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Factors influencing bicycle use: a binary choice model with panel data

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Abstract

Cycling has been commonly neglected in urban transport planning. In the same fashion, there is a shortage of available data on cycling mobility, especially in countries with low rates of bicycle share. Nevertheless, a modal shift towards soft modes such as cycling appears to be one of the keys for progressing towards a sustainable urban mobility paradigm. Understanding the factors that influence bicycle choice is necessary for implementing efficient *probike* transport policies. This research identifies the main factors affecting bicycle choice for commuting. It analyses an ad-hoc panel survey conducted in Vitoria-Gasteiz, a medium-sized city in northern Spain where cycle rate has rocketed in few years. Data from commuters, either workers or students, were collected in 2012, 2013 and 2014. An unbalanced binary panel model includes both objective – such as gender, age, occupation, car availability, or trip distance – and subjective variables – as attitudinal beliefs towards cycling–. The research confirms the importance of individual´s perceptions on cycling for understanding their modal choice and identifies main factors related to higher bicycle use likelihood.

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Keywords: Bicycle choice, panel survey, cycling promotion

1. Introduction

Cycling has been commonly neglected in urban transport planning. In the same fashion, there is a shortage of available data on cycling mobility, especially in countries with low rates of bicycle share. Nevertheless, a modal

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shift towards soft modes such as cycling appears to be one of the keys for progressing towards a sustainable urban mobility paradigm.

In this aim, policy-makers need to recognize the most relevant factors affecting bicycle choice in order to promote cycling with the most effective –and less expensive– measures. Moreover, the conditions could differ significantly from one city to another, regarding the natural and built environment but also the culture context of the city. Researchers demand prudence when transferring conclusions or policies from one context to another (Dufour, 2010; Marsden and Stead, 2011). Many of the studies on cycling come from cities with an established cycling culture but there is research to be addressed particularly on cities with lower bicycle-friendly stages.

Therefore, it is essential to further study what moves people to choose the bicycle as their mode of transport in different locations. But research on cycling for utilitarian purposes requires not only considering the classical time and cost aspects but also including subjective variables that were not (Muñoz, 2016; Willis et al., 2015). And longitudinal analyses are among the research challenges on cycling mobility (Handy et al., 2014).

This research proposes a model to better understand bicycle choice, based on a panel survey conducted in Vitoria-Gasteiz (Spain). This paper is structured as follows. After the introduction hereby, the next section sets the base to discuss the factors influencing bicycle choice. The third section introduces the city of Vitoria-Gasteiz in terms of cycling. The fourth one describes the data collected and the methodology used for its analysis. Its results are interpreted in section number five. Finally, the conclusions and further research are included in the sixth section.

2. Bicycle choice

Traditionally when modelling the modal choice, travel was considered a derived demand and it was simplified mainly to time and cost, on a maximization of utility approach. The need of modelling bicycle choice besides modelling other modes of transport appears as they are understood to obey a different range of factors from other modes.

Psychological approaches, distinctly from utility maximization approaches for modal choice, focus on identifying and defining key psychological and social variables which are meant to determine behaviour. Willis et al. (2015) review focus on the importance of such variables, which are increasingly included in recent research. The most known of such theories, the Theory of Planned Behaviour (TPB) (Ajzen, 1991), identifies beliefs as determinant. Ajzen proposes three constructs to determine the intention to perform the behaviour (commuting by bicycle in our case), and the intention in turn to determine the behaviour itself. Those constructs are the attitude towards the behaviour – beliefs predisposal towards commuting by bicycle –, the subjective norm – the support or rejection of the social environment – and the perceived behavioural control – the perceived feasibility of perform such trip by bicycle because of my own ability or external conditions to overcome–.

Travel habits and cycling experience appear as key elements in cycling consideration in several researches as well. Research results have been significant when using cycling familiarity and type of previous cycling experiences (commuting versus non-commuting) as segmentation criteria (Kroesen and Handy, 2014; Rondinella, 2015).

Regarding socio-demographic characteristics, strong connections to cycling have been found out, particularly on gender and age. Nevertheless, different results are figured out in different studies. Differences on bicycle use by gender vary notably with the cycling culture (Garrard et al., 2008). One of the main indicators of many low-cycling contexts is finding unequal proportions of men and women cycling, with men being likely to cycle more than women. In turn, in places where cycling is more normalised the participation of both genders tends to be even or even higher for women (Dill and Voros, 2008; Heinen et al., 2010). In the same fashion, the age profile of cycling users tends to be associated to younger people in many low-cycling contexts, but this difference attenuates in strong cycling cultures (Aldred et al., 2015; Simons et al., 2014; Winters et al., 2015). The influence on cycle use of other socioeconomic variables, as the household income or the study level, is not clear, but the family size seems to be positively related to bicycle use. Higher levels of motorization appear to be negatively related to bicycle choice; on the other hand, access to a bicycle is logically positively related to bicycle use (Muñoz, 2016). This aspect is also treated from the public bicycle systems approach (Fishman, 2015).

Natural issues as non-usual weather conditions or steep slopes may discourage bicycle use (Dill and Voros, 2008; Menghini et al., 2010). But the built environment of the city is also important. Urban form and urban design of spaces can directly affect bicycle use; in particular, a dense urban development mixing different activities and land uses favours cyclist mobility (Kemperman and Timmermans, 2009). Many studies also found that the availability of bicycle infrastructure is positively associated with cycling for transport, which is often measured in terms of miles of bicycle lanes or of all types of bicycle facilities (Pucher and Buehler, 2012).

Although the interest and number of studies on the factors influencing bicycle use in urban mobility have increased considerably in the last years, there is still a lot to address (Handy et al. 2014). Many case studies locations are cities with a consolidated cycling culture (e.g. the review by Pucher & Buehler (2008), focused on The Netherlands, Denmark and Germany). And several researches are focused on certain population segments as university or school students. Thus, it is needed to nourish the knowledge with more general case studies, with a wide range of variables collected.

Several studies support policies focused on bicycle commuting, and particularly in cycling to work (Heinen et al., 2010; Kroesen and Handy, 2014). On the one hand, this regular trips data could be better than information available about other purpose trips (Handy et al., 2014). On the other hand, commuting trips have to do with habits more than other non-regular trips, and it has been already pointed out the importance of the habits, the frequency of bicycle use and familiarity with cycling (Rondinella, 2015). Moreover, Kroesen & Handy (2014) highlight the reciprocal influence of cycling to work and non-work cycling on each other.

3. The case study of Vitoria-Gasteiz

This research addresses the particular case study of Vitoria-Gasteiz. It is a city in northern Spain with over 240,000 inhabitants with a moderately cold climate, flat topography apart for a hill in the medieval city-centre and a compact urban design. Bus and tram lines constitute the public transport service of the city. The industrial sector is important in the city, concentrated in various industrial parks (see Fig. 1). For the analysis of the spatial information by zones, we used a subdivision of the municipality that had already been used in other transportation analyses in the city (see Fig.2).

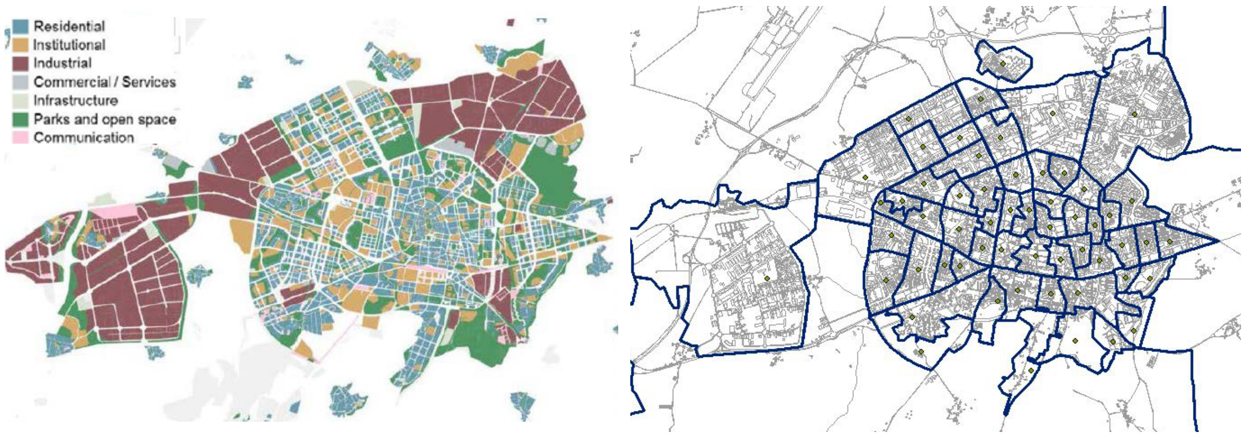

Fig. 1. Land use distribution (left) zones for transportation analysis (right) in Vitoria-Gasteiz. Source: City of Vitoria-Gasteiz (2009).

In Vitoria-Gasteiz the cycle rate has rocketed in few years (from 3.3% in 2006 to 12.3% in 2014), performing the context of a climber cycling city (Dufour, 2010). The city has been historically associated to cycling and with a strong civil and political consensus on environmental concern (Andrés Orive and Dios Lema, 2012). In their recent plans included several measures to enhance the city towards sustainability, part of them focused on the transport system of the city. Cycling has been directly addressed with some of them as the increasing the bicycle lanes network, cycling facilities, imparting cycling safety courses, traffic calming the city centre and modifying regulations on the city mobility.

In Vitoria-Gasteiz, in 2014 (Vitoria-Gasteiz Household Mobility Survey 2014) the number of non-commuting trips was way higher than the number of commuting trips; nevertheless, the interest in commuting trips is based also in the different modal split depending on the purpose. The car prevails for trips to work, while soft modes clearly predominate for journeys made for other purposes (Barberan and Monzon, 2016). In the perspective of limiting the car use for a more sustainable urban environment, this becomes another reason to focus on these trips that are feasible to be made by other modes.

With the panel survey data used in this research, it can be confirmed the difference in the modes used for commuting to work or to study. The following table includes separately the modal split for the habitual commuting trips of workers, students and respondents who both work and study.

Table 1. Main mode used for the commuting trip by occupation, for the Vitoria-Gasteiz Panel Mobility Survey sample.

Occupation	Main commuting mode	Total	Worker	Student	Both	Total	Worker	Student	Both
Total	Car	603	565	26	12	41.6%	49.6%	9.6%	30.8%
	Moto	18	15	2	1	1.2%	1.3%	0.7%	2.6%
	Public transport	223	183	35	5	15.4%	16.1%	12.9%	12.8%
	Bicycle	208	111	83	14	14.3%	9.7%	30.5%	35.9%
	Walking	399	266	126	7	27.5%	23.3%	46.3%	17.9%
	Total	1451	1140	272	39	100.0%	100.0%	100.0%	100.0%

4. Methodology and data

This paper analyses a panel survey focused on cycling commuting conducted in three waves in Vitoria-Gasteiz, in 3 consecutive years (2012, 2013 and 2014). Respondents were required to be 16 to 64 years old and commute at least once a week within Vitoria-Gasteiz´s municipality. The number of respondents suffered attrition from one wave to another. The sample analysed consisted of a total of 1451 observations, with the following characteristics.

Table 2. Sociodemographic distribution of the Vitoria-Gasteiz Panel Mobility Survey sample, compared between cyclist and non-cyclist group.

Factor	Category	Absolute value						Share of the category			Share of the group		
		Total	2012	2013	2014	Non-Cy	Cy	Total	Non-Cy	Cy	Total	Non-Cy	Cy
Gender	Female	767	370	234	163	695	72	53%	56%	35%	100%	91%	9%
	Male	684	322	212	150	548	136	47 %	44%	65%	100%	80%	20%
	Total	1451	692	446	313	1243	208	100%	100%	100%	100%	86%	14%
Age	16-24	292	145	88	59	199	93	20%	16%	44%	100%	68%	32%
	25-34	351	184	108	59	309	42	24%	25%	20%	100%	88%	12%
	35-44	412	190	124	98	370	42	28%	30%	20%	100%	90%	10%
	45-54	278	123	88	67	249	29	19%	20%	14%	100%	90%	10%
	55-64	118	50	38	30	116	2	8%	9%	1%	100%	98%	2%
	Total	1451	692	446	313	1243	208	100%	100%	100%	100%	86%	14%
Occupation	Worker	1140	553	339	248	1029	111	79%	83%	53%	100%	90%	10%
	Student	272	132	88	52	189	83	19%	15%	40%	100%	69%	31%
	Both	39	7	19	13	25	14	3%	2%	7%	100%	64%	36%
	Total	1451	692	446	313	1243	208	100%	100%	100%	100%	86%	14%

Note: Non-Cy: Non-cyclists; Cy: Cyclists

The analysis included socioeconomic (e.g. gender, age, occupation), travel characteristics (e.g. car availability, commuting distances and times), land use (zone characteristics and distance to Victoria-Gasteiz centre) and subjective variables, based on the on the Theory of Planned Behaviour (TPB) structure (Ajzen, 1991). The subjective variables were observed through to a series of 1-7 Likert scale questions and subsequently, their underlying latent variables were obtained through a factor analysis. In the factor analysis, unweighted least squares (ULS) method was employed. Varimax with Kaiser normalisation was applied for obtaining an orthogonal rotation and Anderson-Rubin method was the method used for calculating the factor scores. Four latent variables were found under the measures of attitudinal beliefs (17 items). One single latent variable for subjective norm beliefs (3 items) were grouped into one single latent variable. And finally, three latent variables stemmed from the perceived behavioural control items (8 items) . These latent variables were in line with the ones defined in Rondinella (2015) and Muñoz (2016), and so the labels adopted were based on theirs. The items included in each of the factors and their factor loadings are shown in Table 3.

Table 3. Rotated factor matrix of the factor analysis on the subjective items (KMO=.851; total explained variance=44.8%; displayed factor loadings over .300).

Items	Factors							
	Attitude - Efficient	Attitude - Green & Smart	Attitude - Pleasant & Suited life-style	Attitude - Comfortable & Safe	Subjective norm	Self-efficacy over unpredictable issues	Self-efficacy over predictable issues	Controllability of built environment issues
I (would) know how long will take to get to my destination	.608							
I (would) move quickly	.602							
I (would) have liberty, not depending on any other mode of transport	.465	.311						
I (would) pollute less the environment		.580						
I (would) save money compared to other modes of transport		.578						
I (would) take physical exercise		.558						
I (would) park easily		.464						
I (would) enjoy during the trip			.704					
I (would) relax during the trip			.642					
I (would) cause a good impression on others			.369					
(I could)/ I can wear appropriate clothing for my activities	.315		.322					
(I would not)/ I do not have a high risk of having an accident				.559				
(I would not)/ I do not arrive stressed to my destination	.383			.456				
(I would not)/ I do not cause nuisances to pedestrians				.439				
(I would not)/ I do not arrive sweaty to my destination	.409			.438				
(I would not)/ I do not breathe polluted air				.433				
(I would not)/ I do not have a high risk of getting my bicycle stolen or damaged				.407				
My friends (would) support me commuting by bicycle					.882			
My mates (would) support me commuting by bicycle					.830			
My family (would) support me commuting by bicycle					.717			
(I would be)/ I am able to ride with traffic						.723		
(I would be)/ I am able to repair a punctured tyre						.655		
(I would be)/ I am able to go uphill						.399	.697	
(I would be)/ I am able to plan my route							.600	
(I would be)/ I am able to manoeuver safely						.402	.585	
Existing infrastructures (lanes, paths and tracks) (would) make it easy								.512
My commuting trip distance (would be)/is suitable for going by bicycle	.313							.490
Traffic is manageable to commute by bicycle on the road						.329		.450

In order to identify those variables which influence people do or do not commute by bicycle (binary response) based on panel data (repeated observations by individual) a random effects binomial logit model was applied.

$$y_{it}^{*} = \gamma' X_{it} + \varepsilon_{it} \quad (1)$$

$$\varepsilon_{it} = \upsilon_{it} + \mu_{i} \quad (2)$$

$$y_{it} = 1(y_{it}^{*} > 0) \quad (3)$$

The random effects model assumes that the error term is composed of two independent components. ε_{it} is the global error term with two components, ν_{it} specific for each individual and time period and μ_i specific for each individual (for more details about the binomial panel models see Greene & Hensher (2010)).

5. Results and discussion

The model results are presented and discussed below. The model presents a good fit with an adjusted rho-square (relative to the constants only model) of 0.301. Also, the variance (Sigma) of u is significantly different from zero, indicating that the random parameters model is adequate. Table 4 presents the model coefficients and marginal effects derived from it.

Table 4. Model coefficients and marginal effects.

	Coefficients		Marginal effects	
Commuting by bicycle (dependent variable)	Value	p-value	Value	p-value
Constant	0.40720	0.4287		
Age	-0.05662	0.0002	-0.01001	0.00020
Both worker and student	1.85423	0.0018	0.28770	0.00000
Travel duration	-0.05438	0.0003	-0.00961	0.00030
Subjective norm	0.51260	0.0016	0.09062	0.00160
Self-efficacy over unpredictable issues	0.64474	0.0000	0.11398	0.00000
Attitude – Comfortable & Safe	0.72681	0.0000	0.12848	0.00000
Attitude – Efficient	1.71850	0.0000	0.30379	0.00000
Attitude – Pleasant & Suited life-style	0.80547	0.0000	0.14239	0.00000
Self-efficacy over predictable issues	0.50904	0.0019	0.08999	0.00190
Distance origin-city-centre 0.5km	-1.42296	0.0359	-0.23227	0.01350
Distance origin-city-centre 0.5-1km	-1.00915	0.0070	-0.17119	0.00330
Distance destination-city-centre <0.5km	0.92475	0.0663	0.15789	0.04880
Travel distance <1km	-3.32238	0.0000	-0.41288	0.00000
Destination zone mainly industrial	-0.75676	0.0349	-0.13067	0.02700
Car available	-0.67262	0.0424	-0.1189	0.04240
Sigma(u)	1.66518	0.0000		

The model results indicate that younger people which study and work at the same time have a higher likelihood of using a bicycle in their daily commutes. Having a car available also reduces the probability of using bike in commuting travel. As expected, commuting duration reduces the probability of commuting by bicycle, so we can suppose that – although such trip duration depends on the transport mode chosen –the longer the distance the less likely the bicycle will be used.

From the psychological factors, three of the four attitudinal variables where found to be relevant, only excluding the factor based on cycling attributes more obvious to the respondents in general. Therefore, cycling use likelihood seem to be related with believing cycling to be efficient, pleasant and suited to your life-style, and not uncomfortable nor unsafe. In addition, social disapproval and the perceived personal limitations to ride decrease the likelihood of commuting by bicycle. This is not the case of the perceived lack of control on the build environment, which does not appear to be significant.

Travel distance has a nonlinear effect on the likelihood of using bicycle in commuting trips. As expected, in shorter commutes with distances below one kilometer the bicycle is less likely to be used, mainly because walking might become more attractive.

Land use related variables or more precisely location related variables point to the following. Zones very close to the city centre – less than 1000 meters– are less likely to generate commuting bicycle trips. It is possible that people living in the centre or closer to it, might have much shorter commutes more adequate to be made on foot, particularly if they also work close to the centre. Destination zones close to the centre– less than 500 meters – have a higher likelihood of being reached by bicycle. Thus, the model captures more likely incoming trips to the centre generated outside of the centre. Also, working in a mainly industrial area reduces the probability of commuting by bicycle.

In terms of marginal effects, which represent partial changes in the probabilities, it could be seen that travel distance and the distance of the zones to the centre as well as the attitudinal variables are the ones with globally the highest values –apart from professional occupation– (see Table 4). These results are potentially interesting, particularly the high marginal effects on attitudinal variables, since they hint the possibility of policies aimed at changing perceptions and attitudes towards the bicycle being effective.

6. Conclusions and further research

This paper has proposed a model on bicycle choice for regular commuting trips gathering objective and subjective variables. The research confirms the importance of sociodemographic and trip characteristics but also of individual´s attitude towards cycling for understanding their modal choice, in line with most of the research reviewed by Willis et al. (2015). Four attitudinal latent variables were defined throughout a factor analysis. Also one latent variable was determined for the subjective norm items and three latent variables for the perceived behavioural control. The attitudinal latent variables of efficiency, pleasant and suited with life-style and comfortable and safe, as the latent variables of subjective norm and perceived self-efficacy are significant for increasing the likelihood of bicycle use, according to the random effect binomial model that was built. Among the objective variables, being a young person who studies and works simultaneously and does not have a car available for their commuting trips, was identified as positively associated to higher bicycle use likelihood. In Vitoria-Gasteiz, bicycle choice likelihood appeared to be greater also for those who do not live in the city-centre but work or study close from there, and not at an industrial park. It is also significant on favour of the likelihood of choosing the bicycle for commuting to address commuting journeys with an acceptable travel distance, not under one kilometer or too long either deriving on a long trip duration. This goes in line with some of the literature. Age and distance were also highlighted as key determinants in an analysis based on the 2014 Vitoria-Gasteiz´s household mobility survey, in this case for all the population and not only for commuting trips (Barberan and Monzon, 2016). Nevertheless, gender was also pointed out in that study but was not significant in this binary logit model. It should be highlighted the role of changing perceptions and attitudes to promote cycling, so probike policies should entail this approach. This could be addressed by awareness campaigns, infrastructure and facilities enhancement or other interventions. If they get to make the citizens experience the bicycle use for commuting, that would affect the individual´s perceptions and attitudes, in a reconsideration cycle (Rondinella, 2015).

Limitations from a binomial model could be overcome in future research by using a multiple choice model – on panel data as well –. This way, differences between walking, public transport and car commuters would be considered. Further analysis on the origin, destination and even the estimated route characteristics could lead to relations with alternative modes competitiveness and with measures implemented in certain zones of the city. Other modelling techniques on the panel data (e.g. conditional change model, latent transition model, etc.) could help to better understand the influence of the measures taken in the city, or which groups are more likely to shift their modal choice towards cycling.

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