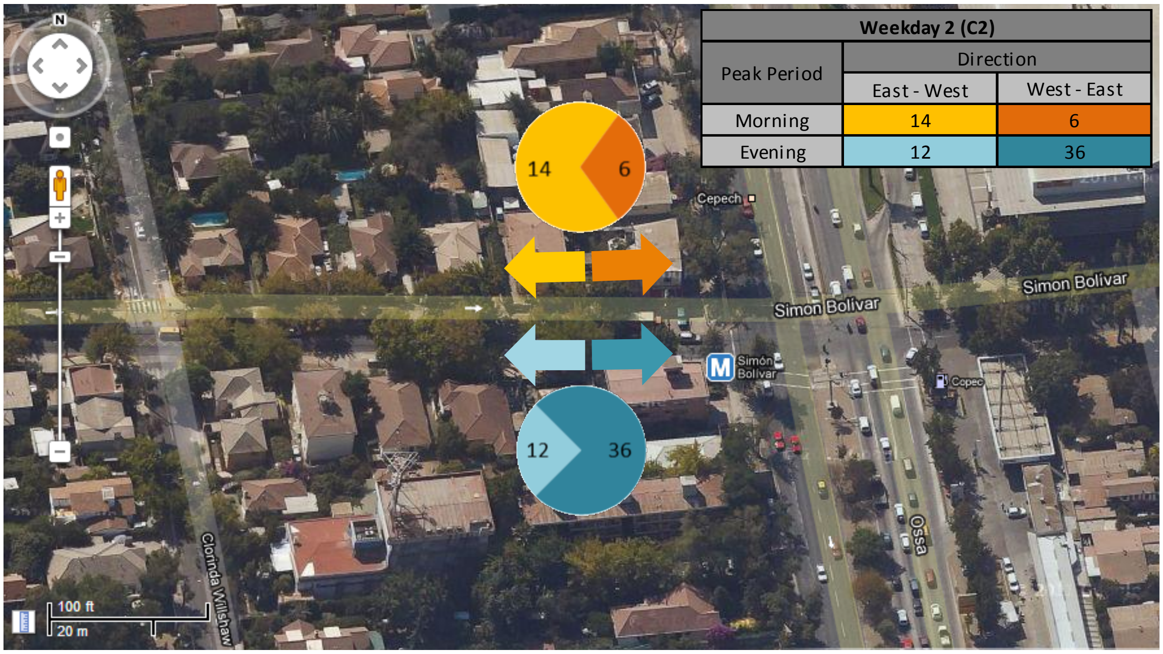
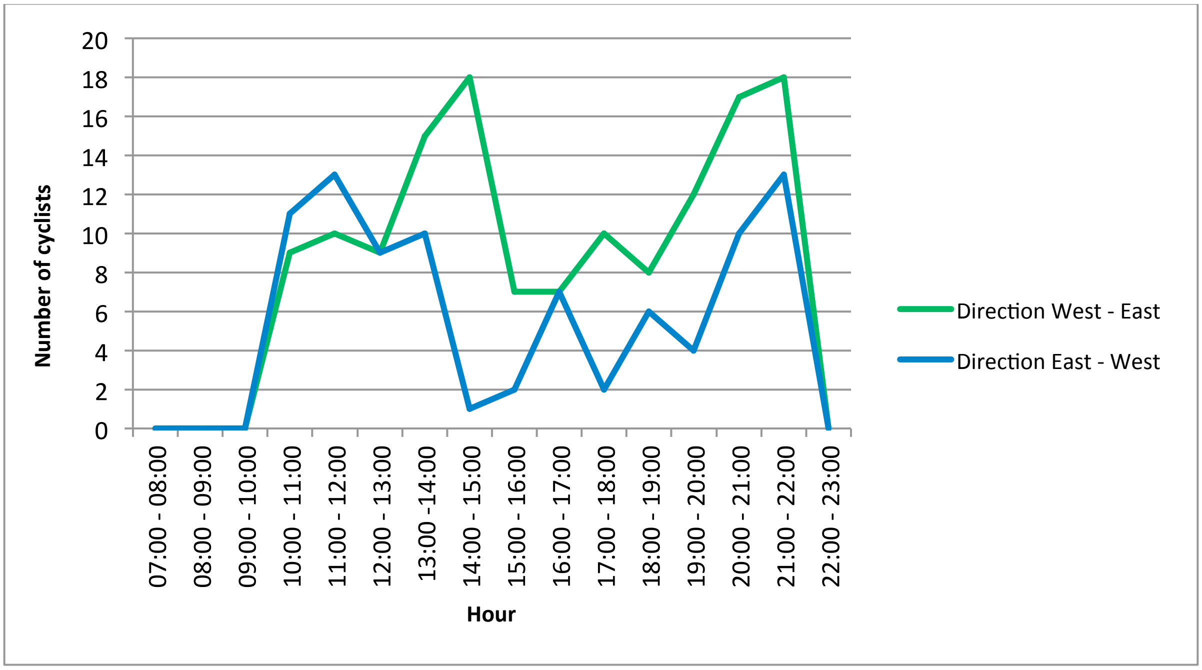


Figure 21. Flow Diagram for peak times. Weekday 2, Simon Bolivar cycle lane (C2)

2.4.2.1.3.3 Non-working Day. Simon Bolivar Cycle Lane (C2)

On non-working days, it could be appreciate that morning peak period is not so marked when we compare with weekdays. However, we notice some peaks hour between 11:00 - 12:00 hrs and 21:00-22:00 hrs direction East-West while direction West-East present some peaks between 14:00 - 15:00 hrs and 21:00-22:00 hrs.



Graph 8. Flow histogram by direction. Non-working Day, Simon Bolivar cycle lane (C2)

Taking into account the information obtained for non-working day, we can see that the flow distribution for morning peak period is very similar for cyclists for cyclists who travel West - East and East - West directions. The morning peak period for non-working day is 23 cyclists of which 10 are mobilized West - East and 13 East - West. On the other hand, we can see that the flow distribution for the evening peak for non-working day is 31 cyclists of which 18 are mobilized West - East and 13 East - West. Figure 22 shows the information above-mentioned.

Figure 22. Flow Diagram for peak times. Non-working day, Simon Bolivar cycle lane (C2)

2.4.3 Calculation of Average Flow

In this section, it is reported the calculation procedure to obtain average flow per hour, per day and per measurement point. The estimation is achieved as a result of the sum of all measured flow within a measurement period, divided by the total number of counting hours. This outcome represents the average number of cyclists, which cross the section of measurement. For purposes of this estimation we used the following equation.

$$\frac{\sum_{i=1}^{n} Total\ flow\ by\ day}{\sum_{i=1}^{n} Total\ counting\ Tours} = Average\ hourly\ flow$$

Equation 1. Equation of average hourly flow (cycles/ hrs)

Table 10 shows the average hourly flow for each measurement point, reported separately for weekday and non-working day.

Table 10. Average Hourly Flow Summary for each measurement point (C1 and C2)

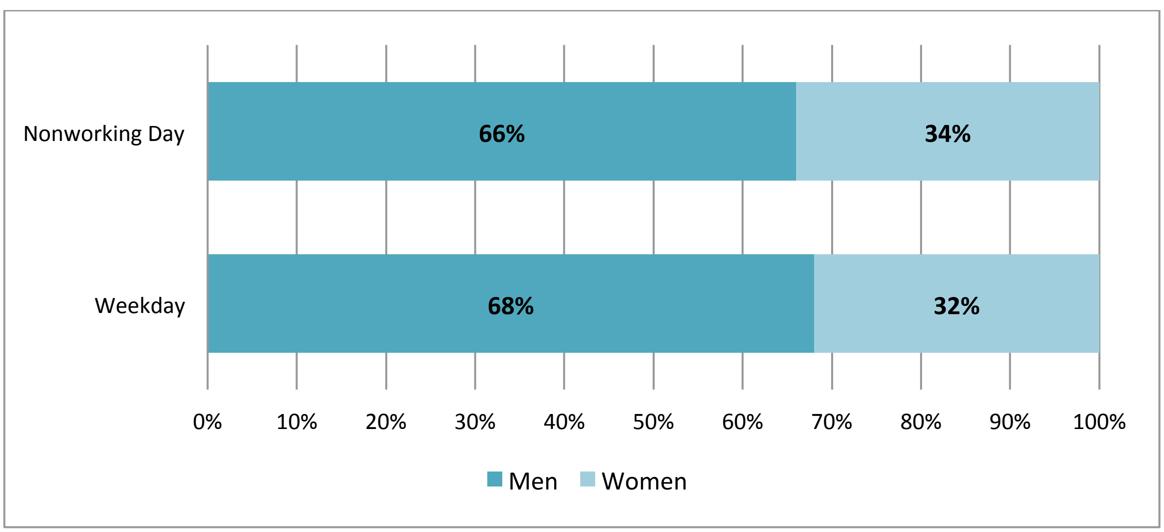
Point	Cycle Lane	Section	Average Hourly Flow (cycle/hrs)	
			Weekday	Non-working Day
C1	Antonio Varas	Arturo Claro - Carlos Wilson	106	65
C2	Simón Bolívar	Clorinda Wilshaw - A. Vespucio	21	19

2.4.4 Characteristics of Cyclists

The characterization of cyclists was obtained from the information collected with the measurements performed manually. As previously described, the measurements were visually recorded, focusing on the gender and use of safety equipment (helmet and carrying lights -front and rear light). In the next sections we present the statistics associated with each of these variables, differentiated according by the day of measurement.

2.4.4.1 Gender of Cyclists

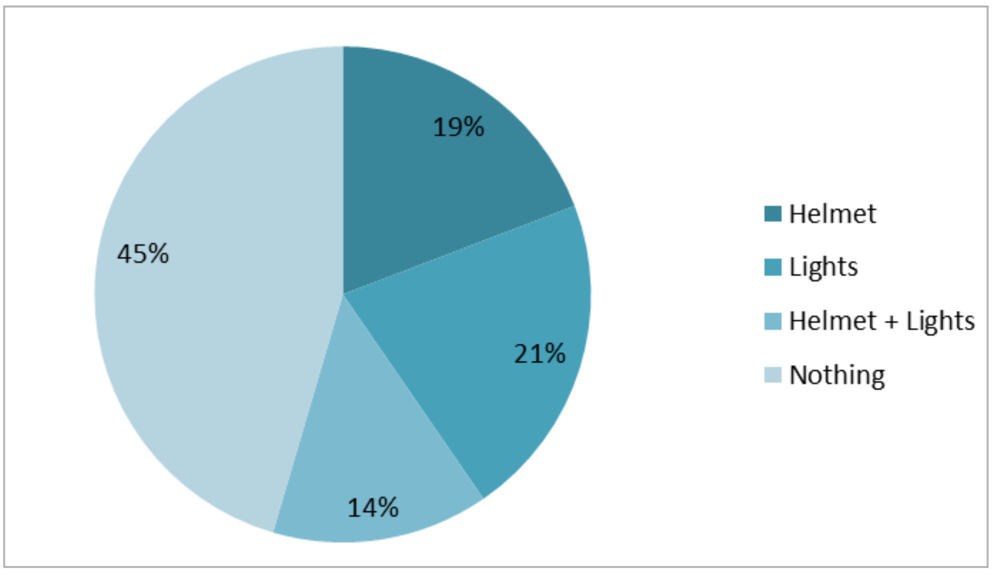
Measurements show that male is the dominant gender of cyclists in the measured section, representing two thirds of cases, while women represent approximately one third of cases. Graph 9 shows the distribution of cyclists by gender considering total users of both points s (C1 + C2).



Graph 9. Distribution of Gender (C1 + C2)

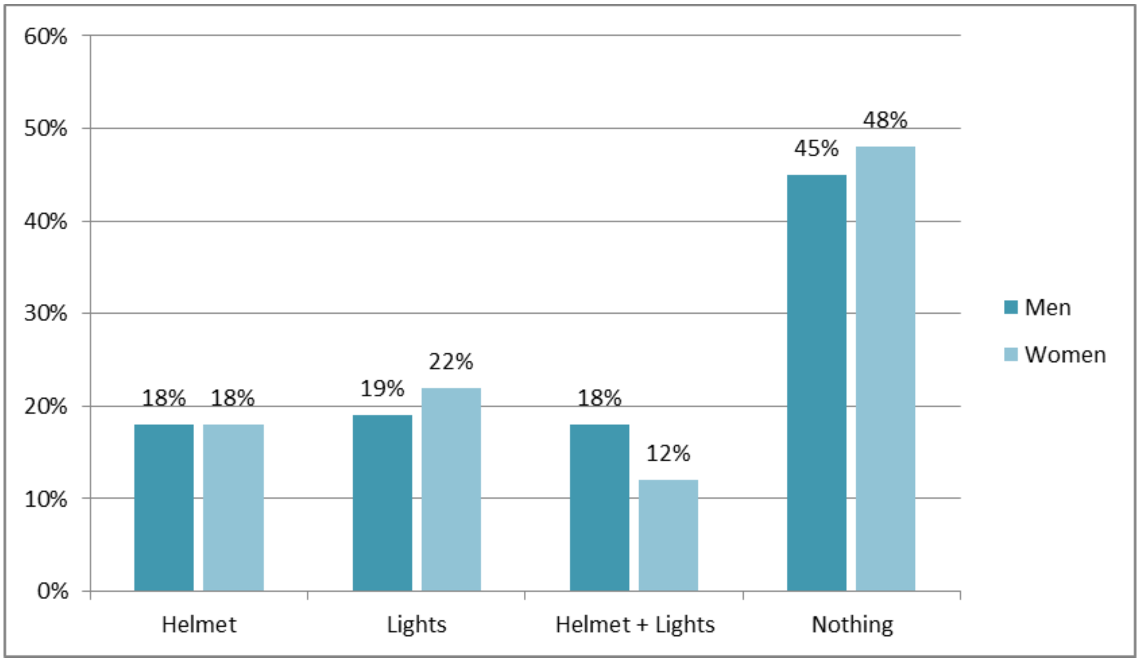
2.4.4.2 Use of Safety Equipment by Cyclists

Measurements show that considering the total number of cyclists who travel by cycle lanes C1 and C2, just a 19% use helmet, 21 % just carry on lights, 14% use helmet and carry on lights, and 45% avoid the use of helmet or carry on lights. Graph 10 shows the distribution of cyclists considering the use of safety equipment (C1 + C2).

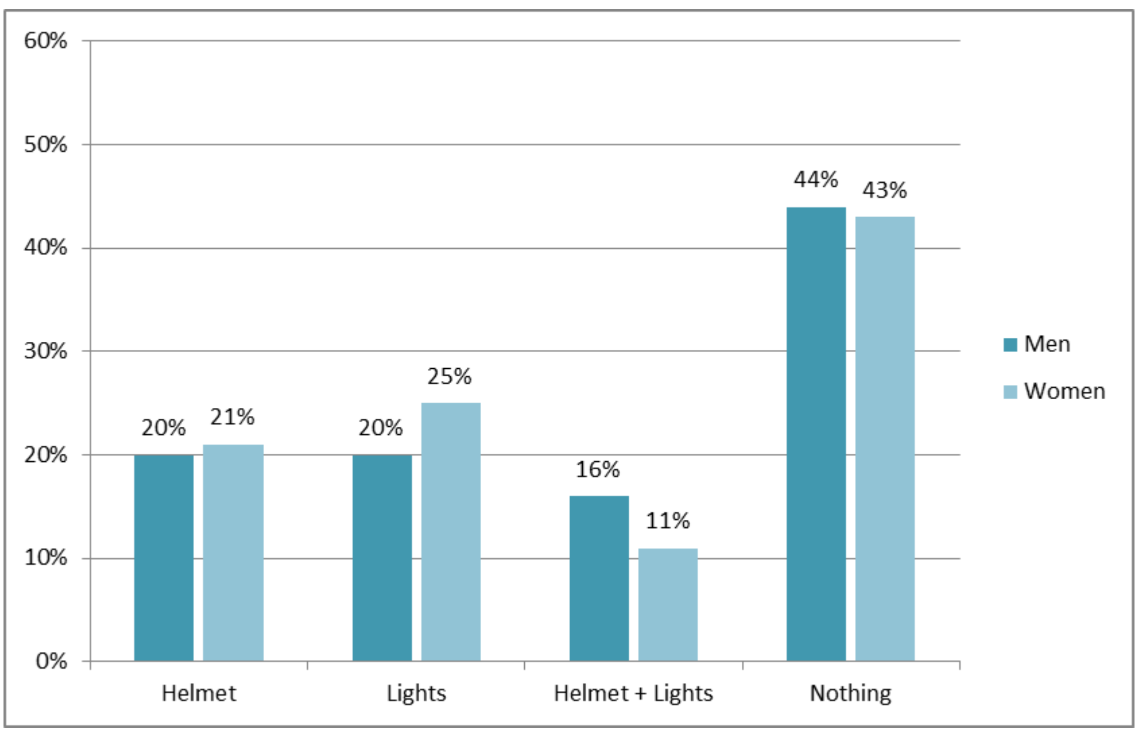


Graph 10. Distribution by use of safety equipment (C1 + C2)

Graph 11 and 12 show the percentages of use of safety equipment by gender for both weekdays and non-working days.



Graph 11. Distribution of use of safety equipment by gender, Weekday (C1 + C2)



Graph 12. Distribution of use of safety equipment by gender, non-working day (C1 + C2)

2.4.5 Evolution of Bicycles Flows

In this section, the analysis related to the historical evolution of bicycle users in the measurement points is reported, taking into consideration the results of cycle counts made as a part of this research in conjunction with continuous measurements made in study “Monitoring Plan for the Promotion of bicycle use in comunes of Santiago, Providencia and Ñuñoa. Flow Measurement and Profile of Users and Traffic Safety” (UNDP 2005-2008).

It is important to notice that as a weekday, we use the average of flow measured between weekday 1 and 2.

2.4.5.1 Flow Evolution of Bicycles for Period 2008 - 2012

For the analysis of the evolution of bicycles flows, we use an average of the annual rate according to the growth of the period calculated according with the following expression:

$$AGR\ (n, n+1) = \frac{flow\ (n+1) - flow\ (n)}{flow\ (n)} \times \left(\frac{1}{t(n+1) - t(n)}\right)$$

Equation 2. Annual Growth Rate of bicycles flows

Where:

AGR: Annual Growth Rate

Flow (n): Flow Year x

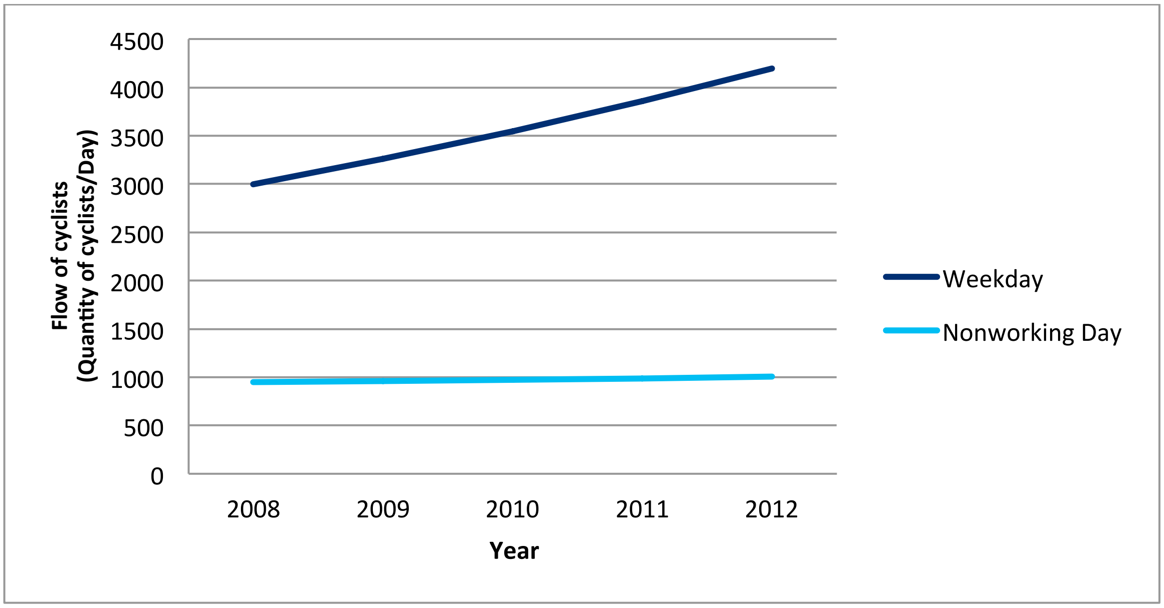
Flow (n+1): Flow Year x+1

t (n): Year n

t (n+1): Year n+1

Graph 13 shows the evolution of flows considering continuous measurements for both weekdays and non-working day, using the data of bicycles counts made in 2008 (UNDP 2005-2008) and 2012 as a part of this research.

It is worth mentioning that the trend is obtained by adding the total flows of count points C1 and C2 by day of measurement, for both 2008 (UNDP 2005-2008) and 2012, and then applying the growth function of the period calculated according to Equation 2. Annual Growth Rate.



Graph 13. Annual Growth Rate of bicycles flows, 2008 - 2012 (C1+C2)

It should be noted that there is a growing trend in the flow of cyclists in the count points C1 and C2, this growth is 8.8% annually while non-working day behaviour presents a very slight variation between the last four years, with an estimated growth of 1.4% annually.

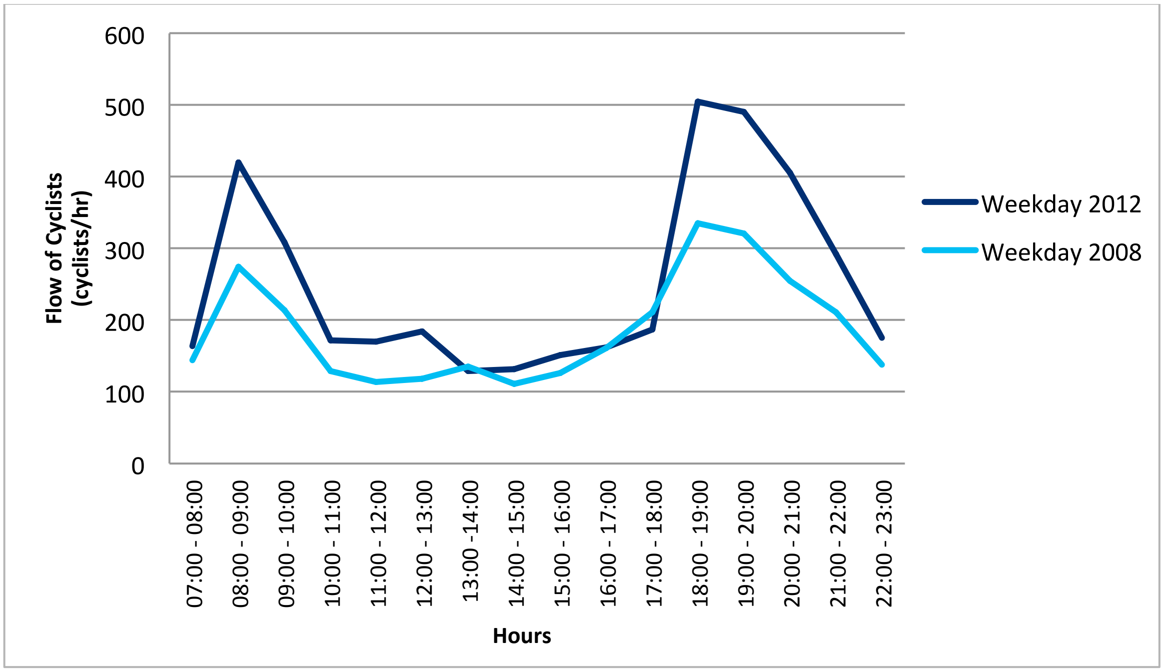
For the above, it could be inferred that principally the increment in the use of the bicycle as a transportation mode is during weekdays. In other words, these are commuting travels.

2.4.5.2 Hourly Flow Evolution of Bicycles for Weekdays, 2008 - 2012

According to data collected for weekday's flows in 2008 (UNDP 2005-2008) and 2012, which are shown in Table 11, we developed a benchmarking histogram shown in graph 14. With this information it is possible to compare the hourly profiles between different years of measurement.

Table 11. Total flow data of cyclists for weekday C1 + C2, 2008-2012

Measurement Points C1 and C2		
Hour	**Weekday 2008**	**Weekday 2012**
07:00 - 08:00	144	164
08:00 - 09:00	274	420
09:00 - 10:00	214	308
10:00 - 11:00	129	172
11:00 - 12:00	114	170
12:00 - 13:00	118	184
13:00 -14:00	135	129
14:00 - 15:00	111	132
15:00 - 16:00	126	151
16:00 - 17:00	161	162
17:00 - 18:00	211	187
18:00 - 19:00	335	505
19:00 - 20:00	321	490
20:00 - 21:00	255	406
21:00 - 22:00	211	292
22:00 - 23:00	138	175
Total	**2,997**	**4,047**



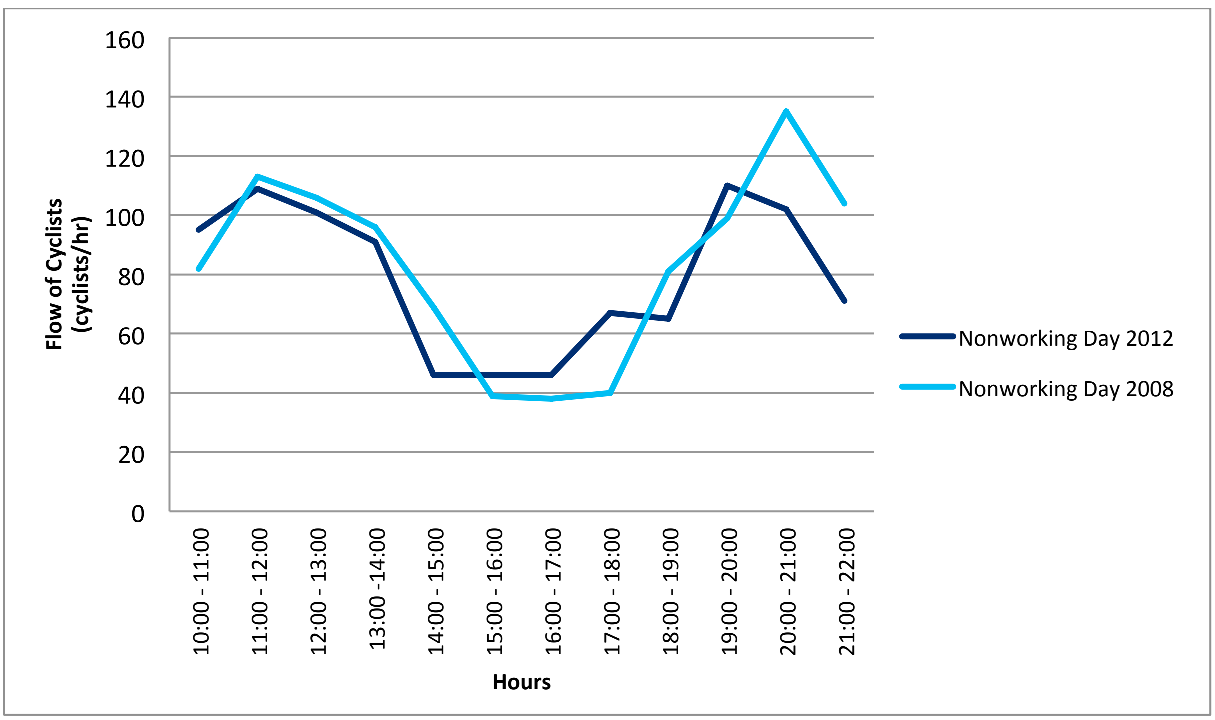
Graph 14. Comparative histogram of Evolution of Flows bicycles for weekday, 2008-2012

2.4.5.3 Hourly Flow Evolution of Bicycles for Non-working Days, 2008 - 2012

According to data collected for non-working day flows in 2008 (UNDP 2005-2008) and 2012 which are shown in the Table 12, a benchmarking histogram is developed (graph 15). With this information it is possible to compare the hourly profiles between different years of measurement.

Table 12. Total flow data of cyclists for non-working day C1 + C2, 2008-2012

Measurement Points C1 and C2		
Hour	**Non-working Day 2008**	**Non-working Day 2012**
10:00 - 11:00	95	82
11:00 - 12:00	109	113
12:00 - 13:00	101	106
13:00 -14:00	91	96
14:00 - 15:00	46	69
15:00 - 16:00	46	39
16:00 - 17:00	46	38
17:00 - 18:00	67	40
18:00 - 19:00	65	81
19:00 - 20:00	110	99
20:00 - 21:00	102	135
21:00 - 22:00	71	104
Total	**949**	**1,002**



Graph 15. Comparative histogram of Evolution of Flows bicycles for non-working day, 2008-2012

2.4.5.4 Flow Growth of Cyclists 2005-2012

Complementary to that reported in Section Flow Evolution of bicycles for period 2008 - 2012, we present the results obtained considering the evolution of flows per year from 2005. In other words, we consider count obtained in the same measurement points for the years 2005, 2006, 2007 and 2008 (UNDP 2005-2008), and then we add them to those obtained in 2012.

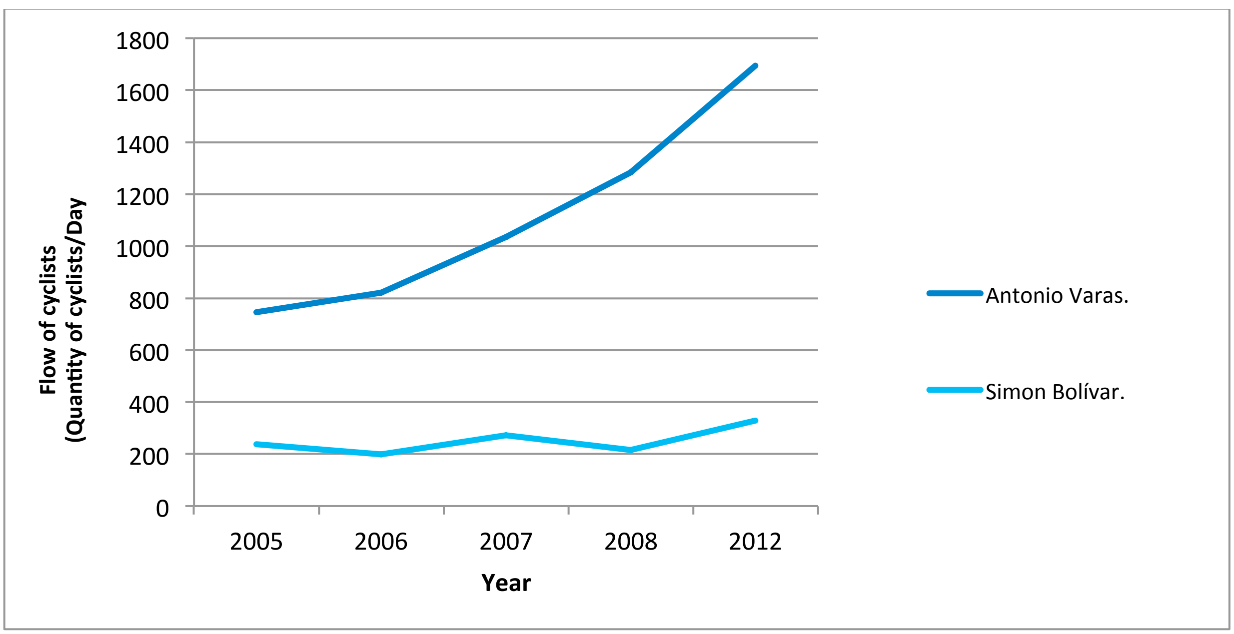
For growth analysis of flows we used the annual growth rate, depending on the growth period calculated according to equation 2 presented above.

2.4.5.5 Annual Growth Rate of Flow for Weekday, 2005-2012

In this section, it is reported the total flows (sum of flows obtained in weekdays) for each measurement point by year. Table 13 and Graph 16 show the evolution of total flow of bicycles for a weekday between 2005 and 2012.

Table 13. Average Flow of Bicycles by day for Weekday (C1+C2)

Measurement Point			Year				
ID	Cycle Lane	Section	2005	2006	2007	2008	2012
C1	Antonio Varas	Arturo Claro - Carlos Wilson	746	821	1,034	1,283	1,694
C2	Simon Bolívar	Clorinda Wilshaw -Av. Américo Vespucio	237	199	273	215	330



Graph 16. Evolution of total flow of bicycles for a weekday, 2005-2012

Considering the above data, the annual growth rates of flow calculated according to the expression indicated in Equation 2 is shows in Table 14.

Table 14. Average Annual Growth Rate for Weekday

Measurement Point		Year				
ID	Cycle Lane	2005-2006	2006-2007	2007-2008	2008-2012	2005-2012
C1	Antonio Varas	10,1%	25,9%	24,1%	8,0%	18,2%
C2	Simon Bolívar	-16,0%	37,2%	-21,2%	13,4%	5,6%

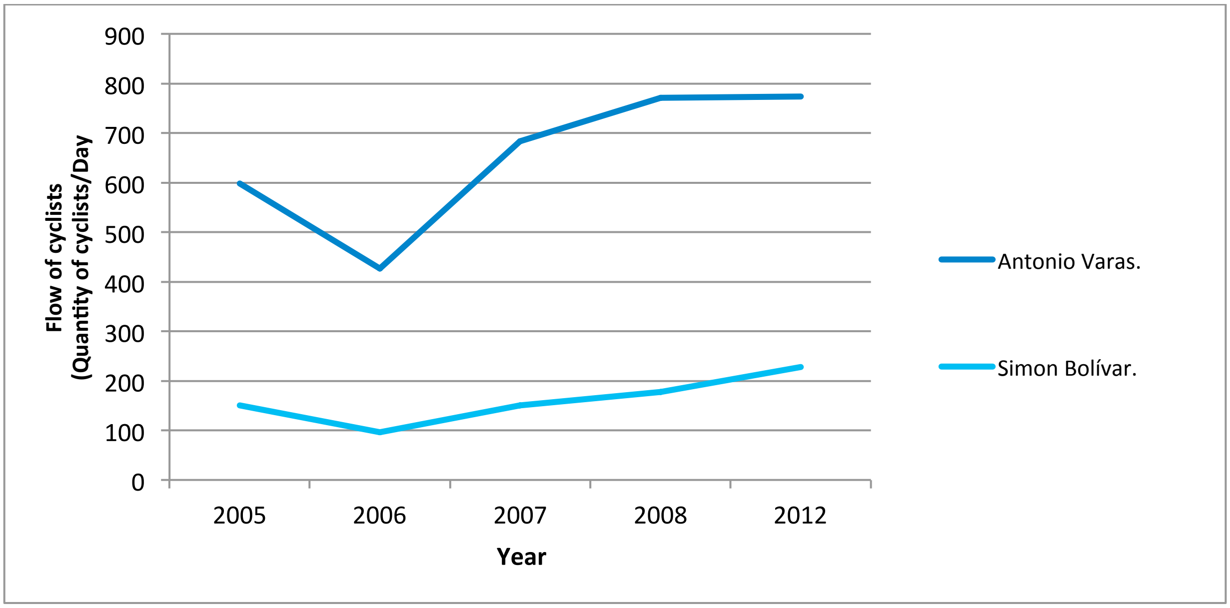
According to graph 16, it is important to notice that the use of the bicycle has grown more in cycle lane C1 than in C2, in the period between 2005 and 2012. There is no any research or document to indicate and explain which are all factors that influence this difference, so far. Nevertheless, this situation is possibly due to C1 is located in a high density mixed-use sector (Bramley, Dempsey et al. 2009). This facilitates the use of bicycles to get to places of interest such as work, educational activities or others spaces. Furthermore, cycling might be even faster than car or public transportation in the area, because during peak hours Antonio Varas Ave. presents high level of congestion. On the other hand, C2 is located in a low density residential sector with no work or educational places near Simon Bolivar Ave. (McDonald 2007). Moreover, this street presents lower levels of congestion in peak hours.

2.4.5.6 Annual Growth Rate of Flow for Non-working Day, 2005-2012

In this section, it is reported the total flows (sum of flows obtained in non-working days) for each measurement point by year. Table 15 and Graph 17 show the evolution of total flow of bicycles for non-working days between 2005 and 2012.

Table 15. Average Flow of bicycles by day for Non-working day (C1+C2)

Measurement Point			Year				
ID	Cycle Lane	Section	2005	2006	2007	2008	2012
C1	Antonio Varas	Arturo Claro - Carlos Wilson	598	426	683	771	774
C2	Simon Bolívar	Clorinda Wilshaw -Av. Américo Vespucio	151	96	150	178	228



Graph 17. Evolution of total flow of bicycles for a Weekday, 2005-2012

Considering the above data, annual growth rates of flow calculated according to the expression indicated in Equation 2 is shown in Table 16.

Table 16. Average Annual Growth Rate for Non-working Day

Measurement Point		Year				
ID	Cycle Lane	2005-2006	2006-2007	2007-2008	2008-2012	2005-2012
C1	Antonio Varas	-28,8%	60,3%	12,9%	0,1%	4,2%
C2	Simon Bolívar	-36,4%	56,3%	18,7%	7,0%	7,3%

According to graph 17, it is important to notice that the use of the bicycle is growing in both cases since 2006. However, this growth has no considerable difference comparing cycle lane C1 and C2, principally because the principal use in a non-working day is recreational more than commute. It is important to mention there is no any research or document to indicate and explain which factors influence this behaviour, so far.

2.5 Results. Case Study 2 "Measuring bicycle activity in cycle lanes of Pocuro Ave., Antonio Varas Ave. and Andrés Bello Ave."

The results obtained are presented in detail with the complete data collection generated by automated counts for defined points P1, P2 and P3. Additionally, we present statistical information in order to compare data between 2005 and 2012 and obtain the respective annual growth rate for the period.

2.5.1 Measuring Point (P1). Pocuro Ave. Cycle Lane

Table 17 presents the hourly flows detail recorded of measurement for point P1.

Table 17. Flow of bicycles, both directions and Time. Morning and Evening Peaks. Pocuro cycle lane (P1)

Flow measured (cycle / hrs) Pocuro cycle lane		
Hour	Direction	
	East - West	West - East
07:00 a 8:00	78	77
08:00 a 09:00	267	178
09:00 a 10:00	169	125
18:00 a 19:00	195	239
19:00 a 20:00	234	286
20:00 a 21:00	136	188
Total	**1,079**	**1,093**

For growth analysis of flows we used the annual growth rate, depending on the growth period calculated according to equation 2 presented above.

Table 18. Total Flow of Cyclists by Hour per Year. Morning Peak (P1)

Total Flow of Cyclists by Hour per Year. Morning Peak				
Year	Period			Average of
	07:00 - 8:00	08:00 - 09:00	09:00 - 10:00	Bicycles/Hour
2005	58	80	79	72
2012	155	445	294	298
Average annual growth rate			**23%**	

Table 19. Flow of Cyclists by Hour per Year. Evening Peak (P1)

Total Flow of Cyclists by Hour per Year. Evening Peak				
Year	Period			Average of Bicycles/Hour
	18:00 - 19:00	19:00 - 20:00	20:00 - 21:00	
2005	104	125	110	113
2012	434	520	324	426
Average annual growth rate			**21%**	

With the information presented above, we may show the representative maximum flows for the counting point for each period (morning peak and evening peak) and their respective average annual growth rate from 2005 to 2012.

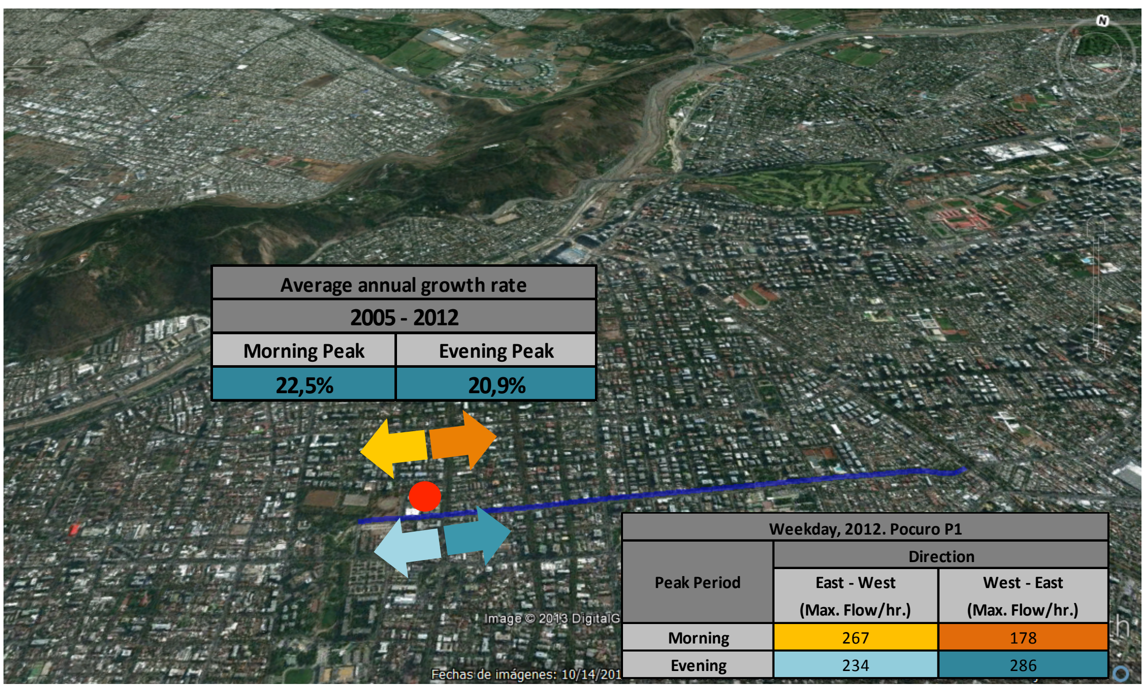


Figure 23. Maximum flow per hour and Average annual growth rate in measuring point (P1) for peak period. Pocuro Ave. cycle lane

In the previous figure, the arrows represent the directions of traffic flows measured in the counting point. The Table within the figure shows the maximum flows that represent the most charged number of bicycles that passed, for each direction of traffic, in the morning and evening peak. Additionally, the figure shows the average annual growth rate for each of the peak periods (Punta and Punta Tomorrow Afternoon) considering flow information of 2005 and 2012.

2.5.2 Measuring Point (P2). Antonio Varas Cycle Lane

Table 20 presents the hourly flow detail recorded of measurement for point P2.

Table 20. Flow of bicycles, both directions and Time. Morning and Evening Peaks. Antonio Varas cycle lane (P2)

Flow measured (cycle / hrs) Antonio Varas cycle lane		
Hour	Direction	
	North - South	South - North
07:00 a 8:00	29	98
08:00 a 09:00	68	258
09:00 a 10:00	36	136
18:00 a 19:00	205	94
19:00 a 20:00	196	94
20:00 a 21:00	120	52
Total	**654**	**732**

For growth analysis of flows we used the annual growth rate, depending on the growth period calculated according to equation 2 presented above.

Table 21. Total Flow of Cyclists by Hour per Year. Morning Peak (P2)

Total Flow of Cyclists by Hour per Year. Morning Peak				
Year	Period			Average of Bicycles/Hour
	07:00 - 8:00	08:00 - 09:00	09:00 - 10:00	
2005	36	55	49	47
2012	127	326	172	208
Average annual growth rate			**24%**	

Table 22. Total Flow of Cyclists by Hour per Year. Evening Peak (P2)

Total Flow of Cyclists by Hour per Year. Evening Peak				
Year	Period			Average of Bicycles/Hour
	18:00 - 19:00	19:00 - 20:00	20:00 - 21:00	
2005	79	68	52	198
2012	299	290	172	761
Average annual growth rate			21%	

With the information present above, we may show the representative maximum flow for the counting point for each period (morning peak and evening peak) and their respective average annual growth rate from 2005 to 2012.

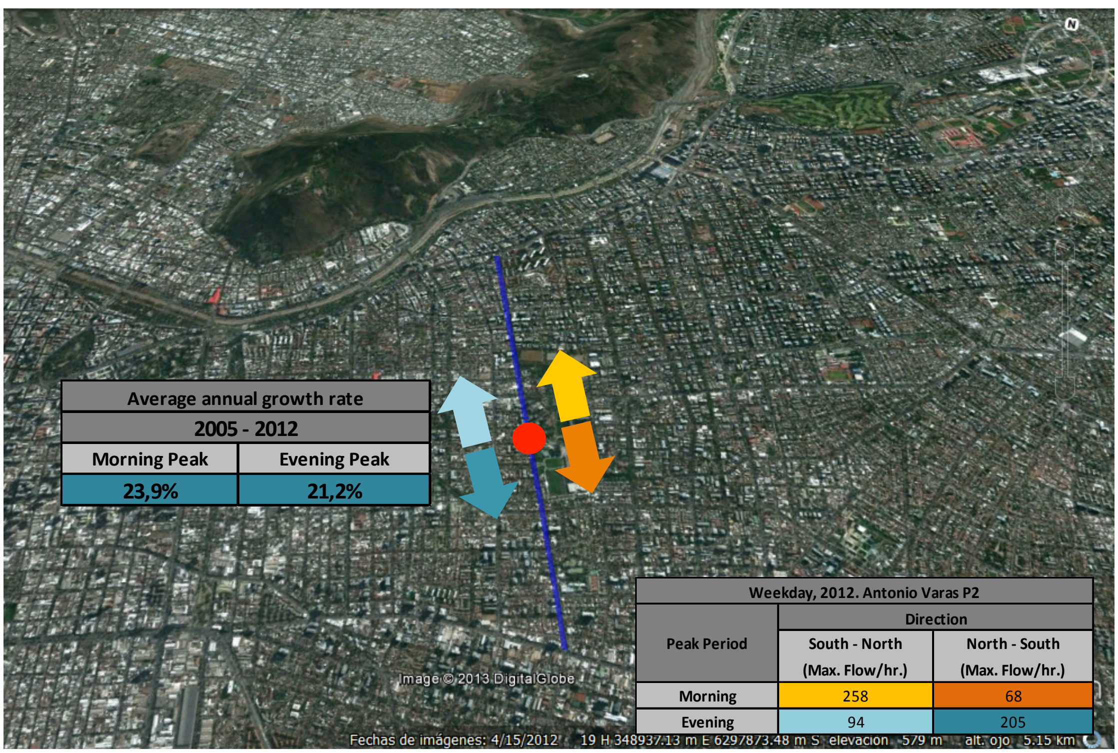


Figure 24. Maximum flow per hour and Average annual growth rate in measuring point (P1) for peak period. Antonio Varas cycle lane

In the previous figure, the arrows represent the directions of traffic flow measured at the counting point. In the Tables we can see the maximum flows that represent the most charged number of bicycles that passed, for each direction of traffic, in the morning and evening peak.

Additionally, the figure shows the average annual growth rate for each of the peak periods (Punta and Punta Tomorrow Afternoon) considering flow information of 2005 and 2012.

2.5.3 Measuring Point (P3). Andres Bello Ave. Cycle Lane

Table 23 presents the hourly flow detail recorded of measurement for point P3.

Table 23. Flow of bicycles, both directions and Time. Morning and Evening Peaks. Andrés Bello cycle lane (P3)

Flow measured (cycle / hrs) Andrés Bello cycle lane		
Hour	Direction	
	East - West	West - East
07:00 a 8:00	29	78
08:00 a 09:00	65	231
09:00 a 10:00	56	129
18:00 a 19:00	262	39
19:00 a 20:00	190	74
20:00 a 21:00	165	52
Total	**767**	**603**

For growth analysis of flows we used the annual growth rate, depending on the growth period calculated according to equation 2 presented above.

Table 24. Total Flow of Cyclists by Hour per Year. Morning Peak (P3)

Total Flow of Cyclists by Hour per Year. Morning Peak				
Year	Period			Average of Bicycles/Hour
	07:00 - 8:00	08:00 - 09:00	09:00 - 10:00	
2005	54	57	64	58
2012	107	296	185	196
Average annual growth rate			**19%**	

Table 25. Total Flow of Cyclists by Hour per Year. Evening Peak (P3)

Total Flow of Cyclists by Hour per Year. Evening Peak				
Year	Period			Average of Bicycles/Hour
	18:00 - 19:00	19:00 - 20:00	20:00 - 21:00	
2005	98	76	82	85
2012	301	264	217	255
Average annual growth rate			**17%**	

With the information present above, we may show the representatives maximum flows for the counting point for each period (morning peak and evening peak) and their respective average annual growth rate from 2005 to 2012.

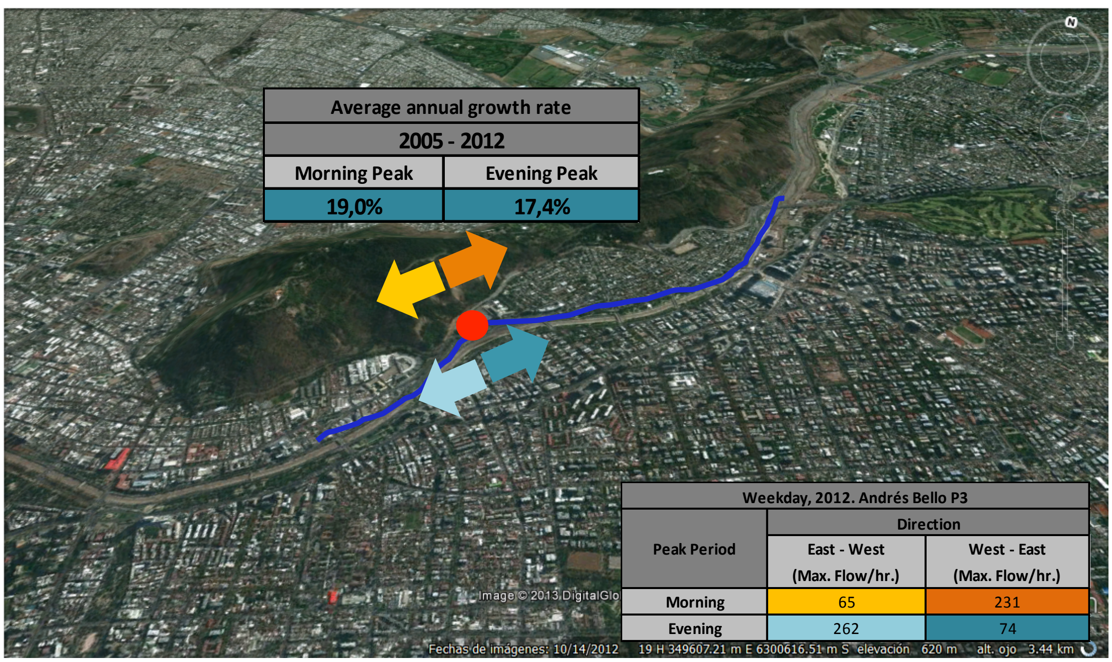


Figure 25. Maximum flow per hour and Average annual growth rate in measuring point (P1) for peak period. Andrés Bello Ave. cycle lane

In figure 25 the arrows represent the directions of traffic flows measured in the counting point. In the Tables we can see the maximum flows that represent the most charged number of bicycles that passed, for each direction of traffic, in the morning and evening peak. Additionally, the figure shows the average annual growth rate for each of the peak periods (Punta and Punta Tomorrow Afternoon) considering flow information of 2005 and 2012.

2.6 Conclusions

The data obtained through the period of measurement shows remarkable change from previous observations of non-motorized traffic collected by UNDP (UNDP 2005-2008) considering that the days (weekday and non-working day) and hours of counting were the same being outcomes comparable, including weather with no rain or cold temperatures. Focusing on the counting point located on Antonio Varas Ave. cycle lane for instance, the annual growth rate is 18.2% for the period 2005 to 2012. This means that in just over seven years the demand has more than the doubled, nearly tripled for this counting point. Instead, for cycle lane of Simon Bolivar Ave. the annual growth rate is 5,6% for the same period. Unfortunately, there is not examples of other places where gains of cycling shares have been observed from 2008, just the counting points defined by the study of UNDP (UNDP 2005-2008).

One of the important points that this section of the research displays is the significant participation of women as bicycle users who represent over 30% of the study population. In 2003 the participation of women was 8% while in 2008 was 20% according to the study of UNDP (2005-2008). The possible factors that affects the increment of female users is based on safety of use cycle lanes instead of share the road with cars (UNDP 2005-2008; Stronegger, Titze et al. 2010) and the latest increment of a bicycle culture in social networks (Goetzke and Rave 2011). However, there is no research or document to explain this factor that influence this increment. The latest effort in characterized travel behaviour show that there are differences in gender use and factors such as demographic, socio-economic, security, physical and psychological influence travel behaviour. According with Kim and Ulfarsson (2008) females have a higher proportion of short automobile trips than males, and tis behaviour is also apparent to active modes of transportation where cycling is more common among men than women (Gatersleben and Appleton 2007).

Given the paucity of data, it is unclear whether participation rates would be the same at other locations throughout the city that lack cycle lanes or where standards are looser. For this reason, a direction for future work would be to expand the investigation to better understand the gender distribution and the principal factors that affect the decision to travel by bicycle.

Considering the daily structure of demand, it is possible to say that the daily flow profiles obtained are very discernible and easily recognizable for weekday because the flow behaves orderly and predictable, both in distribution time and volume. This is verified by comparing different peak periods for different weekdays. Furthermore, the flow pattern is quite similar to motorized transportation. For this reason, it could be possible that motorized users are transferring to non-motorized modes, but this assumption would require more information and analysis to be validated. On the other hand, non-working days present great variability in both time and volume distribution. The latter indicates that trips made on non-working days are subject to flexible hours of commuters and they are likely to be replaced or deleted due to external factors such as or weather conditions (e.g. Miranda-Moreno and Nosal 2011).

In the case of use of safety equipment, we highlight the lack of understanding of bicycle safety which is reflected in the low grade of use of safety equipment by cyclists. Measurements show that considering the total number of cyclists who pass by cycle lanes C1 and C2, only 19% use a helmet, 21 % carry on lights, 14% use a helmet and carry on lights, and 45% do not use a helmet or carry on lights.

In the morning peak period we appreciate that for both Weekday 1 and 2, the peak period is set between 08:00 and 09:00 hrs. For weekday 1 the morning peak presents a total flow of 185 cyclists per hour while for weekday 2 morning peak presents 191 cyclists per hour. For non-working days the morning peak period was run between 11:00 and 12:00 hrs, which presents a total flow of 90 cyclists per hour. On the other hand, in the evening peak period we may appreciate that for both weekday 1 the evening peak period is set between 18:00 and 19:00 hrs which presents a total flow of 223 cyclists per hour. For weekday 2 the evening peak period is set between 18:00 and 20:00 hrs which presents an average of 205 cyclists per hour (204 cyclists between 18:00 and 19:00 hrs and 206 cyclists between 19:00 and 20:00 hrs). For non-working days the evening peak period was runs between 20:00 and 21:00 hrs, which presents a total flow of 108 cyclists per hour.

The results are noteworthy regarding the magnitude of flows during peak periods. In Antonio Varas Ave. cycle lane for example, the maximum flow count reached was 180 bicycles/hour/direction in the morning peak. Considering this result with the annual growth rates exceeding 10%, this serves as an urgent wake-up call to the authorities and decision makers in order to improve design standards, especially the consolidation of new cycle lanes considering these new measures of flows in cycle lanes.

It is important to mention that the comparison made in this chapter between the measurements obtained in 2012 and those that were made in 2008, have the particularity in that although they were taken at the same hours, days and measurement points, results of 2005, 2006, 2007 and 2008 were obtained in the spring season, while in 2012 measurements made in summer and at the beginning of fall. For this reason this aspect takes vital importance when making comparisons because the results reported in this section of the research are conservative. This is because in the summer or fall season, people are on vacation including students from schools and Universities who are not in classes, eliminating a pool of potential users of cycle lanes. For these reasons, we realize that the flow growth of users might be even greater than shown.

According to the Origin - Destination (OD) survey conducted by UNDP (2005-2008) in previous years and making the comparison with data collected in 2012 shows that the bicycle is used mainly with working purpose through weekdays and for recreational and sporting purposes on non-working days. According to the OD, the main destinations are distributed among the comune of Santiago and Providencia, these centers of attraction are located to the north of Point C1 and northeastern of point C2.

With regards Providencia comune, it is possible to conclude from the data collected and processed that on average, bicycle flows in have been growing since 2005, at a rate of 20% annually, 1.8% more than the percentage found in the first measurements. This means that within the last 7 years the demand has almost tripled. Unfortunately, we do not know what happened before 2005 because statistics are not available related to cycling, but we can ensure that this growth has been sustained for the past seven years, and everything seems to ensure that this trend will continue in the future due to the large degree of vehicular congestion present in the city. Additionally, this has important implications for the environment, mainly associated with the reduction of the number of cars circulating and thus it is associated with a significant reduction of pollution emissions, but the analysis of this point was not within the scope of this research.

In the measured points, it was observed that in some cases, flows (in both directions) exceeded 300 bicycles per hour, which means one cyclist every 12 seconds. These numbers show that the infrastructure available is approaching maximum capacity. This symbolizes a clear call to the authorities and urban planners to accelerate and extend the understanding of bicycle users throughout the city by means of counting, surveys and so on, in order to develop strategies to promote the use of bicycles which requires new cycle paths, parking lots, safety actions, etc.

This research reports periodic measurements; this means that flows of bicycles were counted during peaks hours (07:00 to 10:00 hrs for morning peak and 18:00 to 21:00 hrs for evening peak). This decision was based on previous continuous measures developed, which determined that the flow behaviour has two well-defined morning and evening peak points.

The government, through its official public policy program, defined that at the end of the government period (2014) there will be double the number of bicycles users in major cities of the country. In this sense, all public departments should cooperate in achieving this goal. Keep in mind that at the end of the period, the president will be assessed regarding the level of fulfillment of this goal and the remaining time to take action on the matter is limited. Therefore, our recommendation is to begin, as soon as possible, implementing some count flow campaigns of bicycle users through permanent automatic counters across the principal cities of the country, because databases are the basis of future modeling. In other words, we propose to create and materialize counting networks in order to know how many people move at different times of the day and during different months of the year, using the streets and bike lanes, by national, regional and local scales with the aim to promote non-motorized modes of transport and thus contribute to lower pollutant output and a more sustainable future.

Like many cities in the world, this is not a new endeavour. For example, the Planning Department of the New York City has monitored the demand for bicycle transportation since 1999. This information has become the basis for planning, projects and participatory processes in the generation, design and construction of bicycle paths and facilities to promote the use of bicycles, reducing the use of cars[9].

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[9] More information: http://www.transalt.org/

Chile should start as soon as possible to implement a plan for ongoing monitoring of flow of bicycle users becoming a standard for all bicycle paths. Thus, knowledge of this behaviour will allow us to improve urban and transportation planning, management and help to be more active and effective in the participation of the development of projects with communities, groups, organizations, the public and private organizations.

It is clear that bicycle growth rates are growing. Probably, this due to a change of decision mobility pattern of people and not necessarily correspond as a result of a public policy. Considering the above, it is urgent that authorities intensify their efforts in order to further improve these results, because it is fruit of the work of all. Moreover, considering results obtained in this section, one question for future research is to investigate if the actual public investment is consistent and related with bicyclist growth, and if public policies are considering this transportation mode as a real contribution to improve congestion and urban development.

CHAPTER 3. MEASURING BICYCLE AND PEDESTRIAN ACTIVITY IN THE METROPOLITAN PARK OF SANTIAGO

3 Measuring Bicycle and Pedestrian Activity in the Metropolitan Park of Santiago

3.1 Introduction

In Chapter 2 a method to count bicycle trips on major arterials in Santiago, Chile, was presented. An additional aspect of the use of cycling is for recreative purposes. In 2012, in coordination with the administration of the metropolitan park of Santiago – Chile, was considered the idea of measuring the total number of users who access to this park during Ciclorecreovía´s program during weekend, considering the large quantities of people walking, running or using their bicycles for recreational use. For this reason, it was developed a counting plan, which included cyclist and pedestrian flows.

One of the principal contributions of this research is to know and understand the actual number and distribution through the day of cyclists and pedestrian who resort to these spaces to exercise during weekends.

3.2 Context and Objectives

The metropolitan park of Santiago that is located within the city of Santiago, the capital of Chile. Consisting of the San Cristóbal, Chacarillas and Los Gemelos hills, and the areas of Tupahue, Lo Saldés, Pirámide and Bosque Santiago, the park is located between four comunes of Santiago (Huechuraba, Providencia, Recoleta and Vitacura) and covers approximately 722 hectares, making it the largest urban park in Chile and one of the largest in the world. The park was created in April 1966, by incorporating the Chilean National Zoo and the services of San Cristóbal Hill, and is managed by the Ministry of Housing and Urban Development. In September, 2012, the Chilean government launched a plan to refurbish and expand the park between 2012 and 2016, a plan which includes building new footpaths, planting 100,000 more trees and expanding the National Zoo.

In this context, the measuring of bicycle and pedestrian flows were made at the beginning of the fall term (April) of 2012. We measured one weekend (Saturday and Sunday) from 09:00 to 21:00 hrs during the operating period of "Ciclorecreovía" (bicycle recreation lanes) program which provides incentive for people to use their bicycles or walk in different places through the city for sporting events.

To carry out the development of these measurements and ensure the quality of the results, the technology to measure bicycles was the same used in the case studies in Chapter 2 for one of the counting points.

The Ciclorecreovía program is uniquely in favor of bicycle traffic through the installation of signage, safety cones and monitoring personnel. Also, the volunteers of Ciclorecreovía have the authority to prohibit motor vehicle access to the park during the entire period of operation that develops from 09:00 to 13:30 hrs on Saturday and Sunday.

The importance of measuring trips undertaken for recreational purposes lies in the relationship between these users and their physical activity habits, and therefore, with active transport. In this sense, this work constitutes a contribution to enlighten decision makers who work in promoting this type of mobility.

Focusing on the medium and long-term prospects, it is relevant to consider the value of this monitoring technology in a place like the Metropolitan Park of Santiago. The park could have a permanent monitoring system of park users, both bicycle and pedestrian, along all roads and trails, providing information which is crucial to justify new investments and management in order to improve the actual conditions of the network for cyclists and pedestrians.

The results shown in this section are not sufficient to establish trends over time, because this is the first time that measures of cyclist and pedestrian flows have been conducted at this particular location. This will only be possible if these measures are repeated in subsequent periods and under similar conditions of counting. Therefore, the data presented correspond to a snapshot of the behaviour of the demand, whose importance lies in the magnitudes and composition obtained.

3.2.1 Objective

The main objective is to measure bicycle and pedestrian activity in the urban Metropolitan Park of Santiago, Chile. More specifically, we aim to:

- Quantify the volume of bicycle and pedestrian users circulating by Ciclorecreovias`s program in the urban metropolitan park of Santiago for non-working days, using an automated count system.
- Characterize the volume of bicycle and pedestrian users by gender using manual observational counting.

- Quantify the use of safety equipment (Helmet) by bicycle users using manual observational counting.

3.3 Methods

The methodology used to measure bicycle and pedestrian flows are classified as continuous measurements due it corresponds to a cyclists and pedestrian record passing through a point during a certain amount of time for a significant number of hours in a day. Measurements were performed for two non-working days (Saturday and Sunday) from 09:00 to 21:00 hrs.

The measuring method is mixed. This means that flow counts are performed using automated counters (pneumatic tubes) which was detailed in chapter 2 while, on the other hand, manual observational counting was used for the quantification and characterization of the distribution of users by gender, age range and use of safety equipment.

3.3.1 Planning for Measuring Bicycles

To record the volume of bicycle users, an efficient and orderly measurement process was implemented by planning each activity, such as:

- Planning and logistics of flow measurements of cyclists in the Metropolitan Park of Santiago.
- Selection of specific points to count.
- Determination of days and measurement periods (hours).
- Development of field sheets for manual observational counting.
- Installation of automatic measuring equipment.

3.3.2 Selection of Specific Points to Count

The determinations of the measuring sections are performed taking into account site visits and coordination with the entities responsible for the operation and administration of Ciclorecreovía´s program and Metropolitan Park of Santiago.

Measuring sections are chosen for the bicycle and pedestrian flow counts. In the particular case of the sections of Ciclorecreovía is determined that only the bicycles flow passing through the street. The Table 26 shows the location of these counting points:

Table 26. Measurement Points

ID	Cycle Lane	Location	Point of Reference
P1	Abate Molina	Metropolitan Park of Santiago	Pedro de Valdivia entrance
P2	Abate Molina	Metropolitan Park of Santiago	Mapulemu garden sector

Figures 26 and 27 show the location of the Metropolitan Park of Santiago and both measurement points within the section where ciclorecreovías´s program operates.

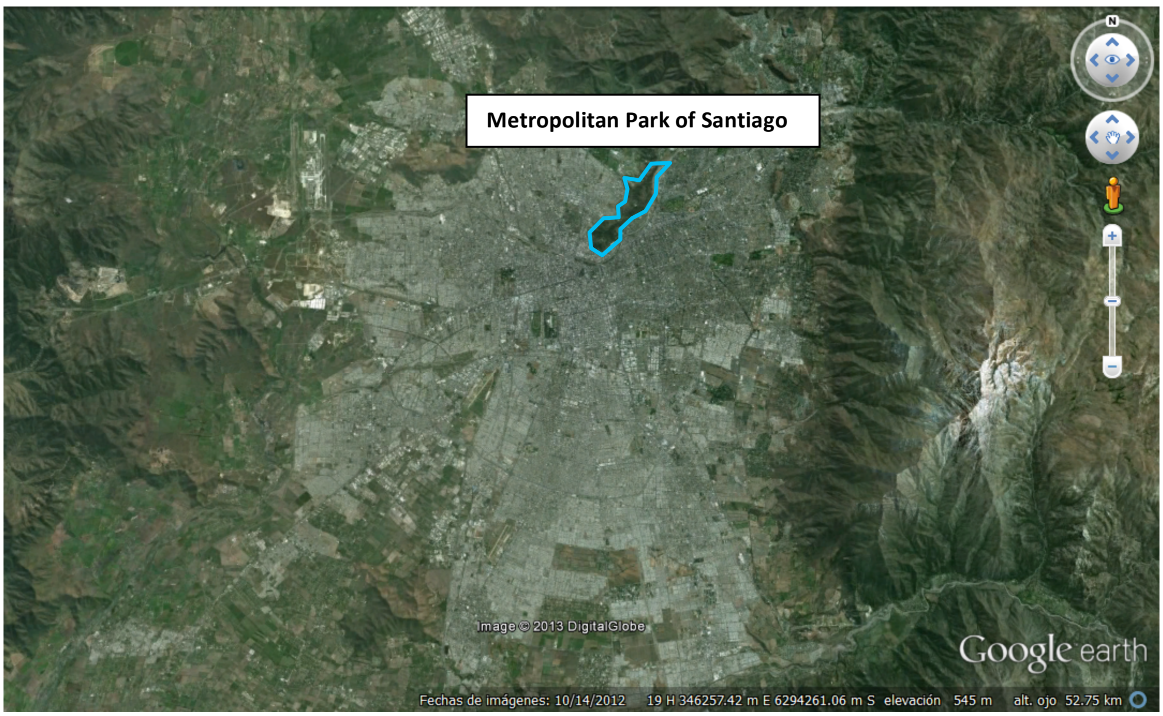


Figure 26. Location of the Metropolitan Park of Santiago

Figure 27. Zoom of the Location of the Metropolitan Park of Santiago

The section where the program Ciclorecreovía operates corresponds to Abate Molina Street, between access Pedro de Valdivia North and Mapulemu Garden sector. This section has a length of approximately 1,500 meters. Figures 28 and 29 shows the extension and location of these counting points:

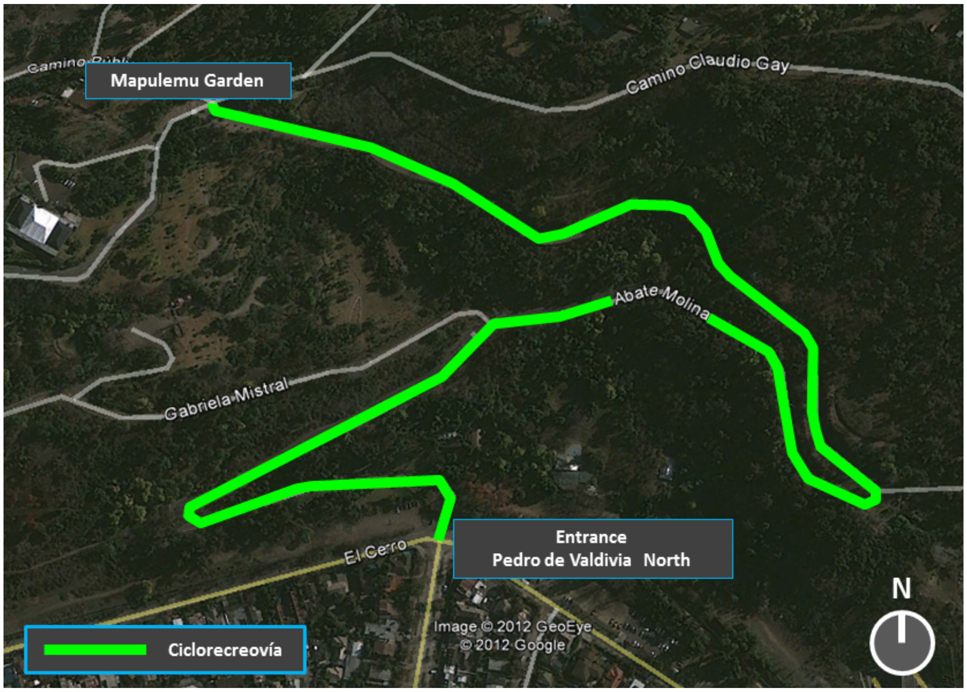


Figure 28. Extension of Ciclorecreovía

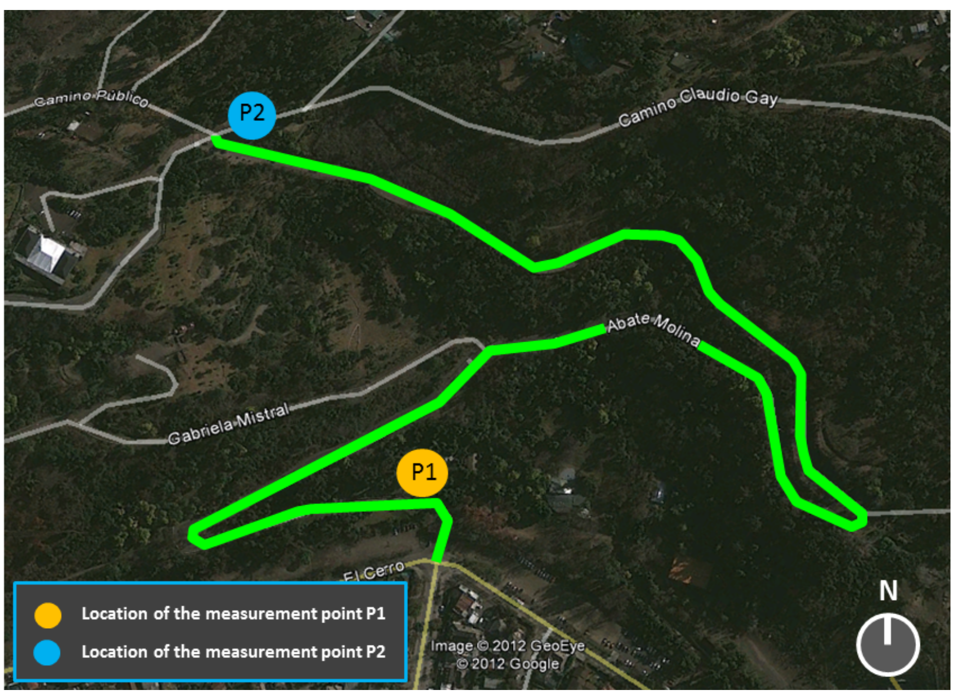


Figure 29. Location of the measurement points

The first measurement point (P1) is located a few meters inside the entrance of Pedro de Valdivia North Street and is selected as a strategic location for automatically measuring the flow of cyclists. This location is also important because this is the bottom access where Ciclorecreovía operates.

The second measurement point (P2) is located a few meters before the junction of Claudio Gay St. and Abate Molina St., in front of the entrance of Mapulemu Garden. This location is a strategic location for measuring the flow of cyclists because it is a mandatory point to pass through.

3.3.3 Determination of Days and Measurement Periods (hours)

The determinations of the days and times to perform continuous measurements are set for Saturday 21st and Sunday 22nd of April, 2012[10]. The continuous measurement period is defined taking into consideration the schedule operation of the Ciclorecreovía program in the Metropolitan Park of Santiago which is held every Saturday and Sunday from 9:00 am to 2:00 pm. Additionally, for point P2 we count cyclists continuously from 09:00 am to 9:00 pm in order to continue measuring at this point during the day to observe the cyclist flow behaviour at this measurement point in hours after the operation of Ciclorecreovía. The detail is shown in the Table 27:

Table 27. Hours of Measurements

Measurement Point	Measurement Periods (hours)
	Saturday 21st and Sunday 22nd
P1	09:00 am – 2:00 pm
P2	09:00 am – 9:00 pm

3.3.4 Automatic and Manual Measurement

Methods of data collection are separated into two types, the automatic and manual measurement.

For each measurement point we plan to use different counting methods, depending on the type of information to be obtained, according to the objectives defined previously. The details of the method for measuring the flow of bicycles at each point are shown in Table 28:

[10] Temperatures: 27°C (sunny) for Saturday 21st and 22°C (sunny) for Sunday 22nd

Table 28. Measuring Methods for each measuring point

Measurement Point	Method of Measurement	Type of Sensor
P1	Automatic Measurements	Pyro Box Compact
P2	Automatic + Manual Measurements	Pneumatic Tube

3.3.4.1 Method of Measurement for Point P1

To execute measurements automatically, we used electronic measuring equipment brand Eco-counter called Pyro Box Compact that has the technology to capture the flow and direction of cyclists and pedestrians that cross through the measurement section.

The Installation of Pyro Box Compact is very simple and minimally invasive. Installation involves placing the device on a pole using a mounting kit, allowing its installation in minutes. Besides, technical features make it a very effective portable device for measurement of bicycle and pedestrian users. It is 100% autonomous, because it uses a long duration battery to capture and process data. As part of the installation, the equipment requires a configuration and sensor calibration. This task is performed using software called Eco-link, which has a user-friendly interface.

Figure 30. Pyro Box Compact

Figure 31. Calibration and Configuration of Pyro Box Compact in Measurement Point P1

The Pyro Box Compact counter uses a combination of passive infrared pyro electric technology patented by Eco-counter and a high precision lens to detect a change in the detected temperature when a person passes in the range of the sensor. Thanks to its extremely high sensitivity, the sensor can detect two different people with only a small gap between them. The sensor is self-calibrating for a simple installation. This system is designed to count pedestrians and bicycles in an urban environment. The box containing the system is vandal resistant and can be installed temporarily or permanently.

Figure 32. Pyro Box Compact Device Installed in measuring point P1

The benefits of using the Eco-counter technology are:

- Automatic collection and data storage.
- Extraction of the data through wireless technology.
- High accuracy (+/- 5%, even in heavy traffic).
- Counts bikes passing side-by-side or closely following each other.
- Specifically designed to monitor bicycles on dedicated bicycle lanes and greenways.
- Automatic Statistical processing of data.
- Bidirectional count of flows.
- No maintenance
- High autonomy: 10 year battery life
- 2 year data storage
- Waterproof
- Range up to 15m / 50'
- Hourly or 15 min recording intervals

3.3.4.2 Method of Measurement for Point P2

In point P2 the measuring method is mixed. This means that flow counts are performed using automated counters (pneumatic tubes) while, on the other hand, manual observational counting were used for the quantification and characterization of the distribution of users by gender and use of helmet.

To carry out the development of these automatic measurements and ensure the quality of the results, the technology to measure bicycles was the same explained in section 2.3.4.1 “Automatic Measurement”.

3.3.4.2.1 Manuals Measurements

To execute manual measurements we generate some form sheets in order to identify the following characteristics of bicycle and pedestrian users:

- Gender
- Group of Age (just for pedestrian)
- Use of Helmet (just for cyclists)

In Tables 29 and 30, we present the form sheet that volunteers use in order to generate data of gender, group of age and use of helmet by cyclists.

Table 29. Form sheets of Gender and Use of Helmet

MEASURING BICYCLE ACTIVITY IN METROPOLITAN PARK OF SANTIAGO
Gender and Use of Helmet

Place of Measuring	Metropolitan Park of Santiago
Measure Point	
Direction of Flow	
Date	
Name of Volunteer	

Hour	Man	Man with Helmet	Woman	Woman with Helmet	Otros
09:00 - 10:00					
10:00 - 11:00					
11:00 - 12:00					
12:00 - 13:00					
13:00 -14:00					
14:00 - 15:00					
15:00 - 16:00					
16:00 - 17:00					
17:00 - 18:00					
18:00 - 19:00					
19:00 - 20:00					
20:00 - 21:00					
Comments:					

Table 30. Form sheets of Gender and Range of Age

MEASURING BICYCLE ACTIVITY IN METROPOLITAN PARK OF SANTIAGO
Gender and Age Range

Place of Measuring	Metropolitan Park of Santiago
Measure Point	
Direction of Flow	
Date	
Name of Volunteer	

	Man (Range of Age)			**Woman (Range of Age)**		
Hour	**1 to 20**	**20 to 40**	**40 or more**	**1 to 20**	**20 to 40**	**40 or more**
09:00 - 10:00						
10:00 - 11:00						
11:00 - 12:00						
12:00 - 13:00						
13:00 -14:00						
14:00 - 15:00						
15:00 - 16:00						
16:00 - 17:00						
17:00 - 18:00						
18:00 - 19:00						
19:00 - 20:00						
20:00 - 21:00						
Comments:						

3.4 Results

The results obtained are presented in detail with the complete data collection generated both through automatic and manual counts for defined points.

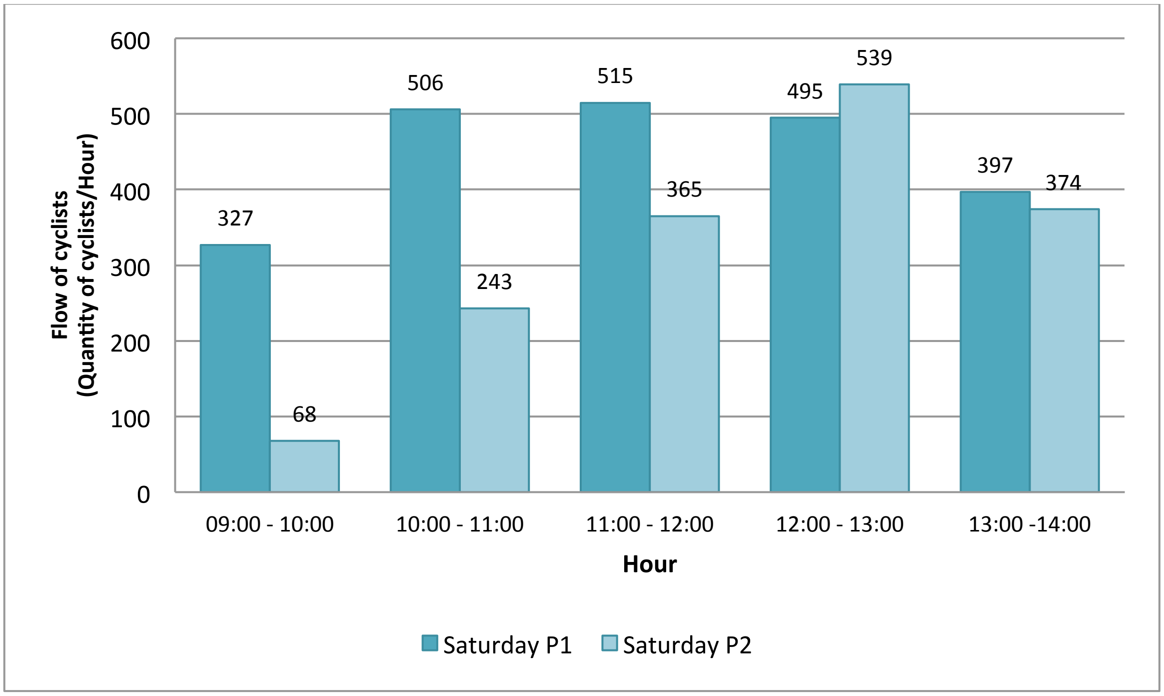
3.4.1 Total Number of Cyclists Entering to Ciclorecreovía

Table 31 presents the details of total flows of cyclists entering to Ciclorecreovía for both points of measure (P1 and P2) and for both days.

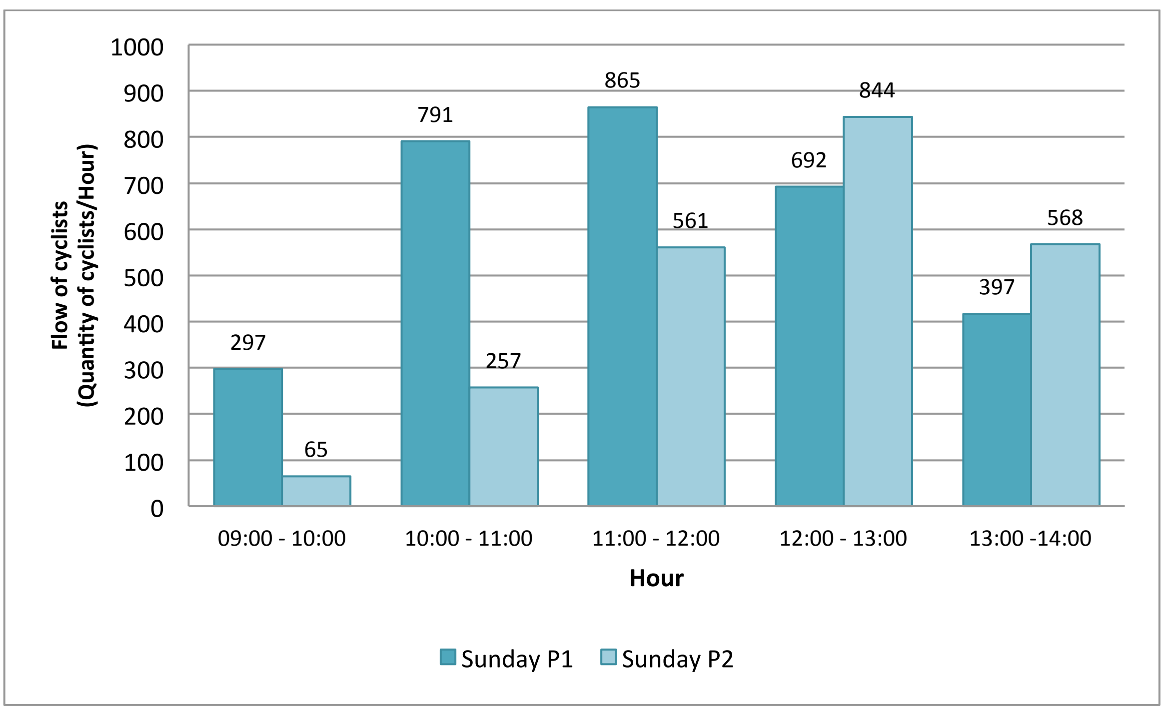
Table 31. Entrance flow measurements of Ciclorecreovía for each point

Hour	Saturday		Sunday	
	P1	P2	P1	P2
09:00 - 10:00	327	68	297	65
10:00 - 11:00	506	243	791	257
11:00 - 12:00	515	365	865	561
12:00 - 13:00	495	539	692	844
13:00 -14:00	397	374	417	568
Total by Point	**2,240**	**1,589**	**3,062**	**2,295**
Total by day	**3,829**		**5,357**	

With the information collected from Table above, a flow histogram by day of measure is developed and presented in graphs 18 and 19.



Graph 18. Entrance flow measurements of Ciclorecreovía, Saturday



Graph 19. Entrance flow measurements of Ciclorecreovía, Sunday

Taking into account the information obtained for both days, we can see that the total flow distribution for Saturday is 3,829 cyclists and pedestrian of which 2,240 belong to P1 and 1,589 belong to P2. For Sunday the total flow is 5,357 cyclists and pedestrian of which 3,062 cyclists belong to P1 and 2,295 belong to P2. The peak hour of both days is set between 12:00 and 13:00 hrs. Figure 33 shows the information above-mentioned.

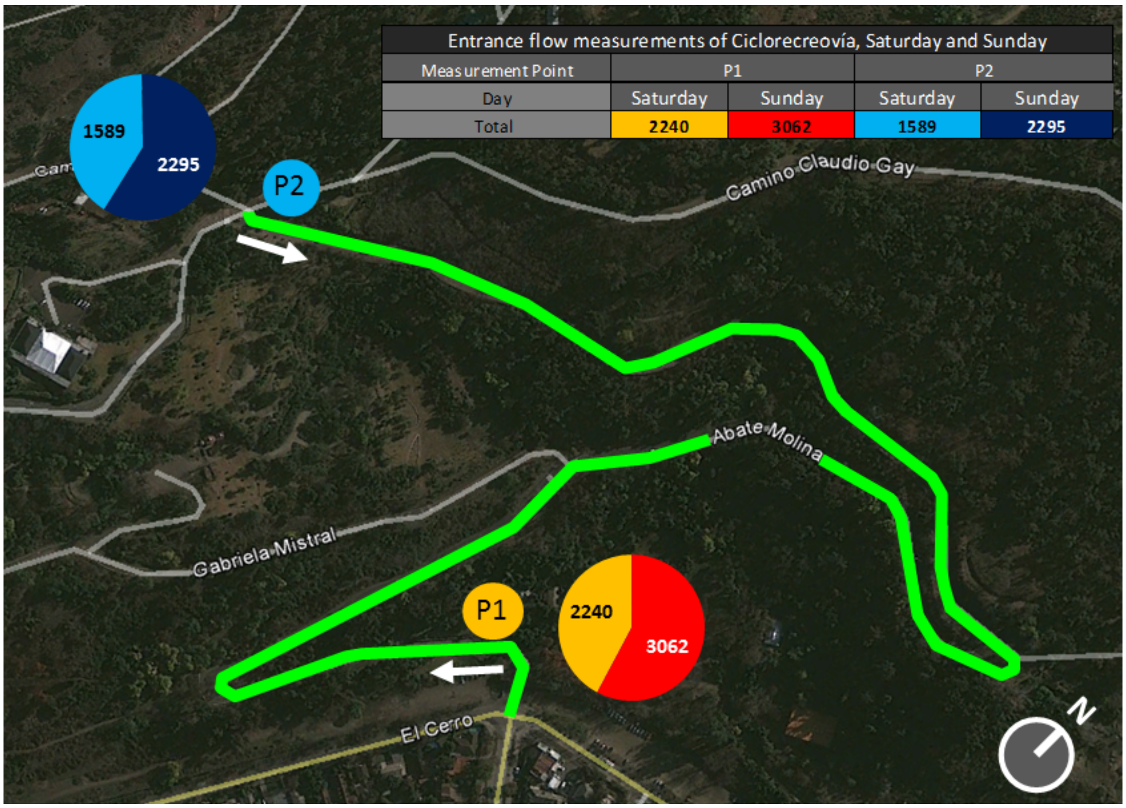


Figure 33. Entrance flow measurements of Ciclorecreovía, Saturday and Sunday

3.4.1.1 Flow of Entrance and Exit of People Cycling or Walking through the Access Pedro de Valdivia North (P1)

Table 32 presents the details of total flows of people entering to Ciclorecreovía through the Access Pedro de Valdivia North (P1) for both days.

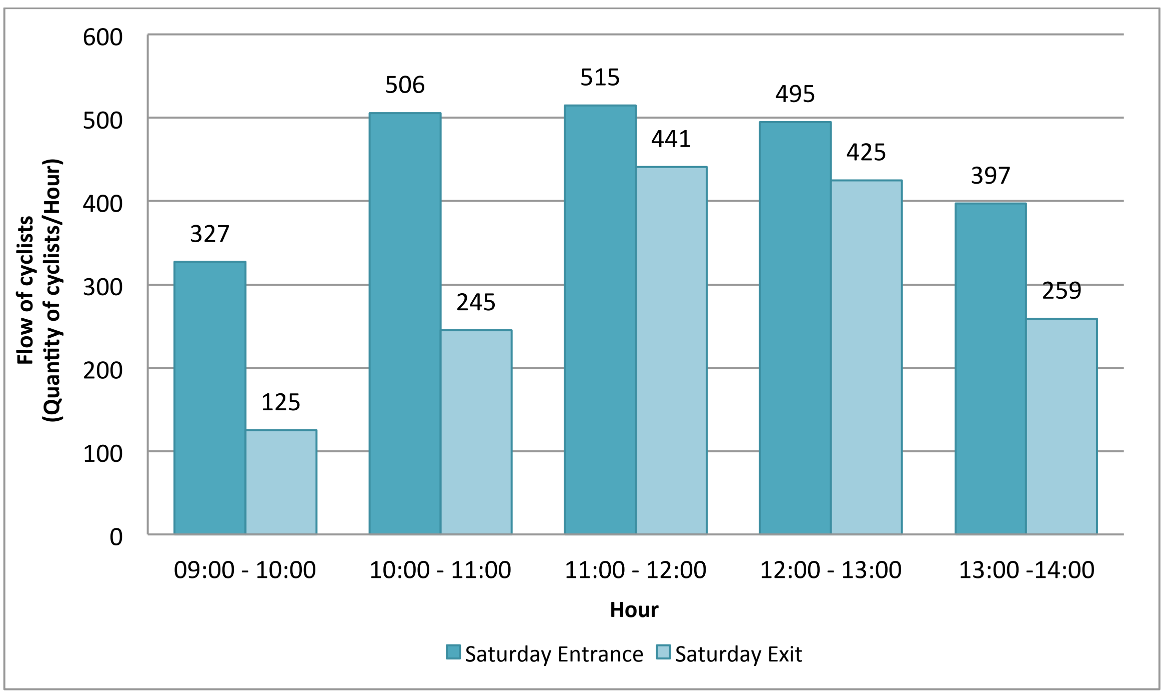
Table 32. Flow of entrance-exit of People through the Access Pedro de Valdivia North, both days.

Hour	Saturday		Sunday	
	Entrance	Exit	Entrance	Exit
09:00 - 10:00	327	125	297	72
10:00 - 11:00	506	245	791	330
11:00 - 12:00	515	441	865	599
12:00 - 13:00	495	425	692	944
13:00 -14:00	397	259	417	759
Total	**2,240**	**1,495**	**3,062**	**2,704**

With the information collected from Table above, a flow histogram by day of measure is developed and presented in the following graphs and figures.

3.4.1.1.1 Saturday (P1)

By Saturday, the total flow of people cycling or walking through Pedro de Valdivia North access (P1) is 2,240 people for entrance and 1,495 people for exit.



Graph 20. Distribution of People (entrance-exit) through the Access Pedro de Valdivia North (P1), Saturday

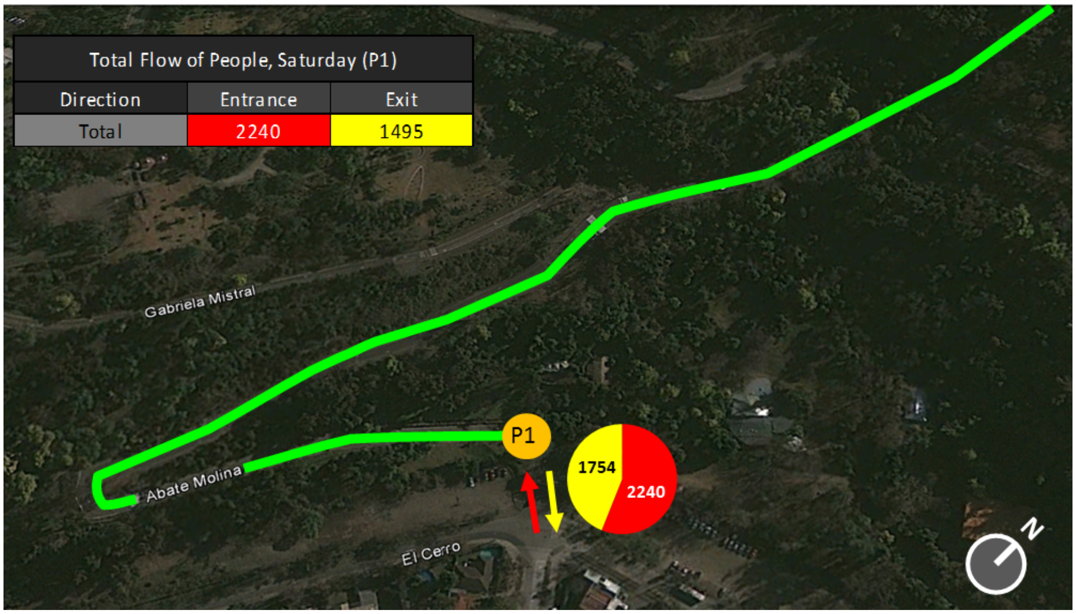
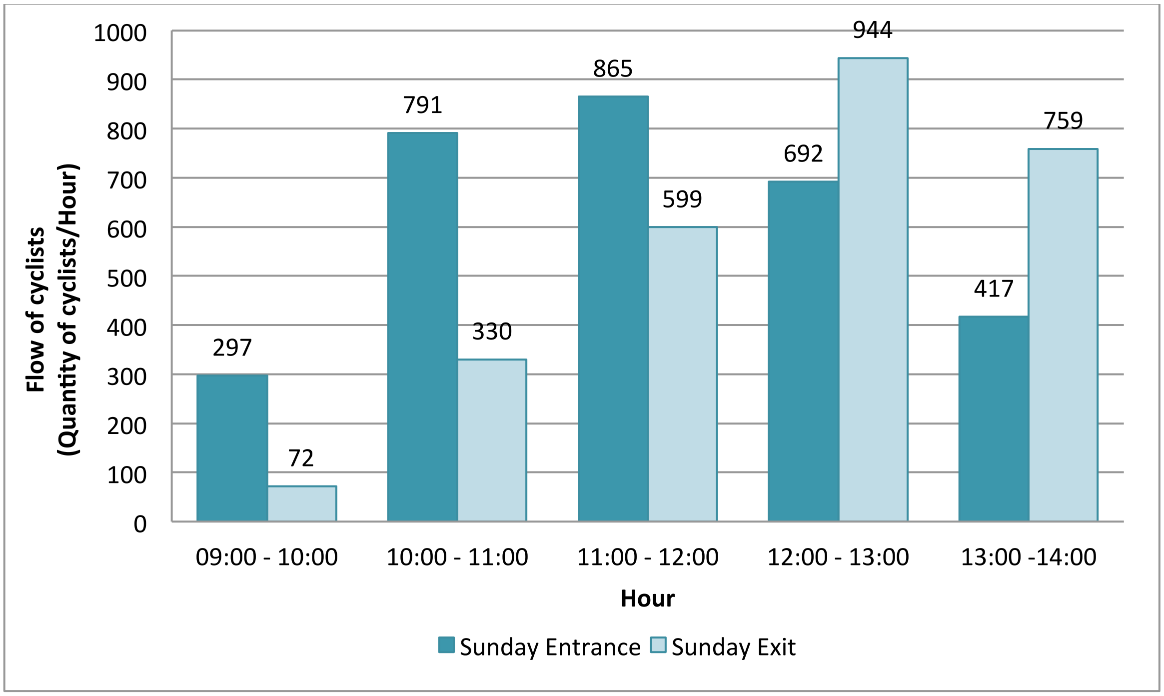


Figure 34. Total Flow of People, Saturday (P1)

3.4.1.1.2 Sunday (P1)

By Sunday, the total flow of people cycling or walking through Pedro de Valdivia North access (P1) is 3,062 people for entrance and 2,704 people for exit.



Graph 21. Distribution of People (entrance-exit) through the Access Pedro de Valdivia North (P1), Sunday

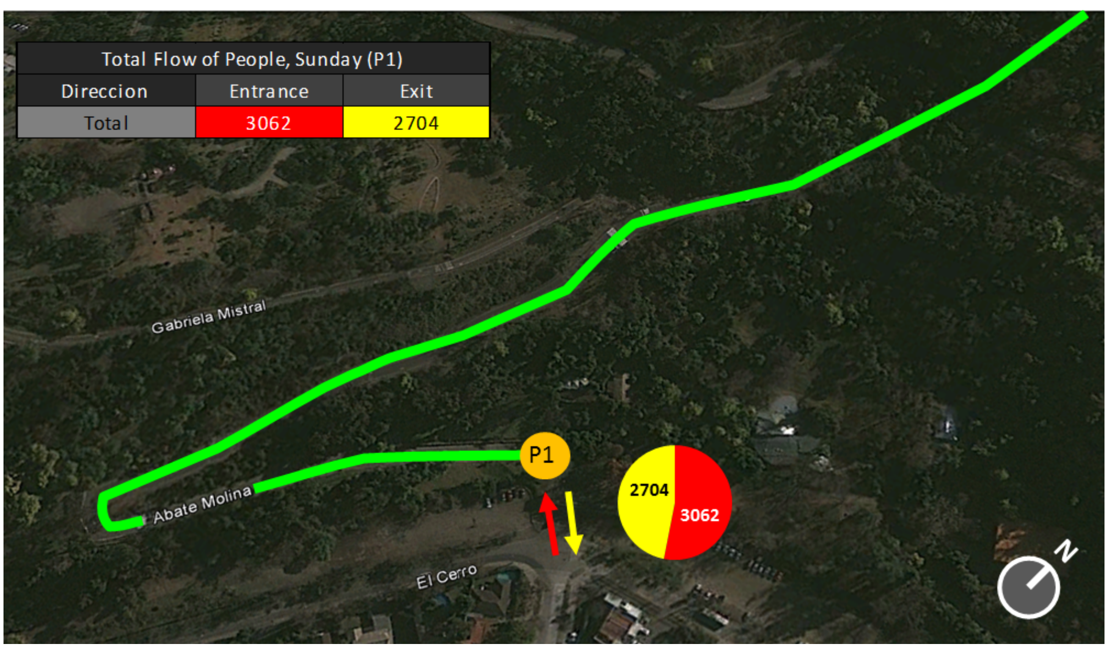


Figure 35. Total Flow of People, Sunday (P1)

3.4.1.2 Flow of Entrance and Exit of People Cycling or Walking Through Mapulemu Garden (P2)

The characterization of the flow of bicycles and pedestrians that pass through the point P2 for Saturday and Sunday is obtained from the information obtained with the automatic and manual measurements allowing the characterization of users in relation with the following aspects:

- Total flow of cyclists passing in both directions (up and down).
- Gender of bicycle users.
- Use of helmet by cyclists.
- Total flow of pedestrians passing in both directions (up and down)
- Gender of pedestrians.
- The age range of pedestrians.

It is important to note that while measurement at point P2 is taken as the basis for the Ciclorecreovía operation schedule, it is decided to measure during the normal operating day in order to gather information of flows for the Metropolitan Park of Santiago during this period.

The following information presents the details of total flows of cyclists and pedestrians entering to Ciclorecreovía for points of measure (P2) and for both days.

3.4.1.2.1 Characterization of Cyclists

To quantify the bicycle flow passing through the point P2, automatic continuous measurements are made as mentioned above. Furthermore, manual measurements are performed in order to characterize bicycle users using some sheet forms where gender and use of helmet are measure.

3.4.1.2.1.1 Quantification Flows of Cyclists

The total flow of bicycles that pass through the point P2 in both directions for each day is detailed in Table 33. It is noteworthy that the descent measures consider people that go from the top to the bottom of the hill. By contrast, the ascent measures consider people going from the bottom to the top of the hill.

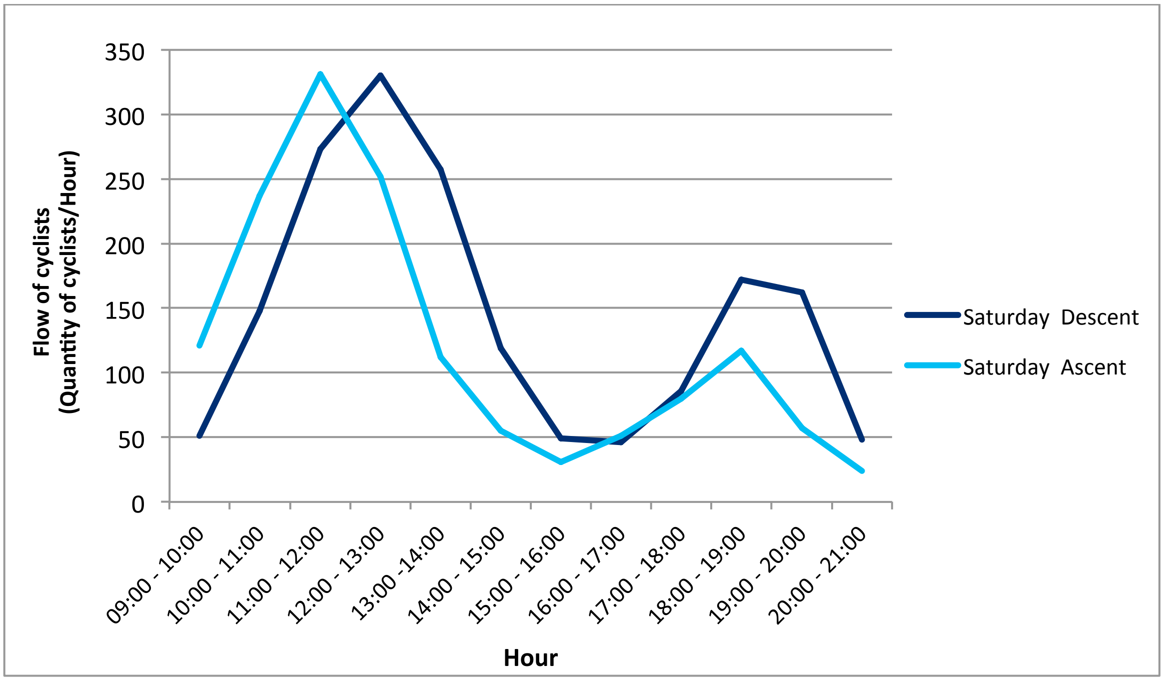
Table 33. Total flow of bicycles that pass through the point P2 in both directions for each day

Hour	Saturday		Sunday	
	Descent	Ascent	Descent	Ascent
09:00 - 10:00	51	121	42	150
10:00 - 11:00	148	237	209	372
11:00 - 12:00	273	331	391	480
12:00 - 13:00	330	252	583	404
13:00 -14:00	257	112	387	192
14:00 - 15:00	119	55	208	61
15:00 - 16:00	49	31	94	50
16:00 - 17:00	46	51	60	59
17:00 - 18:00	86	80	84	117
18:00 - 19:00	172	117	151	119
19:00 - 20:00	162	57	140	63
20:00 - 21:00	48	24	27	10
Total	**1,741**	**1,468**	**2,376**	**2,077**

With the information collected from Table above, flow histograms by day of measure are developed and presented in the following graphs.

3.4.1.2.1.1.1 Saturday - Cyclists (P2)

By Saturday, the total flow of people cycling through Mapulemu Garden (P2) is 1,741 people for Descent and 1,468 people for Ascent. Graph 22 and Figure 36 show the distribution of cyclist’s flows that circulates through P2 for both Descent and Ascent.



Graph 22. Flows of Descent and Ascent for Saturday

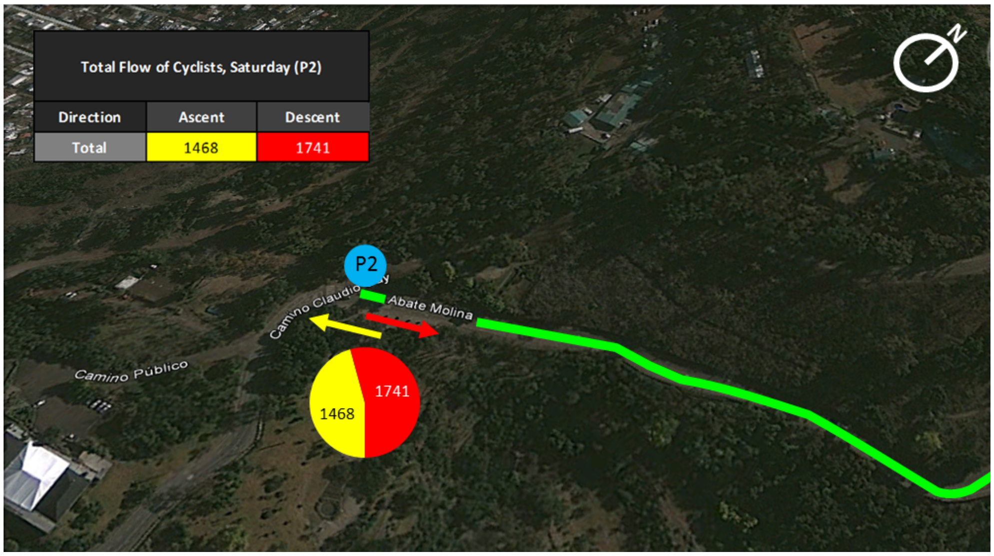
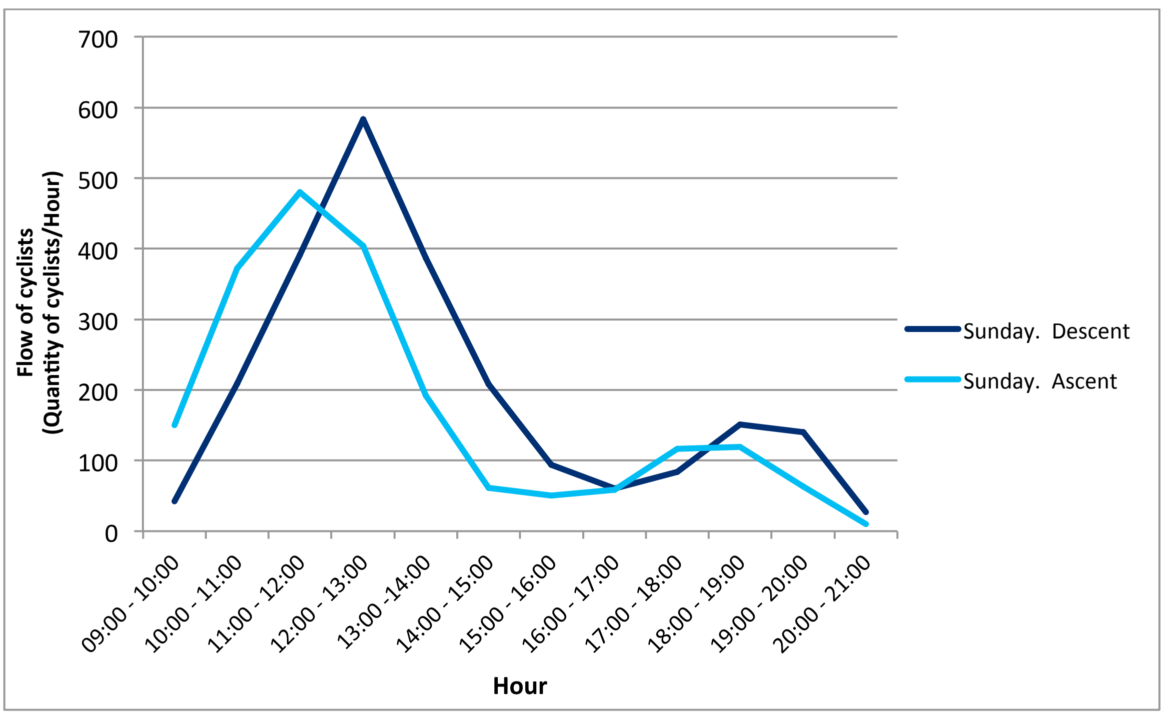


Figure 36. Flow Diagram for total flows of cyclists, Saturday (P2)

3.4.1.2.1.1.2 Sunday - Cyclists (P2)

By Sunday, the total flow of people cycling through Mapulemu Garden (P2) is 2,376 cyclists for Descent and 2,077cyclists for Ascent. Graph 23 and Figure 36 show the distribution of cyclist's flows that circulates through P2 for both Descent and Ascent.



Graph 23. Flows of Descent and Ascent for Sunday

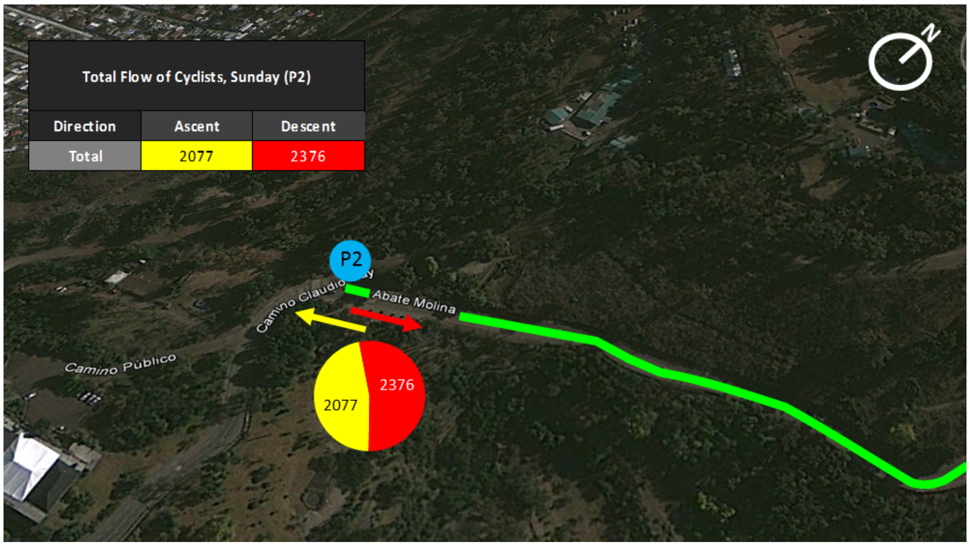


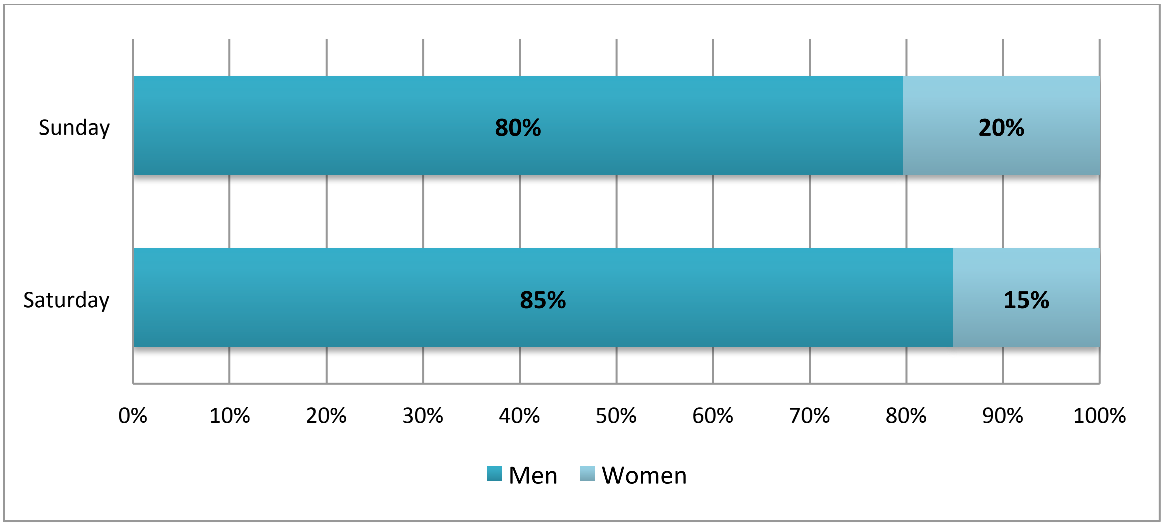
Figure 37. Flow Diagram for total flows of cyclists, Sunday (P2)

3.4.1.2.1.2 Gender of Cyclists

Considering the total flow of bicycle users that transit for the point P2 both days, as an average 82% are men and 18% women. The total number of men for Saturday is 2,720 while for Sunday is 3,580. On the other hand, the total number of women for Saturday is 489 while for Sunday is 873. Table 34 and Graph 24 show the information of gender of each day of measure.

Table 34. Distribution of gender of cyclists by day (P2)

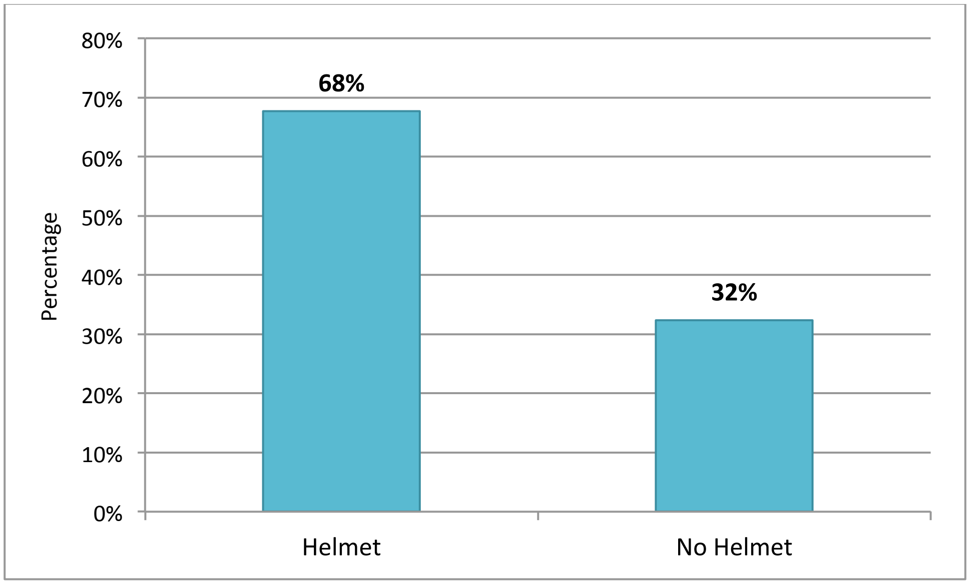
Hour	Saturday		Sunday	
	Men	Women	Men	Women
09:00 - 10:00	151	21	174	18
10:00 - 11:00	332	53	485	96
11:00 - 12:00	508	96	697	174
12:00 - 13:00	502	80	762	225
13:00 -14:00	299	70	440	139
14:00 - 15:00	142	32	217	52
15:00 - 16:00	65	15	116	28
16:00 - 17:00	85	12	96	23
17:00 - 18:00	144	22	173	28
18:00 - 19:00	242	47	224	46
19:00 - 20:00	191	28	165	38
20:00 - 21:00	59	13	31	6
Total	**2,720**	**489**	**3,580**	**873**



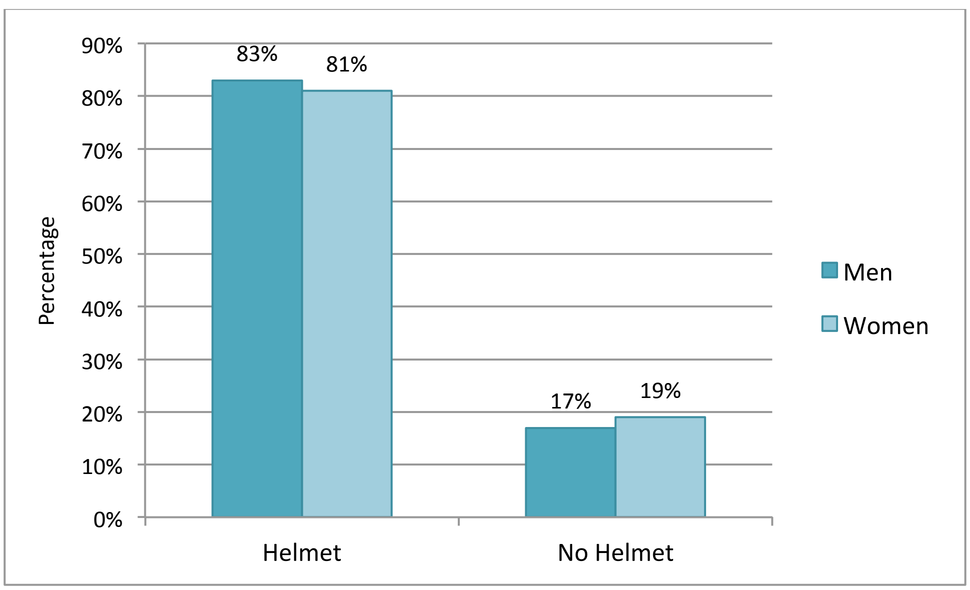
Graph 24. Percentage distribution of gender of cyclists by day (P2)

3.4.1.2.1.3 Use of Helmet by Cyclists

In order to characterize the use of safety equipment by bicycle users, we decide to consider the use of helmets for both men and women users. The result of the helmet use by cyclists shows that 68% of users actually use it. From this percentage, 83% of men used it while in the case of women, 81% use it. Graphs 25 and 26 show the information presented above.



Graph 25. Percentage of Use of Helmet by Cyclists



Graph 26. Percentage of Use of Helmet by Gender

3.4.1.2.2 Characterization of Pedestrians

To quantify pedestrian flow passing through the point P2, manual continuous measurements are made using the sheet forms showed above in order to characterize pedestrian users by gender and group of age.

3.4.1.2.2.1 Quantification Flows of Pedestrians

The total flow of pedestrians that pass through the point P2 in both directions for each day is detailed in Table 35.

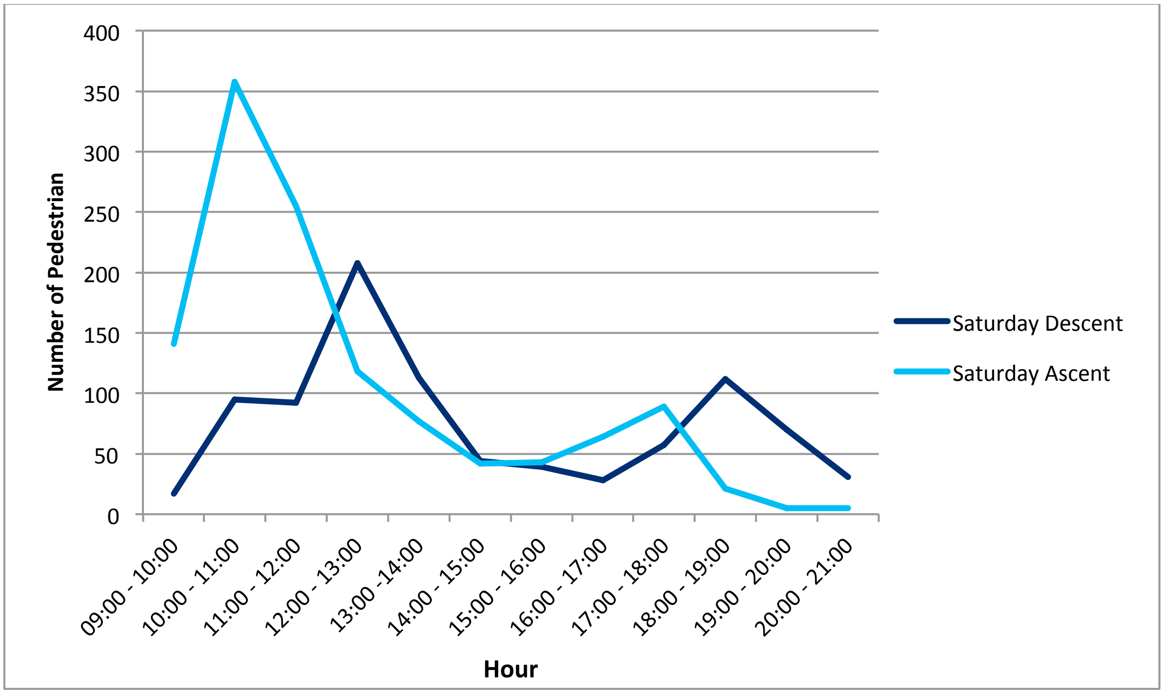
Table 35. Total flow of pedestrian that pass through the point P2 in both directions for each day

Hour	Saturday		Sunday	
	Descent	Ascent	Descent	Ascent
09:00 - 10:00	17	141	23	108
10:00 - 11:00	95	358	48	269
11:00 - 12:00	92	255	170	403
12:00 - 13:00	208	118	260	270
13:00 -14:00	113	77	179	109
14:00 - 15:00	44	42	89	44
15:00 - 16:00	39	43	55	69
16:00 - 17:00	28	64	58	99
17:00 - 18:00	57	89	91	70
18:00 - 19:00	112	21	190	45
19:00 - 20:00	70	5	66	9
20:00 - 21:00	31	5	27	2
Total	**906**	**1,218**	**1,256**	**1,497**

With the information collected from Table above, a flow histogram by day of measure is developed and presented in the following graphs and figures.

3.4.1.2.2.1.1 Saturday - Pedestrian (P2)

By Saturday, the total flow of pedestrian passing through Mapulemu Garden (P2) is 906 people for Descent and 1,218 people for Ascent. Graph 27 and Figure 38 show the distribution of pedestrian flows that circulates through P2 for both Descent and Ascent.



Graph 27. Flows of Pedestrian. Descent and Ascent for Saturday (P2)

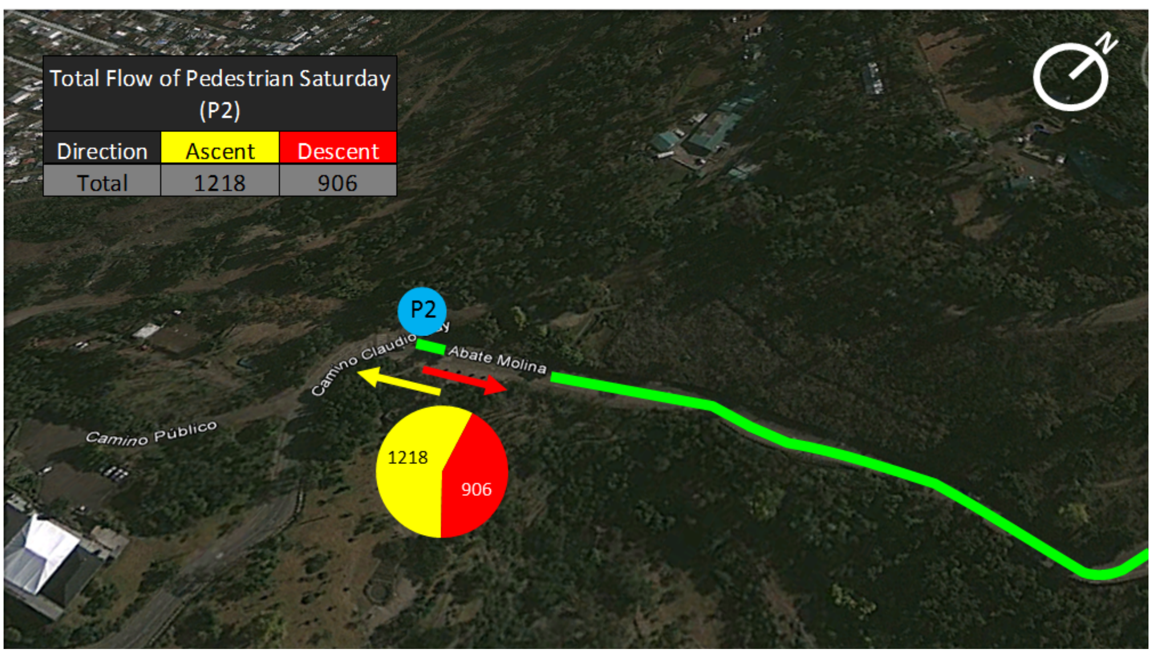
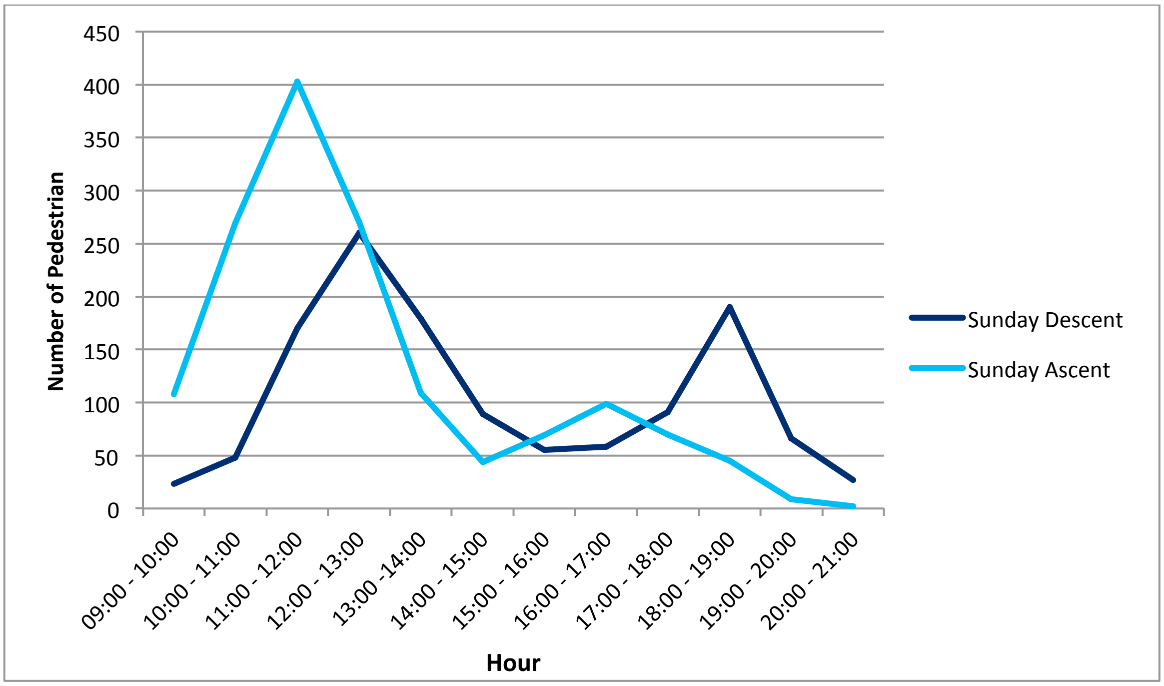


Figure 38. Flow Diagram for total flows of pedestrian, Saturday (P2)

3.4.1.2.2.1.2 Sunday - Pedestrian (P2)

By Sunday, the total flow of pedestrian through Mapulemu Garden (P2) is 1,256 pedestrian for Descent and 1,497 pedestrian for Ascent. Graph 28 and figure 39 show the distribution of pedestrian flows that circulates through P2 for both Descent and Ascent.



Graph 28. Flows of Pedestrian. Descent and Ascent for Sunday (P2)

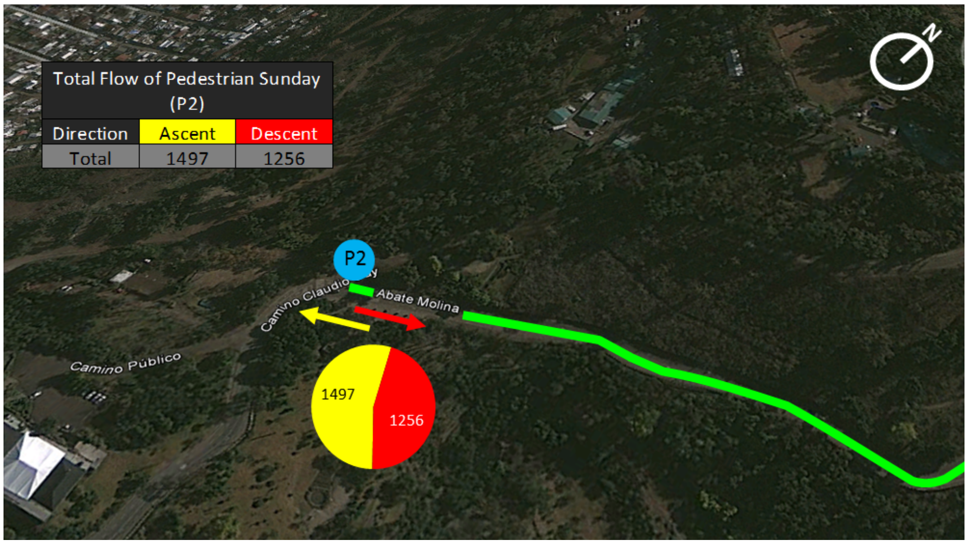


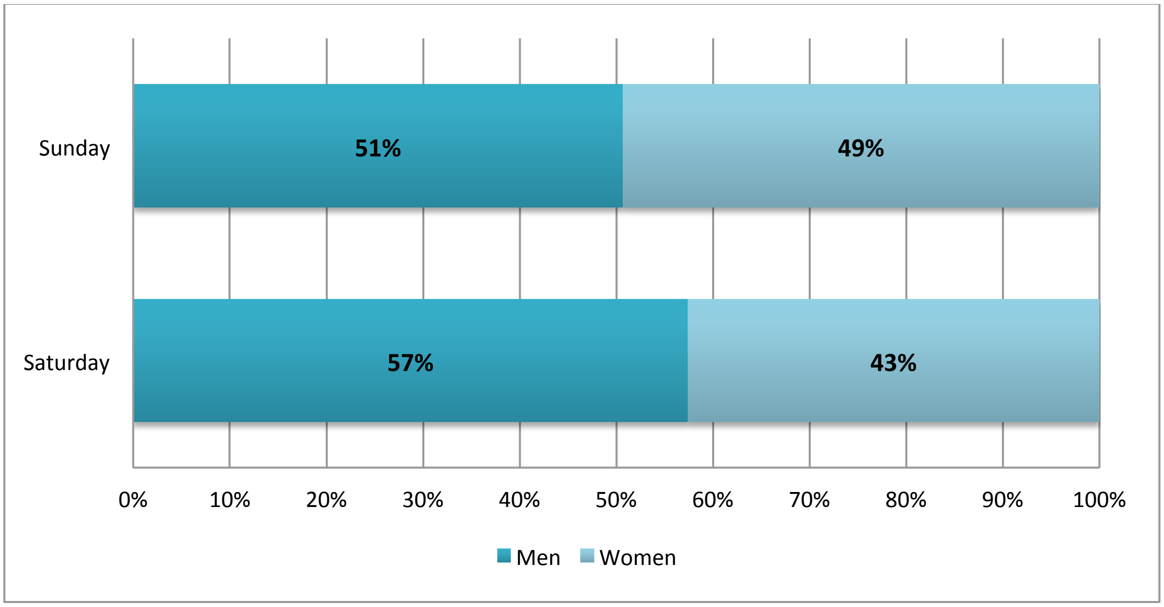
Figure 39. Flow Diagram for total flows of pedestrian, Sunday (P2)

3.4.1.2.2.2 Gender of Pedestrians

Considering the total flow of pedestrian that transit for the point P2 both days, as an average 54% are men and 46% women. The total number of men for Saturday is 2,720 while for Sunday is 3,580. On the other hand, the total number of women for Saturday is 489 while for Sunday is 873. Table 36 and graph 29 show the information of gender of each day of measure.

Table 36. Distribution of gender of pedestrian by day (P2)

Hour	Saturday		Sunday	
	Men	Women	Men	Women
09:00 - 10:00	92	66	84	47
10:00 - 11:00	280	173	162	155
11:00 - 12:00	200	147	293	280
12:00 - 13:00	179	147	246	284
13:00 -14:00	113	77	141	147
14:00 - 15:00	52	34	59	74
15:00 - 16:00	39	43	63	61
16:00 - 17:00	47	45	82	75
17:00 - 18:00	81	65	83	78
18:00 - 19:00	55	78	121	114
19:00 - 20:00	63	12	43	32
20:00 - 21:00	18	18	18	11
Total	**1,219**	**905**	**1,395**	**1,358**



Graph 29. Percentage distribution of gender of pedestrian by day (P2)

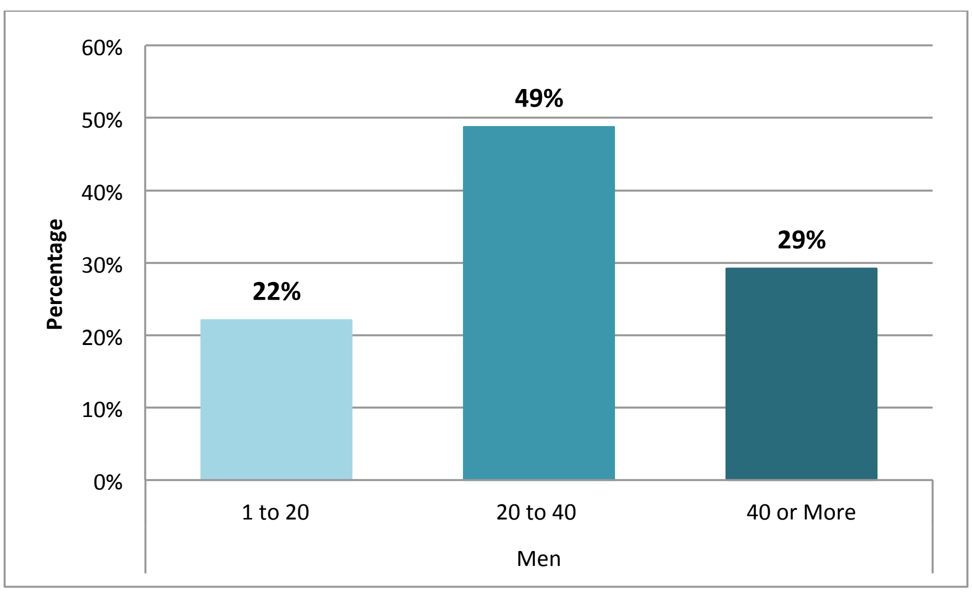
3.4.1.2.2.3 Range of Age of Pedestrian

In order to characterize the range of age of pedestrian, we decide to consider three categories of ages for both men and women users. The categories are pedestrians up to 20 years, 20 to 40 years and 40 years or more. Note that this characterization is just as a reference because it is realize through visual record, which aims is to get an approach of the general age of pedestrians passing through the point P2. The following Table shows the information of range of age for point P2.

Table 37. Total flow of pedestrian that pass through the point P2 in both directions by Range of Age

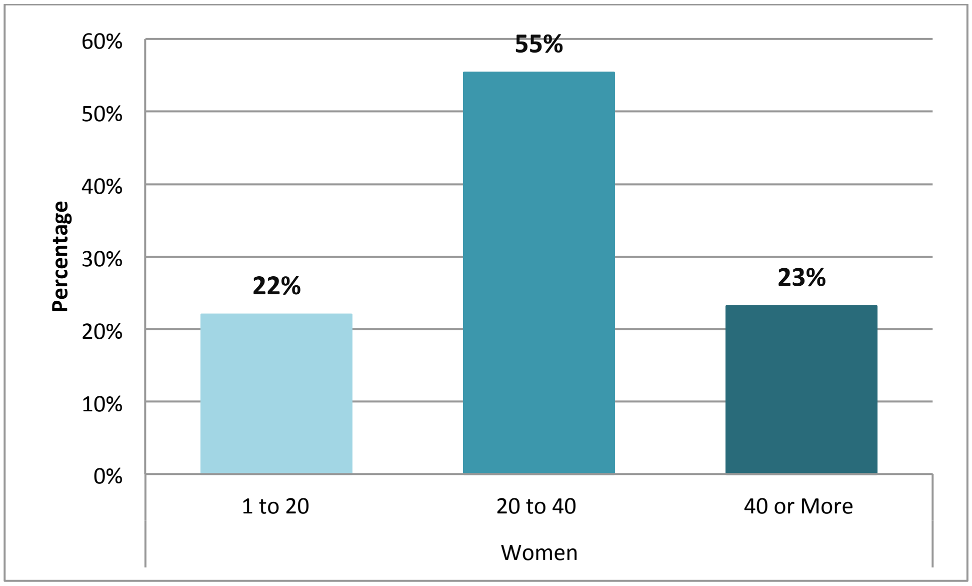
Hour	Men			Women		
	1 to 20	20 to 40	40 or More	1 to 20	20 to 40	40 or More
09:00 - 10:00	15	94	67	20	58	35
10:00 - 11:00	166	145	131	94	155	79
11:00 - 12:00	109	213	171	83	226	118
12:00 - 13:00	95	186	144	67	246	118
13:00 -14:00	45	140	69	45	126	53
14:00 - 15:00	22	56	33	18	74	16
15:00 - 16:00	21	62	19	34	61	9
16:00 - 17:00	23	77	29	19	77	24
17:00 - 18:00	35	96	33	42	79	22
18:00 - 19:00	26	99	51	42	113	37
19:00 - 20:00	15	78	13	16	17	11
20:00 - 21:00	5	28	3	6	21	2
Total	**577**	**1,274**	**763**	**486**	**1,253**	**524**

With the information collected from Table above, charts that show the range of age of pedestrian are presented below.



Graph 30. Range of Age Distribution of Men (P2)

The result shows that 49% of men are between 20 to 40 years old while the other 51% is divided, with 22% for men from 1 to 20 years old and 20% for men from 40 or more years old.



Graph 31. Range of Age Distribution of Women (P2)

The result shows that 55% of women are between 20 to 40 years old while the other 45% is divided, with 22% for women from 1 to 20 years old and 23% for women from 40 or more years old.

3.4.2 Conclusions

The results obtained through this experience are a picture of the behaviour of the demand for bicycles and pedestrians that use the Metropolitan Park of Santiago because it was the first experience measuring people. Therefore, it would be interesting to replicate this experience in other periods of the year and beyond, and this information will allow researchers to better understand the growth trends in demand and seasonal behaviour (summer, autumn, winter and spring). On the other hand, it would also be important to gather information on the behaviour of cyclists and pedestrians and the demand on weekdays in order to handle initiatives related to data management, projects, public investments and so on.

Taking into account the information obtained for both days, we can see that the total flow distribution for Saturday is 3,829 cyclists and pedestrian of which 2,240 belong to P1 and 1,589 belong to P2. For Sunday the total flow is 5,357 cyclists and pedestrian of which 3,062 cyclists belong to P1 and 2,295 belong to P2. The peak hour of both days is set between 12:00 and 13:00 hrs By Saturday, the total flow of people cycling through Mapulemu Garden (P2) is 1,741 people for Descent and 1,468 people for Ascent. The total flow of people cycling through Mapulemu Garden (P2) is 2,376 cyclists for Descent and 2,077cyclists for Ascent.

Considering the total flow of bicycle users that travel through the point P2 both days, as an average 82% are men and 18% women. The total number of men for Saturday is 2,720 while for Sunday is 3,580. On the other hand, the total number of women for Saturday is 489 while for Sunday is 873.

In order to characterize the use of safety equipment by bicycle users, we decided to consider the use of helmets for both men and women users. The result of helmet use by cyclists shows that 68% of users actually use it. From this percentage, 83% of men used it while in the case of women 81% use it.

The results obtained for pedestrian counting show that for Saturday, the total flow of pedestrians passing through Mapulemu Garden (P2) is 906 people for Descent and 1,218 people for Ascent while for Sunday the total flow of pedestrians through Mapulemu Garden (P2) is 1,256 pedestrians for Descent and 1,497 pedestrians for Ascent.

Considering the total flow of pedestrians that travel through the point P2 both days, as an average 54% are men and 46% women. The total number of men for Saturday is 1,219 while for Sunday is 1,395. On the other hand, the total number of women for Saturday is 905 while for Sunday is 1,358.

The results show that the range of age of pedestrians is principally located between 20 to 40 years old in approximately 50% of cases for both men and women. Specifically, 49% of men are between 20 to 40 years old while the other 51% is divided with 22% for men from 1 to 20 years old and 20% for men from 40 or more years old. On the other hand, the result shows that 55% of women are between 20 to 40 years old while the other 45% is divided with 22% for women from 1 to 20 years old and 23% for women from 40 or more years old.

It is clear that bicycle and pedestrian growth rates may be detected in the future, which will be possible if the administration of the park decides to measure the flow of visitors. Our advice is to use automatic equipment due to ease of use and reliability of the results. Moreover, this experience should be replicated in other urban parks and conservation areas in order to measure the quantity of use during different seasons of the year. The ultimate goal would be to improve the management, public investments, and projects to enhance non-motorized transportation because we will know the real demand.

CHAPTER 4. CONCLUSIONS AND FUTURE RECOMMENDATIONS

4 Conclusions and Future Recommendations

In this research, the flows of bicycle (with historic data) and pedestrian activity were analyzed and compared while implementing new data collection method in Santiago, Chile using strategic measuring points in the city, using automated and manual methods of data collection, and comparison with historic data in two of the three study cases presented.

The approach is motivated by the lack of consistent information on bicycle and pedestrian path usage and demand, which is probably the single greatest impediment to being able to understand these modes. Therefore, counting people is fundamental to understand bicycle use and pedestrian travel and the behaviour of travelers.

As was presented in Chapter 2. bicycle activity in the cycle lanes of Antonio Varas Ave and Simon Bolivar Ave (case study 1) and Pocuro Ave, Antonio Varas Ave. and Andrés Bello Ave (case study 2) indicated that the use of bicycles as a transportation mode is growing each year.

In case study 1, data obtained through the period of measurement shows remarkable change from previous observations of non-motorized traffic collected by UNDP (UNDP 2005-2008) considering that the days (weekday and non-working day) and hours of counting were the same being outcomes comparable. Focusing on the counting point located on Antonio Varas Ave. cycle lane for instance, the annual growth rate is 18.2% for the period 2005 to 2012. This means that in just over seven years the demand has more than the doubled, nearly tripled for this counting point. Instead, for cycle lane of Simon Bolivar Ave. the annual growth rate is 5,6% for the same period. Unfortunately, there is not examples of other places where gains of cycling shares have been observed from 2008, just the counting points defined by the study of UNDP (2005-2008).

One of the important points that this section of the research displays is the significant participation of women as bicycle users who represent over 30% of the study population. In 2003 the participation of women was 8% while in 2008 was 20% according to the study of UNDP (UNDP 2005-2008). Given the paucity of data, it is unclear whether participation rates would be the same at other locations throughout the city that lack cycle lanes or where standards are looser. For this reason, a direction for future work would be to expand the investigation to better understand gender distribution and the principal factors that affect the decision to travel by bicycle.

Considering the daily structure of demand, it is possible to say that the daily flow profiles obtained are very discernible and easily recognizable for weekday because the flow behaves orderly and predictable, both in distribution time and volume. This is verified by comparing different peak periods for different weekdays. Furthermore, the flow pattern is quite similar to motorized transportation. For this reason, it could be possible that motorized users are transferring to non-motorized modes, but this assumption would require more information and analysis to be validated.

In the case of use of safety equipment, we highlight the lack of understanding of bicycle safety, which is reflected in the low grade of use of safety equipment by cyclists. Measurements show that considering the total number of cyclists who pass by cycle lanes C1 and C2, only 19% use a helmet, 21 % carry on lights, 14% use a helmet and carry on lights, and 45% do not use a helmet or carry on lights.

In the morning peak period we appreciate that for both Weekday 1 and 2, the peak period is set between 08:00 and 09:00 hrs. For weekday 1 the morning peak presents a total flow of 185 cyclists per hour while for weekday 2 morning peak presents 191 cyclists per hour. For non-working days the morning peak period was run between 11:00 and 12:00 hrs, which presents a total flow of 90 cyclists per hour. On the other hand, in the evening peak period we may appreciate that for both weekday 1 the evening peak period is set between 18:00 and 19:00 hrs which presents a total flow of 223 cyclists per hour. For weekday 2 the evening peak period is set between 18:00 and 20:00 hrs which presents an average of 205 cyclists per hour (204 cyclists between 18:00 and 19:00 hrs and 206 cyclists between 19:00 and 20:00 hrs). For non-working days the evening peak period was runs between 20:00 and 21:00 hrs, which presents a total flow of 108 cyclists per hour.

The results are noteworthy regarding the magnitude of flows during peak periods. In cycle lane of Antonio Varas Ave. for example, the maximum flow count reached was 180 bicycles/hour/direction in the morning peak. Considering this result with the annual growth rates exceeding 10%, this serves as an urgent wake-up call to the authorities and decision makers in order to improve design standards, especially the consolidation of new cycle lanes considering these new measures of flows in cycle lanes.

In case study 2, it is possible to conclude from the data collected and processed that on average, bicycle flows in Providencia comune have been growing since 2005, at a rate of 20% annually, 1.8% more than the percentage found in the first measurements. This means that within the last 7 years the demand has almost tripled.

In the measured points, it was observed that in some cases, flows (in both directions) exceeded 300 bicycles per hour, which means one cyclist every 12 seconds. These numbers show that the infrastructure available is approaching maximum capacity. This symbolizes a clear call to the authorities and urban planners to accelerate and extend the understanding of bicycle users throughout the city by means of counting, surveys and so on, in order to develop strategies to promote the use of bicycles which requires new cycle paths, parking lots, safety actions, etc.

This research reports periodic measurements; this means that flows of bicycles were counted during peaks hours (07:00 to 10:00 hrs for morning peak and 18:00 to 21:00 hrs for evening peak). This decision was based on previous continuous measures developed, which determined that the flow behaviour has two well-defined morning and evening peak points.

The government, through its official public policy program, defined that at the end of the government period (2014) there will be double the number of bicycles users in major cities of the country. In this sense, all public departments should cooperate in achieving this goal. Keep in mind that at the end of the period, the president will be assessed regarding the level of fulfillment of this goal and the remaining time to take action on the matter is limited. Therefore, our recommendation is to begin, as soon as possible, implementing some count flow campaigns of bicycle users through permanent automatic counters across the principal cities of the country, because databases are the basis of future modeling. In other words, we propose to create and materialize counting networks in order to know how many people move at different times of the day and during different months of the year, using the streets and bike lanes, by national, regional and local scales with the aim to promote non-motorized modes of transport and thus contribute to lower pollutant output and a more sustainable future.

Chile should start as soon as possible to implement a plan for ongoing monitoring of flow of bicycle users becoming a standard for all bicycle paths. Thus, knowledge of this behaviour will allow us to improve urban and transportation planning, management and help to be more active and effective in the participation of the development of projects with communities, groups, organizations, the public and private organizations.

It is clear that bicycle rates are growing every year. Probably, this is due to a change of decision mobility pattern of people and not necessarily corresponds as a result of a public policy. Considering the above, it is urgent that authorities intensify their efforts in order to further improve these results, because it is fruit of the work of all. Moreover, considering results obtained in this section, one question for future research is to investigate if the actual public investment is consistent and related with bicyclist growth, and if public policies are considering this transportation mode as a real contribution to improve congestion and urban development.

As was presented in Chapter 3, automatic and manual counting of bicycle and pedestrian activity was conducted in the Metropolitan Park of Santiago.

It is important to mention that the results obtained through this experience are a picture of the behaviour of the demand for bicycles and pedestrians that use the Metropolitan Park of Santiago, because it was the first experience of counting people. Therefore, it would be interesting to replicate this experience in other periods of the year and beyond, and this information will allow researchers to better understand the growth trends in demand and seasonal behaviour (summer, autumn, winter and spring). On the other hand, it would also be important to gather information on the behaviour of cyclists and pedestrians and the demand on weekdays in order to handle initiatives related to data management, projects, public investments and so on.

Taking into account the information obtained for both days, we can see that the total flow distribution for Saturday is 3,829 cyclists and pedestrian of which 2,240 belong to P1 and 1,589 belong to P2. For Sunday the total flow is 5,357 cyclists and pedestrian of which 3,062 cyclists belong to P1 and 2,295 belong to P2. The peak hour of both days is set between 12:00 and 13:00 hrs By Saturday, the total flow of people cycling through Mapulemu Garden (P2) is 1,741 people for Descent and 1,468 people for Ascent. The total flow of people cycling through Mapulemu Garden (P2) is 2,376 cyclists for Descent and 2,077cyclists for Ascent.

Considering the total flow of bicycle users that travel through the point P2 both days, as an average 82% are men and 18% women. The total number of men for Saturday is 2,720 while for Sunday is 3,580. On the other hand, the total number of women for Saturday is 489 while for Sunday is 873.

In order to characterize the use of safety equipment by bicycle users, we decided to consider the use of helmets for both men and women users. The result of helmet use by cyclists shows that 68% of users actually use it. From this percentage, 83% of men used it while in the case of women 81% use it.

The results obtained for pedestrian counting show that for Saturday, the total flow of pedestrians passing through Mapulemu Garden (P2) is 2,162 people for Descent and 2,715 people for Ascent while for Sunday the total flow of pedestrians through Mapulemu Garden (P2) is 1,256 pedestrians for Descent and 1,497 pedestrians for Ascent.

Considering the total flow of pedestrians that travel through the point P2 both days, as an average 54% are men and 46% women. The total number of men for Saturday is 2,720 while for Sunday is 3,580. On the other hand, the total number of women for Saturday is 489 while for Sunday is 873.

The results show that the range of age of pedestrians is principally located between 20 to 40 years old in approximately 50% of cases for both men and women. Specifically, 49% of men are between 20 to 40 years old while the other 51% is divided with 22% for men from 1 to 20 years old and 20% for men from 40 or more years old. On the other hand, the result shows that 55% of women are between 20 to 40 years old while the other 45% is divided with 22% for women from 1 to 20 years old and 23% for women from 40 or more years old.

It is clear that bicycle and pedestrian growth rates may be detected in the future, which will be possible if the administration of the park decides to measure the flow of visitors. The advice is to use automatic equipment due to ease of use and reliability of the results. Moreover, this experience should be replicated in other urban parks and conservation areas in order to measure the quantity of use during different seasons of the year. The ultimate goal would be to improve the management, public investments, and projects to enhance non-motorized transportation because we will know the real demand.

Finally, this research demonstrate the use of technology and methods that policy makers can use in future data collection efforts being these efficient and low cost, principally the automated counters considering the amount of data that could be collected through long periods of time, thereby supporting to engineers, urban planners, and politicians, to make decision based on actual historic data. Additionally, the analysis and results also provide an evidence-base to develop a bicycle plan for Santiago for urban and non-urban places, for example. This plan, in turn, should be implemented with new investments and infrastructure in order to provide better accessibility and safety for users of non-motorized modes of transportation. With these few efforts in the near future, it should be possible to boost the use of non-motorized transportation modes through the city.

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