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Identification of factors that influence cyclists´ route choice

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Abstract

The objective of the research described in this paper was to evaluate the perception of a group of individuals with respect to factors that might influence their route choice. Data collection was carried out with 65 cyclists that use the bicycle for commuting in a medium-sized Brazilian city. A questionnaire was prepared in which eighteen factors and respondents asked to assess the importance of these factors for their route choice, on a 5-point scale ranging from "Very important" (coded as 1) and "Very Unimportant" (coded as 5). The final part of the questionnaire asked about the respondent's personal characteristics: gender, age, reason why they use the bicycle (work, school, leisure, other), frequency of cycling (a few days month, one day a week, two or three days a week, four or more days a week) and if they usually plan their route before leaving home. The results showed that the most important factors were: motor vehicle speed and number of trucks in the flow (both assessed as 5.0 – very important). Other important attributes were: volume of motor vehicles, security and street lighting (all with a 4.86 score). The least important factor was cycling on a one way street (3.29).

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Keywords: route choice; cyclists route choice

1. Introduction

The widespread use in automobiles in urban areas is causing serious transportation and quality of life problems, especially the deterioration of urban mobility and accessibility. In this context, the bicycle may be a very adequate option for a more sustainable urban mobility.

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Transportation planners and academic researchers are showing increasing interested in analyzing problems related to cycling and many municipal administrations are currently investing in cycle network projects.

One of the key information for the definition of a good cycle network is the routes that cyclists use and their reason for choosing these routes. From this knowledge, it is possible to design a cycling network that meets the desire lines of cyclists, prioritizing those roads with the most attractive features.

The conventional knowledge about route choice is not enough to deal with this problem because the characteristics of the bicycle are very different from the characteristics of a motor vehicle. The cyclist is influenced by factors such as the physical effort required to pedal, interaction with motor vehicles and the quality of the environment.

Many studies have been published concerning the importance of factors for bicycle route choice. However, these surveys were performed in foreign cities and may not be directly transferable to the Brazilian context. Specific studies are needed to understand the behavior of Brazilian cyclists and how they perceive the quality of the environment for cycling. Knowledge of the relative importance of the different factors will allow the estimation value of the trade-offs between them. For example, what additional distance a Brazilian rider is willing to travel to use a route with attributes considered of better quality. The results of this research can be used a basis for the evaluation and improvement of cycle networks, considering the preferences of current and potential users of these infrastructures.

2. Overview of factors that may affect cyclists´ route choice

The literature reveals a large set of factors that are relevant to the choice of routes by cyclists. Most of the researches where these factors were analysed aimed to develop route choice models in which the factors appeared as explanatory variables in the models.

The factors identified as the most relevant, may be grouped into five categories (Table 1).

Table 1. Factors that influence the choice of routes for cyclists

Group	Factors
Characteristics of the roads	Width / Number of traffic lanes
	Type and condition of pavement
	Gradient (slope) of the road
	Existence of infrastructure for cyclists
	Type of parking along the road
Characteristics of the traffic	Traffic volume and speed – Perception of safety
	Sharing the road with motor vehicles
	Functional classification of the road
Characteristics of the environment	Perception of security
	Adjacent land use
Characteristics of the trip	Length and duration
Characteristics of the route	Number of roundabouts and intersections
	Intersection signalization (stop signs and traffic lights)
	Physical barriers

2.1. Characteristics of the roads

- *Roadway width / Number of traffic lanes*

  Petritsch et al. (2006) and Shankwiler (2006) mention that the vast majority of cyclists prefer to cycle on streets with two lanes rather than pedaling on wider roads (with 4 lanes). According to these authors, on wider roads, the drivers tend to pay more attention to other vehicles than to cyclists, leaving them more exposed to accidents.

On the other hand, Hyodo et al. (2000) found in their study, that usually cyclists plan their trips by directing them to main streets, with several traffic lanes. The reason given by the authors is that the wider roads are better known by users, which facilitates the planning of their trips.

- *Pavement type and condition*

  According to Noland and Kunreuther (1995) the bad condition of the pavement on a road may be a major impediment for the cyclist to ride on it, because the lack of a suitable surface for cycling decreases the sense of security, forcing the cyclist to choose other routes. The study by Stinson and Bath (2004) concluded that cyclists avoid cycling on unpaved roads and prefer to use roads with paved and smooth surface. This study also reported that the pavement type and condition are more important for experienced cyclists because these users, according to the authors, are more able evaluate the quality of the pavement. Landis et al. (1997) argue that the pavement state of maintenance may significantly affect the evaluation of the quality of the road by cyclists, especially if the surface is bad condition.

- *Gradient (slope) of the road*

  The existence uphill stretches interfere in the choice of the route because it increases the effort required to pedal. Routes with severe slopes are often avoided by cyclists (Menghini et al, 2010 Rondinela et al, 2012). According to Stinson and Bhat (2005), tolerance with uphill stretches is directly related to the type of cyclist. These researchers found that the preference for flat roads is higher among non-experienced. The more experienced cyclists prefer to ride on roads with steep slopes, because these roads require a greater level of physical exercise. It is noteworthy that the text does not make clear which slope is considered severe. Sener et al (2009) used three categories of slope: flat terrain, some moderate slopes and slope and came to an interesting conclusion that bicyclists prefer routes with moderate slope. In the study by Broach et al. (2012) in Portland - Oregon, one of the attributes considered most important for cyclists route choice was the slope. The researchers found that some cyclists were willing to go 37% longer distances on a flat route to avoid slopes greater than 2%. Winters et al. (2010) claim that there is no consensus on the threshold above witch the slope is considered unsuitable for cycling, but in their study, this limit was considered to be 10%.

- *Existence of continuous road infrastructure for cyclists*

  One of the factors considered to be of prime importance in the choice of routes is the existence of cycling infrastructure (bike paths, bike lanes and bike routes). This urban infrastructure is considered by cyclists as essential for their safety and comfort (Sener et al, 2008; Menghini et al, 2010). Some researchers defined an order of preference for these types of infrastructure and, as expected, cyclists value the segregation from vehicular traffic, preferring: (1) bike paths, (2) bike lanes and (3) bike routes with signs warning for the presence of cyclists (Larsen and El-Geneidy, 2010, 2011; Winters et al, 2010; Hood et al, 2011; Broach et al, 2011). Besides the existence of infrastructure for cyclists, it is necessary that this infrastructure is continuous. Roads with uninterrupted cycling infrastructure are much more attractive to cyclists than roads with only a few stretches of bike lanes or bike paths. The continuity of the infrastructure is so important that interrupted bike paths or lanes are not used by most cyclists (Stinson and Bath, 2003). On the other hand, some studies have concluded that most bicycle users will not use the cycling infrastructure (even if it is very good), if this route implies a very large deviation from the shortest path between their points of origin and destination (Sykes and Driscoll, 1996; Aultman-Hall, 1997; Krizek et al, 2007; Dill, 2009). With respect to the rider profile, the results concerning the preferences for cycling infrastructures are contradictory. Larsen and El-Geneidy (2010) in a study conducted in Montreal, Canada, concluded that there is not a statistically significant difference between men and women with respect to preference for use of bike paths and lanes. In contrast, research by Garrard et al. (2008) in Melbourne, Australia, found that the percentage of women who prefer to use cycling infrastructure is statistically higher than that of men (50.7 % and 41.7 %, respectively). Winters et al. (2010) agree that the existence of segregated cycling infrastructure is more important for non-experienced cyclists.

- *Type of parking on the road (not allowed, in angle or parallel)*
  The influence of the type of parking in the choice of routes by cyclists was cited only in the works of Stinson and Bath (2004) and Sener et al (2008). For the first authors cyclists avoid riding on roads with parallel parking, because, in general, they fear the possibility of colliding with the suddenly opened door of a parked car. The research conducted by Sener et al (2008) just mentions that parking is an item that interferes directly on the choice of routes by cyclists.

2.2. Traffic characteristics

- *Traffic volume and speed*
  According to the literature, high volumes of traffic influence negatively on the choice of a road for cycling. Traffic volume is considered as a very important factor in route choice (EL GENEDY et al, 2007, SENER et al , 2008). Aultman-Hall et al (1997) and Winters et al (2010) concluded that bicycle users prefer roads with low traffic volume. However, it should be noted that this annoyance with the vehicle flow is inversely proportional to the rider experience. Experienced cyclists tend not to bother with the volume and speed of traffic sharing the road with them (HUNT and ABRANHAM, 2007). For Casello et al (2011) what really bothers cyclists is the behavior of drivers (respect to cyclists) and not the flow of vehicles. Several studies emphasize the relationship between speed and volume of motor vehicle traffic and the perceived risk of accidents (Winters et al, 2010; Heinen et al, 2011; Casello et al, 2011; Rondinela et al, 2012). Harvey et al (2008) mentioned cyclists are willing to travel longer distances if they feel safer. Broach et al (2012) found that even experienced riders prefer routes that reduce exposure to vehicular traffic. It should be emphasized that what is important is the perception of road safety and not actual the number of accidents that happen in the road (El-Geneigy, 2010).

- *Sharing the road with motor vehicles*
  Broach et al (2012) in a study conducted in Portland - Oregon, compared the preference of cyclists for bicycle paths or low traffic roads and concluded that both are equally attractive. On the other hand, Menghini et al (2010) found out that cyclists dislike sharing the road with motor vehicles and that some of them may increase the distance they have to travel up to four times to avoid high volume roads. Winters et al (2010) also concluded that cyclists opted for longer routes to avoid motor vehicle traffic.

- *Functional classification of the road (local, collector, arterial)*
  Snizek et al (2013) use the road hierarchy (arterial, collector or local roads) as a proxy for: volume and speed of traffic and the perception of safety that influence the route choice by cyclists.

2.3. Environmental characteristics

- *Perception of security (risk of being assaulted)*
  This item is not often mentioned as important for route choice. One of the few studies which cited the concern about a possible risk of robbery and physical assault was carried out by Sener et al (2008). Nonetheless, the result of this survey showed that only 20% of the cyclists were anxious about their personal safety while biking, and 78 % reported being anxious about traffic accidents. Street lighting is cited in some studies as essential to increase the sense of security for cyclists who cycle at night (MENGHINI et al, 2010).

- *Adjacent land use*
  Certain land uses may pose more potential problems to cyclists than others because they have differing amounts of intersections and types of motor vehicles associated with them. Some researchers have discussed the importance of adjacent land use for route choice, but this characteristic appeared to be the least important (Davis, 1995; Minnesota Department of Transportation, 1996).

2.4. Trip characteristics

- *Trip length (distance and duration)*
  Trip length is one of the attributes most often cited in the literature as a determinant for cyclists´ route choice (MENGHINI et al 2010; HEINEN et al, 2011; RONDINELA et al, 2012; BROACH et al 2012). Many studies compared the paths taken by cyclists with the shortest paths between his origin and destination. The percentage of trips made by the shortest path was different in the surveys conducted by Aultman-Hall (1997), Menghini et al (2010) and Winters et al (2010) (50%, 35% and 75%, respectively). The study by Winters et al (2010) found that cycle trips were around 10% longer than the shortest possible path. Heinen et al (2011) demonstrated that for trips of up to 15 km, the perception of distance is the most important factor for route choice. Tilahun et al (2007) and Hunt and Abraham (2007) concluded that the sensitivity to additional distances varies according to experience (more experienced cyclists are less willing to sacrifice their time in order to ride on more comfortable routes) and by gender (women are more sensitive to longer trips than men).

2.5. Characteristics of the route as a whole

- *Number of roundabouts and intersections*
  Roundabouts have always been regarded by cyclists as hazardous areas because they difficult their movement and demand additional struggle for space with other vehicles (MENGHINI et al, 2010). Regarding the number of intersections, Sener et al (2008) concluded that for many cyclists (mostly male and experienced) a large number of crossings has a negative influence on route choice (note that the authors do not mention what they consider to be a large number of intersections).

- *Intersections signalization (traffic lights and stop signs)*
  The studies that have addressed the influence of traffic lights on route choice attained conflicting results. Some concluded that these devices generate delays at intersections and may be considered as obstacles, especially for more experienced cyclists (STINSON and BATH, 2003; MENGHINI et al, 2010; FAJANS AND CURRY, 2001; BROACH et al, 2012). Fajans and Curry (2001) and Stinson and Bath (2004) describe the difficulty of cyclists in using routes with a large number of STOP signs. This type of sign requires the cyclists to stop and, shortly after, resume the trip, generating additional effort, especially on uphill streets. In general, cyclists avoid stop signs and traffic lights, except when they have to cross roads with high traffic volume. In this case, the sign is considered attractive (SENER et al, 2009; BROACH et al, 2012; WINTERS et al, 2010).

- *Having to overcome physical barriers*
  Emond and Handy (2011) mention that the existence of barriers (such as bridges, railways and roads) directly affects a cyclist's route choice because these elements tend to generate a lot of discomfort. However, the authors do not quantify this level of discomfort and how this influences the choice. On the other hand, Stinson and Bhat (2005) and Aultman-Hall (1996) affirm that bridges, if they have cycling infrastructure, may be attractive because generally decrease the trip length.

2.6. Conclusions about the factors that may influence cyclists route choice

This overview of factors that might influence cyclists´ route choice did not reveal any surprising result. As expected, bicyclists prefer routes with continuous bicycle infrastructure, low traffic volumes, low speeds, fewer stop signs, traffic lights and intersections.

The characteristics of the cyclists are used in this research to stratify the sample and assess the relative importance of gender and experience for route choice.

3. Methodology

The results described in this paper are part of a larger survey designed to identify the attributes and the main features of the city that affect cyclists´ route choice and also assess the relative importance of these attributes. The routes used by cyclists were registered with portable GPSs and analysed with a Geographic Information System. Cyclists, besides carrying the GPSs during one week, also answered a questionnaire about their preferences and personal characteristics.

Based on an analysis of the factors described in Section 2 and considering the typical characteristics of a Brazilian city, 18 factors were selected be included in this survey (Table 2).

Table 2 - Factors influence cyclists´ route choice

Group	Factors
Factors related to characteristics of the roads	Width
	Directions of flow (one way street)
	Type of pavement
	Quality of pavement
	Street slope
	Permission for parking on right side of the street
	Traffic volume
	Number of trucks in the flow of vehicles
	Number of buses in the flow vehicles
	Traffic speed
	Trees
Factors related to the trip	Travel time
Factors related to the route as a whole	Number of stop signs
	Number of traffic lights
	Number of intersections
	Having to go through roundabouts
Factors related to the environment	Security (possibility of assaults and aggressions)
	Street lighting

For each of the factors listed in Table 2, the respondents should state the importance of this aspect to their route choice in a five point scale ranging from “Very important” (coded as 5) to “Completely unimportant” (coded as 1). The second part of the survey instrument had questions about the cyclist´s demographic characteristics.

4. Results

The survey took place between September and December 2013, in São Carlos, SP (a medium sized Brazilian city with around 220 thousand inhabitants). As most Brazilian cities, São Carlos has only a few stretches of cycling infrastructure (bike paths or bike lanes). Thus, most bicycle trips are made on shared traffic roads. The sample was composed of 49 frequent bicycle users (that use this mode of transport for commuting).

Table 3 describes the characteristics of the respondents. Figure 1 and Table 4 show the relative importance of the 18 factors for the cyclists´ route choice (higher values indicate greater importance).

Table 3 - Characteristics of respondents

Gender	Age (years)	Cycling frequency
Masculine: 80%	Less than 18: 0.0%	A few days per month: 0.0%
Feminine: 20%	18 to 24: 23.3%	1 day per week: 0.0%
	25 to 34: 43.3%	2 or 3 days per week: 16.7%
	35 to 44: 16.7%	4 or more days per week: 83.3%
	45 to 64: 16.7%	
	More than 65: 0.0%	

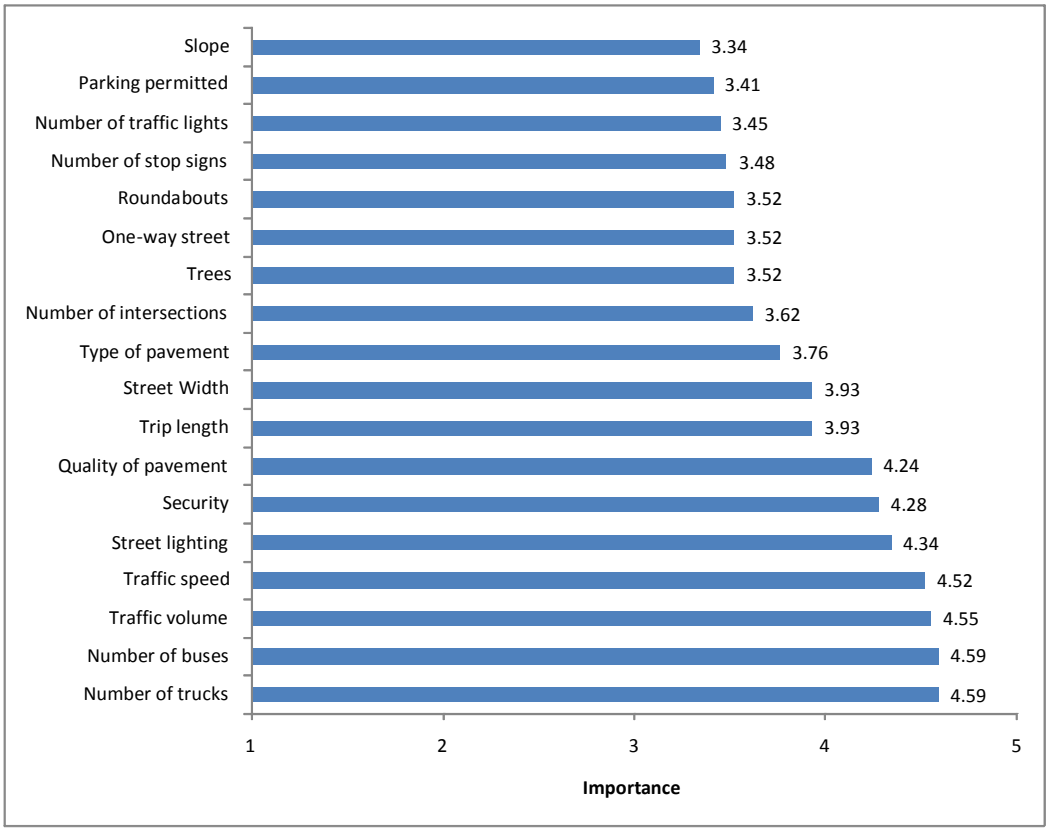

Fig. 1. Importance of factors for cyclists´ route choice

Table 4. Scores for the importance of factors (average and standard deviation)

Factor	Average	Stand Dev	Factor	Average	Stand Dev
1. Number of trucks	4,59	0,82	10. Type of pavement	3,76	1,09
2. Number of buses	4,59	0,73	11. Number of intersections	3,62	1,27
3. Traffic volume	4,55	0,91	12. Trees	3,52	1,09
4. Traffic speed	4,52	0,83	13. One-way street	3,52	1,09
5. Street lighting	4,34	0,77	14. Roundabouts	3,52	1,48
6. Security	4,28	1,03	15. Number of stop signs	3,48	1,06
7. Quality of pavement	4,24	0,87	16. Number of traffic lights	3,45	1,18
8. Trip length	3,93	0,96	17. Parking permitted	3,41	0,94
9. Street Width	3,93	1,07	18. Slope	3,34	1,23

Road gradient (slopes) was the least important factor for route choice and, although surprising, it agrees with other studies. For instance, a revealed preference study in Zürich (Menghini et al. 2009) found that the maximum slope of a route negatively (but very slightly) influenced route selection and that the average slope had no effect.

Number of trucks, number of buses, traffic volume and speed are all related to the road hierarchy and it is possible to infer that cyclists try to avoid these busy streets.

4.1. Comparison of scores according to respondents characteristics

Stratification of the sample according to gender, frequency of bicycle use and age revealed that the importance attributed to barriers may not be considered different among these groups ($p > 0.05$).

5. Conclusions

The objective of the research described in this paper was to evaluate the importance of attributes influencing bicyclists' route choice preferences. One of the motivations for this research was to study the route choice of current commuter cyclists to determine what types of policies and infrastructure programs might encourage the use of the bicycle for utilitarian trips.

Data collection was carried out with 65 cyclists that use the bicycle for commuting in a medium-sized Brazilian city. Most of the study participants (83%) were frequent bicyclists, using bicycle 4 or more days per week.

A questionnaire was prepared in which eighteen factors and respondents asked to assess the importance of these factors for their route choice, on a 5-point scale ranging from "Very important" (coded as 1) and "Very Unimportant" (coded as 5). The final part of the questionnaire asked about the respondent's personal characteristics: gender, age, reason why they use the bicycle (work, school, leisure, other), frequency of cycling (a few days month, one day a week, two or three days a week, four or more days a week) and if they usually plan their route before leaving home.

The results showed that the most important factors for route choice were: motor vehicle speed and number of trucks in the flow (both assessed as 5.0 – very important). Other important attributes were: volume of motor vehicles, security and street lighting (all with a 4.86 score). The least important factor was cycling on a one way street (3.29).

Stratification of the sample according to gender, frequency of bicycle use and age did not show any significant difference in the importance attributed to the factors. The lack of differences by demographic group may be due to the sample size and composition.

It is not possible to consider that bicyclists participating in this study represent all bicyclists. The sample consisted of cyclists from only one Brazilian medium-sized city which with a low bicycle modal share. Moreover, participation in the survey was voluntary and therefore the obtained sample is not random. Different results could possibly be obtained with larger samples and in other contexts.

In addition, these findings are based upon a sample largely made up of confident, regular cyclists. For cycling rates to increase significantly, a wider range of people need to cycle. Therefore, it is important to research the preferences of non-cyclists, occasional cyclists, and cyclists who only ride for recreation but would consider cycling for transportation in different circumstances, including better infrastructure.

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