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# Understanding cyclist traffic behaviour: Contrasting cycle path designs in Santiago de Chile

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A B S T R A C T

Cities around the world have experienced an increase in the number of cyclists, which has resulted in a demand for more cyclist infrastructure. In Santiago de Chile, each local government is in charge of providing bicycle infrastructure according to its own technical and financial restrictions. Thus, infrastructure dedicated to bicycles has increased, but its quality and design standards differ across the city. This creates an ideal test-bed for understanding how cyclists' behaviour changes under different cycle path designs.

The objectives of this research are (i) to explore the conditions of Santiago's cycle path intersections in terms of speed and urban characteristics and (ii) to understand cyclists' behaviour under different cycle path conditions.

Some characteristics of cycle path intersections measured were cycle path's length, slope, lateral clearance, physical segregation, bi-directionality, obstacles, and discontinuities. Also, data taken characterise users by gender and use of helmet.

Linear regression models were calibrated to explain cyclists' speed using intersection characteristics. According to our model, relevant characteristics were location of cycle path, physical segregation, percentage of female users, slope, and existence of vertical discontinuities. We hope that our results will serve as a guide for public authorities on the design of cycle paths.



## 1. Introduction

Cycling is gaining popularity as a mode of transport in many cities for several reasons, including its convenience for short trips, and residents' increased concerns about sustainability and health (Marqués, Hernández-Herrador, Calvo-Salazar, & García-Cebrián, 2015; Oja et al., 2011; Gilbert & Perl, 2008; Nuworsoo & Cooper, 2013). This trend has held true for developing countries, and Santiago de Chile has been no exception: this city has seen a 100% increase in the use of bicycles in recent years. The share of total transportation represented by cycling increased from 1.9% in 2001 to 3.9% in 2012 (SECTRA, 2015).

In addition to this increase in use, different initiatives have focused on expanding urban bicycle infrastructure in Santiago. A project carried by the central government, the Bicentennial Bike Paths Master Plan (*Plan Maestro de Ciclorutas Bicentenario*), identified all the routes in Santiago in need of cycle paths (Ciudad Viva & Interface for Cycling Expertise, 2010). Nevertheless, most bicycle infrastructure is designed and constructed by local governments (i.e. Municipalities). These paths are of varied quality, and are not properly integrated or connected; moreover, many of the public entities that responsible for creating them lack appropriate knowledge and expertise in bicycle infrastructure design.

Thus, the lack of a standardized guidelines and norms in Santiago has resulted in a huge variety of cycle path designs, since each municipality is free to design its own cycle paths on intersections and roads. As a result, Santiago's cyclists encounter a disconnected network with paths of different qualities. For instance, some have proper widths, while others are as narrow as 90 cm or present obstacles (such as trees); some are disconnected at intersections, have holes, or other obstacles.

Faced with this set of diverse cycle paths, how do cyclists respond? Could authorities induce desirable behaviours (safer riding or more bicycle trips) through improved cycle path design? Allen-Munley, Daniel, and Dhar (2004) recommend lower speeds, saying that cyclists' speeds have a direct effect on safety; other

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authors (Akar, Fischer, & Namgung, 2013; Stinson & Bhat, 2003) prefer cycle path designs that encourage faster speeds in order to achieve more travel time savings and improve the cycle path's cost-benefit analysis. Although cycle path design decisions should be made by local authorities in accordance with their public policy objectives (ideally taking experts' and citizens' opinions into account), it is important to understand first how different cycle path designs may affect cyclists' behaviour. As reported in Pucher and Buehler (2008), the Netherlands, Denmark, and Germany have used several traffic calming measures (traffic-calmed residential neighbourhoods, car-free city centers, and special bicycle streets), to enhance the overall bicycling network and offer safer streets (benefitting pedestrians and preventing serious cyclist injuries).

However, there is still a lack of understanding around cyclists' traffic patterns and their relationship with cycle path design in the context of developing countries. Cyclists' individual preferences as regards to speed, space, security, and trip length, as well as the demand for bicycling over other transport modes in a certain urban area, are all factors that add complexity to the use of public spaces such as streets and avenues. Some studies (e.g. Jensen, 2008) utilise Logit Models to estimate the utility gained by users based on bicycle infrastructure's physical characteristics (for instance, cycle path width). Others utilise linear regressions investigating the relationship of users' expectations and the actual physical characteristics of the infrastructure (San Francisco Department of Public Health, 2010). While these studies analyse perceived perception, this paper will address the real effect of infrastructure characteristic on cyclist behaviour.

Above all, the variety of cycle path designs in Santiago gives us an ideal test-bed for understanding how a range of cyclist behaviours relate to different cycle path designs. The objectives of the present research are to: (i) explore the conditions of cycle paths in terms of speed and urban conditions; and (ii) understand cyclists' traffic behaviour, estimating traffic parameters for characteristics at each intersection. This is particularly relevant because the majority of the studies related to cycle path design and cyclist behaviour are qualitative or stated preference (SP) surveys, but lack quantitative analysis of traffic behaviour (Kamargianni, 2015; Marqués et al., 2015). Moreover, many relate experiences of local success in developing this kind of infrastructure, but lack a quantitative component, especially in terms of cyclist behaviour (Pettinga et al., 2009; NACTO, 2011; Ministerio de Vivienda y Urbanismo, 2015).

The present article is organized as follows: section two explains the data collected for the study, section three analyses the dataset and the model specifications, and section four summarizes our main conclusions and points to possible future research.

## 2. Data collection

The data gathered consist of the amount of time that a cyclist spends at a cycle path intersection. The data collection process required us to (i) select the intersection, and (ii) record passing cyclists' behaviour. The selected intersections for this research were chosen based on the locations of automatic cyclist counting devices placed in nine cycle facilities in Santiago (SECTRA, 2013). These devices are suitable for the present study and they will allow future analyses to be conducted during times of the year and of the day that the present study could not address.

Next, in accordance with the methodology proposed and implemented by SECTRA (2013), we (i) listed and mapped all the existing networks of bicycle facilities in Santiago, identifying the most important routes, (ii) selected the most homogenous and representative segment of each route, and (iii) chose a point along each segment for counting.

In order to have a variety of conditions represented in the study, we selected three cycle paths with differing locations and infrastructure designs: (i) Vicuña Mackenna, where paths are on the sidewalk; (ii) Andrés Bello, where they are on Uruguay Park; and (iii) Santa Isabel, where cyclists have a dedicated lane in the roadway. We also selected a specific intersection within each cycle path segment, choosing the largest intersections with stop lights, nearest to flow counters. The final selected intersections were: Vicuña Mackenna and Gerónimo de Alderete, Andrés Bello and La Concepción, and Santa Isabel and Vicuña Mackenna.

Three additional intersections were chosen in order to refine and broaden the analysis: Pocuro and Ricardo Lyon, one of the first junctions between two cycle paths in Santiago, and Rosas and Teatinos, one of the first cycle facilities that conforms to the new high standard defined by the local government. The chosen cycle paths and their respective intersections are presented below in Fig. 1.

Finally, in order to have a control point without any type of cycle facility, we added the intersection of Dominica and Purísima, chosen by its proximity to the cycle path of Pío Nono (which is the same street as Dominica, but which has a different name in that part of the city). Designating a control point close to a cycle path made it more likely to have bicycle traffic (see Fig. 1). In this street, bicycles mix with private vehicles and buses – with low frequency – turning it an ideal point of reference for other cycle path designs that share road space with motorized vehicles.

Cyclist information was videotaped in summer during the last week of November, 2014. The weather in Santiago was partially cloudy and sunny. As was suggested by Pettinga et al. (2009), we recorded cycle traffic and movements along the cycle path intersections during the morning rush hour, between 8 and 9 am. At that time, the city is in full daylight.

As all the points selected were intersections, the speed of a cyclist could be affected both by the amount of cycle path space shared with pedestrians and motorized vehicles, and by the gradient of the cycle path before the intersection. Two intersections share the sidewalk with pedestrians, while the other four are on the street and do not share any space with them. These four cycle paths, however, do share space with motorized vehicles, but three of them are physically separated from the car lane.

In order to determine cyclists' speeds, we needed a horizontal wide lateral view of the cycle path. Since the streets that the cycle facility crosses were too wide, we used two cameras, one on each side. Each cycle path intersection was divided into three sections: arrival, crossing, and departure. The time a cyclist spent at each section was obtained through video processing. Cyclists' times in a section were marked when a cyclist crossed the beginning of the section and when he or she crossed the end. The difference between the two was calculated as the time a cyclist spent in that section. This time is directly related to cyclist characteristics and behaviour; however, since assigning these values to each observation required extra processing time, aggregated values were used.

Specifically, we recorded which of the possible options the cyclist was using (cycle path, sidewalk or street, if available). We also recorded any instances of a cyclist abandoning a section of the cycle path at a point other than the defined end of the section; that is, if a cyclist left the cycle path without crossing the intersection. Similarly, we recorded any instances of cyclists entering a section of the cycle path at a point other than the beginning of the section.

Speed was calculated as the quotient of the length of the section and time spent by any one cyclist on a cycle path section. Cycle path length was measured for every cycle path section, along with other characteristics. Each section was divided into three parts, altogether as wide as the video was able to capture. Thus, sections lengths were between 7.5 and 20 m.