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Drivers' Preferences for Road Roundabouts: A Study based on Stated Preference Survey in Italy

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Abstract

It is now known that roundabouts offer high levels of safety, but different researches on this type of intersection show that several factors influence the driver's behavior, causing occasionally wrong driving behaviors that can degenerate into accidents. Understanding driver's preferences is an important goal in order to encourage an efficient and safe road design. This study aims to understand user's preferences on the geometrical-functional characteristics of roundabouts, and to associate these preferences with specific driver features. For this purpose, a stated preference survey was carried out. The declared preferences were collected through face-to-face interviews. Collected data were then processed by applying the correspondence analysis (CA). This research revealed that drivers' preferences are different depending on the type of driving behavior exhibited by drivers and, only in a less obvious manner, according to gender. Drivers with exemplary driving behavior prefer design elements that ensure a greater safety. Men with wrong driving behavior prefer roundabout configurations that are less safe but that ensure fast trajectories. Drivers with acceptable driving behavior expressed preferences that are specifically geared towards specific geometric/functional configurations of the roundabouts. The results of this work represent practical implications for a correct and safe design of road roundabouts.

Keywords: *road safety, driving behavior, 3D modeling, face-to-face interviews, correspondence analysis*

1. Introduction

Nowadays, roundabouts are certainly the most common type of intersection. Many conventional intersections have been converted into roundabouts. The safety advantages of roundabouts are confirmed by numerous studies. Also the advantages in terms of operational performance are amply demonstrated. Road roundabouts may have different geometric configurations. The radius of the roundabout, the width and number of lanes, the presence or absence of materialized islands, etc. may vary between different configurations. Many researches have defined the influence of the geometric elements of roundabouts on safety performances. Several studies specifically examined the relationship between geometric elements and safety benefits in roundabout. Elvik (2017) studied the safety effects of converting intersections in roundabouts by a meta-analysis. the results of this study show that converting intersections in roundabouts reduces the fatal accidents of about 65% and the injury accidents of about 40%. Daniels *et al*. (2010) have studied the severity of the crashes in order to determine which elements could influence injury severity in traffic. The consequences for drivers of cars in accidents involving multiple vehicles are less serious. Injury severity increases with higher age. While the accidents that occur outside the urban areas and at night are more serious. Accidents involving only one vehicle have worse consequences than those involving multiple vehicles. Kim and Choi (2013) have identified the factors that most influencing the crashes at roundabouts by studying accidents. In order to define the correlation between accidents and roundabout geometry a statistical analysis was performed. This study defined a model that defines the correlations between roundabout geometric elements (number and width of circulating roadway, number of legs, number and width of entering lanes, etc.) and the accidents at roundabouts. Finally, it is shown how the number of accidents at roundabouts is higher on the roundabout with entry approach and circulatory roadway with 2 lanes. Also, Farag and Hashim (2017) have defined two crash-prediction models in order to evaluate the roundabouts safety performance. These models take into account: the traffic flow variables, accidents frequency and severity, and geometric. The first model is based only on the flow of traffic, while the second containing exposure functions, geometry and traffic variables. The results of this study shows that the circulatory roadway width, number of lanes in entry or exit, entry angle, and 85th percentile speed affect the safety performance of a roundabout.

Kamla *et al.* (2016) examined the influences of roundabout geometric and traffic characteristics on the number of accidents. This study shows that the number of traffic accidents in the

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roundabouts examined is influenced by traffic on roundabout leg (both in entry and in exit), heavy vehicles percentage, lane entry width, circulatory roadway outer diameter, number of lanes, and road marking and sign. Particularly significant was the influence of the number of lanes on approaches: the majority of the two-lane approaches (66%) had more accidents.

Gross *et al.* (2013) evaluated the safety effectiveness of converting of the signalized intersections in roundabouts. The safety effects have been estimated by an observational before-after study using a Empirical Bayes (EB) method. The results show a safety benefit for converting of signalized intersections in roundabouts. The authors of this study declare in conclusion that roundabouts have the potential to significantly reduce accidents and severity at signalized intersections.

De Brabander *et al.* (2005) have 95 roundabouts in Flanders in the mid-1990s and have determined the effects in terms of road safety. This study showed that for a main road with a speed limit greater than 90 km/h and a minor road with a speed limit less than 50 km/h roundabouts are most effective respect traditional intersections. Analysis of road accident data before and after the construction of roundabouts revealed a average reduction of 34% for the total number of road accidents, in particular, accidents with minor injury are reduced on average by 30% while those with serious injury are reduced on average by 38%.

From the analysis of the sector literature it can be concluded road roundabouts have high safety standards, but despite this the driver's wrong behavior, due to poorly designed configurations of this type of intersection, can lead to accidents. The geometric elements that mainly influence driving behavior are: deflection angle, number of lanes and width of circulatory roadway, number of lanes and width of approaches, entry radius, etc.).

In recent years, sector research has increasingly focused on defining the driver's safety perception in the different roundabout configurations. It is believed that the driver will adopt a correct driving behavior and therefore safer if he perceives the road infrastructure better.

A study by Ram and Chand (2016) explains that risk perception during the driving tasks significantly affect drivers' road safety performance. Higher drivers' perception of risk and driving tasks will improve their road safety attitude. Distefano *et al*. (2018) conducted a study in order to detect the roundabout geometric features which may influence driver safety perception while during the maneuvers of entry, circulation, and exit in roundabout. The results of this study show that the users prefer single lane on circulatory roadway; also the single entry lane has an important significance in the driver safety perception; the geometric coherence of the consecutive elements has less importance than individual geometric elements with single lane.

The aim of this study is to define the user's preferences regarding the functional-geometric features of the road roundabouts. In fact, we want to investigate whether road user preferences are more oriented towards safer geometrical configurations or instead if the driver prefers configurations that offer better operational performance at the expense of safety. The study will take into account different types of drivers, classified in terms of demographic characteristics and driving behavior. Understanding driver's preferences is an important goal in order to encourage efficient design from the point of view of safety, that takes into account measures that encourage a correct driving behavior and therefore safer. The tool used to determine the preference of road users is the stated preference (SP) survey, in which the project alternatives will be submitted to the respondents through specially created 3D simulated scenarios. Data collected through face-to-face interviews will be then processed by applying the correspondence analysis (CA). The sample of interviewees was chosen in such a way that the respondent was highly educated in order to better understand the contents of the interview.

Perdomo *et al.* (2014) used a stated preference surveys for to analyzed the importance of roundabout geometry and operational performance in defining the safety perception of pedestrians on the roundabout. Moreover, they emphasize the effectiveness of 3D simulation tools in order in order to propose attributes difficult to imagine in SP survey based on paper images. Their research illustrates that vulnerable users are more likely to prefer roundabouts in terms of safety perception if they have pedestrian crossings and that they consider flashing pedestrian crossing signs to be preferable than other (or no) signs. Moreover, respondents have demonstrated through the survey that they feel safer when traffic volume and speed are low.

Majumdar *et al.* (2017) sought to develop a methodology to evaluate various bicycle-specific attributes from user perception using stated preference survey in small-sized Indian cities. This study shows that safety is one of the major factors influencing bicycle route choice in cities with a diverse mix of traffic modes.

Rizzi and Ortúzar (2003) carried out a stated preference experiment in order to assess the value of a statistical life for Chilean interurban motorways. Interviewees had to choose among different routes for a hypothetical trip, based on the following attributes: travel time, toll charge and level of risk. The results of this experiment showed that people were sensitive to the risk variable, thus "stating" a preference for safer routes.

CA is usually used to to simplify complex data and to provide a detailed description of the data, yielding a simple, yet exhaustive analysis. The applications of this method to road safety issues are still not widespread. Jalayer and Zhou (2017) have applied multiple correspondence analysis (MCA) in order to evaluate the roadway, environmental, motorcycle, and motorcyclist related variables that influence the severity and frequency of accidents involving motorcyclists. Factor *et al.* (2010) studied the correspondence between social characteristics and road-accident involvement. Using a big database that contains Israeli road-accident data. Das and Sun (2016) used MCA to identify the combination of factors involved in Run-Off-Road fatal crashes. Leonardi *et al.* (2019) used MCA to define the links between geometric features and traffic conditions of roundabouts and characteristics of young users, in order to determine the perception of the risk of this category of users.

It is believed, however, that the CA is a valid tool for to understand user's preferences on the geometrical-functional characteristics of road roundabouts, this being a technique capable of taking into account the data of a large database.

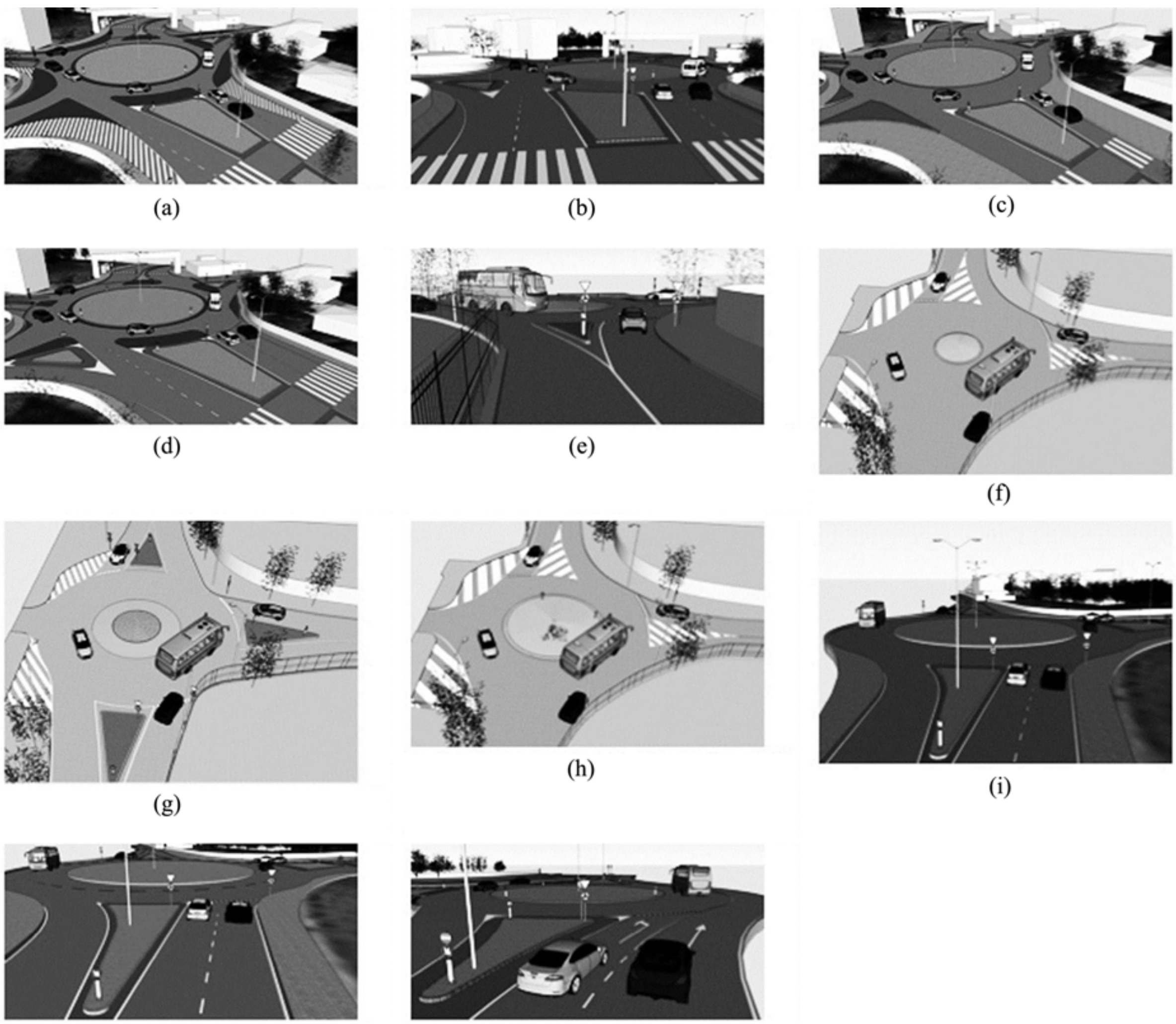
2. Method

The term "Stated Preference Methods" refers to a family of techniques which use individual respondents' statements about their preferences in a set of options to estimate utility functions. The options are typically descriptions of situations or contexts constructed by the researcher. By their nature, stated preference methods require purpose-designed surveys for their collection of data.

In this research, the declared preferences were collected by face-to-face interviews. An ad hoc questionnaire, based on the findings of a focus group composed by road safety experts, was administered to respondents. The purpose of the interviews is to register the stated preferences of a selected sample of respondents, as far as the geometrical-functional characteristics of the roundabouts in terms of safety are concerned. The alternatives of the project, representing different geometric elements or urban furniture of the roundabouts, were presented to the interviewees through specially created 3D simulated scenarios.

2.1 Focus Group

In order to define the attributes of the roundabouts to be taken into account in defining the questionnaire useful for the interviews to collect the preferences of the respondents, a focus group of eight individuals was established. The focus group participants were selected among the DISS members (Italian



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

Fig. 1. Project Scenarios Identified by the Focus Group: (a) Optical Narrowing of the Circulatory Roadway and Approaches with Single Lanes, (b) Approaches with Double Lanes, (c) Approaches with Single Entry Lane through Later Narrowing of the Roadway, (d) Optical Narrowing of the Circulatory Roadway and Approaches with Double Lanes, (e) Materialization of the Painted Traffic Island, (f) Small Central Island and Wide Circulatory Roadway, (g) Realization of Truck Apron and Materialization of the Painted Traffic Islands, (h) Wide Central Island and Small Circulatory Roadway, (i) Approach with Double Entry Lane and Single Lane on Circulatory Roadway, (j) Approaches with Double Entry Lane and Double Lane on Circulatory Roadway, (k) Separate Lane for Crossing

Centre of Road Safety). DISS members are university professors and researchers who are engaged in research activities on road safety issues (infrastructure, vehicle, human factor). A focus group is an exploratory research tool where by a group of potential respondents are asked to identify which attributes they consider to be important on a specific topic. The focus group members were chosen to have a different age and gender. At the beginning we asked the members of the focus group to express their general opinion on the roundabouts with particular reference to safety performance. We then asked them to express their opinion on particular configurations of roundabouts, which were made up of different geometric elements. the opinions expressed by the experts of the gruop focus were used to define the design alternatives to be submitted to the interviewees. On the basis of Italian standards on road design and the analysis of the geometric conformations of the most popular roundabouts in the national territory, 11 attributes of geometrical-functional characteristics of the roundabout were confirmed to be important for safety road experts.

All the identified attributes have been simulated using a 3D software provided by Google, Google SketchUp. SketchUp is a computer program for 3D modeling where by the user is considered as a camera that looks at the device during its work.

Figure 1 shows the 11 scenarios simulated by Google SketchUp.

2.2 Survey

An important issue in the use of stated preference methods is the quality of the survey and the context in which the questions are asked. It is the view of the authors that, if useful results are to be obtained from stated preference methods, the survey needs to be of the highest possible quality and the context in which the stated preference questions are asked should be as realistic as possible. For this reason, the authors have a strong preference for face-to-face interviews, conducted by experienced interviewers.

For this study, the authors produced an ad hoc questionnaire. This questionnaire is divided into 3 sections. The first one is related to the responder's general data (age, gender, mean of transport used mainly). The second section is intended to understand the responder's driving behavior (exemplary, acceptable, wrong). In order to understand the driving behavior, respondents were subjected to planimetric views of several project scenarios and were asked to trace the trajectories that they would run to go from one specified point to another. In total, the trajectories traced by each respondent were 42. Fig. 2 shows an example of the classification of trajectories in case of exemplary, acceptable or wrong driving behavior.

The third part of the questionnaire is intended to capture the

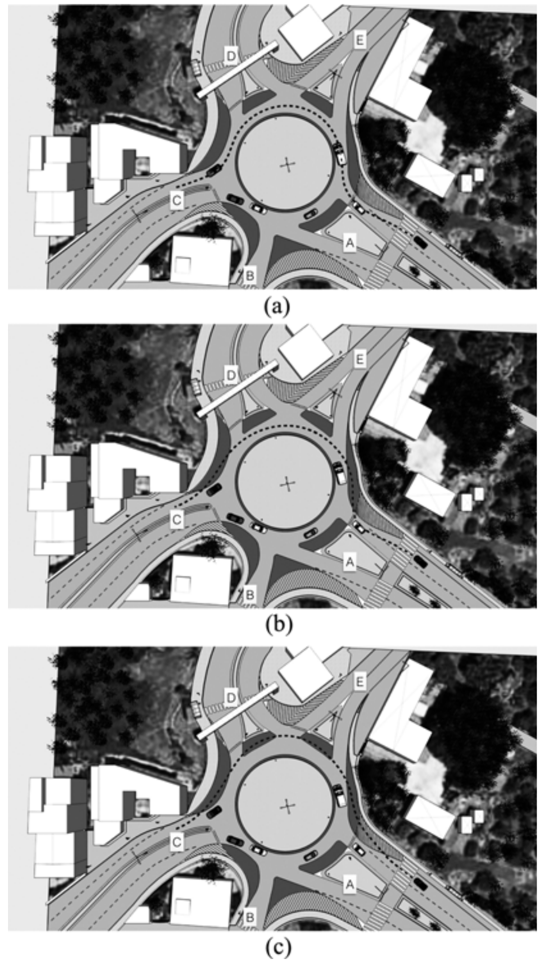
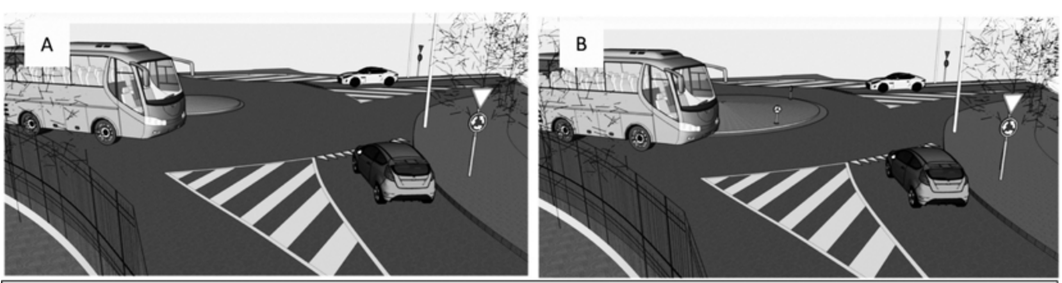


Fig. 2. Examples of Driving Behavior's Classification: (a) Exemplary Driving Behavior, (b) Acceptable Driving Behavior, (c) Wrong driving Behavior



Alternative A vs Alternative B is:		
Safer	Equally safe	Less safe

Fig. 3. Comparison between Alternatives 6 and 8

preferences declared by the respondents by comparing two different design alternatives. The total comparisons contained in the questionnaire are 49 (the same project proposals were submitted to respondents from different points of view). Fig. 3 shows an example of comparison of two different design scenarios for the same roundabout (Alternative A is representative of a wide circulatory roadway, whereas Alternative B is representative of a small circulatory roadway). It is important to note that the views of alternatives to the interview were shown not through paper images (such as those in Fig. 3) but through 3D interactive scenarios on computer, so that they could better understand all the details of the proposed intervention.

Each respondent was asked to evaluate, for each comparison and from the safety point of view, alternative A and alternative B. The judgment scale included: safer, equally safe, less safe.

420 face to face interviews were made. The average duration of each interview was of about one hour.

2.3 Respondents

The target of the interviewees consists of highly educated individuals. This specific choice was made as this category of persons is the most available to be subjected to long interviews, keeping a high level of attention for the duration, moreover highly educated people better understand the alternatives proposed through 3D interactive scenarios on computer. Respondents were chosen from employees of the University of Catania (Professors, researchers and administrative staff) and managers of public and private organizations not directly involved in the transport system.

Respondents were mainly academics (74%) in disciplinary areas other than road safety. Those in policy-making roles made up 18% of the sample, whilst 7% were in industry. The remainder of the sample were classified as "other".

As regards the gender of respondents, 48% are men, while 52% are women. The sample was deliberately chosen to be homogeneously distributed in gender. All respondents are between the ages of 30 and 55 in order to exclude young and old drivers from the study.

Following the trajectories traced to each respondent, as provided in section 2 of the questionnaire, they were classified according to their driving behavior: 33% of respondents have an exemplary driving behavior, 52% have an acceptable driving behavior, and 15% have a wrong driving behavior.

2.4 Correspondence Analysis

CA was used to investigate the relations between the gender, the type of driver, and the stated preference about the roundabout' features. CA is generally employed to visualize a graphical representation of the rows and columns of a cross-tabulation or contingency table. It is especially useful for exploratory analysis with more variables and no preliminary hypothesis. Plot interpretation consists in assigning a meaning to the factorial axes, depending on the variables they are formed by and in interpreting the relationships between variables using the factorial axes. Graphically, the categories with similar distribution will be represented as near points in space, while the categories that have very different distributions will be positioned far away.

Table 1. Variables and Related Categories

Variable 1 – Type of driver			
D1	Man with exemplary driving behavior		
D2	Man with acceptable driving behavior		
D3	Man with wrong driving behavior		
D4	Woman with exemplary driving behavior		
D5	Woman with acceptable driving behavior		
D6	Woman with wrong driving behavior		
Variable 2 – Stated Preference between two different scenarios of project			
C1	Alt. 1 preferred to Alt. 2	C12	Alt. 8 preferred to Alt. 7
C2	Alt. 2 preferred to Alt. 1	C13	Alt. 5 preferred to Alt. 7
C3	Alt. 3 preferred to Alt. 4	C14	Alt. 7 preferred to Alt. 5
C4	Alt. 4 preferred to Alt. 3	C15	Alt. 8 preferred to Alt. 6
C5	Alt. 3 preferred to Alt. 2	C16	Alt. 6 preferred to Alt. 8
C6	Alt. 2 preferred to Alt. 3	C17	Alt. 9 preferred to Alt. 10
C7	Alt. 1 preferred to Alt. 4	C18	Alt. 10 preferred to Alt. 9
C8	Alt. 4 preferred to Alt. 1	C19	Alt. 9 preferred to Alt. 11
C9	Alt. 5 preferred to Alt. 6	C20	Alt. 11 preferred to Alt. 9
C10	Alt. 6 preferred to Alt. 5	C21	Alt. 10 preferred to Alt. 11
C11	Alt. 7 preferred to Alt. 8	C22	Alt. 11 preferred to Alt. 10

In this study, the variables considered for CA are 2 (Table 1). The first variable (V1) defines the type of driver, on the basis of the combination of gender and driving behavior. The second variable (V2) identifies the comparisons between the two different project scenarios.

The CA graphical representations help simplify the process of interpreting the relationships among variables. In a graphical display of the data, categories sharing similar characteristics are located close together, forming point clouds.

In order to compare rows to columns in a general fashion, we standardized data using symmetrical normalization. Standardization consents for a more evenly weighted distribution in distances between points among large differences and small, in order to compare them without big differences skewing the data and overbearing the smaller differences.

The magnitude of information associated with each dimension is called eigenvalue. The eigenvalue of each dimension, which is a value between 0 and 1, indicates the total variance between variables. Every point on each plot is uniquely coordinated for all dimensions, and, obviously, the scale of the plot depends heavily on the total amount of contributions by each dimension.

In order to assign a meaning to the axes, we used the modalities which most contribute to the inertia they explain. The variables category, which was then projected onto the axes, describes the different geometrical-functional characteristics of the compared roundabouts (V2).

3. Results

In order to identify the links between the variables through

CA, we used the statistical software SPSS version 24.0 to process the dataset and to plot graphs.

The input data was provided in such a way that each category of variable 1 matched a variable category 2; the relative frequency was then assigned to each of these combinations (for example, the overall frequency with which Alternative A was preferred to Alternative B in the comparison C_i by type D_j respondent).

The first step of the methodology provides the so-called row profiles and column profiles (Table 2), which are obtained by transforming the frequencies of the contingency matrix into relative percentages, ie comparing the frequency of each cell to the respective row or column total.

Each row (and column) profile can be considered as a coordinate of a point in a space with as many dimensions as there are categories of the variable in row (or in column). The representation of the profiles makes it possible to conclude that the profiles of two rows (or columns) are the closest, the closer to each other the respective points in space. Similarly, two very different profiles will be far from each other.

The Table 3 show the Summary table provided as output of CA from SPSS software.

In order to test for total variance explained and the associated probability it is used the chi-square statistic. The high value of chi-square (8956,781) indicates that there is a high correspondence between the rows and columns of the correspondence table. With regard to this study, SPSS generated 5 dimensions to explain our model. The inertia explained by the model never covers 100% because the SPSS output does not include all the dimensions that explain something about the model, but only those that can be interpreted. The Inertia column reports the total variance explained by each dimension in the model. In our model, the total inertia (total variance explained) is 36.8%. This data indicates that the knowledge of the type of driver explains around 37% about preferences of the roundabout's geometric elements and vice versa. This relation is weak, but anyway highly significant as indicated by chi-square statistic. The values in column of the Proportion of Inertia represent the percent of variance that each dimension explains of the total variance explained by the model. In this case, Dimension 1 explains approximately 54% of the total (37%) of variance explained in the model. Dimension 2 explains approximately 33% of the total (37%) of variance explained in the model. Also, Dimensions 3, 4 and 5 explain only a small part of the total variance explained to be used for further analysis.

The values in column of the Proportion of Inertia represent the percent of variance that each dimension explains of the total variance explained by the model. In this case, Dimension 1 explains approximately 54% of the total (37%) of variance

Table 2. Row Profiles and Column Profiles

	Row Profiles																					
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
D1	0,139	0,000	0,093	0,037	0,120	0,019	0,139	0,000	0,037	0,009	0,019	0,019	0,019	0,019	0,037	0,000	0,009	0,093	0,019	0,083	0,093	0,000
D2	0,079	0,021	0,046	0,054	0,058	0,037	0,079	0,021	0,108	0,004	0,116	0,004	0,000	0,116	0,095	0,025	0,000	0,041	0,008	0,037	0,050	0,000
D3	0,019	0,078	0,000	0,087	0,010	0,087	0,019	0,058	0,126	0,010	0,107	0,000	0,019	0,097	0,146	0,000	0,010	0,049	0,000	0,029	0,049	0,000
D4	0,095	0,000	0,051	0,051	0,080	0,029	0,088	0,022	0,051	0,000	0,073	0,000	0,000	0,073	0,051	0,015	0,007	0,102	0,022	0,080	0,109	0,000
D5	0,081	0,038	0,034	0,088	0,063	0,066	0,078	0,047	0,091	0,006	0,084	0,006	0,009	0,084	0,088	0,006	0,009	0,038	0,019	0,019	0,047	0,000
D6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,090	0,134	0,149	0,075	0,045	0,179	0,119	0,104	0,000	0,045	0,000	0,045	0,015	0,000
Mass	0,077	0,026	0,040	0,063	0,060	0,046	0,075	0,030	0,087	0,014	0,090	0,010	0,010	0,091	0,087	0,017	0,006	0,055	0,013	0,042	0,059	0,000
	Column Profiles																					
D1	0,200	0,000	0,256	0,066	0,220	0,044	0,205	0,000	0,047	0,071	0,023	0,200	0,200	0,022	0,047	0,000	0,167	0,185	0,154	0,220	0,172	0,000
D2	0,253	0,200	0,282	0,213	0,237	0,200	0,260	0,172	0,306	0,071	0,318	0,100	0,000	0,315	0,271	0,353	0,000	0,185	0,154	0,220	0,207	0,000
D3	0,027	0,320	0,000	0,148	0,017	0,200	0,027	0,207	0,153	0,071	0,125	0,000	0,200	0,112	0,176	0,000	0,167	0,093	0,000	0,073	0,086	0,000
D4	0,173	0,000	0,179	0,115	0,186	0,089	0,164	0,103	0,082	0,000	0,114	0,000	0,000	0,112	0,082	0,118	0,167	0,259	0,231	0,268	0,259	0,000
D5	0,347	0,480	0,282	0,459	0,339	0,467	0,342	0,517	0,341	0,143	0,307	0,200	0,300	0,303	0,329	0,118	0,500	0,222	0,462	0,146	0,259	0,000
D6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,071	0,643	0,114	0,500	0,300	0,135	0,094	0,412	0,000	0,056	0,000	0,073	0,017	0,000
Active Margin	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	0,000

Table 3. Summary Table

Dimension	Singular Value	Inertia	Chi Square	Sig.	Proportion of Inertia		Confidence Singular Value	
					Accounted for	Cumulative	Standard Deviation	Correlation
								2
1	0,447	0,199			0,542	0,542	0,009	0,220
2	0,347	0,120			0,327	0,869	0,005	
3	0,158	0,025			0,068	0,937		
4	0,128	0,016			0,044	0,982		
5	0,082	0,007			0,018	1,000		
Total		0,368	8,956,781	,000[a]	1,000	1,000		

a. 105 degrees of freedom

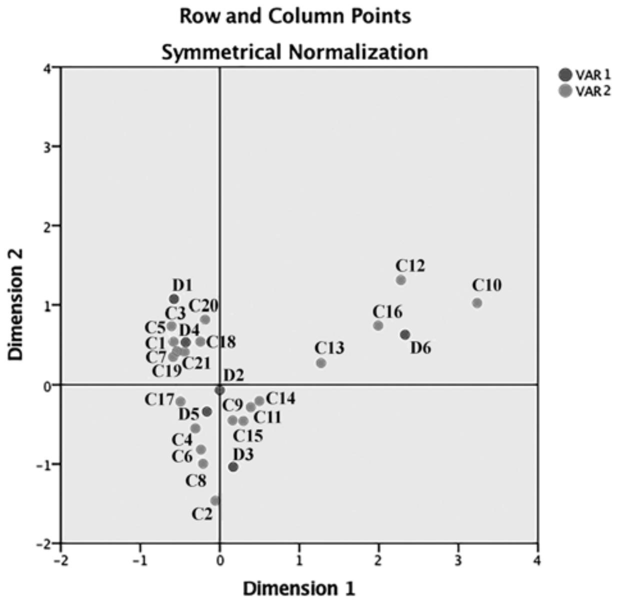


Fig. 4. Biplot of All Study Variables

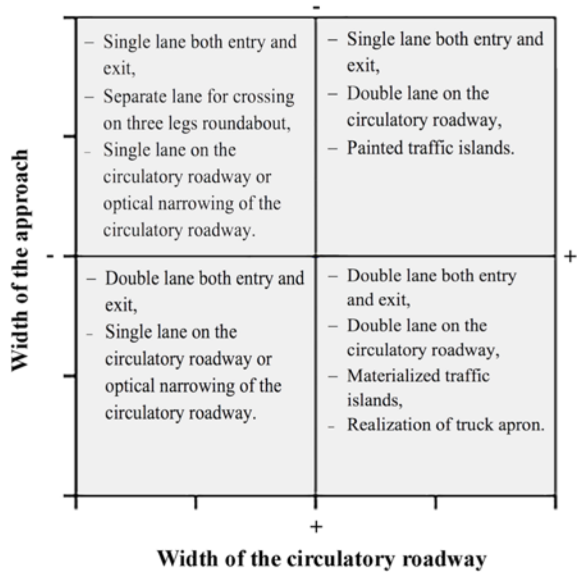


Fig. 5. Definition of Sectors by State Preference

explained in the model. Dimension 2 explains approximately 33% of the total (37%) of variance explained in the model. Also, Dimensions 3, 4 and 5 explain only a small part of the total variance explained to be used for further analysis.

At the end of the process, SPSS realizes a plot, which offers a visual display of each of the values in the dataset plotted with factorial axes. This plot provides an overview of the trends within the data. In this study, as only two dimensions were extracted, SPSS displays the results in 2D in the form of a Biplot (Fig. 4).

Points that are represented close to one another identify attributes with similar profiles, therefore they represent strong links. Whereas points represented far away from one another identify attributes with different profiles, and therefore represent weak links.

The Biplot (Fig. 4) provides an overall representation of the items with the highest contributions in each quadrant. Characterizing or interpreting an axis means giving the axis a specific meaning based on the contrasts and associations that the projections of the variables categories assume on it. Each factorial axis is individually characterized by looking at the profiles of the rows and columns separately, with particular reference to the categories that have an extreme coordinate.

In order to define the axes, we only considered the variable 2 (Stated Preference between two different scenarios of the project).

Dimension 1 (principal axis) represents the width of the circulatory roadway, with greater widths (double lane on the circulatory roadway) on the positive axis and smaller width (single lane on the circulatory roadway) on the negative axis. The categories of variable 2 with higher positive coordinates are the C10 and the C16, which represent both preference for "Small central island and wide circulatory roadway". The categories of variable 2 with higher negative coordinates are C1 and C19, respectively representing the preference for "Optical narrowing of the circulatory roadway and approaches with single lanes" and for "Approach with double entry lane and single lane on circulatory roadway".

Dimension 2 (secondary axis) represents the width of the approaches, with smaller widths (single lane both entry and exit) on the positive axis and greater width (double lane both entry and exit) on the negative axis. The categories of variable 2 with higher positive coordinates are the C20 and the C3, which respectively representing the preference for "Approach with single entry lane through later narrowing of the roadway" and for "Separate lane for crossing". The categories of variable 2 with higher negative coordinates are C2 and C8, respectively representing the preference for "Approaches with double lanes" and for "Optical narrowing of the circulatory roadway and approaches with double lanes".

The two axes define four sectors, which we shall name on the basis of their position. Within the four sectors, the characteristics of the roundabouts considered similar in terms of preferences are reported (Fig. 5).

In order to correlating the types of users with reported the preferences who defined the four sectors of the Fig. 5, the 6 categories of variable 1 were projected within the representative scheme of the sectors (Fig. 6). As in the CA Biplot output categories D1 and D4 are into the top left quadrant, the D5 is in the bottom left quadrant, the D6 is in the top right quadrant and the D3 is in the bottom right quadrant. Category D2 is centered with the principal axis and slightly below the 0 of the secondary axis.

4. Discussions

This study is based on face-to-face interviews done with a selected sample of individuals. The sample included participants

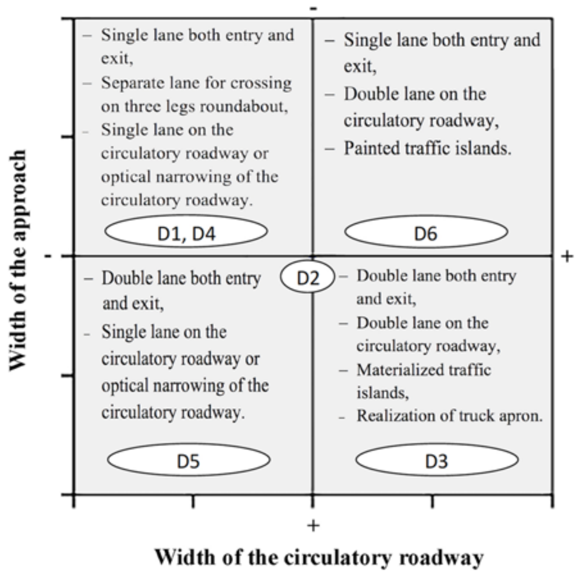


Fig. 6. Projection of Variable 1 Categories within the 4 Sectors

with a high level of instruction in order to avoid the distortion of driving behavior by the lack of knowledge of the driving rules. By doing so, it is certain that wrong driving behavior solely derives from the driver and not from the ignorance of the rules, as well as exemplary driving behavior only depends on the respect of the rules.

The number of respondents was equally distributed among men and women. As regards the age range, participants between 30 and 55 years of age were specifically selected to ensure that judgment on driver behavior was not affected either by the typical features of young drivers or by the typical features of the old drivers.

The first outcome of this study is the classification of respondents on the basis of their driving behavior following the traced trajectories (second part of the questionnaire). In particular, about half of the sample showed an acceptable driving behavior (24% men, 28.5% women), about 1/3 of the sample had an exemplary driving behavior (14% men, 19% women), and only 1/6 of respondents resulted in wrong driving behavior (9.5% men, 5% women).

The authors believe that these results reflect the driving behaviors in many road contexts. In everyday life it is common for most users to manifest acceptable behaviors and that truly misguided users to be reduced in percentage terms, as well as drivers with an exemplary driving behavior. Several studies in literature also confirm that men have a greater propensity to violate the rules than women (González-Iglesias *et al.*, 2012; Sullmann *et al.*, 2017; Oppenheim *et al.*, 2016).

The identification of different roundabout geometric configurations, characterized by elements that are equally preferred by the different types of drivers, is another result of this work. The output of the CA, applied to the two considered variables (the type of driver and the Stated Preference between two different project scenarios), allowed to define specific grouping of geometric elements according to the preferences stated by the respondents. That is, different geometric elements that have a strong link between them have been grouped together to define various configurations of roundabouts. The different geometric configurations of the roundabouts have been defined starting from the categories of the variable 2 that allowed to define the two axes of the Biplot (width of the circulatory roadway and width of the lanes on the approaches).

The meaning of each grouping (Fig. 5) can be interpreted through considerations related to two aspects that are often in conflict with each other: 1) road safety; 2) operational performance and comfort. In particular:

1. The top left sector groups together design elements typically associated with the best roundabout safety performance. The presence of a single entry lane, as shown by several studies, is the design solution that, in comparison with the two-lane entrance, guarantees lower accident rates (Kim and Choi, 2013; Farag and Hashim, 2017; Kamla *et al.*, 2016). The presence of a single lane on the circulatory roadway, imposed by the Italian Legislation, or the optical narrowing of the circulatory roadway offer better safety performance compared to the two lanes on circulatory roadway or to the configuration with a very wide circulatory roadway (Kim and Choi, 2013; Farag and Hashim, 2017; Kamla *et al.*, 2016). It is known that, in the case of a double lane on the circulatory roadway, there are conflicting points between the parallel traffic flows and, consequently, the risk of lateral collision accidents increases (Kim and Choi, 2013; Kamla *et al.*, 2016).
2. The bottom right sector groups together those design elements that are typically associated with the best operating performance and the best driving comfort conditions. The presence of the double entry lane, double exit lane and double lane in circulatory roadway guarantees a significant performance increase in terms of capacity and service levels compared to single lanes. This is especially evident during the hours of vehicular traffic increase. At less intense traffic hours, however, the greater widths of the lanes offer drivers a more comfortable ride and the possibility to approach the intersection at higher speeds than geometric configurations featuring a single lane. However, these configurations are characterized by the lowest levels of safety (Kim and Choi, 2013; Farag and Hashim, 2017; Kamla *et al.*, 2016).
3. The top right sector groups together those design elements that can't be catalogued or solely beneficial from the point of view of safety, or overall adequate to ensure better operational performance and comfort. This sector is indicative of how both the single entry and exit lane (best for safety but not for functionality) and the double lane on the circulatory roadway (best for the benefit of operational performance and comfort but not of safety) are preferred. It should be noted that in Italy a roundabout so shaped could no longer be realized since the Italian law forbids to have more than one lane on the circulatory roadway.

4. The sector at the bottom left, as the sector placed in a diametrically opposite position, groups together those design elements that can't be catalogued or solely beneficial from the point of view of safety, nor generally suitable for improved operational performance and comfort. This sector is indicative of how the double lane on the entry and exit approaches is likewise preferred (to guarantee better performance in terms of capacity and service level but not of safety), as well as the single lane on the circulatory roadway (to benefit from safety performance but not from functionality). It should be noted that in Italy a roundabout so shaped could no longer be realized since the Italian law forbids the double lane on the exit approach.

The final result of the present study consists of associating with the different roundabout configurations (more or less safe, more or less functional) the types of drivers that, on the basis of their stated preferences, allowed the definition of such project scenarios.

This result was obtained by projecting the points of the Biplot, which are representative of the different types of drivers characterized by gender and driving behavior (Variable 1 of the Biplot represented in Fig. 4) in the four identification sectors of the roundabout configurations, which were defined following the the CA and represented in Fig. 5.

The correlations between the different categories of the two variables considered in the present study will thus be defined. This step allows to interpret the obtained results by taking into account the role of the human factor in conditioning the preferences on the elements of the road networks.

Authors believe that this is the most important aspect of the research, which offers interesting discussion topics. In particular, it should be noted that:

1. The categories of drivers D1 and D4 are both located in the top left sector. These categories of users, catalogued as "with exemplary driving behavior", are those that express their preference to those roundabouts with the best performance in terms of safety. Therefore, the design elements that ensure the safety of the roundabout, regardless of the gender of the users, are preferred by those drivers who approach the intersections in an optimum manner, both from the point of view of driving behavior and of respect for the rules. It is noted that the correlation between the preferences expressed for the geometric elements contained in this sector and the characteristics of the D1 and D4 drivers is very strong. In fact, the cloud of points relating to the categories of Variable 2 in this sector of the Biplot is very dense and the representative points of the two categories of Variable 1 fall within it (Fig. 4).
2. The D2 driver category, represented by "men with acceptable driving behavior", is located slightly downward to the origin of the axes. This position is representative of user preferences that are never specifically geared towards specific geometric/functional configurations of the roundabouts. Therefore, this category of users has not shown clear preferences towards any of the configurations identified.
3. The D3 driver category, represented by "men with wrong driving behavior", is located in the bottom right sector. Unfair male drivers therefore prefer those roundabout configurations that ensure trajectories that are smooth, fast and less conditioned by geometric constraints and, therefore, can support their ruthlessness in driving behavior.
4. The category of users D5, consisting of "women with acceptable driving behavior", is positioned in the bottom left sector. Women who have an intermediate driving behavior between the best and the most damaging one are therefore in favor of those roundabout configurations that allow easy entry and exit maneuver, while simultaneously limiting transverse travel on the circulatory roadway. This could reflect the fear of women against the conflicts that are notoriously generated on the circulatory roadway.
5. The category of users D6, represented by "women with wrong driving behavior", is located in the sector at the top right. Women with the most unconventional and less respectful driving behavior prefer those roundabout configurations that allow the circulation on parallel lanes in the circulatory roadway (in the case of significant vehicular flows) and the possibility of taking unrestricted circulation trajectories (in the case of low traffic flows). This category of drivers also prefers the roundabout configurations with painted traffic islands, which obviously do not constitute a constraint, neither physical nor psychological, as it seems to inhibit incorrect driving behaviors.

5. Conclusions

This paper presented the results of a stated preference survey carried out to assess users' choices on the geometric elements of roundabouts in terms of road safety in Italy. The survey included 22 comparisons between 11 different attributes of geometrical-functional characteristics of roundabouts, which have been identified by an appropriate focus group. For this study, the authors produced an ad hoc questionnaire, which is founded on project scenarios 3D modeling. Based on the answers to a specific part of the questionnaire, three different driving behaviors were identified (exemplary, acceptable, wrong). The people interviewed were chosen according to the criterion of high socio-cultural level, in order to acquire the opinions of a qualified sample of users even if not directly involved in the transport sector.

The use of a stated preference survey for assessing the driver's preferences regarding the elements of the roundabouts have revealed that such preferences are different depending on the type of driving behavior exhibited by the driver and, only in a less obvious manner, according to gender.

For data processing, the method of CA was very useful. Whit this statistical analysis tool and the support of the SPSS software it was possible to schematically represent the considerable amount of starting data. Consequently, also the deduction of the results and their discussion resulted particularly easy and useful for the determination of the suggestions for the design of the roundabouts and, in general, for the planning of transport infrastructures.

The results of the CA show the following interesting results:

1. Drivers with exemplary driving behavior, regardless of the gender, prefer design elements that ensure a greater safety of the roundabout (i.e. single lane both entry and exit, separate lane for crossing on three legs roundabout, single lane on the circulatory roadway or optical narrowing of the circulatory roadway).
2. Drivers with acceptable driving behavior expressed preferences that are never specifically geared towards specific geometric/functional configurations of the roundabouts. This aspect is particularly evident for men; women, instead, show a preference for roundabouts with the following characteristics: double lane both entry and exit, single lane on the circulatory roadway or optical narrowing of the circulatory roadway.
3. Men with wrong driving behavior prefer those roundabout configurations that are less safe but that ensure smooth and fast trajectories, and which are less conditioned by geometric constraints (i.e., double lane both entry and exit, double lane on the circulatory roadway, materialized traffic islands, realization of truck apron).
4. Women with wrong driving behaviors prefer roundabouts with single lane both entry and exit and allow circulation on parallel lanes in the circulatory lane. This category of drivers also prefers the roundabout configurations which do not constitute a constraint, neither physical nor psychological (this is guaranteed by painted traffic islands).

The results of this study provide a practical guidance for the Administrations in the design and for the implementation of roundabout management practices. Effective and safe planning should take into account the preferences of those users who exhibit exemplary driving behaviors and avoid design preferences from those users with wrong driving behaviors, as they explicitly expressed preferences in order to support their ruthlessness in driving behavior. Therefore, road design practices in addition to being compatible with the design standards, should be compatible with the preferences of the most virtuous users from the point of view of driving behavior. The two-lane entry of the roundabout, for example, although admitted by Italian law, is however preferred mainly by aggressive users and with an incorrect driving behavior. In this case, therefore, the design option that requires single lane entry, safer and preferred by users with exemplary driving behavior should be adopted. Even when managing infrastructures the same criterion should be adopted, implementing requalification and functional adaptation interventions aimed at satisfying the preferences of users who are more respectful of the rules. The transformation of the painted divisional islands into materialized islands is an intervention that, for example, fits with the criterion that emerged as a result of this research.

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References

Daniels, S., Brijs, T., Nuyts, E., and Wets, G. (2010). “Externality of risk and crash severity at roundabouts.” *Accident Analysis and Prevention*, Vol. 42, No. 6, pp. 1966-1973, DOI: 10.1016/j.aap.2010.06.001.

Das, S. and Sun, X. (2016). “Association knowledge for fatal run-off-road crashes by multiple correspondence analysis.” *IATSS Research*, Vol. 39, No. 2, pp. 146-155, DOI: 10.1016/j.iatssr.2015.07.001.

De Brabander, B., Nuyts, E., and Vereeck, L. (2005). “Road safety effects of roundabouts in Flanders.” *Journal of Safety Research*, Vol. 36, No. 3, pp. 289-296, DOI: 10.1016/j.jsr.2005.05.001.

Distefano, N., Leonardi, S., and Pulvirenti, G. (2018). “Factors with the greatest influence on drivers' judgment of roundabouts safety. An analysis based on web survey in Italy.” *IATSS Research*, Vol. 42, No. 4, pp. 265-273, DOI: 10.1016/j.iatssr.2018.04.002.

Elvik, R. (2017). “Road safety effects of roundabouts: A meta-analysis.” *Accident Analysis and Prevention*, Vol. 99, pp. 364-371, DOI: 10.1016/j.aap.2016.12.018.

Factor, R., Yair, G., and Mahalel, D. (2010). “Who by accident? The social morphology of car accidents.” *Risk Analysis*, Vol. 30, No. 9, DOI: 10.1111/j.1539-6924.2010.01423.x.

Farag, S. G. and Hashim, I. H. (2017). “Safety performance appraisal at roundabouts: Case study of Salalah City in Oman.” *Journal of Transportation Safety & Security*, Vol. 9, No. 1, DOI: 10.1080/19439962.2016.1199623.

González-Iglesias, B., Gómez-Fraguela, J. A., and Luengo-Martín, Á. (2012). “Driving anger and traffic violations: Gender differences.” *Transportation Research Part F*, Vol. 15, pp. 404-412, DOI: 10.1016/j.trf.2012.03.002.

Gross, F., Lyon, C., Persaud, B., and Srinivasan, R. (2013). “Safety effectiveness of converting signalized intersections to roundabouts.” *Accident Analysis and Prevention*, Vol. 50, pp. 234-241, DOI: 10.1016/j.aap.2012.04.012.

Jalayer, M. and Zhou, H. (2017). “A multiple correspondence analysis of at-fault motorcycle-involved crashes in Alabama.” *Journal of Advanced Transportation*, Vol. 50, pp. 2089-2099, DOI: 10.1002/atr.1447.

Kamla, J., Parry, T., and Dawson, A. (2016). “Roundabout accident prediction model random-parameter negative binomial approach.” *Transportation Research Record*, Vol. 2585, pp. 11-19, DOI: 10.3141/2585-02.

Kim, S. and Choi, J. (2013). “Safety analysis of roundabout designs based on geometric and speed characteristics.” *KSCE Journal of Civil Engineering*, Vol. 17, No. 6, pp. 1446-1454, DOI: 10.1007/s12205-013-0177-4.

Leonardi, S., Distefano, N., and Pulvirenti, G. (2019). “Multiple correspondence analysis (MCA) for the evaluation of risk perception of roundabouts for young people." *European Transport / Trasporti Europei*, Vol. 72, No. 4, pp. 1-23.

Majumdar, B. B., Asce, S. M., and Mitra, S. (2017). "Valuing factors influencing bicycle route choice using a stated-preference survey." *Journal of Urban Planning and Development*, Vol. 143, No. 3, DOI: 10.1061/(ASCE)UP.1943-5444.0000380.

Oppenheim, I., Oron-Gilad, T., Parmet, Y., and Shinar, D. (2016). "Can traffic violations be traced to gender-role, sensation seeking, demographics and driving exposure?" *Transportation Research Part F*, Vol. 43, pp. 387-395, DOI: 10.1016/j.trf.2016.06.027.

Perdomo, M., Rezaei, A., Patterson, Z., Saunier, N., and Miranda-Moreno, L. F. (2014). "Pedestrian preferences with respect to roundabouts - A video-based stated preference survey." *Accident Analysis and Prevention*, Vol. 70, pp. 84-91, DOI: 10.1016/j.aap.2014.03.010.

Ram, T. and Chand, K. (2016). "Effect of drivers' risk perception and perception of driving tasks on road safety attitude." *Transportation Research Part F*, Vol. 42, pp. 162-176, DOI: 10.1016/j.trf.2016.07.012.

Rizzi, L. I. and Ortúzar, J. de D. (2003). "Stated preference in the valuation of interurban road safety." *Accident Analysis and Prevention*, Vol. 35, pp. 9-12, DOI: 10.1016/S0001-4575(01)00082-3.

Sullman, M. J. M., Paxion, J., and Stephens, A. N. (2017). "Gender roles, sex and the expression of driving anger." *Accident Analysis and Prevention*, Vol. 106, pp. 23-30, DOI: 10.1016/j.aap.2017.05.016.