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Identifying Latent Variables for Active Cycling Mobility. An Application for University Students

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Abstract

This paper proposes the definition of possible latent variables that determine the choice of cycling as a mode of transport. To this end, an ad hoc survey was carried out among university students at the University of Las Palmas de Gran Canaria. In this survey, in addition to characterising the student's journey, a specific section on the use of bicycles allows the identification of possible latent variables for this choice and target sample. A Principal Component Analysis (PCA) was carried out with the aim of identifying the latent variables. The PCA identifies three latent variables: *convenience*, *infrastructure* and *safety*. Preliminary models of intention to cycle show that the most influential variables are distance, whether the user is female, and the latent variable convenience, which has a positive effect on intention to cycle.

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Keywords: acitve mobility; bicycle; latent variables.

1. Introduction

Active mobility by cycling has outstanding advantages as a sustainable transport mode. However, the modal shift of using bicycles for urban mobility is not as high as could be expected. The main issue of the bicycle as a transport mode is the specific factors that influence the decision of the individual choice. Thus, a specific analysis of the determining factors in the choice of using a bicycle as the transport mode for daily mobility was required, and specifically for commuting (Heinen, et al., 2010). In countries with a high number of bicycle shares, such as the Netherlands, Denmark, and Germany, it has been identified that adequate and correct planning of the promotional policies for this mode of transport encourage active mobility by bicycle (Pucher and Buehler, 2008).

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Despite the efforts of the European Union (UE) to promote transport systems, private vehicles continue to be the main mode of transport for urban mobility (European Commission, 2022). Accordingly, the UE strategy is defined in the reduction of emissions by at least 55% in 2030 and to zero in 2050 through the design of action plans that promote the use of more sustainable modes of transport, as well as a correct incentive policy that promotes the necessary change (European Commission, 2020). According to data from the EU, 50% of motorised journeys in European cities are less than 5 km. In this case, using a bicycle would be a good alternative. In addition, 64% of Europeans consider it necessary to have policies that promote more sustainable transport modes, such as the bicycle compared to private vehicles.

The strategy in Spain, in line with the EU and the United Nations Sustainable Development objectives, also aims to promote more sustainable modes of transport to reduce the use of private vehicles. The advantages of the bicycle as a mode of transport contribute to its consideration in policies to promote more sustainable modes and the increase in sharing this mode of transport in cities (Ministerio de Transporte, 2021).

The aim of the study is threefold. Firstly, the study tries to evaluate the willingness of university students to change the current transport mode to using bicycles. Secondly, the study tries to identify the latent variables for active cycling mobility in the research context. Finally, to evaluate the main factors in defining the modal shift and to have a preliminary analysis for future research. The paper is organised as follows. Section 2 presents a short review of literature. The case study and the design of the survey is described in section 3. The identification of latent variables is presented in section 4 as well as the models estimated for the willingness to change the current transport mode to using a bicycle and finally, section 5 presents the main conclusions.

2. Literature Review

This section provides a short review of the literature focusing on the main variables that determine the choice of cycling as a transport mode. The promotion of active cycling mobility should take into account different characteristics that are specific to this type of transport. The first characteristic is that the infrastructure should include a network of bicycle lanes, specific parking spaces for bicycles, and toilet facilities in the workplace or study centres (Akar and Clifton, 2009; Buehler and Dill, 2016; Dill and Voros, 2007; Hunt and Abraham, 2007; Moudon et al., 2005; Pucher et al., 2011; Gutiérrez et al., 2020a; Gutiérrez et al., 2020b). The second refers to the environmental context, which covers aspects related to the urban environment such as climate, topography, and the design of cities (Sallis et al., 2013; Nielsen et al., 2013). In this sense, the distance variable is particularly relevant; with the bicycle being a more efficient mode for journeys between 1 and 15 km long. It is also noteworthy that active cycling mobility must focus on urban mobility (Dekoster and Scholaret, 2000).

Muñoz et al. (2016a) present a detailed review of the increasing role of latent variables (non-measurable variables) in modelling the bicycle as a transport choice. Bahamonde-Birke et al. (2017) differentiate attitudes and perceptions in the definition of latent variables for models of bicycle use. Attitudes are defined as latent characteristics that are specific to each individual. On the other hand, perceptions are related with the latent attributes specific to a particular alternative.

The economic, social, and sustainable advantages as well as the health benefits could be identified in the latent variable referred to as bicycle convenience. This latent variable includes the individual's perception of using a bicycle as a suitable transport mode (Fernández-Heredia et al., 2016; Muñoz et al, 2016b). The latent variables can be defined as perceptions of specific attributes related to cycling, where the the main latent variable is safety referring to the risk of accidents and theft. Safety or risk are perceived differently by each individual, depending on the alternative transport mode (Feenstra et al., 2011; Rossetti et al., 2018). This risk perception is higher when bicycle users share the space with other modes but it can be reduced with the existence of specific infrastructure, such as a network of cycle lanes (DiGioia et al., 2017; Lawson et al., 2013; Noland and Kunreuther, 1995; Hopkinson and Wardamn, 1996;). In recent years, there has been an increase in the number of empirical studies that incorporate the attitudes and the perceptions into choice models of using a bicycle as a mode of transport (Gutierrez et al., 2020b; Muñoz et al., 2016b, Fernández-Heredia et al., 2014).

3. Research Context

3.1. Case Study

This section provides a brief overview of the case study. Las Palmas of Gran Canaria is the capital of the Gran Canaria (Spain) with a population of 378,797 inhabitants in 2022, that is, 44% of the total population of the island of Gran Canaria (ISTAC, 2022). According to the Sustainable Urban Mobility Plan of the city, 67% of trips made in the city are made by private vehicle, 13% by public transport, 15.1% on foot, 4.5% by taxi (and others) and only 0.4% by bicycle (Ayuntamiento de Las Palmas de Gran Canaria, 2015). In this context, the cycling master plan was designed to promote active cycle mobility. Thus, the cycling master plan for the city proposes the design of a functional and comfortable network of cycle lanes of about 52 km in total. The network will be made up of bidirectional cycle paths of 2.30-2.50 metres wide. These cycle lanes will occupy space that has traditionally been occupied by private vehicles, that is, parking areas or circulation lanes. For more details see Calvo (2016).

The study is concerned with the analysis of the willingness to change the mode of transport used by university students as well as the identification of latent variables for using a bicycle as the main transport mode. The population under study is the university students who go to Obelisco Campus. The University of Las Palmas of Gran Canaria (ULPGC) has six campuses. The Obelisco Campus is located in the city and benefits from the future network of bike lanes planned in the cycling master plan of the city.

3.2. Survey

The questionnaire consisted of three blocks of questions. The first block included information about the commuting trip, that is, from the home to the campus with a specific section for bicycle users. The second block included an assessment of the main factors of using a bicycle as a mode of transport and the third and final block collected socio-economic information on both the household and the interviewee.

The second block presents 15 statements measured on a 5-point Likert scale. A review of the literature firstly allowed selecting the main statements that could be defined as the latent variables for active mobility by cycling. Second, a focus group was conducted with 14 students of the Obelisco Campus to identify the main statements. Two of those students were bicycle users at that moment. After the focus group, the main statements were reduced from 16 to 15 statements and the definition of another one was modified taking into account some of the students' comments. In addition, a pilot exercise was conducted for a sample of 20 students, which allowed assessing the adequacy of the questionnaire.

Data collection was done online via a questionnaire using Google forms. A trained student administered the questionnaires between March and April 2018. To this end, the trained student visited different classes after receiving the permission of the teaching staff for every subject during the spring semester at ULPGC. During the 2017-2018 academic year, this campus had around 3,314 students, of which 26% were male and 74% were female (University of Las Palmas of Gran Canaria, 2018). The sample has 315 valid responses, which implies some 10% of the total population of students in this campus. There is no data availability on mobility in and around the campus. Therefore, the structure of the sample could not reflect this.

Concerning the descriptive analysis of the sample used in this study, the main transport mode used to get to the campus is the bus with 47% of students using this mode; this is followed by private vehicles with 38.1%. 13.3% of the university students walk to the campus. Only 0.6% of students go by bicycle, although the response was that 47% of students had a bicycle available to them to make the trip. 66.7% of the interviewees were female and 33.3% were male. Around 85% of the sample was less than 26 years old, that is, a young population who could be seen to have greater willingness to change their mode of transport as oppose to other populations such as university staff.

Regarding the analysis of the willingness to change the current mode to using a bicycle, the results show that 48% are willing to change. As far as the transport mode used is concerned, 47% are bus users, 21% walk and 29% go by car. In addition, there are nine different conditions that could affect this decision according to the students' responses. There were six most notable conditions with more than 50% of the responses. The first condition is the existence of a network of bicycle lanes. The second condition is the safety of riding a bicycle in the city. The third condition is the improvement of the public bicycle system and the fourth is cycling promotion from the University. It is noteworthy

that the fifth condition is that the University may promote cycling policies. This is a challenge that the University administration could face to improve access to the campus by bicycle. These policies need to be studied by analysing the demand factors in order to define the adequacy of the action plan. The sixth condition is the speed limit for private vehicle users that share the roads with the cyclists. This condition is directly related to the existence of cycling networks (the first condition indicated by 86.8% of responses) that reduce the perception of the risk of accidents (Akar and Clifton, 2009).

4. Data Analysis

4.1. Latent variable identification

This section provides the analysis of the latent variables for active cycling mobility. Table 1 presents the assessment of the 15 statements used for active cycling mobility. The interviewee had to score each statement on a 5-point scale Likert, where 1 – was totally disagree and 5 - totally agree. The table shows the average, the mode and the standard deviation. A brief analysis of the assessment, the statements 1-5 are referring to the cycling infrastructures and there is a general agreement that the responses are lower than 3. This result shows that there is not a cycling infrastructure in the city. The statements 11-15 refer to the bicycle as a mode of transport and there is a general agreement that the responses are greater than 4 and the mode is 5. There is no doubt about the advantages of the bicycle as a transport mode for university students. The safety perceived of cycling in the city is defined by statement 6 and 7 and the responses are around level 3.

Table 1. Assessment of active cycling mobility.

Statements of the active mobility by bicycle	Average	Mode	Standard Deviation
1. There is a network of safe and functional bicycle lanes	2.4	2	1.0
2. There are public parking areas for bicycles on the university campus	2.9	2	1.2
3. There are facilities for personal hygiene on the university campus	2.8	2	1.3
4. Limited speed for vehicles in areas shared with cyclists	2.6	3	1.1
5. There are public parking areas for bicycles in the city	2.8	3	1.0
6. Cycling is not safe due to the increase in traffic accidents	3.0	3	1.2
7. There is a risk of bicycle theft in public car parks	3.4	4	1.2
8. Cycling is appropriate when the distances to travel are short (less than 15 km)	3.7	4	1.1
9. It is necessary to be in good physical shape to cycle	2.2	2	1.0
10. The good climate of the city favours cycling	3.8	4	1.1
11. The use of the bicycle allows physical activity	4.2	5	1.0
12. It is a means of transport that does not pollute	4.5	5	1.0
13. It is a means of transport without restrictions on schedules or frequencies	4.0	5	1.2
14. It is a cheaper means of transport than others	4.3	5	1.0
15. The public bicycle service must be improved	4.2	5	1.0

The latent variables are variables that are not easily measurable because they are based on attitudes and perceptions of individuals. However, such latent variables could influence the choice of transport mode and therefore, are relatively important when it comes to assessing the use of a bicycle as a transport mode. Principal Component Analysis (PCA) is a data reduction or scaling technique that makes it possible to identify factors defined as a set of variables starting from a broader set of data with minimal loss of information (García et al., 2000; Hair et al., 2007). In this study, the hypothesis to be studied is whether the scale proposed in section 2 of the survey, made up of 15 items, can be reduced to several latent variables that make it possible to explain the use of the bicycle as a transport mode.

The SPSS v.27 is the software used to make the analysis. Firstly, it is necessary to measure the internal consistency of the 15 statements (see Table 1). The Cronbach's alpha coefficient should be greater than 0.7 to confirm the closely related set of 15 statements as a group (Cronbach, 1972). The result is 0.85 for the scale defined in section 2 and can be seen in Table 2. Secondly, the Kaiser Meyer Olkin (KMO) test and the Bartlett's test of sphericity were used as measures of the adequacy of the sampling to perform the PCA. As we obtained a KMO value equal to 0.85 and a Bartlett spherical value equal to 0,000, the PCA is appropriate in our case. Finally, we applied the PCA using a Varimax rotation. The PCA obtained suggested an aggregation of the statements of the questionnaire into 3 latent variables that jointly account for 62% of the variance.

Table 2 shows the latent variables considered and the items included in each variable, ordered according to the percentage of total variance explained. The *latent variable 1-Convenience* includes the main advantages of cycling as a transport mode. This factor explains more than the half of the total variance and it could indicate the relative importance of these elements in the choice of cycling as a transport mode. The *latent variable 2- Infrastructure* includes bicycle facilities (network, parking and limited speed). In this case, the total variance explained is 15.8%, which means a relative weight of the latent variable 2 of 25%. The *latent variable 3-Safety* includes the perception of safety when riding a bicycle and the total variance explained is 10%. The three latent variables identified by PCA indicates the students' perceptions and are similar to those reported in the literature mentioned in section 2. Items 9, 10 and 15 are not included in any latent variable or factor because the communalities are lower than 0.35 (Hair et al., 2007).

Table 2. PCA and latent variables.

Latent Variable	Statements of the active mobility by bicycle	
Convenience	8. Cycling is appropriate when the distances to travel are short (less than 15 km)	
	11. The use of the bicycle allows physical activity	
	12. It is a means of transport that does not pollute	36.2%
	13. It is a means of transport without restrictions on schedules or frequencies	
	14. It is a cheaper means of transport than others	
Infrastructure	1. There is a network of safe and functional bicycle lanes	
	2. There are public parking areas for bicycles on the university campus	
	3. There are facilities for personal hygiene on the university campus	15.8%
	4. Limited speed for vehicles in areas shared with cyclists	
	5. There are public parking areas for bicycles in the city	
Safety	6. Cycling is not safe due to the increase in traffic accidents	10.0%
	7. There is a risk of bicycle theft in public car parks	
Total variance explained		62%

4.2. Modal change analysis: estimation and results

The discrete choice models provide a useful analysis when the individual response is a discrete variable. The theoretical basis for the specification of the econometric model is random utility theory (McFadden, 1981). Discrete choice models that arise from different assumptions about the probability distribution of the random term (Ortúzar and Willumsen, 2011). The modal change analysis is evaluated by estimating the binary logit model. The willingness to change the current mode of transport to using a bicycle is a binary choice, that is, where the dependent variable is equal to 1 if the students' responses show willingness to change the current mode to using a bicycle and to 0 otherwise. The models are estimated using NLOGIT 6.0 (Greene, 2016).

Almost 50% of the interviewees are willing to change the current mode with the majority being women (64.9%). The three latent variables identified by PCA are considered in the estimation process as well as the distance (if the distance is less or equal to 15km) and the sex (if the student is female). The estimation results are presented in Table

4. Different variables are considered in the model specification. The model presented shows the better estimate results. Of the five variables considered, only three variables are significant. The distance variable has a positive sign and is significant at the 1% level. This result indicates that the probability of willingness to change the current mode to using a bicycle increases if the distance is less or equal to 15km. When the student is female, the parameter has a negative sign, and is significant at 5%. This result is usual in the cycling mode analysis where being female reduces the probability of choosing a bicycle as a transport mode (Akar et al., 2013; Aldred et al., 2016). The *latent variable 1-Convenience* has a positive sign and is significant at 5%. The advantages of using a bicycle as a mode of transport have a positive effect on the modal change. The other two latent variables are not significant although there are considered important issues for cycling. Infrastructure is considered to be one of the most important factors in promoting this mode of transport in the city (Pucher et al., 2010; Garrad et al, 2008) and safety is the second because the perception of risk is greater than other transport modes (Feenstra et al., 2011; Molino et al., 2009).

Table 3. Estimate results.

Variables	Model 1		Model 2	
	Parameter (t student)	Marginal Effects (t student)	Parameter (t student)	Marginal Effects (t student)
Latent variable 1-Convenience	0.25713** (2.17)	0.06176** (2.16)	0.25720** (2.17)	0.06179** (2.17)
Latent variable 2-Infrastructure	0.00898 (0.08)	0.00216 (0.08)	-	-
Latent variable 3-Safety	0.01730 (0.15)	0.00416 (0.15)	-	-
Sex (1=Female, 0=Male)	-0.45544** (2.49)	-0.10987** (-2.55)	-0.45544** (-2.49)	-0.10982** -2.55
Distance (Km≤15)	0.53110*** (2.70)	0.12863*** (2.77)	0.53152*** (2.70)	0.12873*** (2.77)
Log-likelihood	-218.07303		-218.07303	
McFadden Pesudo R-squared	0.028		0.028	
Observations	318			

***, **, * significance at 1%, 5%, 10% level.

5. Conclusions

To analyse the latent variables of active cycling mobility a survey with a sample of 315 universities students was conducted at ULPGC (Obelisco Campus). The questionnaire included three sections about the trip from the home to the study centre, socioeconomic variables and a specific section on cycling to identify the perceptions of the individual as latent variables. This section presents 15 statements to be valued in a 5-level Likert scale regarding cycling specific features.

This research has identified three latent variables by PCA that may influence the choice of using a bicycle as a mode of transport. The latent variable 1-Convenience includes the main advantages of cycling as a transport mode, that is, cheaper transport mode than others, generates less pollution, no schedule restrictions, more appropriate for trips of less than 15 km and allows for physical activity. The latent variable 2- Infrastructure includes bicycle facilities, such as a network of bicycle lanes, public parking at ULPGC and at the city, and limited speed on the roads. The latent variable 3-Safety includes the perception of safety when riding a bicycle and the perception of theft risk. The perception of students in terms of the latent variables is similar to those reported in the literature as mentioned above.

Using an econometric model, the willingness to change the current mode of transport to cycling is identified through different variables, such as the latent variables identified through PCA and socio-economic variables. The

empirical results show that only the latent variable 1 is significant at 1% level with a positive effect. The other significant variables are if the student is female and if the distance is less than or equal to 15km. The willingness to change the current mode to cycling increases if the student is male, if the distance from home to campus is less than or equal to 15km and this disposition to change is influenced by the convenience of cycling identified as a latent variable.

Overall, this research presents a previous analysis of active cycling mobility for further study. The most outstanding feature is the exploratory analysis of the use of the bicycle context at the moment of the study, and this could be taken as a base for future research. Future research would be needed to assess further scenarios with more detailed data from the demand side, including a stated-preference experiment that presents the possibility of choice between the current mode and the new mode of cycling taking into account the existence of a network of bicycle lanes as well as the latent variables identified in this work. From a transport policy perspective, finding the effective policy to promote the active mobility of the cities is a key priority. A better understanding of potential bicycle users' preferences is an important aspect of the transport policy of the city and it would be promoted in line with ULPGC administration.

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