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IDENTIFICATION FACTORS INFLUENCING BICYCLIST`S SAFETY IN URBAN CONDITIONS

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Abstract: Drafting urban policies which aims at increasing the use of cycling requires an understanding of bicycle requirements. The purpose of this paperwork is to research the key factors that may affect the safety of bicyclists' riding in the city of Prishtina. To carry out this research, a survey was conducted with 202 bicylitsts on 13 streets of the capital of Kosovo, Pristina. For analysing the data ordinal regression model has been used. Following the analysis of the results, it was concluded that infrastructure factors and traffic turnover have an important role in the perception of bicyclists' riding safety. Increased traffic turnover, the level of speed and the presence of heavy vehicles have a negative impact on the bicyclists' safety. For some variables, the impact on bicyclists` riding safety are more or less the same for separated bicycle paths and on-street bicycle lanes and the presence of lanes and cycling paths have a positive impact in riding safety.
Keywords: bicyclists` riding safety, on-street bicycle lanes, separated bicycle paths, roadway and traffic factors

1. INTRODUCTION

In many parts of the world, riding a bicycle is increasingly being considered the most appropriate way of moving in urban conditions, as an option that has multiple benefits such as ecological, health and economic. Despite these many benefits, the use of bicycles on the streets of the city of Pristina is apparently at a very low level. One of the reasons for the low use of the bicycle is also related to the poor urban planning that the city of Pristina has experienced in the last two decades. During this period, the rapid increase of the motorization rate has affected the planning and construction of the road infrastructure to be primarily focused on the accommodation needs for vehicles. As a consequence, the necessary cycling infrastructure is not properly addressed. Consequently, in recent years the roads in the city of Pristina are increasingly congested by vehicles. On the other hand, considering the fact that the average age of cars moving in Kosovo are 18 years old, or 10 years older than the average of vehicles moving within the European Union [1], then the use of the bicycle for transport will to be the adequate solution.

Promotion of cycling includes the provision of appropriate cycling infrastructure. Based on the previous surveys the presence of special bicycle paths results in a 55% increase in bicycle use[2]. In order to assess whether a road meets the conditions for bicycling and in specific cases which improvements should be undertaken in order to increase it, it is necessary to know how cyclists perceive the key factors that affect their safety and comfort while riding the bicycle. Investigating the factors that influence the risk perception while riding a bicycle can provide a useful help to authorities in planning and designing the adequate cycling infrastructure.

The efforts in indentifying the factors that might have an impact in making cycling a transport mean have started earlier. The concept of compatibility of a roadway for bicyclists based on a bicyclist's perspective of geometric and traffic conditions has started with the research conducted by Geelong Bikeplan Team, 1978. Based on the experience of Geelong Bikeplan Team, initially only three main factors to rate the stress during cycling were selected - curb lane width, motor vehicle speed, and traffic volume (Geelong Bike Plan Committee, 1978).

In recent years, the identification of relevant factors that affect the comport and safety of bicycling have received increasing attentions from researchers.

Based on previous researches, the perception of cycling comfort was considered by evaluating the level of service (LOS) of bicycle facilities).

In the manual of road capacity (HCM 2010), it's concluded that Level of service - LOS for urban roads (bicycling on the roads or cycling paths) is set based on the effective width of the outside through lane, the proportion of on-street parking occupied), traffic, the number of lanes in one direction, the speed of vehicles, the proportion of heavy vehicles presence and pavement conditions[3].

Other publications have also addressed various factors affecting the Bicycle Level of Service-BLOS). In the final report published by NHCRP 2010, the main factors that were considered to affect the BLOS are:number of right hand side driveways, segment lengths, parking and sholder width, pavement condition and parking occupancy [4].

Bicycle Level of Service – BLOS concept in an explicit way is conducted based on the (Landis, 1997) researches. The Bicycle Level of Service Model (Bicycle LOS Model) is an evaluation of bicyclist perceived safety and comfort with respect to motor vehicle traffic while travelling in a roadway corridor. In this model is clearly reflected the impact of the following factors: per-lane traffic volume, traffic speed, traffic mix, cross-traffic generation (traffic flow turbulence), pavement surface condition, and available roadway width for bicycling[5]

In general, the factors that affect the use of bicycle as a transport mean are classified in three groups, individual factors (age, gender, bicycling preference, bicycling comfort etc), social-environment factors (other bicyclists, vehicle drivers', etc) and Physical-environment factors (the infrastructure for cyclists, the use of land, etc) [6]. Individual factors contribute to the motivation to bicycle, while social and physical environment factors determine the quality of bicycling conditions and may enable and encourage bicycling, or hinder and discourage it [7].

2. OBJECTIVES AND HYPOTHESIS

This paperwork is part of a wider study which focuses on the perception of the risk, namely the safety of bicyclists, where more influential factors are involved and consequently there will be a tendency to get wider and deeper in researching the problem. In this paperwork, the main objective is to test the impact of both infrastructure and environmental factors as well traffic factors in risk perception, namely the sense of safety when riding a bicycle.

Specifically, in this paperwork the impact of the most important factors that can affect the safety of cycling on streets with vehicles and the physically separated bicycle paths will be tested. The findings from this study will be of interest to promote the movement of bicycles on the road as an ecological and sustainable form of transport. Also this work can serve planners when working on urban planning to take into account the need for cycling infrastructure and security conditions for accommodating cyclists in the urban road network.

Methods and procedures

The statistical analysis of the results, ie statistical methods to be applied in this paperwork, aims at testing the hypothesis and depending on the type of variables and data. The variable of interest or dependent variable is the sense of security, namely risk, so it will be seen how variables appear in this variable. The measurement of these variations is most conveniently done by using the Likert scale assessment, where we will have five categories. This form of measurement, or the ordinal nature of the dependent variable on one side and a set of factors that appear as independent, categorical and continuous variables, does not allow us to use OLS but implies other forms of general linear model such as Ordinal Regression,or PLUM (Polytomous Universal Model) which can be applied through SPSS.

Ordinal regression model, is applied in cases when dependent variable appears in more than two categories [8, 9], and in such a case we measure proporcional odds by passing from one scale to another, if the value of the independent variable varies for one unit.

In its linearized form, the model is presented in this form:

$$\mathrm{Log}\left[\frac{p_i}{1-p_i}\right] = a_i + \sum_{i=1}^{n} b_i X_i + \varepsilon_i \qquad (1)$$

where: $p_i = \text{probability of an outcome} \leq i;\ \text{eg. probability (Veryuncomfortable)}$,
$a_i = \text{intercept for outcome} \leq i$, $b_i = \text{coefficient}, X_i = \text{independet variable}$, $\varepsilon_i = \text{error}$, $\frac{p_i}{1-p_i} = \text{odds}$

In order to reduce the multicolinearity effect between the variables on the right side of the ordinal regression equation, the correlation analysis will initially be made for the possible links between independent variables and the relation between independent variables with the dependent variables.

Data and survey administration

Data for this study were collected in the Kosovo capital, Pristina. The city of Pristina has about 200,000 inhabitants, while the district reaches up to 500,000[10]. The study area is defined based on the analysis of the commuting population, according to locally available census data and housing data within Pristina.

For this paper, the number of possible factors was initially selected based on previous studies conducted so far related to the impact of these factors on the use of bicycles. Then, the number of key factors has been revised by different focus groups. During the discussions a test survey was conducted with focus groups between daily bicycle users, in discussions by the cycling club "Prishtina" in Pristina and local experts from the Faculty of Mechanical Engineering - Department of Communication. Focus groups were mainly small groups, who made the assessment of the factors according to certain criteria, taking into account the particular experience, attitudes and special experience in the areas of transport and cycling. Therefore, this type of survey does not result in statistically significant data, but can be useful when collecting qualitative information [11]. Based on the discussions it is estimated that for the needs of this study will be analyzed the impact of the road characteristics, traffic and environmental infrastructure. (Table 1)

Table 1. Characteristics of the road, traffic and environmental selected after group discussion

Thematic categories	Attributes
Traffic characteristics	≡ Traffic volume ≡ Vehicle speed ≡ Heavy vehicles
Road characteristics	≡ Right-hand width ≡ State of the road surface ≡ The presence of Cycle Lane ≡ Physically separated bicycle paths ≡ The presence of parking ribbon
Environmental characteristics	≡ Climatic conditions

Demographic questionnaires

Following the selection of factors related to the characteristics of the road and the traffic deriving from focus group discussions, the forms for measuring the impact of factors on the risk perception, while driving the bicycle on urban roads, were drafted.

The questionnaires were compiled for the purpose of obtaining the respondents' assessment of the key factors that affect the road safety. As part of the questionnaires, apart from data on age and gender, questions were asked about the road impact, traffic and environmental characteristics on the safety of movement while riding the bicycle. All respondents who were randomly selected have assessed the impact of key factors on comfort and safety while riding the bicycle on the road, according to Likert scale from 1-5.

Initially, testing of the questionnaire was done in 18 cases and after its review, the collection of data started. The data for this paperwork were collected between 15 April 2017 to 24 May 2017. 202 cyclists were surveyed throughout the research. Two genders were included in the research, 66% of respondents were males and 34% females. Also, for the purpose of inclusion of all ages in the research, respondents between the age 17 to 70 were selected. Respondents under the age of 17 have not been taken into account due to age and real-life assessment.

3. RESULTS AND INTERPRETATION

Descriptive statistics regarding the perception of safety while riding a bicycle is presented in Table 2.

Table 2. Descriptive statistics regarding the perception of safety

Characteristics	Very uncomfortable -1		Uncomfortable -2		Medium 3		Comfortable - 4		Very comfortable -5		Total		Median	Mode
	Fi	%	Fi	%	Fi	%	Fi	%	Fi	%	Fi	%		
Overall perception	17	8.4	49	24.3	71	35.1	55	27.2	10	5.0	202	100	3	3

As can be seen in Table 2, from the general perception of security, the highest percentage of about 35.1% was observed in the average perception of security, 27.2% of respondents felt comfortable and about 24.3% uncomfortable. While, 8.4% stated that they feel very uncomfortable and only 5% of respondents felt very comfortable during bike riding.

The SPSS statistical software package is used to process the realization of the ordinal regression model. Initially, we looked at the correlation between independent variables with the dependent variables and the correlation between independent variables. It was evidenced a high correlation between two variables: "total number of vehicles" and "number of heavy vehicles" (r=0.784). High correlation has been also recorded among the variables: “Bicycle path” and “physically separated path” (r = 0.774). It is also important to note that with the dependent variable indicates significant correlation (spearman's rho), only variables: “number of heavy vehicles” (r = -0.156); “Physically separated path” (r = 0.350); “Bike for cyclists” (r = 0.261); The presence of the parking lane (r = 0.151).

In order to avoid multicolinearity problems, several variants have been tested, in which the independent variables mentioned above for strong correlation between them are not inserted at the same time in the model. For testing purposes, the following variables observed during the research were inserted: Bicycle path; Physically separated paths; Climatic conditions; The presence of the parking lane; the moving speed of the vehicles; total number of vehicles and number of heavy vehicles;

After several tests, by removing the non-statistically important variables, we came the first model with the best features presented in Table 3.

Table 3. Model I

Parameter Estimates		Estimate	Std. Error	Wald	df	Sig.
Threshold	[OvPerc = 1.00]	-4.621	.495	86.982	1	.000
	[OvPerc = 2.00]	-2.894	.434	44.415	1	.000
	[OvPerc = 3.00]	-1.277	.399	10.253	1	.001
	[OvPerc = 4.00]	1.196	.432	7.678	1	.006
Location	HV	-.003	.002	4.789	1	.029
	[PhSepLane=1.00]	2.061	.386	28.515	1	.000
	[PhSepLane =.00]	0[a]	.	.	0	.
Link function: Logit.						
a. This parameter is set to zero because it is redundant.						
Note: OvPerc- Overall perception; HV-Heavy Vehicle; PhSepLane- The physically separated bicycle paths						

Source: SPSS output -Field survey

Model 1

As can be seen in Table 2, according to this model, in which the "total number of vehicles" variable is not included, the presence of heavy vehicles in traffic and the physical division of cycling paths result in statistically significant element in the safety of bicyclists during riding. This impact is evidenced in all Likert scale categories if we look at the Threshold. In order to see the tendency of this correlation, based on the prior signs of coefficients, we see that the first variable is negative, where the increase of heavy traffic vehicles on the roads most likely increases the insecurity of cyclists or worsens the comfort while driving, while in the case of the second variable the tendency is positive where by crossing by into the roads with physically separated paths, increases the sense of security amongst bicyclists.

So, if the presence of heavy vehicles increases for one point, his ordered log-odds would decrease by 0.033 while the other variables in the model are held constant. Precisely, there is an odds ratio of 0.997004496 ($e^b = 2.718282^{-0.003}$) to move for one better step of Likert scale to a worse one, once the presence of heavy vehicles increases. There is also an odds ratio of 7.85382 ($e^b = 2.718282^{2.061}$) of moving into a better Liker scale of assessment, once the cyclists move into a road with physically divided lanes.

This model has shown that there there is a better fit for explaining the existence of statistically significant linkage between the dependent variables with independent ones. As can be seen in table 3 and 4 the model of high level security shows that at least one of model coeficoents is different from zero, namely the Chi-Square value (32.603) which is Likelihood Ratio (LR) Chi-Square test <0.01; the null hypothesis is that all of the regression coefficients in the model are equal to zero.

Table 4. Model Fitting Information 1

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	264.306			
Final	231.703	32.603	2	.000
Link function: Logit.				

Table 5. Goodness-of-Fit 2

	Chi-Square	Df	Sig.
Pearson	118.102	90	.025
Deviance	123.171	90	.012
Link function: Logit.			

Source: SPSS output -Field survey Source: SPSS output -Field survey

Model 2

As mentioned above, due to the appearance of multicolinearity, the second model was also tested, in which the "heavy vehicles" variable is not included but the "total number of vehicles" and other variables. The results of this model are given in Table 6.

Table 6. Model 2

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[OvPerc = 1.00]	-7.741	1.274	36.914	1	.000
	[OvPerc= 2.00]	-5.942	1.230	23.353	1	.000
	[OvPerc= 3.00]	-4.311	1.199	12.938	1	.000
	[OvPerc= 4.00]	-1.857	1.185	2.456	1	.017
Location	VTVolume	-.001	.000	18.120	1	.000
	VSpeed	-.054	.025	4.854	1	.028
	[BL=1.00]	2.419	.409	34.950	1	.000
	[BL=.00]	0a	.	.	0	.
Note: OvPerc - Overall perception; VT Volume - Vehicle Traffic Volume; VSpeed - Vehicle Speed; BL- on-street bicycle lanes						

Source: SPSS output -Field survey

As shown in Table 7, the vehicle traffic volume, the moving speed and the existence of on-street bicycle lanes statistically have a significant influence on the bicyclists' perception on riding safety. The impact is evident in all Likert scale categories, if we look at Threshold, in column sig. all p-valuesare <0.05. While we notice that the vehicle traffic volume and the speed of movement are negatively related to the perception of safety, whereby the increase of the number of vehicles in the traffic is likely to worsen the sense of comfort during riding, as explained in the speed report, the increase of the vehicles presence increasesalso the sense of uncertainty. Whereas the existence of on-street bicycle lanes has a positive impact on the safety perception, where with the existence of cycling lanes, there is a chance to increase the sense of safety. While in the case of the second variable the connection is positive, in which the move into physically separated lanes, increases the chances for bicyclists to feel safer.

So, if the presence of vehicles is increased by one point his ordered log-odds would decrease by 0.01 while the other variables in the model are held constant. Namely, there is an odds ratio of 0.999 ($e^b = 2.718282^{-0.001}$) to move from one Likert scale point assessment into a lower one, once the number of vehicles increases. Also there is an odds ratio of 0.947432107 ($e^b = 2.718282^{-0.054}$) to move from one Likert scale point of assessment into a lower one, once the speed of the vehicles increases. Meanwhile, when the cyclists get into a street with cycling lanes, there is an odds ratio of 11.23461908 ($e^b = 2.718282^{2.419}$) of moving into a better assesses level of Likert scale.

Table 7. Model Fitting Information 2

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	267.429			
Final	229.626	37.803	3	.000
Link function: Logit.				

Table 8. Goodness-of-Fit 2

	Chi-Square	df	Sig.
Pearson	105.983	93	.049
Deviance	118.233	93	.031
Link function: Logit.			

Source: SPSS output -Field survey

This model has also shown that there is a good fine-tuning for explaining the existence of statistically significant linkage between the dependent variables with the independent ones. As seen in Tables 7 and 8, a model of high security shows that at least one of the coefficients of the model is different from zero; the null hypothesis is that all of the regression coefficients in the model are equal to zero.

4. CONCLUSIONS

The results from this study show the important role of infrastructure factors and vehicle movement in the perception of safety during cycling. For some variables, their impact on bicyclists` riding safety is roughly similar for separate bicycle paths and on-street bicycle lanes and the presence of lanes for cyclists and cyclist streets physically divided have a positive effect on the cycling safety. On the other hand, this study has also shown the impact of traffic flow volume, vehicle speed and the increase of heavy vehicles. As a matter of fact the increase in the traffic flow, speed and heavy vehicles negatively affects the cyclists' safety.

Environmental factors such as climatic conditions and the presence of street parking have proved statistically insignificant for this study.

Measures like reduction of heavy vehicles in urban streets and car congestion charges are the most important perceived policy interventions. These findings may be useful in providing richer information to increase the effectiveness of future cycling campaigns aiming to provide an indication to the aspects such campaigns may want to address in order to promote cycling.

By comparing the bicyclists` perception of safety and the contributing physical-environment factors, the results may help transportation engineers to improve the safety perception of bicycle travelers during their traveling on roads. The authors recommend that future studies could focus on the effect of social-environment and physical-environment factors on safety perceptions of bicyclists and non-bicyclists.

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