ROADWAY AND TRAFFIC CHARACTERISTICS FOR BICYCLING

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ABSTRACT

The promotion of bicycle transportation includes the provision of suitable infrastructure for cyclists. In order to determine if a road is suitable for bicycling or not, and what improvements need to be made to increase the level of service for bicycles on specific situations, it is important to know how cyclists perceive the characteristics that define the roadway environment.

The present paper describes a research developed to define which roadway and traffic characteristics are prioritized by users and potential users in the evaluation of quality of roads for bicycling in urban areas of Brazilian medium-sized cities.

A focus group discussion identified 14 attributes representing characteristics that describe the quality of roads for bicycling in Brazilian cities. In addition, an attitude survey was applied with individuals to assess their perception on the attributes, along with the importance given to each one of them. The results were analyzed through the method of Successive Intervals Analysis, which allows the transformation of categorical data into an interval scale.

The analysis suggests that both the roadway and traffic characteristics related to segments and those related to intersections are important to the survey respondents. The five most important attributes, in their opinion, are: 1) lane width; 2) motor vehicle speed; 3) visibility at intersections; 4) presence of intersections; and 5) street trees (shading). Therefore, the research suggests that to promote bicycle use in Brazilian medium-sized cities, these attributes must be prioritized.

Keywords: bicycle, roadway and traffic characteristics, quality of roads for bicycling, Brazil, method of successive intervals.

INTRODUCTION

The promotion of bicycling is part of the current strategy of urban planning and transport, in which one of the goals is to reverse urban problems caused by prioritizing the use of the car, such as congestion, air quality degradation and increase of energy consumption. Other advantages of using the bicycle as a mode of transport include: greater equity (between members of society) in the provision of access to activities, due to reduced costs of this mode of transport, and the possibility of promoting a more physically active lifestyle for the population.

One of the ways to promote bicycle transportation is to provide suitable infrastructure for cyclists. In order to determine if a road is suitable for bicycling or not, and what improvements need to be made to increase the level of service for bicycles on specific situations, it is important to know how cyclists perceive the characteristics that define the roadway environment.

In this context, as part of the development of a bicycle level of service model that can be applied to the context of Brazilian cities, the present paper describes a research developed to define which roadway and traffic characteristics are prioritized by users and potential users in the evaluation of quality of roads for bicycling in urban areas.

A focus group discussion identified 14 attributes representing characteristics that describe the quality of roads for bicycling in Brazilian cities, related to segments and intersections: motor vehicle traffic volume, motor vehicle speed, signalization of intersections, heavy vehicles, presence of intersections, direction of roadways, visibility at intersections, pavement condition, lane width, driveways and side streets, on-street vehicle parking, roundabout, grades, and street trees (shading).

In addition, an attitude survey was applied with individuals to assess their perception on the attributes, along with the importance given to each one of them. The respondents indicated their agreement with statements related to the 14 quality attributes (in a five-point Likert-type scale). The results were analyzed through the method of Successive Intervals Analysis, which allows the transformation of categorical data into an interval scale.

Therefore, the paper includes the identification of roadway and traffic characteristics that describe the quality of roads for bicycling in Brazilian medium-sized cities, the application of the survey, the analysis of results and the main conclusions that were found.

ROADWAY AND TRAFFIC CHARACTERISTICS FOR CYCLING

In order to identify the roadway and traffic characteristics that describe the quality of roads for cycling in Brazilian medium-sized cities, a focus group discussion was carried out in the Brazilian city of Rio Claro, in the state of Sao Paulo.

The focus group methodology is based on a small number of people, who are specially recruited according to a predetermined set of criteria, to exchange experiences, attitudes and beliefs about a particular issue. Therefore, this type of survey does not result in statistically significant data, but can be useful when collecting qualitative information (Richardson, 1995).

The focus group discussion was conducted with eight participants, whose profile varied among: experienced bicyclists, participants of a local NGO related to bicycling, students and professors from the Department of Geography of a local University (UNESP – Rio Claro) involved in transportation planning or similar fields, and members from the Secretary of Transportation of the local municipality.

The data collected in the discussion was then analyzed through the method of Content Analysis, developed by Bardin (1995). Thus, the comments made during the focus group discussion were transcribed from audio to text, and then organized and separated into themes. The thematic categories chosen for the analysis were: traffic, infrastructure, conflicts, and environment. The subcategories were the roadway and traffic characteristics mentioned by the participants. As a result, 14 attributes representing characteristics that describe the quality of roads for cycling in Brazilian medium-sized cities, related to both segments and intersections, were identified, as show on Table 1.

Table 1 – Roadway and traffic characteristics for bicycling gathered from the focus group discussion

Thematic categories	Attributes
Traffic	Motor vehicle traffic volume
	Motor vehicle speed
	Signalization of intersections
	Heavy vehicles
	Presence of intersections
	Direction of roadways
Infrastructure	Visibility at intersections
	Pavement condition
	Lane width
Conflicts	Driveways and side-streets
	On-street vehicle parking
	Roundabout
Environment	Grades
	Street trees (shading)

THE SURVEY

Based on the roadway and traffic characteristics found in the focus group discussion, an attitude survey was applied with individuals to assess their perception of the attributes, along with the importance given to each one of them.

The method chosen to assess the perceptions of individuals was the application of questionnaires developed based on the Likert-type scale. According to Oppenheim (1999), the Likert scale is one of the scales available to assess attitudes, in which the subject can be placed, for each question, in one of the following positions: "totally agree", "partly agree", "no opinion", "partly disagree" and "totally disagree". Fourteen questions were formulated, one for each attribute identified in the focus group discussion.

Besides the attitude survey, structured on the basis of the Likert scale, participants also answered a series of questions about their profile: gender, age, education level, whether or not they know how to ride a bicycle, bicycle availability at the household, what type of cyclist they are, travel motives in which the bicycle is used, types of infrastructure used to ride a bicycle, and frequency of bicycle use.

The survey was conducted between March and April of 2009. In total, 451 questionnaires were applied in the Brazilian cities of Sao Carlos and Rio Claro, in the state of Sao Paulo. Both cities are considered medium-sized Brazilian cities with 212,956 and 185,421 inhabitants, respectively, according to a population estimate from 2007 (IBGE, 2009). As most of the medium-sized Brazilian cities, Sao Carlos and Rio Claro do not have a great number of dedicated infrastructures for bicycles. As a result, most urban bicycle trips are made along roads of shared traffic.

The survey was applied in six educational institutions that ranged from technical education for 13 through 17 years old students to graduate university and adult alphabetization courses. The educational institutions were chosen because of the higher personal availability that individuals who are in a student position (even as a part time activity) have for the survey application. Moreover, the choice of the six different sites for survey application attempts to include distinct profiles of participants, regarding their age and socioeconomic characteristics.

Questionnaires were completed in the presence of the researcher, and were then returned. Thus, all questionnaires distributed were returned. However, three questionnaires were excluded because they presented four or more invalid answers, either blank or with more than one answer marked for each question. Therefore, the analysis was performed on 447 completed questionnaires.

Survey results

Most of the participants are 13 to 17 years old and have incomplete secondary education or less. This result confirms the significant participation of young students in the study. It is emphasized that young people are known to be the part of population that uses the bicycle more often, even in countries where its use is widespread, as the Netherlands (Rietveld, 2004). Furthermore, the results of a study conducted in the United States also indicated that young people are more inclined to use the bicycle for utilitarian purposes (Dill and Koros, 2007). Therefore, the profile of the participants is considered acceptable, since the survey sample is consistent with the profile of potential bicycle users.

Men and women are almost equally represented in the sample. The great majority of respondents has a bicycle at home and knows how to ride a bicycle. Although they do not use the bicycle weekly, but only "occasionally", most respondents considered themselves to be experienced riders.

The great majority of respondents stated to use the bicycle for leisure and exercise. As for the infrastructure used to travel by bicycle, the interviewees indicated to use both busier and calmer urban streets significantly. A smaller number of respondents stated to use dedicated infrastructure for bicycles, maybe due to the small presence of such infrastructure in the cities where the questionnaires were applied. Some people even indicated to use sidewalks for riding a bicycle, although the Brazilian Traffic Code, in Article 59, only allows the movement of bicycles on the sidewalk if authorized and properly flagged by the local agency or entity (Brasil, 1997).

The profile of respondents is shown in Table 2.

TABLE 2 – Profile of respondents

Question	Answer	Number	%
Gender	Male	241	53,9
	Female	203	45,4
	missing answer	3	0,7
Age	13 to 17	252	56,4
	18 to 24	130	29,1
	25 to 29	36	8,1
	30 to 39	12	2,7
	40 to 49	12	2,7
	50 or more	5	1,1
Education	incomplete primary education	84	18,8
	complete primary education	58	13,0
	incomplete secondary education	126	28,2
	complete secondary education	56	12,5
	incomplete higher education	98	21,9
	complete higher education	13	2,9
	graduation	11	2,5
	missing answer	1	0,2
Knows how to ride a bicycle	Yes	440	98,4
	No	7	1,6

Has bicycle in household	Yes	343	76,7
	no	102	22,8
	missing answer	2	0,4
Type of cyclist	not very experienced	168	37,6
	very experienced	198	44,3
	not a cyclist	80	17,9
	missing answer	1	0,2
Bicycle travel motives*	work	23	3,5
	school	88	13,4
	leisure	288	43,8
	exercise	159	24,2
	all previous alternatives	19	2,9
	other	1	0,2
	do not ride a bicycle	79	12,0
Infrastructure used for bicycle trips*	not very busy streets	300	40,1
	main roads and busy streets	164	21,9
	sidewalks	65	8,7
	dedicated infrastructure for bicycles	71	9,5
	off-road cycle paths	65	8,7
	do not ride a bicycle	83	11,1
Weekly frequency of bicycle trips	1 day	29	6,5
	2 to 4 days	78	17,4
	5 to 6 days	57	12,8
	everyday	52	11,6
	only once in a while	142	31,8
	do not ride a bicycle	85	19,0
	missing answer	4	0,9
* The total number of responses is greater than the number of completed questionnaires (447) because there was the possibility of multiple responses.			

The results of the Likert scale based survey are presented in Table 3. Each of the statements evaluated by the participants is related to one of the attributes representing characteristics that describe the quality of roads for cycling in Brazilian medium-sized cities. Table 3 shows the percentage of respondents who choose each one of the five possible answers.

TABLE 3 – Results of the attitude survey

Attribute	Statement	Totally agree	Partly agree	No opinion	Partly disagree	Totally disagree
Motor vehicle traffic volume	Cyclists ride calmly through streets with great movement of vehicles.	6,5%	17,9%	1,8%	28,2%	45,6%
Motor vehicle speed	When the vehicles are too fast, cyclists are in risk of accidents.	79,9%	15,2%	0,9%	2,0%	2,0%
Signalization of intersections	It is better for a cyclist to cross streets where there are traffic lights.	56,4%	30,0%	6,5%	4,7%	2,5%
Heavy vehicles	Trucks and buses disturb who ride bicycles on the streets.	59,5%	29,3%	4,0%	4,5%	2,7%
Presence of intersections	Crossings are dangerous for cyclists.	66,0%	25,7%	3,4%	3,4%	1,6%
Direction of roadways	It is easier to ride a bicycle in one-way streets than in two-way streets.	54,8%	24,2%	8,7%	6,9%	5,4%
Visibility at intersections	Lack of visibility in crossings disturbs the cyclist.	74,9%	16,3%	4,0%	2,5%	2,2%
Pavement condition	Street pavement does not influence in cyclist's comfort.	23,0%	10,7%	8,5%	6,7%	51,0%
Lane width	It is better to ride a bicycle in wider streets.	72,0%	23,7%	2,5%	1,3%	0,4%
Driveways and side-streets	The number of streets that cross the cyclist's way does not influence in his/her comfort.	12,5%	22,1%	18,3%	17,2%	29,8%
On-street vehicle parking	Who rides a bicycle is afraid that drivers suddenly open the door of cars parked on the street.	61,7%	26,6%	4,5%	4,9%	2,2%
Roundabout	Cyclists feel safe when riding in roundabouts.	5,8%	13,9%	9,4%	24,2%	46,8%

Grades	People avoid riding a bicycle when they have to go through streets with many slopes.	50,6%	33,1%	4,5%	7,8%	4,0%
Street trees (shading)	It is better to ride a bicycle when there are trees (shade) on the streets.	68,5%	21,7%	4,5%	3,1%	2,2%

Method of Successive Intervals Analysis

The results of the Likert scale based survey were then analyzed through the Method of Successive Intervals Analysis, which allows the transformation of categorical data into an interval scale.

There are several computational procedures that can be used to obtain interval measures from ordinal categorical data resulting from surveys in which psychometric scales are used. Some examples are: the least squares method and the method of maximum likelihood (Takane, 1981; Hensler e Stipak, 1979; Lipovetsky, 2007). An alternate approach is the logistic model proposed by Rasch (Aldrich, 1978).

In this research, the Method of Successive Intervals Analysis, developed by Guilford (1975) was chosen. It is based on psychometric scales for estimation of individuals' opinion, originally proposed by Thrustone (1927). These scales have been broadly used in fields such as applied psychology, health and marketing (Blischke et al, 1975), and also in several works in the field of transportation (Correia e Wirasinghe, 2007).

The Method of Successive Intervals Analysis considers that the variable related to the choice of individuals follows a normal probability distribution. Therefore, the values of categories can be estimated from the observed frequencies (the observed categories correspond to different segments under a standard normal curve).

The lower and upper limits of each category ($z1_j$ and $z2_j$) can be obtained through an area table under the normal average curve or though the function INV.NORMP from the software Excel. The lower limit from the first category extends until -∞ and the upper limit of the last category reaches +∞. The ordinates of the lower and upper limits of each category (y1j and y2j) are obtained through the standard normal probability distribution function (Equation 1).

$$y = f(z) = \frac{1}{\sqrt{2\pi}} e^{\frac{-z}{2}} \quad (1)$$

Once the ordinates for the categories' limits are obtained, the values of the categories are estimated using Equation 2:

$$x_j = \frac{y1_j - y2_j}{p_j} \quad (2)$$

Where:
x_j = estimated value for category j
$y1_j$ = ordinate of the lower limit of category j
$y2_j$ = ordinate of the upper limit of category j
p_j = parcel of occurrence of answers in category j

Table 4 illustrates this procedure for the estimation of the values of the 5 categories of the attribute "motor vehicle traffic volume". For the assembly of this matrix, the columns must be ordered in increasing order of category value. Therefore, column 1 corresponds to the smallest priority and column 5 corresponds to the biggest priority.

TABLE 4 – Procedure for the estimation of category values related to the attribute "motor vehicle traffic volume"

Statistical Parameters	Categories (in order of importance)				
	1	2	3	4	5
Frequency (number of answers in each category)	29	80	8	126	204
Relative frequency (p_j)	0,0649	0,1790	0,0179	0,2819	0,4564
Accumulated frequency (P_j)	0,0649	0,2438	0,2617	0,5436	1,0000
Lower limit of the category ($z1_j$)	0,0000	-1,5151	-0,6940	-0,6380	0,1096
Upper limit of the category ($z2_j$)	-1,5151	-0,6940	-0,6380	0,1096	0,0000
Ordinate of the lower limit of the category ($y1_j$)	0,0000	0,1266	0,3136	0,3255	0,3966
Ordinate of the upper limit of the category ($y2_j$)	0,1266	0,3136	0,3255	0,3966	0,0000
Estimated value of the category (x_j)	-1,9515	-1,0446	-0,6658	-0,2521	0,8689

Through the analysis of Table 4, it can be verified that the distances among successive categories are not equal. The distance between categories 4 and 5 is the greatest one (1,1211) while the distance between categories 2 and 3 is the smallest one (0,3788). These discrepancies are sufficient to indicate the inaccuracy in the attribution of the original values (1, 2, 3, 4, 5) to the categories, as if the distances among them were constant (one unit).

Table 4 presents the results of the classification of the 14 attributes representing characteristics that describe the quality of roads for cycling in Brazilian medium-sized cities, in order of importance.

TABLE 5 – Distribution of the answers on the 14 attributes

Attributes	Number of answers in each class of priority				
	1	2	3	4	5
Motor vehicle traffic volume	29	80	8	126	204
Motor vehicle speed	9	9	4	68	357
Signalization of intersections	11	21	29	134	252
Heavy vehicles	12	20	18	131	266
Presence of intersections	7	15	15	115	295
Direction of roadways	24	31	39	108	245
Visibility at intersections	10	11	18	73	335
Pavement condition	103	48	38	30	228
Lane width	2	6	11	106	322
Driveways and side-streets	56	99	82	77	133
On-street vehicle parking	10	22	20	119	276
Roundabout	26	62	42	108	209
Grades	18	35	20	148	226
Street trees (shading)	10	14	20	97	306

Table 6 presents the results of the application of the Method of Successive Intervals Analysis for the estimation of relative importance of the characteristics that describe the quality of roads for cycling in Brazilian medium-sized cities.

TABLE 6 – Estimated values for the categories

Attributes	Corresponding value for each category (x_j)				
	1	2	3	4	5
Motor vehicle traffic volume	-1,95151	-1,04464	-0,6658	-0,25214	0,868921
Motor vehicle speed	-2,41845	-1,88484	-1,69876	-1,17826	0,351951
Signalization of intersections	-2,34376	-1,68	-1,26589	-0,58412	0,698591
Heavy vehicles	-2,31076	-1,66661	-1,33358	-0,67307	0,651272
Presence of intersections	-2,50939	-1,86393	-1,51067	-0,83138	0,555233
Direction of roadways	-2,03278	-1,36191	-0,97243	-0,44536	0,72257
Visibility at intersections	-2,37947	-1,8242	-1,50378	-0,97651	0,424521
Pavement condition	-1,31914	-0,57307	-0,30529	-0,1097	0,781888
Lane width	-2,92689	-2,30626	-1,88846	-1,03691	0,46701
Driveways and side-streets	-1,64572	-0,73579	-0,15625	0,298417	1,164194
On-street vehicle parking	-2,37947	-1,69394	-1,32073	-0,69804	0,617906
Roundabout	-1,99872	-1,16113	-0,6966	-0,22707	0,850418
Grades	-2,15164	-1,42669	-1,07792	-0,46005	0,788981
Street trees (shading)	-2,37947	-1,78514	-1,43804	-0,83853	0,519232

However, to guarantee that all attributes can be evaluated simultaneously, in a common scale, Guilford (1975) suggests that an adequate scale is one that is obtained through the average of the distance between the categories, which can be used as reference scale. Tables 7 and 8 show these proceedings for the 14 attributes that are being analyzed.

TABLE 7 – Distance between the categories (in units of standard deviation)

Attributes	Distance among categories				
		d12=x2-x1	d23=x3-x2	d34=x4-x3	d45=x5-x4
Motor vehicle traffic volume	0,0000	0,9069	0,3788	0,4137	1,1211
Motor vehicle speed	0,0000	0,5336	0,1861	0,5205	1,5302
Signalization of intersections	0,0000	0,6638	0,4141	0,6818	1,2827
Heavy vehicles	0,0000	0,6442	0,3330	0,6605	1,3243
Presence of intersections	0,0000	0,6455	0,3533	0,6793	1,3866
Direction of roadways	0,0000	0,6709	0,3895	0,5271	1,1679
Visibility at intersections	0,0000	0,5553	0,3204	0,5273	1,4010
Pavement condition	0,0000	0,7461	0,2678	0,1956	0,8916
Lane width	0,0000	0,6206	0,4178	0,8515	1,5039
Driveways and side-streets	0,0000	0,9099	0,5795	0,4547	0,8658
On-street vehicle parking	0,0000	0,6855	0,3732	0,6227	1,3159
Roundabout	0,0000	0,8376	0,4645	0,4695	1,0775
Grades	0,0000	0,7250	0,3488	0,6179	1,2490
Street trees (shading)	0,0000	0,5943	0,3471	0,5995	1,3578
Average	0,0000	0,6956	0,3696	0,5587	1,2482
Reference scale (accumulated)	0,0000	0,6956	1,0652	1,6239	2,8721

The last column on the right side of Table 8 shows the average difference between the values of the corresponding scales of each attribute and the values of the scale used as reference. The bigger the average value, greater is the importance of the attribute.

TABLE 8 – Differences between each category's scale and the reference scale

Attributes	Reference scale (xi_j)					Average (m_j)
Motor vehicle traffic volume	1,9515	1,7403	1,7310	1,8760	2,0032	1,86
Motor vehicle speed	2,4184	2,5805	2,7640	2,8022	2,5202	2,62
Signalization of intersections	2,3438	2,3756	2,3311	2,2080	2,1735	2,29
Heavy vehicles	2,3108	2,3623	2,3988	2,2970	2,2209	2,32
Presence of intersections	2,5094	2,5596	2,5759	2,4553	2,3169	2,48
Direction of roadways	2,0328	2,0576	2,0376	2,0692	2,1496	2,07
Visibility at intersections	2,3795	2,5198	2,5690	2,6004	2,4476	2,50
Pavement condition	1,3191	1,2687	1,3705	1,7336	2,0902	1,56
Lane width	2,9269	3,0019	2,9537	2,6608	2,4051	2,79
Driveways and side-streets	1,6457	1,4314	1,2215	1,3255	1,7079	1,47
On-street vehicle parking	2,3795	2,3896	2,3859	2,3219	2,2542	2,35
Roundabout	1,9987	1,8568	1,7618	1,8510	2,0217	1,90
Grades	2,1516	2,1223	2,1431	2,0839	2,0832	2,12
Street trees (shading)	2,3795	2,4808	2,5033	2,4624	2,3529	2,44

In order facilitate the analysis, the differences between the scales can be converted into another preferred scale, such as the interval of 0 and 1, using the Equation 3, where "min" and "max" mean minimum and maximum values among all m_j (Lipovetsky, 2007). Table 9 and Figure 3 show the final obtained results.

$$m'j = \frac{m_{j-} \min(m)}{\max(m) - \min(m)} \quad (3)$$

TABLE 9 – Values of attributes in the interval 0-1

Attributes	Average	0-1
Motor vehicle traffic volume	1,86	0,30
Motor vehicle speed	2,62	0,87
Signalization of intersections	2,29	0,62
Heavy vehicles	2,32	0,64
Presence of intersections	2,48	0,77
Direction of roadways	2,07	0,46
Visibility at intersections	2,50	0,78
Pavement condition	1,56	0,07
Lane width	2,79	1,00
Driveways and side-streets	1,47	0,00
On-street vehicle parking	2,35	0,66
Roundabout	1,90	0,33
Grades	2,12	0,49
Street trees (shading)	2,44	0,73

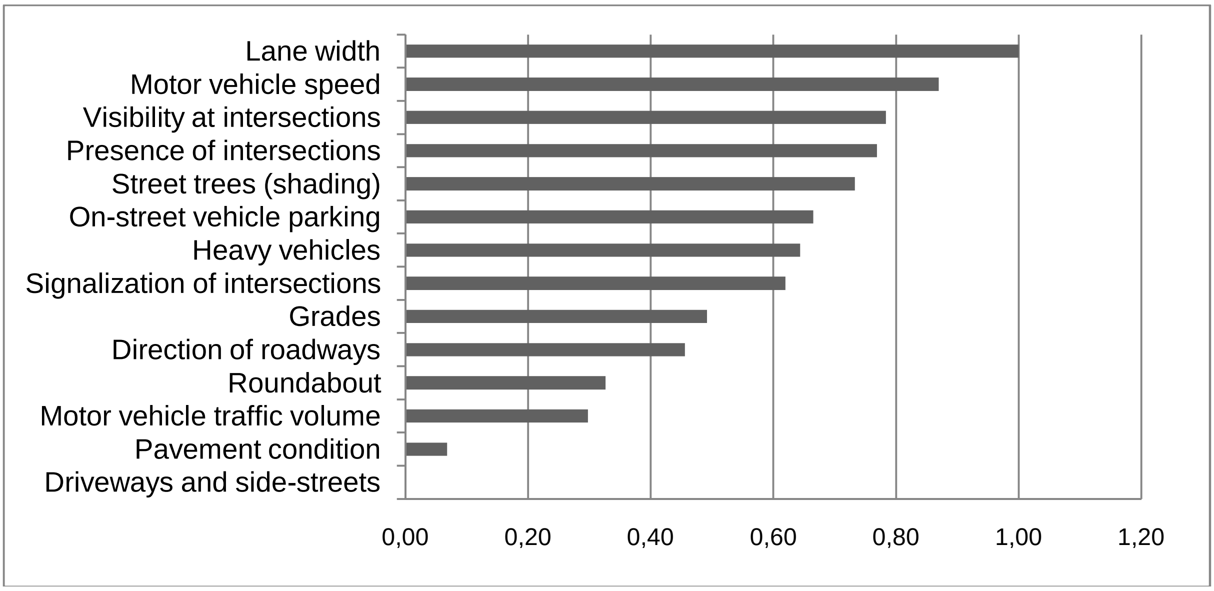

Figure 3 – Attributes ordered by level of preference

Therefore, the research suggests that to promote bicycle use in Brazilian medium-sized cities, the most important attributes show in Figure 3 must be prioritized during roadway and traffic interventions.

CONCLUSIONS

It was verified that the most important characteristic in the evaluation of quality of roads for bicycling was lane width, followed by motor vehicle speed, visibility at intersections, presence of intersections and street trees, followed by the other attributes. It shows that both the roadway and traffic characteristics related to segments and those related to intersections are important to the respondents. In addition, there was no pattern in which the survey participants preferred one of the thematic categories from the focus group discussion (traffic, infrastructure, conflicts, and environment) over another.

One of the interesting findings is that, for these survey participants, the motor vehicle speed is more important than the motor vehicle volume, meaning that they are willing to ride a bicycle sharing the road with a great number of cars, if those are travelling at lower speeds, and as long as the lane is wide.

Further studies on this topic could contribute to the understanding of the opinion of users and potential users on the quality of roads for bicycling. As a suggestion, other surveys focusing a different profile of participants, or including different attributes, would be recommended.

Thus, through the study of roadway and traffic characteristics for the evaluation of quality of roads for bicycling in urban areas, this paper aims to assist transportation planners in promoting bicycle use in Brazilian medium-sized cities.

ACKNOWLEDGEMENTS

The authors would like to thank FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo, for the financial support. This research was also supported by the Cycling Academic Network (CAN), part of Bicycle Partnership Program of Interface for Cycling Expertise (I-CE), Utrecht, The Netherlands.

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