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Understanding cyclists' perceptions, keys for a successful bicycle promotion

Álvaro Fernández-Heredia [a,*], Andrés Monzón [b], Sergio Jara-Díaz [c]

[a] Civil Engineering Department, Universidad Europea, Calle Tajo s/n, 28690 Villaviciosa de Odón, Spain
[b] Transport Department, Universidad Politecnica de Madrid, Calle Profesor Aranguren s/n, 28040 Madrid, Spain
[c] Transport Systems Division, Universidad de Chile, Av. Blanco Encalada 2002, Santiago, Chile

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A B S T R A C T

Many variables that influence bicycle use beyond time and cost have been included in models of various types. However, psycho-social factors that make the bicycle eligible as a modal alternative have not been identified properly. These factors are related to intention, attitudes and perceptions, and their identification can contribute to obtain the keys for a successful bicycle policy. Here, an in-depth investigation of cyclists' perceptions is attempted using a large university survey designed and collected *ad hoc*, and then applying exploratory and confirmatory factor analyses. After identifying fourteen factors, a structural equations model was estimated to find structure and relationships among variables and to understand users' intentions to use the bike. Four (latent) variables are identified, namely convenience, pro-bike, physical determinants and exogenous restrictions. The main conclusion is that convenience (flexible, efficient) and exogenous restrictions (danger, vandalism, facilities) are the most important elements to understand the attitudes towards the bicycle.

1. Introduction

Cycling is increasingly recognized as a clean, sustainable mode of transport and an essential part of an inter-modal plan for sustainable urban travel (OECD, 2004). Improving urban cycling mobility levels also seems a good strategy for healthy cities (Saelens et al., 2003). It counterbalances urban sedentary life and it also helps diminishing motorized vehicle trips with all their legacy of negative externalities. According to Ezzati et al. (2004) sedentary life causes 3,200,000 deaths per year. Externalities (pollution, accidents and others) cause 1,500,000 deaths per year world-wide (World Health Organization, 2009). Indeed, cycling is not the panacea for urban transport-related problems but it has healthy effects through increased physical activity and has positive environmental impacts (Akar and Clifton, 2009; Badland and Schofield, 2008).

Policies of cycling promotion, regarded as very important for a healthier transport and a more sustainable mobility, are based on the identification of factors affecting bicycle use (Pucher et al., 2010). The scientific literature regarding these factors either include qualitative analyses, where bike factors (identified *a priori*) are assessed, or discrete choice models are estimated to predict users' choice. Both research lines provide important insights into cyclist behaviour. Transportation planning efforts at all levels nowadays consider increasing the levels of walking and bicycling as a desirable objective. As Krizek (2007) points out those initiatives are motivated by a desire to reduce car use and its negative environmental

* Corresponding author. Tel.: +34 91 211 56 21
E-mail addresses: alvaro.fernandez@uem.es (Á. Fernández-Heredia), andres.monzon@upm.es (A. Monzón), jaradiaz@ing.uchile.cl (S. Jara-Díaz).

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consequences (e.g., pollution, natural resources consumption). Although they are also motivated by concerns of livability, public health, or physical activity, Börjesson and Eliasson (2012) suggest that these factors by themselves are not the sole elements that explain the cyclist behaviour.

There is an evident need to assess not only factors that can be observed but also factors related to cyclists' emotions, feelings and personal perceptions. The fact that the classic factors which determine transport user behaviour – such as cost and time – are not as influential regarding bicycles use as for other modes may indicate that these other kinds of factors of a psycho-social type gain importance in the correct characterization of cyclist behaviour (Eash, 1999; Pinjari et al., 2008; de Bruijn et al., 2005; Eriksson and Forward, 2011). It could be said that the behavioural part of the *black box* that is not covered by the models is very significant in the case of bicycles, and attention must be paid to it (Barnes and Krizek, 2005; Ben-Akiva et al., 2002; Golob, 2003). Although non-traditional variables have emerged in econometrics models aimed at predicting the use of bicycle, an in-depth investigation of those psycho-social factors that make the bicycle eligible as a modal alternative has not been attempted properly. Therefore, an explicit approach to identify such factors is needed to improve our understanding of bike users' perceptions. The aim of this paper is to capture those factors in a systematic way.

The intention is, on one hand, to identify which are the (subjective) psycho-social factors that play a role in cycling and how these factors inter-relate. On the other hand, we intend to investigate what is their influence on actual behaviour (Ajzen, 1991). This information is useful to gain a better understanding of users' behaviour towards riding a bicycle and to determine the appropriate actions to encourage bicycle use. With this purpose we designed and applied an internet based survey in the Madrid University Campus, where a public bike system is expected to be implemented. In the remainder of this section we summarize factors that have been detected with various techniques in the cycling literature. In Section 2 we describe data and how it was obtained. In Section 3 we show the process to obtain the variables that best represent cyclists' perceptions. Section 4 concludes.

The available literature contains large amounts of information related to factors affecting bicycle use (Heinen et al., 2010). Some articles deal with the problem from a more descriptive perspective, analysing the effects of factors by conducting evaluative surveys on cyclists. Other articles perform a more predictive analysis by linking the factors to final bicycle use. This study aims at combining both perspectives, following the steps of other authors like Li et al. (2013). In order to identify the variables related to psycho-social factors, we need to have a clear composition of all the factors involved. We will group factors influencing bicycle use into *General* socio-demographic characteristics, cyclist *choice factors* and *latent variables* (other classifications can be found in Rietveld and Daniel, 2004, and Heinen et al., 2010). Choice factors are those that can be observed and measured directly, and latent variables deal with perceptions and attitudes. Besides these variables, there are others that are also important to explain bicycle use by providing a context: *cyclist mobility costs in relation to the general transport costs* and *cyclist context conditions* (Rietveld and Daniel, 2004). We now review these in detail.

1. *General socio-demographic characteristics* of the users. Factors such as ***age*** or ***level of income*** yield different results in different studies (Baltes, 1996; Dill and Voros, 2007; Moudon et al., 2005; Pucher and Buehler, 2008). Other factors such as ***family size***, ***car or bicycle availability*** have some direct relation with bicycle use (Ortúzar et al., 2000; Pinjari et al., 2008; Taylor and Mahmassani, 1996). A large family size or bicycle availability is associated positively with bicycle use, as opposed to car availability. Other factors such as ***gender*** seem to be related more to cycling culture than to bicycle use (Garrard et al., 2008).
2. *Choice factors* can be measured directly or obtained from the users. These factors can be divided into those that affect users individually, those that affect them collectively (related to the environment), structural factors (related to the conditions of town planning that are favourable towards bicycles) and declared subjective factors.
   a. *Trip factors*: ***Journey duration*** is extremely important when choosing a mode of transport in general (Börjesson and Eliasson, 2012); however, it does not seem to be a decisive factor when analyzing the use of bikes (Eash, 1999; Hopkinson and Wardman, 1996; Tilahun et al., 2007). Bicycles are highly competitive with all kinds of motorized transport below certain distances (Hunt and Abraham, 2007). However, in most urban areas this does not translate into a large proportion of users (Allen-Munley et al., 2004; Hyodo et al., 2000). In addition to journey time, the ***flexibility*** offered by bicycle must also be considered as an advantage regarding waiting time for public transport or parking cost for car (Akar and Clifton, 2009). ***Trip purpose*** is also a relevant factor mentioned by many in the literature (e.g. Wardman et al., 2007); behaviour and decisions made by cyclists differ completely depending on trip purpose, which makes it necessary to distinguish between mandatory travel from sport, recreational and leisure pursuits (Bergström and Magnusson, 2003; Nkurunziza et al., 2010).
   b. *Environmental factors* include ***weather conditions*** that can affect bicycle use, particularly when they are of a non-permanent nature, i.e. when the user cannot adapt easily to the situation. Non-usual weather conditions have been reported to reduce bicycle use by as much as 30% (Dill and Voros, 2007; Nankervis, 1999; Shiva Nagendra and Khare, 2003). Another environmental aspect is ***topography***, which has a clear influence on bicycle use, noting that maximum gradient seems more relevant than average gradient (Menghini et al., 2010). Nevertheless, there are some towns with adverse topography that exhibit a high modal share in favour of bicycles (Cervero and Duncan, 2003; Parki et al., 2008; Stinson and Bhat, 2003). The ***urban form*** and the urban design of spaces can directly affect bicycle use; in particular, a dense urban development mixing different activities and uses favours cyclist mobility (Kemperman and Timmermans, 2009; Zahran et al., 2008). We call *urban form* those factors which create this favourable conditions or better environment for cycling.

c. *Structural factors* have always been highlighted as those *relating to a city's adaptation* to bicycle use. The existence of a ***bicycle network*** encourages bicycle use (Hunt and Abraham, 2007; Titze et al., 2008) although its importance decreases depending on the users' cycling experience (Broach et al., 2012; Taylor and Mahmassani, 1996). It is worth highlighting that a network alone is insufficient, as it must also be well designed (Carré, 1999; Cour Lund, 2009; McClintock and Cleary, 1996) and with an overall connectivity (Ehrgott et al., 2012). Aside from the network itself, ***safe parking*** areas and lockers appear to be relevant, as well as ***additional facilities*** on site, such as showers and dressing rooms (Hunt and Abraham, 2007; Taylor and Mahmassani, 1996).
d. *Subjective factors* explicitly identified by the users. Riding a bike is perceived as dangerous in certain environments. This, however, is a factor that could be captured by means of objective indices as traffic speed and accident rates (Molino and Emo, 2009; Natarajan and Demetsky, 2009; Noland and Quddus, 2004). However, ***Perception of risk*** is a subjective matter that not always is correlated with actual risk. Real or not, perceived risk is a determining factor in relation to bicycle use (Hopkinson and Wardman, 1996; Noland and Kunreuther, 1995; Rietveld and Daniel, 2004). Other declared subjective factor that affects the convenience of using bike is the ***exercise opportunity*** for busy people (Bergström and Magnusson, 2003).

3. *Latent variables* are aimed at understanding the perception of those subjective factors that are not explicitly identified by the users but are suspected to have an influence on choice and, therefore, should be explored with alternative methods. They can be grouped into concepts that contribute to capture the intention of using the bike: the *latent variables*. Li et al. (2013) advances on this line by using the approach of attitudinal market segmentation; they identify six latent variables related to the perception towards bicycling: need for flexibility, sensitivity to time, need for fixed schedule, desire for comfort, desire for economy and environmental awareness.

The role of perceptions within the described framework can be seen in Fig. 1.

2. Case study and survey procedure

2.1. Case study

Ciudad Universitaria in Madrid is a campus that hosts 3 Universities with a total of 144 centres and an associated population of 112,871 individuals. In the last years car use has increased causing serious problems with the organization of public

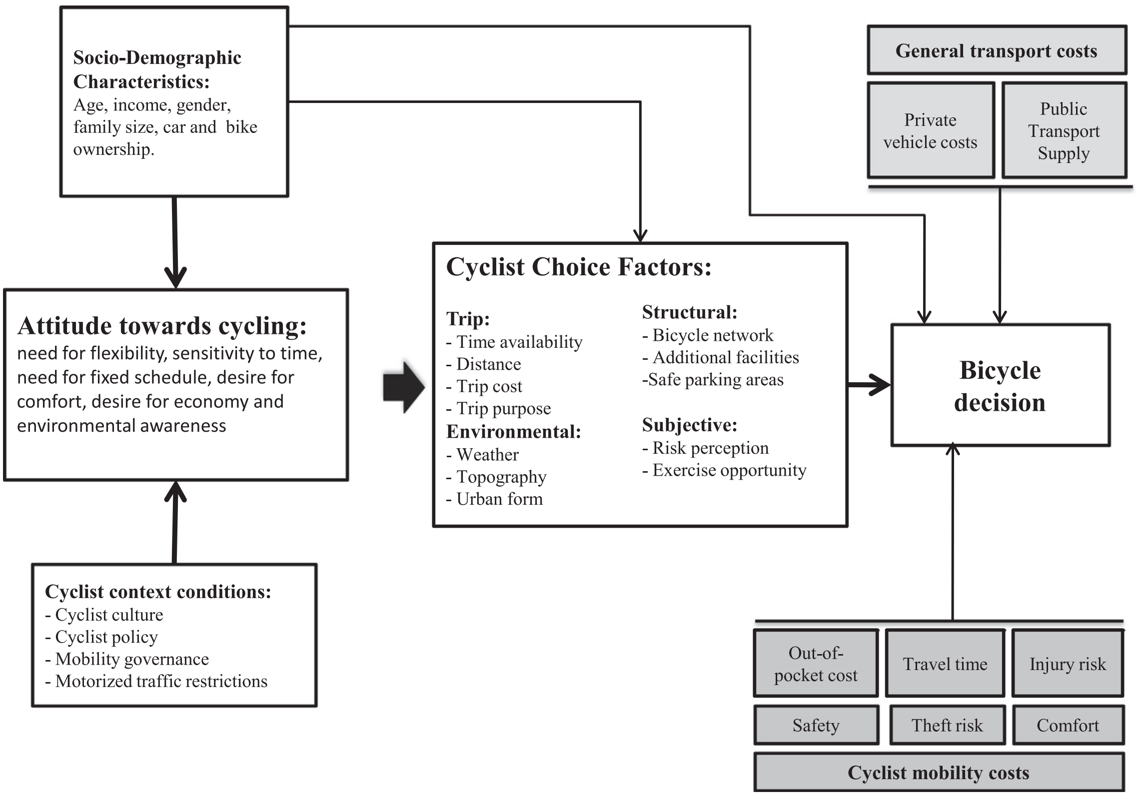

Fig. 1. Conceptual model of factors affecting bicycle use.

spaces. Authorities are considering different actions to recover the campus as a more liveable area. One of these initiatives is to facilitate the use of the bicycle with the UNIBICI project. At present, bicycle is a marginal mode of transport both in the university campus as well as in Madrid itself. To access Ciudad Universitaria, presently 42% of the individuals travel by metro, 26% by car, 16% by bus, 12% by foot and 4% ride their own bike. 78% of the journeys mentioned include a final stage which is made by foot, which shows that walking is the dominant mode in local displacements inside the campus, involving 81% of the trips.

Bicycles can travel across campus routes not covered by public transport. The UNIBICI project consists of bicycle hire system for use within Ciudad Universitaria, aimed at complementing the transport network by connecting its main nodal points with the final destinations. The project consists of a public bike system to be use inside the campus, either for internal movements or as the last stage of the access trip, particularly for those arriving by public transport which is the majority. For the case of internal trips all users could be potential users of this system. Consequently it extends the accessibility of public transport modes and also offers a new and ideal mode of transport for internal mobility, simultaneously rehabilitating communal spaces. The system proposed is a fourth generation, completely automatic, public bicycle system.

The environmental conditions in Ciudad Universitaria can be considered favourable for bicycles: Mediterranean climate, relatively flat and high quality landscape with some isolated slopes.

2.2. Survey procedure: design and participants

The survey was designed to investigate the relationships between the factors and the users' subjective evaluations. The first phase of the design involved two *focus groups* (students and workers) including people who presently use bicycles in *Ciudad Universitaria*. These focus groups helped detecting significant variables and they were instrumental to find out about the true requirements of the potential bicycle users on campus. Using this information plus the antecedents coming from the literature, a questionnaire was prepared, which was tested by conducting a face-to-face pilot survey to 233 users at different locations within Ciudad Universitaria. Lastly, the definitive questionnaire was prepared including four fundamental sections: socio-demographic information, mobility, bicycle use combined with the *perception questionnaire* of different factors and willingness to use the future UNIBICI system in various scenarios.

The *perception questionnaire* covered questions about the factors that promote bicycle use and about the factors that inhibit bicycle use. Respondents were asked to rate each attribute in isolation. The questions in each case were:

- promote bicycle use: "*Assess the reasons that led you to not use the bike or use less than desired*".
- inhibit bicycle use: "*How do you value this factor when you decide whether to use the bicycle as a mode of transport?*"

Both used a *Likert scale* graded in a numeric and semantic way: 1 (no important), 2(very little important), 3 (little important), 4(some important), 5 (very important) and 6(fundamental).

The survey was conducted online from April to July 2008. To contact the target population, an e-mail was sent to the accounts provided by the different universities on campus. As a reward, and to encourage participation in the survey, approximately 1000 reflective bands were delivered and a prize of ten foldable bicycles was offered. Total respondents ascended to 3908 but only 78% completed the questionnaire such that the final (representative sample was of 3048 people). Note that this rejection rate is usual in online surveys (Dixon and Turner, 2007). For a 95% confidence interval, the sampling error was 1.78%.

Some 76% of people accessing the campus on a daily basis were students, the remainder were university staff. The number of people surveyed that had a job was 57%, and 70% of people surveyed had higher education qualifications (many part time students combine work and study). 74% of those surveyed stated that they would be willing to use the UNIBICI system and half of these said they would do so on a regular basis.

2.3. Selection of the psycho-social factors influencing bicycle use selection

The first stage of this analysis involved the study of all of the psycho-social factors that could influence bicycle use. The *a priori* selection of the most important psycho-social factors was extracted from the literature summarized in the introduction, especially those related with subjective factors or the perception of the importance of trip, environmental and structural factors. In order to complete and to check the pre-selection two focal groups were carried out. Finally a group of 14 factors were selected. These were the ones presented for assessment to the individuals in the survey.

Factors related to bicycle use used can be classified in terms of whether they are perceived as a barrier or as an incentive to bicycle use (Titze et al., 2008). We started from the classification showed in Fig. 1:

- Factors that promote bicycle use are:
  - *Efficiency*: avoids traffic problems such as traffic jams, easy to park, enables door to door transport and is competitive with other modes of transport over certain distances.
  - *Flexibility*: no time or frequency restrictions.
  - *Economical*: no fuel expenses, the purchase and maintenance of the bicycle are economical.
  - *Ecological*: does not emit pollutants or greenhouse gases, hardly makes any noise and takes up little space.

  - *Healthy*: it is an active mode of transport that encourages people to exercise.
  - *Fun*: some users take pleasure in riding a bicycle.

- Factors that inhibit bicycle use are:
  - *Distance*: distances to be travelled if they are too long.
  - *Danger*: perception of risk in relation to accidents or falls.
  - *Orography*: mountainous or hilly topography.
  - *Fitness*: poor physical condition.
  - *Climate*: weather limitations such as rain, wind, low or high temperatures.
  - *Vandalism*: fear of the bicycle being stolen.
  - *Facilities*: need for complementary facilities for personal hygiene, bicycle parking area at the destination point, to keep the bicycle at home, etc.
  - *Comfort*: not as comfortable as other modes of transport.

The existence of cycling infrastructures has not been included as a factor because, although it is believed that it plays a subjective role that would fit in this analysis, it is captured under the perception of risk factor.

3. Analytical method, results and discussion

3.1. Evaluation of the psycho-social factors by the respondents

An exploratory factor analysis has to be performed to observe how variables group together and to detect possible existing latent variables. Then a confirmatory factor analysis should be undertaken to validate the results, checking the groups of indicators and the detected latent variables against the hypothesis of their contribution to the explanation of behaviour. Lastly, a structural model can be formulated and estimated based on that results using Lisrel software.

Table 1 shows the evaluation of the factors from the survey, based on the questions presented in Section 2.3. The importance given to the factors that promote bike use is, in general, greater than that given to those that inhibit its use. The factors considered most important are efficiency and the ecological aspect. The most noteworthy amongst the barriers to bicycle use are the importance given to the need for complementary facilities and the perception of danger. Factors do not seem to be correlated regarding the respondents' assessments. Frequency of use has been added (final row) for reasons that will show up later on.

3.2. Identification of latent variables

When working with psycho-social information, subjective evaluations and attitudes towards specific situations are far from the field of the objective variables known by modellers (Li et al., 2013). Consequently they are not in the field in which the theory of discrete choice models is a powerful tool (Fujii and Gärling, 2003; Golob, 2001; Pendleton and Shonkwiler, 2001; Vredin Johansson et al., 2006). As a result, we have preferred to use the structural equation modelling approach, to capture the underlying perceptions (Goldberguer and Duncan, 1973). This technique enabled an analysis that deals with how our factors are grouped, how they interrelate and the existence of latent variables underlying their structure (Golob, 2003).

Exploratory factor analysis (Bollen, 1989; Spearman, 1904) helps determining which indicators contribute towards the measurement of each latent variable. It is also useful for eliminating those indicators that do not contribute to the estimation of the latent variables. The first outcome from this analysis showed no clear structure among indicators, so we examined the responses according to cycling experience considering frequency and type of use. Regarding frequency, we grouped those individuals that did not have a bicycle, did not know how to ride one or were not interested in cycling (*never*), those that used the bike less than four times per week (*occasional*), and those that used it more than four times a week (*habitual*). We use the F of Snedecor test in an ANOVA analysis to check that there were statistically significantly different across the groups. Results in Table 2 show a difference between the idea of riding a bicycle – which produces a diversity of expectations – and the reality of those that do ride a bicycle (analyzed in detail in Rondinella et al., 2012). For example, users that frequently ride a bicycle place greater importance on factors such as efficiency, flexibility or the fun aspect and minimize the importance of factors such as perceived risk. Frequent users also place much less importance on the barriers identified as crucial by infrequent and non-users. Differences according to type of use can also be verified, as users that ride a bicycle for sport assign greater importance to negative factors such as the need for complementary facilities or fear that the bicycle could be stolen, in comparison to people who use bicycle as their usual mode of transport (Gatersleben and Appleton, 2007).

After filtering out responses from the 493 individuals who did not know how to ride a bike, a clear structure was found regarding the perception of factors within the remaining 2555 persons. This confirms that there is a significant difference in attitudes towards the bicycle between those who sometimes use a bicycle and those who never do (Rondinella et al., 2012). The best adjustments were achieved by considering four latent variables. The grouping of indicators into latent variables was statistically supported (as shown in Table 3) and intuitively appealing, which made it possible to validate the structure and to define a meaning for the latent variables found, as we now explain.

Table 1
Importance of the factors and correlations among them. 1 (not important), 2 (very little importance), 3 (little importance), 4 (moderate importance), 5 (very important) and 6 (essential).

	Efficiency	Flexibility	Economical	Ecological	Healthy	Fun	Distance	Danger	Orography	Fitness	Climate	Vandalism	Facilities	Comfort
Mean	5.08	4.87	4.77	5.15	4.89	4.13	3.61	4.09	3.42	2.46	3.63	3.32	4.43	3.18
Median	5.00	5.00	5.00	5.00	5.00	4.00	4.00	4.00	4.00	2.00	4.00	3.00	5.00	3.00
Mode	5.00	5.00	5.00	6.00	5.00	4.00	6.00	6.00	4.00	1.00	4.00	4.00	6.00	3.00
Standard deviation	0.95	1.07	1.20	1.04	0.97	1.29	1.81	1.65	1.54	1.43	1.43	1.58	1.50	1.55
Correlations														
Efficiency	1.00													
Flexibility	**0.62**	1.00												
Economical	**0.44**	**0.51**	1.00											
Ecological	**0.37**	**0.37**	**0.50**	1.00										
Healthy	0.26	0.27	**0.35**	**0.49**	1.00									
Fun	**0.31**	**0.33**	0.26	0.28	**0.44**	1.00								
Distance	−0.15	−0.10	−0.04	−0.04	−0.07	−0.17	1.00							
Danger	−0.08	−0.07	−0.06	0.01	0.01	−0.07	0.12	1.00						
Orography	−0.17	−0.09	−0.07	−0.04	−0.06	−0.17	**0.41**	**0.32**	1.00					
Fitness	−0.22	−0.15	−0.09	0.00	−0.04	−0.18	**0.33**	0.24	**0.48**	1.00				
Climate	−0.10	−0.08	−0.03	−0.07	−0.04	−0.12	0.26	0.16	**0.32**	**0.37**	1.00			
Vandalism	0.05	0.08	0.08	0.02	0.06	0.08	0.00	0.09	0.04	0.04	0.17	1.00		
Facilities	0.11	0.11	0.10	0.07	0.06	0.03	0.02	0.12	0.08	0.04	0.12	**0.42**	1.00	
Comfort	**−0.32**	−0.26	−0.19	−0.14	−0.14	**−0.29**	**0.37**	0.14	**0.35**	**0.36**	0.28	0.00	0.03	1.00
Frequency of use	0.19	0.15	0.07	0.03	0.08	**0.28**	−0.13	−0.10	−0.17	−0.18	0.06	0.08	0.02	−0.25

Statically significant correlations in bold letters.

Table 2
Importance assigned to different factors depending on frequency and type of use (1–6 scale).

	Never (55%)	Occasional (30%)	Habitual (15%)
Frequency of use			
Efficiency	5.0	5.1	5.5
Flexibility	4.8	4.9	5.3
Danger	4.2	4.1	3.7
Fun	3.9	4.3	4.9
	Commuter	Leisure	Sport
Type of use			
Vandalism	3.4	3.3	3.6
Facilities	4.3	4.5	4.7

Table 3
Results from the exploratory analysis.

Exploratory analysis Latent variables												
Endogenous variables	Convenience			Pro-bike			External restrictions			Physical determinants		
Measurement equations												
Efficiency	0.83	*	$R2 = 0.69$									
Flexibility	0.87	(25.77)	$R2 = 0.76$									
Economical				0.78	(19.44)	$R2 = 0.61$						
Ecological				0.74	(21.17)	$R2 = 0.54$						
Healthy				0.68	*	$R2 = 0.42$						
Fun				0.570	(19.04)	$R2 = 0.33$						
Facilities							0.33	(9.25)	$R2 = 0.12$			
Danger							0.66	*	$R2 = 0.44$			
Vandalism							0.82	(8.05)	$R2 = 0.67$			
Fitness										0.60	*	$R2 = 0.36$
Orography										0.76	(4.43)	$R2 = 0.58$

- *Convenience*: measures the practical nature of bicycle as a mode of transport. This latent variable is related to efficiency and flexibility.
- *Pro-bike*: set of characteristics and factors intrinsic to the bicycle which make it an attractive mode of transport. Its indicators related to the fact that it is economical, fun, healthy and ecological.
- *External restrictions*: importance of factors that restrict bicycle use and that are not under the users' control. This variable is related to the aspect of danger perception, vandalism and available facilities.
- *Physical determinants*: measures the impedance to use of the bicycle because it is not motorized. This variable is related to the physical fitness of the user and to orography.

During the process of identification of latent variables and their association with indicators, some were eliminated because they did not add explanatory power to the structure of the factors studied; these indicators were distance, climate and comfort. These results are similar to those obtained by Li et al. (2013), where flexibility and efficiency (convenience), economical, environmental awareness or ecological (pro-bike) also appeared as indicators of the attitude towards the use of the bike. Our biggest difference with the study of Li et al. (2013) is that we have modelled factors also perceived as barriers to use.

3.3. Model of relationship between latent variables and cycling behaviour

The next step is to verify the results of the exploratory analysis by means of a Confirmatory Factor Analysis (Jöreskog, 1969). This type of analysis provides an assessment model of latent variables based on the indicators and relate them with an observed measure of what is being explained, which in this case is frequency of use of the bicycle. This was directly asked to respondents in the survey using six alternatives: never, once a month, several times a month, once a week, several times a week or daily.

The difference between what we measure with our four latent variables in the model and actual behaviour is synthesized with the use of a concept that we can call **intention** or willingness to use; as one potential latent variable (pro-bike) actually reinforces another one (convenience), below we show that intention represents three latent variables. The error between our measure of the intention by means of the latent variables and the real use in the model represented by frequency is the difference between intention and behaviour according to Ajzen (1991). Thus, only 54% of users with a modelled intention of using the bicycle finally used it frequently in our study.

We assessed the goodness of fit of the model using the chi-square test, the root-mean-square-error of approximation (RMSEA), the comparative fit index (CFI) and the adjusted goodness-of-fit index (AGFI). The indexes were computed using the program LISREL 8.80. The value of chi-square is 379.88 with p-value <0.01. Besides, RMSEA = 0.0743, less than 0.08 and within the 90% confidence interval; CFI = 0.955, GFI = 0.971 and AGFI = 0.953 are larger than 0.090. On the basis of these criteria, the model fits the data properly and we can conclude that the model meets our expectations regarding statistical adequacy.

Table 4 shows the coefficients of determination and the relationships of the structural model. The results highlight that the *pro-bike* latent variable explains 76% of the variance of the economical indicator of the bicycle, 70% of its ecological aspect, 62% of its healthy aspect and 60% of the fun aspect. In addition, 85% of the variance in the efficiency indicator and 88% of the flexibility indicator are explained by the *convenience* latent variable. The *external restrictions variable* explains 36% of the variance of need for facilities, 69% of danger, and 77% of vandalism. Lastly, 60% of physical fitness and 76% of orography are explained by the *physical restrictions* variable.

The structure of the model is made of four latent variables and *intention* as shown in Fig. 2: *convenience* (that includes *pro-bike*), *external restrictions* and *physical determinants*. Indicators associated to the *pro-bike* latent variable include the fact that riding a bicycle is *economical*, *fun*, *healthy* and *ecological*. As regards the *convenience* variable, *efficiency* and *flexibility* are the factors behind it, as well as the *pro-bike* variable which explains 77% of its variance. The indicators of *external restrictions*

Table 4
Results from the *bicycle intention use SEM*.

Final results SEM Latent variables												
Endogenous variables	Convenience			Pro-bike			External restrictions			Physical determinants		
Measurement equations												
Efficiency	0.845	*	$R2 = 0.71$									
Flexibility	0.878	(19.36)	$R2 = 0.77$									
Economical				0.757	(18.18)	$R2 = 0.57$						
Ecological				0.697	(20.19)	$R2 = 0.49$						
Healthy				0.617	*	$R2 = 0.38$						
Fun				0.602	(19.43)	$R2 = 0.36$						
Facilities							0.36	(9.18)	$R2 = 0.13$			
Danger							0.69	*	$R2 = 0.48$			
Vandalism							0.77	(12.02)	$R2 = 0.60$			
Fitness										0.596	*	$R2 = 0.36$
Orography										0.764	(4.09)	$R2 = 0.58$
Structural equations												
Convenience				0.772	(14.87)	$R2 = 0.60$						
Intention	0.543	(5.94)	$R2 = 0.88$				0.75	(9.37)	$R2 = 0.88$	0.138	(1.81)	$R2 = 0.88$

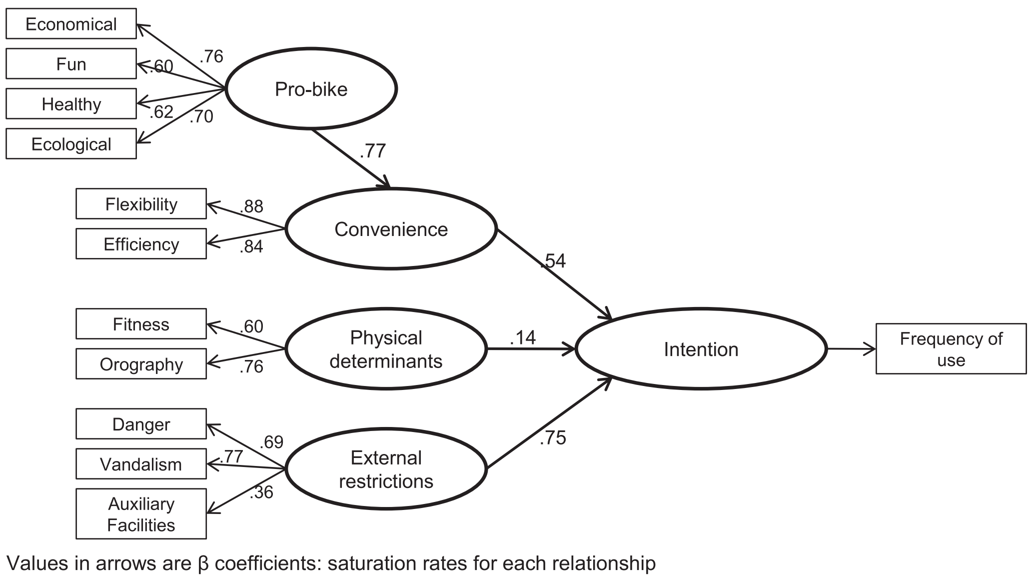

Fig. 2. Path diagram of the proposed model to explain the use of bicycle as a function of latent variables (circles) and their indicators (boxes).

include the aspect of *danger, vandalism* and *needed facilities*. Indicators of *physical restrictions* include the *physical condition of the user* and *orography*. Lastly, *convenience*, *external restrictions* and *physical restrictions* explain 85% of the *intention* measured based on *frequency of use*. *External restrictions* have higher explanatory value on behaviour ($\beta = 0.75$) than *convenience* ($\beta = 0.54$), while *physical restrictions* appear to have a rather low impact ($\beta = 0.14$).

The structure presented herein shows that the positive indicators associated with the bicycle show up through two latent variables: *convenience* and *pro-bike*. The former is linked to indicators that make cycling a competitive mode of transport. The *pro-bike* encompasses indicators related to the pleasure of riding a bike that have an indirect influence on user behaviour through the *convenience* variable. In other words, the model structure indicates that users take their decisions based on the *convenience* variable, which is reinforced by the *pro-bike* aspects. The β coefficients of the model allow us to calculate such indirect influence of the pro-bike variable over behaviour (intention) by using the importance placed on convenience: $\beta = 0.77 \times 0.54 = 0.41$. This means that the influence of *pro-bike* indicators are greater than those associated to *physical determinants* ($\beta = 0.14$). On the other hand, all of them are less influential than *external restrictions* ($\beta = 0.75$).

Results indicate that users assign less importance to those barriers that they can overcome – like *physical determinants* – than to the *external restrictions*, that are out of their control. Consequently, physical indicators have the lowest influence on users' behaviour. This can be explained by their capacity to adapt to these restrictions unilaterally. These results provide the elements to design adequate policies to encourage cycling in cities.

4. Synthesis and conclusions

We have used a large university survey collected in a Spanish campus and designed *ad hoc* to study the psycho-social factors that make the bicycle eligible as a modal alternative. After identifying fourteen factors a structural equations model was estimated to find structure and relationships among variables and to understand users' intentions to use the bike. After finding that experience (frequency and type of use) made a difference, four (latent) variables were identified, namely convenience, pro-bike, physical determinants and exogenous restrictions. The main conclusion is that convenience (flexible, efficient) and exogenous restrictions (danger, vandalism, facilities) are the most important elements to understand the attitudes towards the bicycle. Let us summarize each of these findings and associated policy implications.

4.1. Experience

In our study, there is a clear difference between the perceptions of users that have cycling experience and those that do not have the habit of riding a bicycle (Rondinella et al., 2012; Gatersleben and Appleton, 2007). An adequate direction to follow should involve measures that allow people to experience cycling in real situations (Broach et al., 2012). Policies to promote public-bicycle schemes using monitors and lending bicycles services could serve to this end.

4.2. Latent variables' structure

The model outputs show that there are differences in factors related to bicycle use. On the one hand, users differentiate factors that are perceived as barriers, which could be under their control (*physical determinants*) or not (*external restrictions*). On the other hand, factors which encourage bicycle use are perceived as positive by users (*convenience*). Behind convenience there are some positive factors of bike-use (*pro-bike*) that are not directly related to choosing bikes as transport mode, but they are indeed important to reinforce the image of convenience.

4.3. External restrictions

External restrictions (danger, vandalism and auxiliary facilities) are perceived as quite important by users. Transport planners should pay attention to eliminate this kind of barriers. This perception of safety coincides with the findings by Rietveld and Daniel (2004) and Broach et al. (2012). Regarding vandalism, convenient places to leave the bicycles should be considered. Complementary facilities are not that important, but are very positively evaluated by experimented cyclists: lockers, changing rooms, showers at destination, covered places to leave bikes, space and tools for repair, etc.

4.4. Physical determinants

Physical determinants are not perceived as very important by bicycle users. These factors are highly subjective and have the common characteristic that they are under cyclists' control so they can be changed by training or better bicycles. Only old people or with individuals with mobility restrictions see this factor as a real barrier.

4.5. Convenience and pro-bike

The idea of convenience is related to the idea of an efficient transport mode from many viewpoints: fun, environmentally friendly, healthy; also fast and cheap in medium-distance trips. The more these characteristics are perceived by the cyclist with the use, the more important convenience becomes to explain their decisions. Sustainable policies should be oriented to highlight these aspects of cycling mobility, showing the bicycle as a competitive transport mode for many types of trips.

On the basis of the previous findings we can suggest some additional policy recommendations for the University campus managers. The first would be to reorganize land uses in the campus, giving priority to bikers and pedestrians instead to cars. That means a clear preference for direct bike itineraries and the installation of safe parking lots closer to metro stations and the main entrance of the buildings. Cycling should be promoted as sustainable and healthy mode of transport through university media, and recommended as an access mode to reach university facilities.

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