Understanding Cyclists’ perceptions, keys for a successful bicycle promotion

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ABSTRACT

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 external limitations. The main conclusion is that convenience and external restrictions are the most important elements to understand the attitudes towards the bicycle.

1. INTRODUCTION

Cycling is increasingly recognised 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 could replace motorized vehicle trips with all its 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 Health Organization, 2009). Cycling do not solve all of them but is called to be a transport mode producing healthy effects through physical activity and reducing harmful 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 usually focused on transport demand management and on factors affecting bicycle use (Pucher et al. 2010). The scientific literature regarding these factors include either qualitative analyses, where bike factors (identified a priori) are assessed, or discrete choice models estimated to predict users’ choice. Both research lines provide important insights into cyclist behaviour. Transportation planning efforts at all levels nowadays include increasing the levels of walking and bicycling. As Krizek (2007) points out those initiatives are motivated by a desire to reduce auto use and its negative environmental 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 – as cost and time – do not play a very important role regarding bicycles use may indicate that these other kinds of factors of a psycho-social type gain importance in the correct characterisation of cyclist behaviour (Eash, 1999; Pinjari, et al, 2008; de Bruijn et al. 2005; Eriksson and Forward, 2011). It could be said that the part of the black box of behaviour that the models do not cover 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 and incorporate such factors is needed to improve our understanding of bike users’ perceptions and to increase the explanatory power of models. 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. 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). Let us see all these in some 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 motorised transport below certain distances (Hunt and Abraham, 2007). However, in most urban areas this does not translates 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. Thus, non-usual weather conditions can cause a reduction in bicycle use by a 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, Matthias, 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 Figure 1.
2. CASE STUDY AND SURVEY PROCEDURE

2.1 Case study

_Ciudad Universitaria_ in Madrid is a campus with a total of 144 centres and an associated population of 112,871 people. At present, this campus is threatened by mobility due to the increasingly intensive use of cars and an inadequate organization of its spaces. Authorities are considering different actions to recover the campus as a 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, 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
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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. 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 values the next factor in your willingness 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 1,000 reflective bands were delivered and a prize of ten foldable bicycles was offered.

Total respondents ascended to 3,908 but only 78% completed the questionnaire. The final representative sample gathered comprised 3,048 people. For a 95% confidence interval, the sampling error was 1.78% considering the most unfavourable assumption of maximum indeterminacy.

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 (there are an important number of part time students who 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 figure 1:

- **Factors that promote bicycle use used 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 used 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. 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.

Table 1: Importance of the factors and correlations among them

<table>
<thead>
<tr>
<th></th>
<th>Efficiency</th>
<th>Flexibility</th>
<th>Economical</th>
<th>Ecological</th>
<th>Healthy</th>
<th>Fun</th>
<th>Distance</th>
<th>Danger</th>
<th>Orography</th>
<th>Fitness</th>
<th>Climate</th>
<th>Vandalism</th>
<th>Facilities</th>
<th>Comfort</th>
<th>Frequency of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>5.08</td>
<td>4.87</td>
<td>4.77</td>
<td>5.15</td>
<td>4.89</td>
<td>4.13</td>
<td>3.61</td>
<td>4.69</td>
<td>3.42</td>
<td>2.46</td>
<td>3.63</td>
<td>3.32</td>
<td>4.43</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>median</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>5.00</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>mode</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>6.00</td>
<td>5.00</td>
<td>4.00</td>
<td>6.00</td>
<td>6.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>6.00</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>standard deviation</td>
<td>0.95</td>
<td>1.07</td>
<td>1.20</td>
<td>1.04</td>
<td>0.97</td>
<td>1.29</td>
<td>1.81</td>
<td>1.65</td>
<td>1.54</td>
<td>1.43</td>
<td>1.43</td>
<td>1.58</td>
<td>1.50</td>
<td>1.55</td>
<td></td>
</tr>
</tbody>
</table>

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 (Goldberger 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) allows us to determine 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 (frequency and type of use), grouping those individuals that did not have a bicycle, did not know how to ride one or were not interested in cycling. Results in Table 2 show a substantial distance between the idea of riding a bicycle - which produces a diversity of expectations - and the reality of those that do ride a bicycle, whose perceptions do respond to a verifiable common system. For example, users that frequently ride a bicycle place greater importance on factors such as efficiency, flexibility or the fun aspect and minimise the importance of factors such as perceived risk. 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 had no cycling experience a clear structure was found regarding the perception of factors within the remaining 2,555 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.

- **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 motorised. This variable is related to the physical fitness of the user and to orography.

### Table 3: Results from the exploratory analysis

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>Convenience</th>
<th>Pro-bike</th>
<th>External restrictions</th>
<th>Physical Determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.83</td>
<td></td>
<td>R2=0.69</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.87</td>
<td>(25.77)</td>
<td>R2=0.76</td>
<td></td>
</tr>
<tr>
<td>Economical</td>
<td>0.78</td>
<td>(19.44)</td>
<td>R2=0.61</td>
<td></td>
</tr>
<tr>
<td>Ecological</td>
<td>0.74</td>
<td>(21.17)</td>
<td>R2=0.54</td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>0.68</td>
<td>*</td>
<td>R2=0.42</td>
<td></td>
</tr>
<tr>
<td>Fun</td>
<td>0.570</td>
<td>(19.04)</td>
<td>R2=0.33</td>
<td></td>
</tr>
<tr>
<td>Facilities</td>
<td>0.33</td>
<td></td>
<td>(9.25) R2=0.12</td>
<td></td>
</tr>
<tr>
<td>Danger</td>
<td>0.66</td>
<td>*</td>
<td>R2=0.44</td>
<td></td>
</tr>
<tr>
<td>Vandalism</td>
<td>0.82</td>
<td>(8.05)</td>
<td>R2=0.67</td>
<td></td>
</tr>
<tr>
<td>Fitness</td>
<td>0.60</td>
<td>*</td>
<td>R2=0.36</td>
<td></td>
</tr>
<tr>
<td>Orography</td>
<td>0.76</td>
<td>(4.43)</td>
<td>R2=0.58</td>
<td></td>
</tr>
</tbody>
</table>

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.

Table 4: Results from the bicycle intention use SEM

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>Convenience</th>
<th>Pro-bike</th>
<th>External restrictions</th>
<th>Physical Determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>0.845</td>
<td>*</td>
<td>R²=0.71</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.878</td>
<td>(19.36)</td>
<td>R²=0.77</td>
<td></td>
</tr>
<tr>
<td>Economical</td>
<td>0.757</td>
<td>(18.18)</td>
<td>R²=0.57</td>
<td></td>
</tr>
<tr>
<td>Ecological</td>
<td>0.697</td>
<td>(20.19)</td>
<td>R²=0.49</td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>0.617</td>
<td>*</td>
<td>R²=0.38</td>
<td></td>
</tr>
<tr>
<td>Fun</td>
<td>0.602</td>
<td>(19.43)</td>
<td>R²=0.36</td>
<td></td>
</tr>
<tr>
<td>Facilities</td>
<td>0.36</td>
<td>(9.18)</td>
<td>R²=0.13</td>
<td></td>
</tr>
<tr>
<td>Danger</td>
<td>0.69</td>
<td>*</td>
<td>R²=0.48</td>
<td></td>
</tr>
<tr>
<td>Vandalism</td>
<td>0.77</td>
<td>(12.02)</td>
<td>R²=0.60</td>
<td></td>
</tr>
<tr>
<td>Forma</td>
<td>0.596</td>
<td>*</td>
<td>R²=0.36</td>
<td></td>
</tr>
<tr>
<td>Oography</td>
<td>0.764</td>
<td>(4.09)</td>
<td>R²=0.58</td>
<td></td>
</tr>
</tbody>
</table>

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 Figure 2: convenience, 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 include the aspect of danger, vandalism, needed facilities and climate. 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 (β=0.75) than convenience (β=0.54), while physical restrictions appear to have a rather low impact (β=0.14).

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

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 includes indicators related to the pleasure of riding a bike, which have not direct influence on user behaviour, but they complement the importance given to 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: β=0.77 x 0.54=0.41. This means that the influence of pro-bike indicators are greater than those associated to physical determinants (β=0.14). On the other hand, all of them are less influential than external restrictions (β=0.75).

This logic indicates that users assign less importance to barriers that they can overcome like physical determinants than to the external restrictions that are out of their control. Consequently, the importance that the user places on physical indicators has the least influence on his/her behaviour. This can be explained by the user’s capacity to adapt to these restrictions of their own accord. These results provide a hint to perform adequate policies to encourage cycling in cities.
4. CONCLUSIONS

We have used rich detailed data collected in a Spanish university campus to study the presence of latent variables that contribute to capture cyclists’ perceptions. We conclude that this approach requires the inclusion of individual experience and that there are three latent variables that summarize well these perceptions: convenience, physical determinants and external restrictions. Another latent variable, pro-bike, helps us better understand and measure the variable of convenience in a better way. Let us summarize each of these findings.

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). This result is according with previous results of other authors: the diversity of inexperienced users’ evaluations corresponds to assessments of something that is unknown to them, and it contrasts with the clear data structure shown by experienced users (Gatersleben and Appleton 2007). This leads us to reflect upon the direction that policies geared towards promoting bicycle use in the campus should take. It seems logical that 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 and lending bicycles services could serve to this end.

Latent variables’ structure
The model outputs show that there are differences in factors related to bicycle use. These differences relate directly to user behaviour. On the one hand, users differentiate factors that are perceived as barriers. Within these, they also differentiate between barriers that are under their control (physical determinants) from those that depend on the external actions (external restrictions). On the other hand, factors which encourage bicycle use are perceived as positive by users (convenience and pro-bike). The value of the indicators corresponds to real user behaviour. There are positive factors of bike-use (pro-bike) that are not directly related to choosing cycling as transport mode, but they have a great importance reinforce the image of convenience. Policies recommending bicycle use for better health, for preserving environment and just for fun and better social atmosphere would have clear positive effects.

External restrictions
External restrictions are perceived as much more determinant for users. Therefore, cycling oriented mobility policies can change the conditions and have an important role for promoting bicycle use. Transport planners should pay attention to eliminate this kind of barriers. Bike risk perception is referred as a very important factor in the literature (Rietveld and Daniel, 2004). Relating to the perception of risk associated to the bicycle use, our results show that safety is important for non-users and convenience is important for experienced users, according to Broach et al. (2012). So combining safety and convenience would encourage
non-users to consider the bicycle as an alternative and then, once they try on it, to keep on using it.

Vandalism is also an important external restriction. It is necessary to improve security with convenient places to leave the bicycles. The fear of bikes’ thefts is indeed a barrier for the users, higher for the inexperienced ones.

Complementary facilities are not that important, but are very positively evaluated by experimented cyclists: changing rooms or taking a shower at destination, cover places to leave bikes and lockers, possibility of repairing, etc.

**Physical determinants**

Physical determinants are not perceived as very important for the bicycle users. These factors are highly subjective and have the common characteristic that they are under cyclists’ control so they can be changed. People could overtake them with some training or better bicycles. Only elder people or with mobility’s restriction see this factor as a real barrier.

**Convenience and pro-bike**

The idea of convenience is related to the idea of an efficient transport mode. A convenience mode will be 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, recommended as an access mode to reach university facilities, particularly sports fields and libraries.

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REFERENCES


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