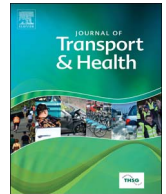




Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Bicycle choice modeling: A study of university trips in a small Colombian city

Mauricio Orozco-Fontalvo^{a,*}, Andrea Arévalo-Támara^a, Thomas Guerrero-Barbosa^b,
Margareth Gutiérrez-Torres^{a,c}

^a Department of Civil and Environmental Engineering, Universidad de la Costa, Carrera 58#55-66, Barranquilla, Colombia

^b Department of Civil Engineering, Universidad Francisco de Paula Santander, Vía Aclosure, Sede el Algodonal, Ocaña, Colombia

^c Department of Transport Engineering and Logistics, Pontificia Universidad Católica de Chile, Avenida Vicuña Mackenna 4860, Santiago, Chile

ARTICLE INFO

Keywords:

Bicycle
Discrete choice
Multinomial logit
Sustainable transport
Active commuting
modal shift

ABSTRACT

Bicycles and public transportation are modes of sustainable transport that reduce both the increasing levels of pollution and traffic congestion and the worrying statistics concerning obesity and physical inactivity. This article shows results of the application of a stated preferences survey in the city of Ocaña, Colombia, to identify factors that influence the modal choice, introducing the bicycle as an alternative for the trips to and from the University Francisco de Paula Santander Ocaña, using discrete choice models. These results show that the infrastructure availability is a key variable for modal shift and that giving incentives such as meals do not influence modal choice. These results were shared with the local authorities as an argument towards cycle lanes investment and public transportation grants for students.

1. Introduction

The social and economic development of cities is highly supported by the quality of urban transport, especially its accessibility. However, the ongoing growth of the vehicle fleet of private cars and negative externalities that it generates, such as accidents and traffic congestion, affects the level of service of public transport if it operates in mixed traffic, reducing its desirability and therefore the daily revenue, creating a vicious cycle. In a small city like Ocaña in Colombia, not only do these negative externalities affect mobility substantially, informal transportation like motorcycle-taxis increase road accidents (Castillo et al., 2013; Hagen et al., 2016). For these reasons, the creation of management policies that favor sustainable modes of transport is a starting point to counteract those externalities. The mode that is becoming a tendency over the last years is the bicycle, already being used extensively in cities like Amsterdam, Copenhagen, and Bogotá as a main mode of transport or at least with a considerable participation in the most recent modal share (Cervero et al., 2009).

On top of mobility issues, using sustainable transport modes have a positive impact on the commuter's health, as proven by several studies. A group of authors studied health impact for cycling and in many cases they concluded that the health benefits of cycling are higher than the costs associated with the investment in infrastructure, improving not only cyclist health but population health (Buekers et al., 2015; Deenihan and Caulfield, 2014). On the other hand, the existence of a relationship between the minutes of cycling and walking and health outcomes, including a small reduction in weight and cholesterol, suggesting that sedentary people should be encouraged to try "active commuting" as a mode of daily transport (Davison and Curl, 2014; Doorley et al., 2016; Schauder and Foley, 2015).

* Corresponding author.

E-mail address: morozco24@cuc.edu.co (M. Orozco-Fontalvo).

Obesity in Colombia is a major health problem, the latest statistics label it as the most sedentary country in the world with more than 60% of its adults being physically inactive (World Health Organization, 2015). In fact, 51% of Colombians are obese, 25% have hypertension and 10% have diabetes (Instituto Colombiano de Bienestar Familiar, 2010). This worrying data urges the establishment of stricter measures to improve these statistics. The keys to improvement could be: improving eating habits, increasing physical activity, and lastly by encouraging a modal shift in daily commutes from motorized vehicles to cycling or walking.

Bogotá is the city with the most daily trips made by bicycle in Colombia, nearly 5% of the modal share. The rise of its use is due to the high congestion rates generated by cars and the inhabitant's determination to improve their quality of life (Cabello et al., 2017; Cervero, 2005). However, only in recent years has the use of bicycles been encouraged, and the needed infrastructure created, throughout the rest of the country. In Ocaña, the second most important city in Norte de Santander (Colombian region), bicycle trips do not exceed 1% of the modal share, compared with the 58% of trips that are made in motorized vehicles (DNP Colombia, 2011).

The low modal share of bicycle use in the city has motivated the undertaking of this investigation which focuses on the university population, with the purpose of identifying the variables that influence the inhabitant's modal choice and their perception on the trips they make to and from the university by bicycle, through the application of a stated preferences survey (SP) to generate discrete choice models. Based on the results, we obtain valid arguments that favor public investment in bicycle infrastructure and policies in the city.

The content of this paper is: In Section 2, the background and state of the art within this topic and bicycle usage in Colombia and other cities around the world are presented. In Section 3, econometric conceptual framework and theoretical basis of the estimated models are described. Section 4 shows a description of the SP, followed by Section 5 which discusses the estimation of each model and their results. Finally, Section 6 summarizes the main conclusions and recommendations.

2. State of the art

The need to create policies that encourage the use of bicycles as an alternative and sustainable mode of transport requires a significant effort on the part of the entities that manage and regulate transport in cities (Chapman, 2011; Pucher et al., 2011b). Considering that the excessive use of private transport and its impacts on the level of service of public transport have increased in the last few years, it is necessary to implement new policies in favor of sustainable transport and give priority to more vulnerable users, such as pedestrians and cyclists (Bacchieri et al., 2010).

In Colombia, rates of private motorization in 2009 were already around 3 million cars and 2.3 million motorcycles (Acevedo et al., 2009), and the numbers are expected to triple in the case of cars and to be five times higher for motorcycles by 2040.

In large cities like Bogotá, there is a tendency to provide space and infrastructure for the use of bicycles, such as parking spaces near feeder routes of the city's BRT (Bus Rapid Transit) system, exclusive lanes, motorized transport, among other facilities. Within the guidelines set forth in the Mobility Master Plan (Bogotá, 2009), the city determines the necessity of declaring the prioritization of sustainable transportation modes as public policy, such as public transport and non-motorized modes like walking or cycling. In terms of infrastructure, Bogotá has the most cycling infrastructure in Latin America, with 392km of dedicated lanes; and, they are second behind Rosario (Argentina) for the most trips made by bicycle (Ríos et al., 2015).

Given this perspective and as a beginning for the management of sustainable transport policies, particularly in the case of bicycles, it is very important to establish the factors that determine the choice of the bicycle as a transport mode for urban trips in comparison with other alternatives of motorized transport. This will enable cities to generate and strengthen policies while not only encouraging their use but also detecting motivating and demotivating aspects in the context of choice (Fernández-Heredia et al., 2014; Olio et al., 2014). Studies to estimate the cycling demand have been developed in cities with similar population, whereby bicycle-sharing systems are increasingly popular as an alternative to encourage bicycle trips. Frade and Ribeiro (2014) designed a model for the authorities of Coimbra (Portugal) to estimate shared-bicycle's demand. This tool has been used by the transport authorities to plan and modify the system according to the current needs of commuters. Another case, in Blacksburg – Virginia (US) the authorities has been able to measure the impact of the infrastructure investment, risks assessment and cycling demand by using a monitor system of bicycles and pedestrians (Hankey et al. 2017). The demand variability is affected in some areas due to seasonal changes, this has been studied in literature, for example in Cambridge where a sinusoidal model was developed with satisfactory results. (Fournier et al., 2017), Blacksburg where the spatial models estimated allowed to measure the impact of infrastructure investment and active commuting benefits. From the point of view of modal choice, factors associated with subjectivity, service level, and the environment are related to the choice. Included in the factors associated with subjective parameters like security, the importance of cycling-inclusive infrastructure is defined as an infrastructure that prioritizes the cyclist over motorized vehicles (Dill et al., 2012). Similarly, it has been demonstrated that as there are more cyclists in the lanes the feeling or perception of security increases (Flügel et al., 2014; Underwood et al., 2014).

On the other hand, studies have shown that socioeconomic variables like gender, income, age, and occupation, are determinants of the use of bicycles (Garrard et al., 2008). Women tend to be more cautious of risk and proximity to mixed traffic (Akar et al., 2013); the percentage of women riding bicycles is normally lower in contrast to men, this amount can be as low as one-fourth of total users in countries like Australia (Garrard et al., 2008) and half in the United States or Canada (Pucher et al., 2011a); however, in countries like Denmark, Germany, and Holland, women use bicycles just as much as men and there is only a slight difference in terms of age, noting a decrease in bicycle use as riders reach 40 years old (Pucher and Buehler, 2008).

In cities with high levels of pollution and traffic congestion, bicycles are suggested as part of the solution, since it allows the number of trips on motorized transport to decrease (Chen et al., 2007). On the other hand, integration with public transport may be affected by the walking distance between bicycle facilities and stations or stops, varying approximately between three kilometers to and from train stations and 1.6km to bus stops in the case of bike sharing systems (Bordagaray et al., 2015; Hochmair, 2014; Romero et al., 2012). Considering distance/time as a key factor for AC, (Chillón et al., 2016) conducted a study to define the association between the distance

from home to the university and identified a 2.6 and 5.1 km the threshold distances which university students were more likely to walk or bike respectively, while Shannon (Shannon et al., 2006) reported the travel time as the most important barrier to AC.

Concerning the parameters that define the level of service of bicycling, such as distance traveled, travel time, cost, access time, and speed, the marginal effects of these variables are clearly evidenced in the choice (Cui et al., 2014; Heinen et al., 2011). Other investigations have focused on studying environmental parameters (topography, climate, the presence of traffic signs, installations, and land use) and their influence on the choice. Understanding that it is ultimately the individual who makes the decision, many variables associated with human factors determine the use of bicycles as a mode of transport (Cervero et al., 2009; Li et al., 2013; Majumdar and Mitra, 2015).

Nowadays, with the development of modern technologies, several apps are available to keep track of physical activity (including bicycle) that help to get data (Bopp et al. 2016) or give incentives (Biko) to encourage AC.

Finally, multinomial logit model continues to be a widely used methodology to estimated mode choice and transport demand (Ortúzar et al., 2000). This last approach is the one presented in this research, where the calibration of a mixed logit model (D. A. Hensher and Greene 2003) is considered to analyze the probability of the use of the bicycle by the university community in the city of Ocaña.

3. Conceptual framework

Discrete choice models are based on the choices observed by individual travelers. The formulation of the model under this theory works on the assumption that the utility derived from a choice, U_{iq} , is a function of the explanatory variables of such decisions. These variables are the attributes proper to each of the alternatives and the characteristics specific to the individual q (Ortúzar and Willumsen, 2011). If the function is linear, the result would be:

$$U_{iq} = X_{iq}\beta_i + \varepsilon_{iq} \quad (1)$$

In which, X_{iq} are the attributes measured or observed associated with each alternative i , β_i is a vector of parameters to be estimated, and ε_{iq} is the random component of the function and it represents all that the modeler does not know or cannot measure, such as idiosyncrasy or particular preferences.

Depending on the statistical distribution considered for the residual ε_{iq} different probabilistic models can be obtained. The most frequently used distributions have been those that have generalized extreme values that give rise to models of the logit type (Train, 2009). However currently, more complex models are studied, such as Mixed logit (ML), which allow us to consider random heterogeneity that previous models do not allow as a consequence of their structure (Gutiérrez and Cantillo, 2014; Ortúzar, 2010). To estimate parameters β_i the maximum likelihood method is used, however, nowadays, the methodology based on Bayesian methods starts to be used. The main virtue of these methods is reflected on estimations of ML models, where the maximization process may be slower (Gutiérrez and Cantillo, 2014).

4. Background and survey design

This investigation focuses on the commuting trips at the University Francisco de Paula Santander in the city of Ocaña. Ocaña is a small city in Colombia and the second in importance of the State of Norte de Santander (Ocaña 2012). It is located approximately 400 km northeast of Bogotá (capital of the country). It has an urban area of 7 km² and a population of 95,958 inhabitants (DNP, 2010). The city has an average temperature of 22 °C, with a minimum of 8 °C and a maximum of 30 °C, which is comfortable for cycling. The main land use is residential, followed by commerce, which is the principal economic activity of the city. Regarding the socioeconomic situation, the 76% of the population lives in poverty (with one or more Unsatisfied Basic Needs) and a 10.3% unemployment rate (Alcaldía de Ocaña 2012).

The public transportation operates with nineteen routes, managed by three companies with a fleet of 168 vehicles, where more than 50% are shared taxis. There are two types of service available: bus and shared taxis (DNP, 2010). A total of 166,321 trips are made daily, of which about 58% are motorized and only 1% of the trips are made by bicycle, which can be explained given the deficiency of adequate infrastructure for the use of this transport mode. The entire modal split is shown in Fig. 1.

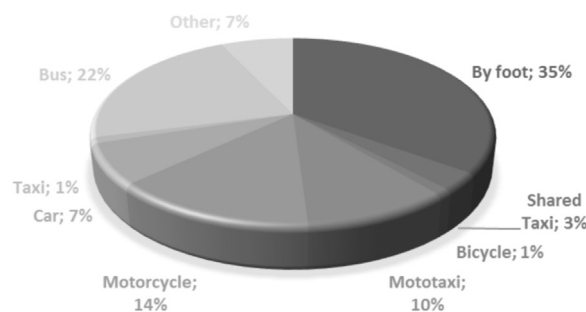


Fig. 1. Daily modal Split, (DNP, 2010).

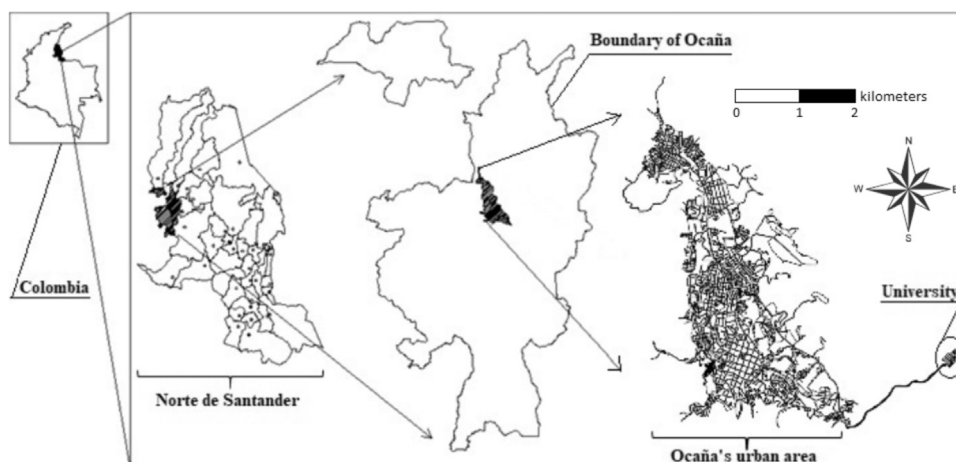


Fig. 2. Case study location.

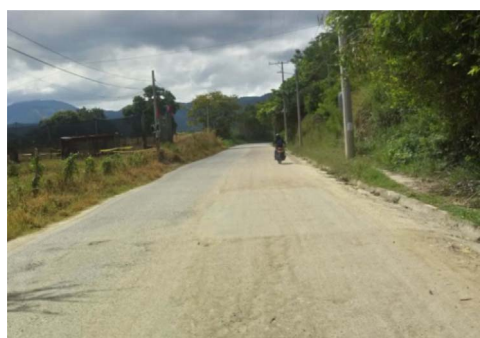


Fig. 3. Road to the UFPSO.

The Universidad Francisco de Paula Santander-Ocaña (UFPSO) is the main center of higher education not only in the city but also in the entire region. Due to the importance of the educational center in the daily activities of the city, it is considered the third generator/attractor of trips in the week after the historical-commercial center (downtown) and the public market. That is why, within the recommendations of the city's mobility plan, the University is projected as a terminal node of urban public transport routes for the next few years (DNP, 2010). The university is located 2.8 km from the urban area of the city and is connected to it by a rural road of one lane in each direction (being the only available route), limiting the options for commuters going from and to the campus (Figs. 2 and 3).

Ocaña develops almost all its activities between two attractors, its center and the public market, which are located a few blocks from each other, making them mandatory nodes for all the public transport routes and the most crowded and congested area of the city. This increases the travel times for public transport and some car and motorcycle users. In this context, we propose the bicycle as a free, non-polluting, flexible (routing), congestion-avoidable and healthier mode of transport, and we expect to identify the variables that influence the mode choice of transport.

We designed a stated preferences (SP) experiment where we compared the most used modes of transport versus the bicycle, with the final purpose to explore the variables which would affect the choice of the bicycle compared to the current mode. Considering that public and private transport has the higher percentage of choice, respondent has to face in one hand, bus or motorcycle-taxi; on the other hand, car or private motorcycle, with the bicycle. Despite the majority of the daily trips in the town are made by foot, this mode was not considered in our survey due to the fact that the university is located in a rural area, too far to walk and with no continuous sidewalk and no separation from traffic, affecting walkability (Lo, 2009). This experiment was conducted based on an efficient design within 2 blocks with six or seven (for public transport) corresponding questions for each individual, taking into account the recommendations of Hensher et al. (1998), in order to avoid fatigue in respondents. It was assumed all the respondents had access to the bicycle due to the shared bicycle service the university provides.

Attending previous modal share distribution, we decided to perform three different SP experiments where respondents faced a hypothetical situation in which they had to choose between their current mode and bicycle: i) faces car vs bicycle, ii) faces motorcycle vs bicycle, or iii) public transport (bus or taxi) vs bicycle. In order to obtain a real perspective of the bicycle attributes, a group of cyclists was equipped with GPS that provided information about the travel time, average speed and altitude, helping to facilitate the survey design and provide the respondents with real alternatives (Ampt and Ortúzar, 2004; Cherchi and Ortúzar, 2002). The university has 40 bicycles available for free, which were used to define the reference trips to and from the university, using three

strategic routes including the main streets and zones of the city. The first route had 3.96 km length and a 10 min travel time. The second had a length of 5.93 km and 25 min travel time and the third route had a length of 6.26 km and 20 min travel time. The purpose of this strategic routes is to have an average trip data. Based in the reference cited before about mean distance of bicycle trips, we chose these three options randomly. People could have different origins but at some point, they will all use some of these routes, because as said throughout the paper, there is only one road to the university and only few routes that take you this road, making valid the data gathered. This was used as a guide to define the levels of the SP attributes.

The attributes were based on information gathered from a focus group of students and employees. The questions to be considered in the cognitive interview were defined based on bibliography about bicycle demand (Ortúzar et al., 2000; Olío et al. 2014; Dill and Voros 2008). The selection criteria of the participants were based on certain characteristics, trying to maintain a level of homogeneity necessary to make focus groups: male and female in the same number, they must be students and employees, their age must be between 16 and 55 years, and finally that they use public transport or private and have available a bicycle.

The focus group was carried out by two professionals from the field of social sciences. It was attended by 7 people, whose main sociodemographic characteristics are presented below: 3 men and 4 women, 4 students and 3 employees, two people under 20 years old, 2 between 21 and 30 years old, 1 person between 31 and 40 and 1 person over 40 years old. The main topics explored in this group were: daily travel routine (origin, destination, purposes, duration, modes used, among others), chosen alternative and available options, accessibility to the bicycle, general attitude toward the use of the bicycle as a daily mode of transport, affective and/or emotional reactions to the variables evaluated, including any type of emotional response to the variables analyzed; for example, anxiety, tranquility, fear, aggressiveness, trust, among others.

From the information gathered in this focus group, the following attributes were defined according to the current mode of transport. The fare defined as the cost of the ticket on public transport, and on private transport (motorcycle or car) the cost of parking plus an operational cost associated with the distance traveled. Likewise, in the case of the bicycle, a cost is charged when the bicycle use a parking lot (inside the campus) with a permanent security guard or no charge in another case.

The access time attribute defined only for public transport was presented as the sum of the waiting time and the walking time. Travel time was defined as the total travel time within the vehicle. Finally, two dummy variables were defined within the utility function of the bicycle: existence or not of a bike path within the route and an incentive given to those arriving at the campus by bicycle: a sandwich with a coffee/juice to enjoy as a breakfast or snack.

The travel time and access time variables were analyzed in three levels, based on the value reported by the individual (current time), and the average time in each of the modes according to an average trip to the campus (considering that the average distance within the urban perimeter and university is approximately 3km). The different levels of these two attributes are described in Tables 1 and 2.

The difference between bus and shared-taxi access time (Table 2) is a consequence of the irregularity in the services, and considering that the shared-taxi is an illegal mode, any private service taxi can make a collective trip if two or more people with a similar tour decide to group and take the service.

Table 3 shows the description of the rest of attributes and the levels in which the experiment of stated preferences was designed. The fare was estimated based on the real value and an increase for each level (in 2017 1\$USD is equivalent to \$3.000 Colombian pesos – \$COP).

Each one of these experiments presented six choice situations for private transport users (car and motorcycle) and seven choice situations for public transport. Figs. 4 and 5.

Beside the experimental design, the complete survey had three more sections: the first one about socioeconomic and demographic information such as gender, age, social background, occupation, and level of study. The second part was related to information about the respondents last commuting trip, where we asked for travel time, access time (public transport) and fare. Finally, the last part is associated with questions about their lifestyle: frequency of exercise per week, and perception about the benefits of an active lifestyle.

5. Data

The SP survey for private car users was applied to 70 individuals, of which 47% are students and 53% are employees. The income distribution of this sample is associated with the occupation, where students in all cases have monthly income less than approximately USD\$330 (where the minimum wage in the country is about USD\$230), therefore in most cases, students used a car as a passenger, not as a driver.

On the other hand, 100 surveys were carried out on motorcycle users, of which only 9% of employees make their trip in this mode, while 91% of these users are students. A comparable situation arises in the use of public transport, where only 13% of trips in these

Table 1
Levels construction for travel time.

Mode	0	1	2
Auto and Motorcycle	Current time	Current time + 5 min	Current time + 10 min
Bus	Current time	Current time + 7 min	Current time + 13 min
Shared Taxi	Current time	Current time + 5 min	Current time + 10 min
Bicycle	Current time – 5 min	Current time	Current time + 5 min

Table 2

Levels construction for access time.

Mode	0	1	2
Bus	Current time	Current time + 3 min	Current time + 6 min
Shared Taxi	Current time	Current time + 5 min	Current time + 10 min

Table 3

Attributes and levels of the SP survey.

Attribute	Auto	Bus	Bicycle	Motorcycle	Shared-taxi
Fare (USD\$)	1-1,33-1,67	0,4-0,46-0,53	0 – 0,17	0,33-0,5-0,67	0,5-0,6-0,67
Infrastructure	–	–	Existence of Cycle –lane Vs Non cycle-lane	–	–
Incentive	–	–	Breakfast for bicycle trip Vs none	–	–

2	CAR	COST (COP)	TRAVEL TIME		
		\$ 3,000.00	5 MIN		
	BICYCLE	COST (COP)	TRAVEL TIME	INCENTIVE	BICYCLE LANE
		\$ 500.00	0 MIN	With snack	Yes

Fig. 4. Example of a choice situation faced by respondents.

modes (100 surveys) are carried out by employees. Fig. 3 shows some socioeconomic information of the profile of the respondents.

The socioeconomic analysis presented shows that 79% of the respondents were students (which is consistent with the real population of the university), this explains that the majority of the sample had a monthly income below US\$330. Regarding travel times, 44% spend 30 or more minutes to arrive, 35% between 20 and 29 minutes and 21% less than 20.

The survey included a question regarding the weekly physical activity done by the respondent, where 57% states to perform physical activity twice a week and only the 20% do physical activity more than three times a week. This clearly favors the bicycle as a transportation mode, since it would increase the physical activity indicators of the UFPSO community.

Out of the 270 respondents, 40% correspond to women and 60% to men, 48% under 21 years old, 34% between 22 and 30 years and 18% > 30 years old.

6. Model estimation

For this investigation, the alternatives considered were: private car, bus, motorcycle, and shared-taxi. The utility function has the following form:

$$U_{iq} = ASC_i + \beta_c C + \beta_v TV_i + \beta_{TA} TA_i + \beta_I I \quad (2)$$

In which:

- C_i : Fare
- TV_i : Travel time
- TA_i : Access time
- I : Infrastructure (dummy variable: 1: presence of dedicated bicycle-lane, 0: another case)
- Inc : Incentive (dummy variable: 1: breakfast or snack, 0: another case)
- ASC_i : Alternative Specific Constant, which is fixed to 0 for the mode bicycle.
- β : Attributes of the mode and user characteristics.

A series of models with different specifications of the utility function were estimated, additionally, we estimated a group of models for each mode and finally chose the best one in each case. The utility function showed in Eq. (2) is a general one, nevertheless,

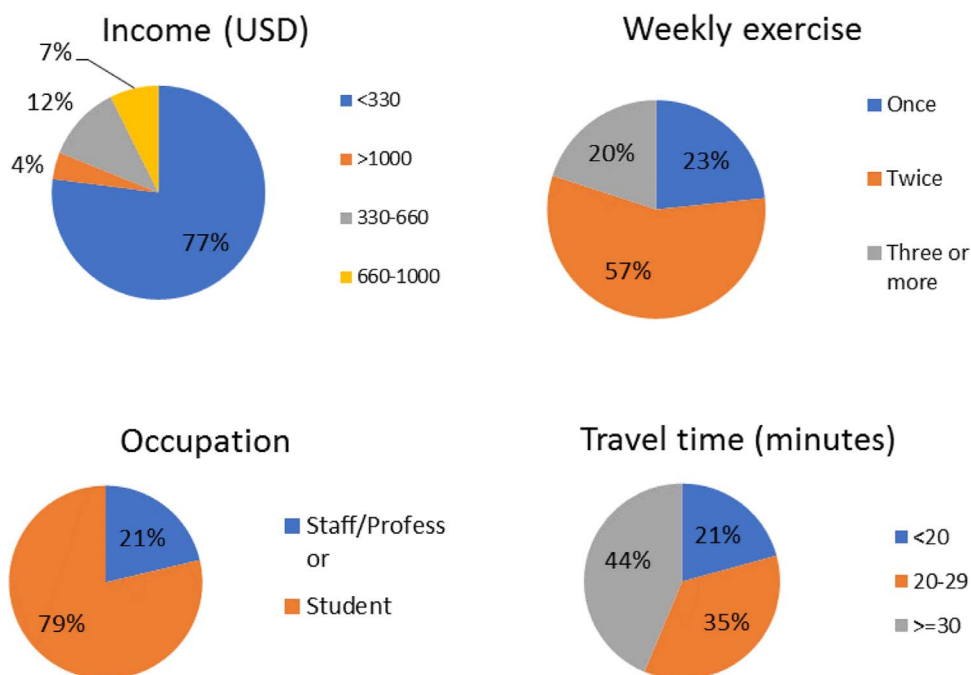


Fig. 5. Socioeconomic data.

Table 4
Private car vs bicycle model result.

Attributes	MNL		MNL-Panel Effect		ML	
	Value (t-test)	p-value	Value (t-test)	p-value	Value (t-test)	p-value
ASC Car (1)	Fixed	–	Fixed	–	Fixed	–
ASC Bicycle (2)	-2.26 (-3.02)	0.00	-3.33 (2.36)	0.02	-3.96 (-4.40)	0.00
Car Travel Time	-0.056 (-3.16)	0.00	-0.087 (-2.73)	0.01	–	–
Bicycle Travel Time	-0.061 (-2.35)	0.02	-0.108 (-2.03)	0.04	–	–
Travel Time	–	–	–	–	-0.091 (-2.69)	0.01
Cost	-0.00032 (-2.28)	0.02	-0.00053 (-2.81)	0.00	-0.00055 (-2.95)	0.00
Infrastructure (1)	2.65 (8.96)	0.00	3.870 (7.93)	0.00	4.15 (7.51)	0.00
Sex_Bicycle Travel	-0.049 (-3.90)	0.00	-0.067 (-2.50)	0.01	-0.061 (-5.42)	0.00
Sigma (panel effect)	–	–	-1.93 (-4.92)	0.00	–	–
η_{travel} (random parameters)	–	–	–	–	0.205 (4.50)	0.00
Initial log-likelihood	-291,122					
Final Log-likelihood	-188.353		-171.192		-174.100	
Number of observations	420		420		420	

we add complexity to models like systematics variations, panel effect and finally random parameters.

Table 4 shows the best 3 models obtained for private car vs bicycle. According to the microeconomic theory (Domencich and McFadden, 1975), the sign of the parameter associated to those attributes that cause disutility to the individual, are negative. In the case of the travel time and cost whose parameters are negative, whereas the presence of exclusive infrastructure for bicycles and an incentive for using it has a positive sign. In this case, we don't show attribute incentive in the utility function because it has a non-significant parameter. This could be interpreted like individuals wouldn't use more bicycle if they have a breakfast or snack. However, the correct sign (positive) could give us a first look that we need to explore another incentive different than the one we used here.

All the estimated parameters are significantly different from zero with a 95% confidence level. The alternative specific constant of the bicycle (ASC) has a negative sign, this could be interpreted like individual perceived a negative utility comparing the car. We estimated specific parameters for cost, but it was not significantly different from each other, that's the reason we presented a generic value for that attribute.

The first model is a multinomial logit model with systematic taste variations (MNL), we incorporate the socioeconomic variables sex and age to capture variations associated with idiosyncrasy or habits (Train, 2009). Sex was used as a dummy variable which takes the value of 1 when the respondent is a man, zero when it is a woman, and it was included in the bicycle travel time parameter. The negative sign can be interpreted as women penalize travel time less than men.

The next model we analyzed is the previous one, with a panel effect incorporation (MNL-Panel). In the same way as the MNL model, all parameters are significantly different from zero and with the expected sign. However, by incorporating a parameter that measures whether there is panel effect, we can capture the influence that incorporates the fact that the same individual responds more than once to each situation, and each choice cannot be treated as if they were from different respondents. In this case, the estimated parameter is negative and significant capturing this way the presence of correlation between answer by the same individual (Bliemer and Rose, 2010; Train, 2009).

Finally, we presented a mixed logit with random parameters into the generic travel time (ML). Previously, we estimated a group of models with random parameters in any attribute, but only incorporating to travel time yielded good results. The significance of this parameter means that travel time varies between individuals with an average value of -0.091 and a deviation of 0.205 , in this case, the subjective value of travel time is not a single value but a distribution.

The second set of models are presented in Table 5. In the same way, as in previous models, all parameters are significant and with the expected sign. Different specifications of the utility function were estimated until the two models presented were obtained. In all cases, the alternative specific constant (ASC) of the motorcycle is fixed and again for the bicycle, this variable has a negative sign, giving a negative perception regarding the motorcycle. We did not find randomness in travel time parameters, which is the reason why we only present the best two models: a multinomial logit with taste variations and a panel effect model.

In the multinomial logit model, the parameter of travel time associated with the bicycle is penalized about twice as much as in the

Table 5
Motorcycle vs bicycle model result.

Attributes	MNL		MNL-Panel Effect	
	Value (t-test)	p-value	Value (t-test)	p-value
ASC Motorcycle (1)	Fixed	–	Fixed	–
ASC Bicycle (2)	-2.99 (-5.46)	0.00	-3.91 (-4.53)	0.00
Motorcycle Travel Time	-0.060 (-4.05)	0.00	-0.079 (-3.80)	0.00
Bicycle Travel Time	-0.110 (-4.98)	0.00	-0.145 (-6.17)	0.00
Cost	-0.0011 (-4.98)	0.00	-0.0015 (-5.36)	0.00
Infrastructure	2.740 (11.26)	0.00	3.650 (10.42)	0.00
Sex_Bicycle Travel Time	0.035 (3.87)	0.00	0.045 (2.71)	0.01
Sigma (panel effect)	–	–	-1.47 (-6.32)	0.00
Initial log-likelihood	-415.888			
Final Log-likelihood	-303.153		-282.939	
Number of observations	600		600	

Table 6
Public transport vs bicycle model result.

Attributes	MNL		MNL-PANEL	
	Value (t-test)	p-value	Value (t-test)	p-value
ASC Bus	Fixed	–	Fixed	–
ASC Bicycle	-6.660 (-11.46)	0.00	-13.40 (-8.09)	0.00
ASC Shared-Taxi	0.200 (1.42)	0.16*	0.291 (1.82)	0.07*
Transit Travel Time	-0.125 (-9.58)	0.00	-0.176 (-9.61)	0.00
Bicycle Travel Time	-0.157 (-9.52)	0.00	-0.136 (-4.09)	0.00
Transit Access Time	-0.053 (-3.66)	0.00	-0.078 (-3.75)	0.00
Cost	-0.0027 (-10.27)	0.00	-0.0034 (-10.54)	0.00
Infrastructure ⁽¹⁾	3.030 (9.96)	0.00	5.42 (9.82)	0.00
Sex_BK Travel Time	0.018 (2.60)	0.01	0.034 (1.59)	0.11*
Sigma (panel effect)	–	–	-3.29 (-6.38)	0.00
Initial log-likelihood	-769.029			
Final Log-likelihood	-518.411		-457.63	
Number of observations	700		700	

motorcycle, being consistent with the fact that in the city of Ocaña the motorcycle is one of the most used and best-valued modes, and the time spent on the bike will cause a disutility compared with the motorcycle. The only socioeconomic variable that was incorporated as a systematic variation in tastes was sex within the travel time. Just as with car users, women penalize more the travel time by bicycle than men. On the other hand, again the panel effect within the model is significant, being this model better than the MNL applying a log-likelihood ratio test.

The last group of models was estimated for public transport (see Table 6). All parameters are significant except the shared-taxi constant; however, this variable is an integral part of the model thus it is maintained.

A travel time parameter for the motorized modes was estimated (bus, and shared-taxi) and a different one for the bicycle. As we can see the relationship of travel time parameters change in these two models: in the MNL is greater the penalty given by bicycle users, however, when included in the model the panel effect, are the users of public transport who have a higher valuation of travel time. This phenomenon can occur because now the responses of individuals are supposed to be correlated, we now capture the effect that the seven questions are answered by the same individual which penalizes more being in a public transport vehicle where it can feel tight or affected by the difference in frequency, in terms of times. While cycling can handle their time, go in their own vehicle and do not share space, this could be an indication of comfort.

On the other hand, access time (sum of waiting and walking time) is less than the travel time, contrary to expectations or found in the literature (Ortúzar and Willumsen, 2011). There are two possible reasons for this: First, there is not physical bus stops or stations, so users can take the bus at any point on the route, making people to be used to uncertainty in the service and therefore not value access time and second, Ocaña is a small city where the rush and urban dynamism is different from larger cities, causing commuters to penalize less the access time as they normally use it to fulfill minor tasks.

The parameter for cost has negative and significant signs. Finally, the attribute of exclusive infrastructure availability for bicycles has a positive effect on the choice of the mode, and it is a highly-valued variable for the users.

7. Conclusions

Given the current conditions of urban mobility and obesity in Colombia, it becomes clear that establishing management policies that favor alternative modes of transport like the bicycle are a necessity.

In the city of Ocaña, Colombia, although there is no proper cycling infrastructure, a small portion of the population is willing to use their bicycles or are already using them, because it is both economical and healthy. Therefore, it is necessary to identify the

attributes and parameters that influence choosing the bicycle as a mode of transport, in order to boost and increase its use. For this purpose, a SP survey was designed and applied to 270 subjects, where they were able to choose the most convenient mode of transport to go to and from university between the current mode they use and bicycle, the current transport modes university staff and students use are motorcycle, bus and car (this one is used mainly by professors and staff).

The results reflect the influence on the people's modal choice in a social context where the bicycle is not integrated into the urban space as a usual mode of transport. From the calibrated models, it was evident that the presence of infrastructure increases the probability of choosing the bicycle as a mode of transport, which is consistent with the results of others authors like (Griffin and Jiao, 2015). This is a clear argument for local authorities to invest in this kind of policies, given that it was demonstrated that the inhabitants are willing to use the bicycle once they are provided with proper infrastructure, thus improving mobility in the city.

For the two models estimated, it can be concluded that the variables that influence the choice of mode of transport for inside city journeys with origin and/or destination as the University Francisco de Paula Santander Ocaña are: travel time, access time, cost and the presence of infrastructure exclusively for bicycles, offering incentives to bike users surprisingly was not significant. The construction of a cycle-inclusive facility for bicycles definitely constitutes an aspect that would increase the probability that individuals would use this mode of transport and as proven by (Buekers et al., 2015) even when ignoring the benefits from congestion, CO2 emissions and noise reduction generated by the modal shift to the bicycle, moreover, new apps like Biko, allows bike users to exchange kilometers traveled for discounts or prizes with allied stores or restaurants. This said, the construction costs of bicycle infrastructure are almost always lower than the health benefits, being that this is evidence for investing in bicycle roads.

One of the challenges to increasing the bicycle modal share is to remove the social stigma associated with it, as proven by (Underwood et al., 2014), this issue discourages users specially young adults and furthermore in countries like Colombia where the use of cars is a synonym of wealth, while non-motorized modes and public transport are supposedly only for people with low income.

This research focused on providing information about the importance of implementing sustainable transport for visitors, alumni and employees of the UFPSO to improve the population's quality of life and encourage the citizens to perform modal shift from motorized modes to bicycle. In order to expand this investigation, it is recommended that by including the entire population of Ocaña and evaluating the impact of the bicycle as a regular mode of transport within the community, including adequate and safe spaces to encourage a sustainable mobility.

References

- Acevedo, Jorge, Bocarejo, Juan, Echeverry, Juan, Lleras, Germán, Ospina, Germán, Rodríguez, Alvaro, 2009. Resumen del libro: el transporte como soporte al desarrollo de Colombia. Una Visión Al 2040. Rev. Ing. 29, 156–162. <http://dx.doi.org/10.16924/riua.v0i29.257>.
- Akar, Gulsah, Fischer, Nicholas, Gung, Minam, 2013. Bicycling choice and gender case study: the Ohio State University. Int. J. Sustain. Transp. 7, 347–365.
- Alcaldía de Ocaña, 2012. Indicadores de Nuestro Municipio. <http://ocana-nortedesantander.gov.co/indicadores_anuales.shtml?Apc=bexx-1-&x=2836864#economica>.
- Ampt, Elizabeth S., Ortúzar, Juan De. Dios, 2004. On best practice in continuous large-scale mobility surveys. Transp. Rev. 24 (3), 337–363. <http://dx.doi.org/10.1080/0144164032000140703>.
- Bacchieri, Giancarlo, Barros, Aluisio J.D., Santos, Janaína V. Dos, Gigante, Denise P., 2010. Cycling to work in Brazil: users profile, risk behaviors, and traffic accident occurrence. Accid. Anal. Prev. 42 (4), 1025–1030. <http://dx.doi.org/10.1016/j.aap.2009.12.009>.
- Bliemer, Michiel C.J., Rose, John M., 2010. Construction of experimental designs for mixed logit models allowing for correlation across choice observations. Transp. Res. Part B: Methodol. 44 (6), 720–734. <http://dx.doi.org/10.1016/j.trb.2009.12.004>.
- Bogotá, A., 2009. “Plan Maestro de Movilidad.”.
- Bopp, Melissa, Sims, Dangaia, Matthews, Stephen A., Rovniak, Liza S., Poole, Erika, Colgan, Joanna, 2016. There's an app for that: development of a smartphone app to promote active travel to a college campus. J. Transp. Health 3 (3), 305–314. <http://dx.doi.org/10.1016/j.jth.2016.02.007>.
- Bordagaray, Maria, Dell'Olio, Luigi, Ibeas, Ángel, Barreda, Rosa, Alonso, Borja, 2015. Modelling the service quality of public bicycle schemes considering user heterogeneity. Int. J. Sustain. Transp. 9 (8), 580–591. <http://dx.doi.org/10.1080/15568318.2013.838722>.
- Buekers, Jurgen, Dons, Evi, Elen, Bart, Panis, Luc Int, 2015. Health impact model for modal shift from car use to cycling or walking in flanders: application to two bicycle highways. J. Transp. Health 2 (4), 549–562. <http://dx.doi.org/10.1016/j.jth.2015.08.003>.
- Cabello, Juan, Orozco, Mauricio, Ayala, Claudia, Hernández, Hernán, Romero, Pedro, 2017. Evaluación de la calidad de vida urbana en las principales ciudades Colombianas. Rev. Bras. Gest. Desenvolv. Reg. 13 (1), 106–127.
- Castillo, Irma, Galarza, Betty, Palomino, Hibeth, 2013. Condiciones de trabajo Y salud de mototaxistas cartagena - Colombia work and health conditions in motorcycle taxi drivers cartagena - Colombia. Salud Uninorte 29 (3), 514–524.
- Cervero, Robert, 2005. Progressive transport and the poor: bogotá's bold steps forward. Access 27, 24–30.
- Cervero, Robert, Sarmiento, Olga L., Jacoby, Enrique, Gomez, Luis Fernando, Neiman, Andrea, 2009. Influences of built environments on walking and cycling: lessons from Bogotá. Int. J. Sustain. Transp. 3 (4), 203–226. <http://dx.doi.org/10.1080/15568310802178314>.
- Chapman, Jeremy R., 2011. Uniform vehicle code and state statutes governing bicycling, 2010. Transp. Res. Rec.: J. Transp. Res. Board 2247 (1), 8–16. <http://dx.doi.org/10.3141/2247-02>.
- Chen, X., Xiong, W., Huang, Z., 2007. Planning bicycle corridor for Shanghai Central City. In: Plan, Build, and Manage Transportation Infrastructure in China Congress, pp. 18–29.
- Cherchi, Elisabetta, Ortúzar, Juan D.E. Dios, 2002. Mixed RP / SP models incorporating interaction effects. Transportation 29 (4), 371–395.
- Chillón, P., Molina-García, J., Castillo, I., Queral, A., 2016. What distance do university students walk and bike daily to class in Spain. J. Transp. Health 3 (3), 315–320. <http://dx.doi.org/10.1016/j.jth.2016.06.001>.
- Cui, Y., Mishra, S., Welch, T., 2014. Land use effects on bicycle ridership: a framework for state planning agencies. J. Transp. Geogr. 41, 220–228.
- Davison, Lisa, Curl, Angela, 2014. A transport and health geography perspective on walking and cycling. J. Transp. Health 1 (4), 341–345. <http://dx.doi.org/10.1016/j.jth.2014.09.001>.
- Deenihan, Gerard, Caulfield, Brian, 2014. Estimating the health economic benefits of cycling. J. Transp. Health 1 (2), 141–149. <http://dx.doi.org/10.1016/j.jth.2014.02.001>.
- Dill, Jennifer, Monsere, Christopher M., McNeil, Nathan, 2012. Evaluation of bike boxes at signalized intersections. Accid.; Anal. Prev. 44 (1), 126–134. <http://dx.doi.org/10.1016/j.aap.2010.10.030>.
- Dill, Jennifer, Voros, Kim, 2008. Factors affecting bicycling demand: initial survey findings from the Portland, Oregon, region. Transp. Res. Rec. 2031 (1), 9–17. <http://dx.doi.org/10.3141/2031-02>.
- DNP, 2010. Formulación del plan maestro de movilidad del municipio de ocaña.
- DNP Colombia, 2011. Plan Nacional de Desarrollo 2010–2014 Colombia. 1. Departamento Nacional de Planeación. Imprenta Nacional de Colombia, Tomo, pp. 541.

- Domencich, Tom, McFadden, Daniel, 1975. *Urban Travel Demand: A Behavioral Analysis*. North-Holland.
- Doorley, Ronan, Pakrashi, Vikram, Ghosh, Bidisha, 2016. Health impacts of cycling in dublin on individual cyclists and on the local population. *J. Transp. Health* 6 (May), 420–432. <http://dx.doi.org/10.1016/j.jth.2017.03.014>.
- Fernández-Heredia, Álvaro, Monzón, Andrés, Jara-Díaz, Sergio, 2014. Understanding cyclists' perceptions, keys for a successful bicycle promotion. *Transp. Res. Part A: Policy Pract.* 63, 1–11. <http://dx.doi.org/10.1016/j.tra.2014.02.013>.
- Flügel, Stefan, Ramjerdi, Farideh, Veisten, Knut, Killi, Marit, Elvik, Rune, 2014. Valuation of cycling facilities with and without controlling for casualty risk. *Int. J. Sustain. Transp.* 9 (5), 364–376. <http://dx.doi.org/10.1080/15568318.2013.798749>.
- Fournier, Nicholas, Christofa, Eleni, Knodler, Michael A., 2017. A sinusoidal model for seasonal bicycle demand estimation. *Transp. Res. Part D: Transp. Environ.* 50 (January), 154–169. <http://dx.doi.org/10.1016/j.trd.2016.10.021>.
- Frade, Inês, Ribeiro, Anabela, 2014. Bicycle sharing systems demand. *Procedia - Soc. Behav. Sci.* 111 (February), 518–527. <http://dx.doi.org/10.1016/j.sbspro.2014.01.085>.
- Garrard, Jan, Rose, Geoffrey, Lo, Sing Kai, 2008. Promoting transportation cycling for women: the role of bicycle infrastructure. *Prev. Med.* 46 (1), 55–59. <http://dx.doi.org/10.1016/j.ypmed.2007.07.010>.
- Griffin, Greg, Jiao, Junfeng, 2015. Crowdsourcing bicycle volumes: exploring the role of volunteered geographic information and established monitoring methods. *Compend. Transp. Res. Board Annu. Meet.* 27 (1), 1–19.
- Gutiérrez, Margaret, Cantillo, Víctor, 2014. Classic and bayesian estimation of subjective value of time. *Dyna* 81 (187), 158–166. <http://dx.doi.org/10.15446/dyna.v81n186.40863>.
- Hagen, Jonas, Pardo, Carlos, Valente, Johanna, 2016. Motivations for motorcycle use for urban travel in Latin America: a qualitative study. *Transp. Policy* 49, 93–104. <http://dx.doi.org/10.1016/j.tranpol.2016.04.010>.
- Hankey, Steve, Lu, Tianjun, Mondschein, Andrew, Buehler, Ralph, 2017. Spatial models of active travel in small communities: merging the goals of traffic monitoring and direct-demand modeling. *J. Transp. Health* 7 (December), 149–159. <http://dx.doi.org/10.1016/j.jth.2017.08.009>.
- Heinen, Eva, Maat, Kees, Wee, Bert Van, 2011. The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances. *Transp. Res. Part D: Transp. Environ.* 16 (2), 102–109. <http://dx.doi.org/10.1016/j.trd.2010.08.010>.
- Hensher, David A., Greene, William H., 2003. The mixed logit model: the state of practice. *Transportation* 30 (2), 133–176. <http://dx.doi.org/10.1023/A:1022558715350>.
- Hensher, David, Louviere, Jordan, Swait, Joffre, 1998. Combining sources of preference data. *J. Econ.* 89 (1–2), 197–221. [http://dx.doi.org/10.1016/S0304-4076\(98\)00061-X](http://dx.doi.org/10.1016/S0304-4076(98)00061-X).
- Hochmair, Hartwig H., 2014. Assessment of bicycle service areas around transit stations. *Int. J. Sustain. Transp.* 9 (1), 15–29. <http://dx.doi.org/10.1080/15568318.2012.719998>.
- Instituto Colombiano de Bienestar Familiar, 2010. *Situación Nutricional En. Encuesta Nac. Situac. Nutr. Colomb.*
- Li, Zhibin, Wang, Wei, Yang, Chen, Ragland, David R., 2013. Bicycle commuting market analysis using attitudinal market segmentation approach. *Transp. Res. Part A* 47, 56–68. <http://dx.doi.org/10.1016/j.tra.2012.10.017>. (<https://doi.org/>).
- Lo, Ria Hutabarat, 2009. Walkability: what is it? *J. Urban. Int. Res. Placemaking Urban Sustain.* 2 (2), 145–166. <http://dx.doi.org/10.1080/17549170903092867>.
- Majumdar, B., Mitra, S., 2015. Identification of factors influencing bicycling in small sized cities: a case study of Kharagpur, India. *Transp. Policy* 3, 331–346.
- Ocaña, A., 2012. Plan básico de ordenamiento territorial. <http://ocana-nortedesantander.gov.co/index.shtml?Apc=CExx-2835203&x=2835077>.
- Olio, Luigi, Angel Ibeas, Maria Bordagaray, Juan De Dios Ortúzar, 2014. Modeling the effects of pro bicycle infrastructure and policies toward sustainable urban mobility, pp. 1–8. [http://dx.doi.org/10.1061/\(ASCE\)UP.1943-5444.0000190](http://dx.doi.org/10.1061/(ASCE)UP.1943-5444.0000190).
- Ortúzar, Juan De. Dios, 2010. Estimating individual preferences with flexible discrete-choice-models. *Food Qual. Prefer.* 21 (3), 262–269. <http://dx.doi.org/10.1016/j.foodqual.2009.09.006>.
- Ortúzar, Juan De. Dios, Iacobelli, Andrés, Vazele, Claudio, 2000. Estimating demand for a cycle-way network. *Transp. Res. Part A: Policy Pract.* 34 (5), 353–373. [http://dx.doi.org/10.1016/S0965-8564\(99\)00040-3](http://dx.doi.org/10.1016/S0965-8564(99)00040-3).
- Ortúzar, J., Willumsen, L., 2011. Modelling transport.
- Pucher, John, Buehler, Ralph, 2008. Making cycling irresistible: lessons from The Netherlands, Denmark and Germany. *Transp. Rev.* 28 (4), 495–528. <http://dx.doi.org/10.1080/01441640701806612>.
- Pucher, John, Buehler, Ralph, Seinen, Mark, 2011a. Bicycling renaissance in north america? an update and re-appraisal of cycling trends and policies. *Transp. Res. Part A: Policy Pract.* 45 (6), 451–475. <http://dx.doi.org/10.1016/j.tra.2011.03.001>.
- Pucher, John, Garrard, Jan, Greaves, Stephen, 2011b. Cycling down under: a comparative analysis of bicycling trends and policies in Sydney and Melbourne. *J. Transp. Geogr.* 19 (2), 332–345. <http://dx.doi.org/10.1016/j.jtrangeo.2010.02.007>.
- Ríos, R., Taddia, A., Pardo, C., Lleras, N., 2015. Ciclo-inclusión En América Latina y el caribe: guía para impulsar el uso de la bicicleta. <http://dx.doi.org/10.1017/CBO9781107415324.004>.
- Romero, Juan P., Ibeas, Angel, Moura, Jose L., Benavente, Juan, Alonso, Borja, 2012. A simulation-optimization approach to design efficient systems of bike-sharing. *Procedia - Soc. Behav. Sci.* 54, 646–655. <http://dx.doi.org/10.1016/j.sbspro.2012.09.782>.
- Schauder, Stephanie, Foley, Mark, 2015. The relationship between active transportation and health. *J. Transp. Health* 2 (3), 343–349. <http://dx.doi.org/10.1016/j.jth.2015.06.006>.
- Shannon, Tya, Giles-Corti, Billie, Pikora, Terri, Bulsara, Max, Shilton, Trevor, Bull, Fiona, 2006. Active commuting in a university setting: assessing commuting habits and potential for modal change. *Transp. Policy* 13 (3), 240–253. <http://dx.doi.org/10.1016/j.tranpol.2005.11.002>.
- Train, Kenneth, 2009. *Discrete Choice Methods with Simulation*. Cambridge University Press <http://dx.doi.org/10.1017/CBO9780511753930>.
- Underwood, Sarah K., Handy, Susan L., Paterniti, Debora a, Lee, Amy E., 2014. why do teens abandon bicycling? A retrospective look at attitudes and behaviors. *J. Transp. Health* 1 (1), 17–24. <http://dx.doi.org/10.1016/j.jth.2013.12.002>.
- World Health Organization, 2015. Prevalence of insufficient physical activity among adults data by country.