Multiple Correspondence Analysis (MCA) for the evaluation of risk perception of roundabouts for young people

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Abstract

Risk perception, i.e. the ability to "read the road" in relation to potentially dangerous situations in the traffic environment, is strongly related to accident involvement. Human driving behavior is strongly conditioned by the road environment in its entirety, as driving involves complex interactions between the driver and the environment. This study investigated the risk perception of roundabouts for young people in order to identify the major factors which influence such perception. A road users survey was developed to obtain young people feedback on roundabouts. Multiple Correspondence Analysis (MCA) was used in order to understand how the young people features, the geometric characteristics and the traffic conditions of roundabouts affect the respondents' risk perception. Finally, a risk perception scale was defined for the configurations of roundabouts identified. The research findings provides insight into young people risk perception of roundabouts: traffic conditions strongly affect risk perception of roundabouts; the roundabouts with small circulatory roadway (smaller than 7 m), with a diameter less than 40 m and with one lane on the legs and on the circulatory roadway are generally perceived as more dangerous than those with a medium/large circulatory roadway (larger than 7 m), with a diameter longer than 40 m and with two lanes n the legs and on the circulatory roadway; the right-turn bypass lane affects the respondents risk perception, but not in a clear and unambiguous manner. The authors believe that the results presented on this paper provide updated findings which may be useful to improve roundabouts design.

Keywords: Road safety, risk of accident, driving behavior, human factor, intersections, geometric design elements.

1. Introduction

Road users' awareness of potential risks is an important factor in many accidents. Risk perception, i.e. the ability to "read the road" in relation to potentially dangerous situations in the traffic environment, seems to be the only component of driving skills that has been found to be related to accident involvement (Horswill and McKenna, 2004). For many decades road safety researchers have been attempting to explain how people perceive and understand risk (McKenna and Crick, 1991 and 1997; Hull and Christie, 1992; Borowsky

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et al., 2010; Horswill et al., 2015; Horswill et al., 2016). The reason that risk perception ability has retained interest over the years is because anticipation of hazardous traffic situations is one of the major contributions to driver safety. For example, Horswill et al. (2015) found that drivers who failed a risk-perception test had 25% more active crashes (i.e. crashes in which the driver's vehicle was moving, excluding parking or reversing) in the year following the test. In contrast to most driver education and assessment interventions, risk-perception testing and training have the capability to reduce crash risk (Horswill, 2016). It is acknowledged that human factors may contribute to accident involvement in traffic (Grayson and Maycock, 1988). Based on a study of 2041 traffic accidents, Sabey and Taylor (1980) concluded that human factors were contributing elements in 95% of the accidents. In particular, driving behavior was identified as the most central of these factors. Driving attitude, which is manifested by driving behavior, strongly affect the risk perception of drivers (Cheng et al., 2011). Therefore, it is important to understand the aspects affecting the drivers' ability to perceive danger and risk and, thus, affecting their driving behavior. Human driving behavior is strongly affected by the road environment, as driving involves complex interactions between the driver and the environment. For example, Lim et al. (2013) found that familiarity with the driving environment facilitated drivers' ability to discriminate risks in a timely manner. Considering the extreme complexity of road networks, the aspects affecting the driving behavior should be studied with specific regard to the elements of road networks as, for example, the intersections. It is well known that intersections are among the most complex road environments: their geometric configuration, the signs and the markings, the road furniture, the qualitative and quantitative characteristics of traffic, the vehicular conflicts are all elements which weigh the driver workload, a therefore affect the driving behavior and the risk of accident. Among intersections, roundabouts are the most popular nowadays. Converting junctions to roundabouts has been found to reduce the number of accidents, in particular fatal accidents (Elvik, 2003 and 2017; Persaud, 2001; Vujanić, 2016). Studies of roundabouts in various countries have shown that roundabout can significantly improve functional characteristics (Al-Madan, 2003; Easa and Mehmood, 2006; Ma et al., 2013; Mauro and Cattani, 2012), as well as traffic safety (Bie and Wong, 2008; Chen et al., 2013; Gross et al., 2013).

Several studies have highlighted the safety advantages of roundabouts in urban contexts, although roundabouts do not always guarantee adequate levels of safety for vulnerable users, such as pedestrians and cyclists (Pilko and Šarić, 2018; Lakouari et al., 2018; Pilko et al., 2017; Meneguzzer and Rossi, 2013, Sacchi et al., 2011). Giuffrè and Grana (2013) presents an exploratory analysis aimed at modeling the crash phenomenon for a set of injury crash data of urban roundabouts operating in the road network of Palermo City, Italy.

Engineering design is considered one of the most important factors affecting the efficiency and safety of a roadway system especially for roundabouts, which directly influences the maneuvering behavior and driver's speed adoption. It was found that at least one geometric factor is responsible for 60% of the total crashes (Montella, 2010). Therefore, geometric design plays a vital role in roundabouts safety. A lot of researchers tried to identify the geometric factors of roundabouts affecting the safety of this type of intersection. Numerous studies focused particularly on the relationship between roundabout geometric design, traffic conditions, and crash rates (Arndt and Troutbeck, 1995; Kennedy et al., 2005; Kim and Choi, 2013; Mahdalova et al., 2013; Anjana and Anjaneyulu, 2015; Kamla et al., 2016; Farag and Hashim, 2017; Daniels et al., 2010;

Pecchini et al., 2014; NCHRP, 2010). The results are consistent about the relationship of some variables, such as entry radius, circulatory roadway width, inscribed circle diameter and angle to the next leg, with crash frequency. An increase in the value of entry radius, circulatory roadway width, inscribed circle diameter increases crash frequency. With an increase in angle to the next leg, crash frequency decreases. Geometric variables such as entry width, gradient and central island diameter show instead an inconsistent relationship with crash frequency across different studies. A lot of studies have also suggested some models to optimize the geometric design of roundabouts (e.g. Easa and Mehmood, 2006; Šurdonja et al., 2013). While previous studies have provided valuable information as to the relationship between roundabout geometrical features, traffic conditions and crash rates, to the best of our knowledge, few similar analyses for risk perception of roundabouts have been carried on (e.g. Distefano et al., 2018). Despite the high level of safety recognized for roundabouts, there are several factors influencing the driver behavior. These factors can cause incorrect behaviors which can degenerate into accidents. Therefore, this study intends to contribute for a better understanding of the factors that affect the risk perception of roundabouts.

Specifically, we will focus on roundabouts risk perception for young people. Young people are more frequently involved in traffic accidents as compared to other age groups (ISTAT, 2017; World Health Organization, 2017). The complexity of young people safety problem is widely acknowledged. It is well established, for example, that young novice drivers play a disproportionately large role in traffic crashes. The risk of a crash for young drivers is higher than for any other age group (Shope, 2006; Williams, 2003). Young people have a higher risk for crash involvement, in part because they are more likely to take risks while driving (Ferguson, 2003; Williams, 2003). They may also be particularly vulnerable to distractions because of their greater propensity to engage in distracting activities (Olsen et al., 2005). Accumulated evidence suggests that experienced drivers possess better risk perception skills than young-inexperienced drivers (e.g., Borowsky et al., 2010; Pollatsek et al., 2006; Wallis and Horswill, 2007). Research has shown that novices are slower in detecting risks, and that they often detect fewer risks than experienced drivers (Underwood et al., 2005). Driving experience, instead, improves drivers' awareness of potential risks and guides drivers' eye movements to locations that might embed potential risks (Borowsky et al., 2010). Compared with younger drivers, older drivers have more experience and are more likely to adjust their driving behaviors to suit traffic and road conditions (Begg and Langley, 2001; Bingham and Shope, 2004). It has also been established that young drivers have stronger motivations for risky driving than older drivers do (Hatfield and Fernandes, 2009). Road traffic injuries are the leading cause of death among people aged between 15 and 29 years (World Health Organization, 2017). Therefore, it is necessary to develop some road safety strategies to reduce road traffic injuries especially for young people. A successful road safety strategy should use a combination of education aimed at road users' behavior improvements and skills training, along with road environment improvements. For this reason, the final aim of this study is to assess how risk perception of roundabouts for young people varies according to their demographic characteristics (sex, age), to the travel mode, to the geometric characteristics of roundabouts (number of lanes, inscribed circle diameter, circulatory roadway width, presence or absence of the right turn by pass-lane), and to the traffic conditions.

2. Method and Variables

2.1 Survey and study area

A road user questionnaire was developed in order to collect opinions regarding the risk perception of four existing roundabouts (Figure 1) located in different urban contexts in the city of Catania (Italy).

Considering that the final aim of the questionnaire was to evaluate the risk perception of these roundabouts based on the participants driving experience, it was necessary to select participants who had a certain driving experience of the roundabouts studied. Because of this, participants were recruited in person. Specifically, a pre-selection test was used in order to select drivers who knew well the four roundabouts. This pre-selection test contained questions about the knowledge of the four roundabouts and the frequency of use. The drivers who didn't know the four roundabouts or who used them less than once a week were excluded. Only the drivers who used the roundabouts at least once a week started the questionnaire.

Figure 2: Geometric plan views of the four roundabouts studied

The questionnaire contained 73 items and consisted of the following four sections:

- Section A: participants reported their age, their gender, the means of transport mainly used and other basic socio-demographic characteristics information;
- Section B: this section included questions regarding the knowledge of how a roundabout works and the overall opinion on roundabouts;

- Section C: this section contained questions about the characteristics of the four roundabouts analyzed. Specifically, for each roundabout, participants were asked questions about the geometry, the road furniture, the speed and the traffic.
- Section D: this section regarded the risk perception of the four roundabouts studied. Specifically, for each roundabout, participants were asked questions about the risk perception of the three possible maneuvers (entry, circulation, exit) and about the overall risk perception.

Figure 2 shows the questionnaire structure.

The four roundabouts studied were chosen in order to have a certain heterogeneity of geometric-constructive characteristics (inscribed circle diameter, presence or absence of the double entry lane or the double circulatory roadway, legs slope, visibility, etc.) and of operational conditions (traffic flows, presence of vulnerable users, etc.). The geometric characteristics of the four roundabouts were obtained from Google Maps. Table 1 shows the geometric features of the selected roundabouts. All roundabouts have four-arms and they are classified according to the number of lanes per approach (one or two lanes), the presence or absence of right-turn bypass lane, the inscribed circle diameter and the circulatory roadway width.

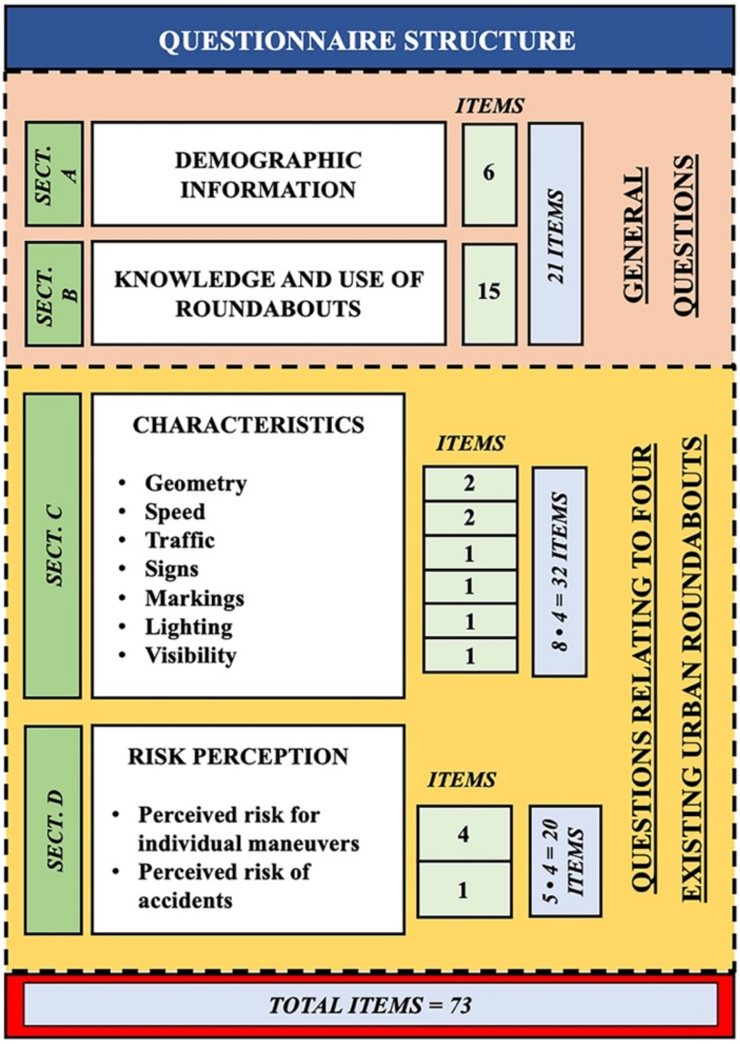

Figure 2: Questionnaire structure

Table 1: Roundabouts geometric characteristics

ROUNDABOUT A					
	Entry (En)	**Exit (Ex)**	**Right turn bypass-lane**	**Inscribed circle diameter (D)**	**Circulatory roadway width (C)**
Approach A1	9,30 m (2 lanes)	6,90 m (2 lanes)	No	70,00 m	9,00 m (2 lanes)
Approach A2	4,40 m (1 lane)	5,80 m (1 lane)	Yes		
Approach A3	8,00 m (2 lanes)	7,05 m (2 lanes)	Yes		
Approach A4	7,70 m (2 lanes)	8,90 m (2 lanes)	Yes		
ROUNDABOUT B					
	Entry (En)	**Exit (Ex)**	**Right turn bypass-lane**	**Inscribed circle diameter (D)**	**Circulatory roadway width (C)**
Approach B1	4,40 m (1 lane)	6,15 m (1 lane)	Yes	32,00 m	6,50 m (single lane)
Approach B2	5,80 m (1 lane)	4,45 m (1 lane)	No		
Approach B3	4,70 m (1 lane)	6,60 m (1 lane)	Yes		
Approach B4	5,90 m (1 lane)	4,15 m (1 lane)	No		
ROUNDABOUT C					
	Entry (En)	**Exit (Ex)**	**Right turn bypass-lane**	**Inscribed circle diameter (D)**	**Circulatory roadway width (C)**
Approach C1	5,55 m (2 lanes)	6,75 m (2 lanes)	No	41,00 m	7,85 m (double lane)
Approach C2	8,30 m (2 lanes)	7,00 m (2 lanes)	No		
Approach C3	5,25 m (1 lane)	4,95 m (1 lane)	No		
Approach C4	8,10 m (2 lanes)	5,66 m (2 lanes)	No		
Note: *This roundabout also has a fifth approach. However, it was not considered in the analysis because it is one-way and it is characterized by extremely low vehicular flows.*					
ROUNDABOUT D					
	Entry (En)	**Exit (Ex)**	**Right turn bypass-lane**	**Inscribed circle diameter (D)**	**Circulatory roadway width (C)**
Approach D1	4,45 m (1 lane)	3,20 m (1 lane)	No	33,00 m	7,10 m (single lane)
Approach D2	4,50 m (1 lane)	4,15 m (1 lane)	No		
Approach D3	5,60 m (1 lane)	4,75 m (1 lane)	No		
Approach D4	4,25 m (1 lane)	5,00 m (1 lane)	No		

As for the operational conditions, it was defined an easy-understanding criterion in order to obtain from the respondents' opinions regarding the traffic conditions on the roundabouts studied. The final aim was to obtain an opinion regarding the traffic conditions on the basis of the driving situations dealt with in the phases of approach and entry on the circulatory roadway. Because of this, three types of traffic conditions were considered: low, medium and high. The "low traffic" means that the traffic conditions are not affecting significantly the achievement of the yield line on the entry lane and the entry on the circulatory roadway. The "medium traffic" means that the traffic conditions create some delay in the achievement of the yield line on the entry lane and in the entry on the circulatory roadway. The "high traffic" is associated with significant delays during the approach (e.g. slow queue dissipation speed) and/or during the entry on the circulatory roadway (e.g. difficulties in finding the gap to enter the circulatory roadway).

The concepts of high, medium and low traffic were considered questionable. Because of this, "surrogate" indicators were adopted. Therefore, a criterion based on the lost-time t associated to the entry on the roundabout was chosen. The 1-minute time interval was considered as time base for the lost-time because the 1-minute interval is easily identified by drivers on the base of their driving experience. A lost-time of more than 1 minute is always perceived as an uncomfortable situation, near to the traffic congestion. The lost-time of half-minute (or less) is considered to be a fluid traffic condition. Thus, a question related to the lost-time t associated to the entry on the roundabout was included in the questionnaire. The possible answers were three: 1) less than half minute; 2) between half minute and one minute; 3) more than one minute. Based on this, they were identified low ($t < 30$ sec), medium ($30 \text{ sec} < t < 60$ sec) and high ($t > 60$ sec) traffic flows for each of the four roundabouts.The choice of the base value of 1 minute is consistent with the indications of the Highway Capacity Manual. Table 2 shows the average control delays associated to the corresponding level of services for roundabouts according to the Highway Capacity Manual (2010). These values are associated with three levels of satisfaction: 1) high level of satisfaction (LOS from A to C); 2) average satisfaction level (LOS from D to E); 3) low degree of satisfaction (LOS = F).

Table 2: Level of Service Criteria for Roundabouts

Level of service	Average Control Delay (seconds/vehicle)
A	0 – 10
B	> 10 – 15
C	> 15 – 25
D	> 25 – 35
E	> 35 – 50
F	> 50

Source: Highway Capacity Manual 2010, Transportation Research Board, 2010

2.2 Participants and procedure

In order to obtain young drivers' opinion, the survey was conducted at the University Campus of Catania over a 3-month period. Participants were briefed of the nature and time required to participate in the study prior to commencement. After their consent was obtained, the questionnaire started. It was decided to question directly the participants, instead of left them alone with the questionnaire, in order to provide visual aids and detailed explanations and clarifications. Each survey lasted approximatively 25 minutes. The interviewer asked to the respondent the questions with the aid of a tablet. The digital form of the survey was created with Google Forms Software. This allowed to record the data in digital format and to speed up the data collection phase and the post-processing phase. The Section C and Section D questions (related to the four roundabouts located in Catania) were answered while showing to the respondent a photographic catalogue in digital form. The photographic catalogue was created using Google images representing each roundabout from different perspectives.

The total sample comprised 977 students (629 males and 348 females) between the ages of 18 and 35 years. Participants who didn't complete the questionnaire or who didn't answer well the questions regarding the knowledge of how a roundabout work (Section B of the questionnaire) were excluded. The respondents excluded were 5% of the sample. The final sample was 928 participants. All participants included in the study had a driving license. Participants were assured of anonymity and confidentiality. The majority of respondents (around 84%) were below the age of 25; only 16,38% were aged between 26 and 35 years. As for sex, males were more numerous than females (64,66% of the sample was made up by men and 35,34% were women). The travel mode most frequently used was the car (73,28%). About 14% of the sample were motorcyclists, while pedestrians were about 13%. Participants' characteristics are shown in Table 3.

Table 3: Characteristics of survey respondents

Category	**Number**	**Percent**
Age		
18-21	352	37,93 %
22-25	424	45,69 %
26-35	152	16,38 %
Total	928	100,00 %
Sex		
Male	600	64,66 %
Female	328	35,34 %
Total	928	100,00 %
Travel mode		
Car	680	73,28 %
Motorcycle	128	13,79 %
Pedestrian	120	12,93 %
Total	928	100,00 %

2.3 Analytical method

Starting from the survey data, the final aim of this study was to analyze the factors influencing the roundabouts risk perception for young people. Multiple Correspondence Analysis (MCA) was chosen to conduct this analysis.

MCA is part of a family of descriptive methods that reveal patterning in complex datasets. Specifically, MCA is used to represent and model datasets as "clouds" of points in a multidimensional Euclidean space; this means that it is distinctive in describing the patterns geometrically by locating each variable/unit of analysis as a point in a low-dimensional space. The results are interpreted on the basis of the relative positions of the points and their distribution along the dimensions; as categories become more similar in distribution, the closer (distance between points) they are represented in space. Although it is mainly used as an exploratory technique, it can be a particularly powerful one as it "uncovers" groupings of variable categories in the dimensional spaces, providing key insights on relationships between categories (i.e., multivariate treatment of the data through simultaneous consideration of multiple categorical variables), without needing to meet assumptions requirements such as those required in other techniques widely used to analyze categorical data (e.g., Chi-square analysis, G-statistics, and ratio test). The use of MCA is, thus, particularly relevant in studies where a large amount of qualitative data is collected, often in pair with quantitative data, and where qualitative variables can become sub optimized in the data analysis. MCA plot are a better way of presenting information graphically and one can interpret them by examining the distribution of variable groupings in space. Points (categories) that are close to the mean are plotted near the MCA plot's origin and those that are more distant are plotted farther away. Categories with a similar distribution are near one another in the map as groups, while those with different distributions stay farther apart. In a two-dimensional graphical display of the data, categories sharing similar characteristics are located close together, forming point clouds. MCA is performed on an I × Q indicator matrix in which I is the set of i individual records, runway excursion accidents, and Q is the set of categories of all variables, characteristic features. Given this, the component in the cell (i, q) consists of the individual record i and category j. Associated categories in MCA are placed close together in a Euclidean space, leading clouds, or a combination of points that have similar distributions. Notably, MCA produces point clouds, which are usually defined by two-dimensional graphs.

Suppose, the number of individual records associated with category k is denoted by nk (with nk >0), where fk=nk/n is the relative frequency of individuals who are associated with category k. The values of fk will generate a row profile. The distance between two individual records is created

by the variables for which both have different categories. Suppose that for variable q, individual record i contains category k and individual record i’ contains category k’ which is different from k. The squared distance between individual records i and i’ for variable q is defined by Eq (1):

$$d_q^2(i,i') = \frac{1}{f_k} + \frac{1}{f_{k'}} \qquad (1)$$

Denoting Q as the number of variables, the overall squared distance between i and i’ is defined by Eq. (2):

$$d^2(i,i') = \frac{1}{Q}\sum_{q\in Q} d_q^2\,(i,i') \qquad (2)$$

The cloud of categories is a weighted cloud of K points (by category k, a point denoted by Mk with weight nk is represented). For each variable, the sum of the weights of category points is n, hence for the whole set K the sum is nQ.

If nkk’ indicates the number of individual records having both categories (k and k’), then the squared distance between Mk and Mk’ is defined by Eq (3):

$$(M^k M^{k'})^2 = \frac{n_k + n_{k'} - 2n_{kk'}}{n_k n_{k'}/n} \qquad (3)$$

The numerator is the number of individual records associated with either k or k’.

In this study, MCA was determined to be the better choice for data processing. MCA was chosen mainly because it allows to perform efficient dimensionality reductions and to compile results into easy-to-read plots. The research team used statistical software SPSS version 24.0 to perform the MCA technique in order to examine how risk perception in roundabouts by young people varies with the characteristics of the respondents and with the geometric characteristics and the traffic conditions of roundabouts.

2.4 Variables

The variables used in MCA concerned the socio-demographic characteristics of the respondents (gender, age, travel mode), the geometric characteristics of roundabouts (number of lanes, inscribed circle diameter, circulatory roadway width and right turn bypass lane), the traffic conditions of roundabouts and the risk of accidents perceived by the respondents in the analyzed roundabouts. Specifically, the variable associated with the risk of accident perceived in the four roundabouts studied (Section D of the questionnaire), is divided into three categories: high, medium and low. Figure 3 provides data related to the risk of accidents perceived by the respondents in the four roundabouts.

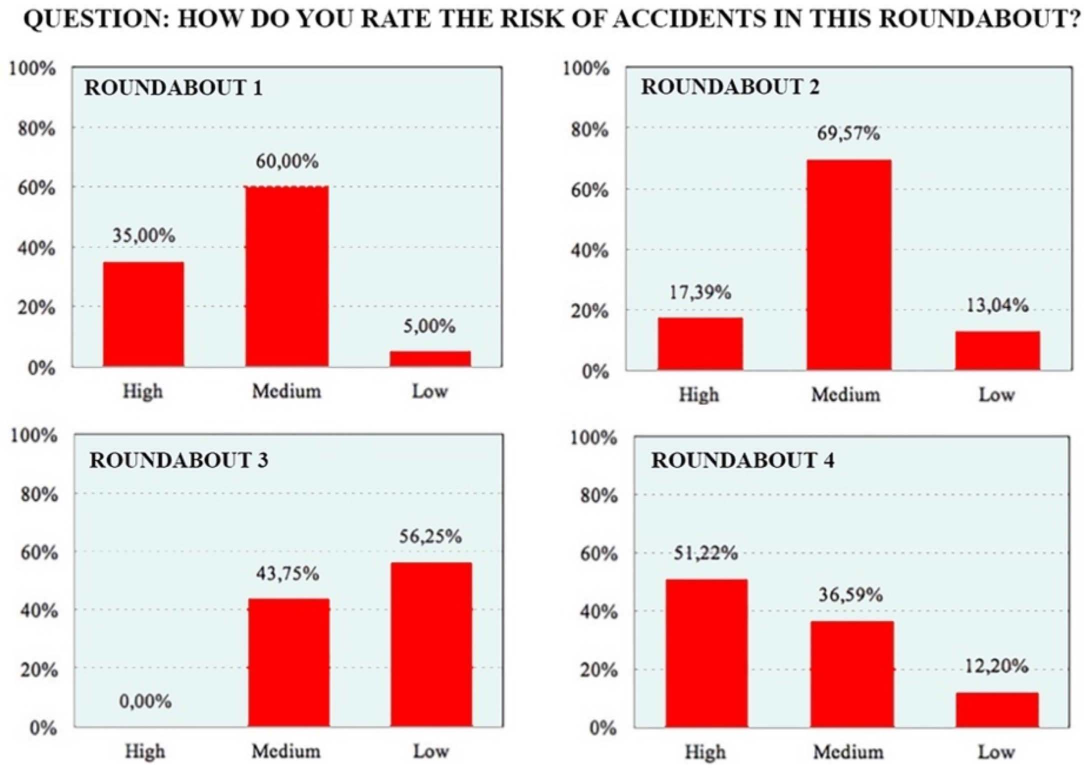

Figure 3: Summary of risk of accidents perceived in the four roundabouts

Table 4 shows the 9 variables individuated and all the categories defined for each variable.

Table 4: Variables and related categories

Variable	Categorie	Code
Gender	Male	G1
	Female	G2
Age	18-21	A1
	22-25	A2
	26-35	A3
Travel mode	Car	M1
	Motorcycle	M2

	Pedestrian	M3
Number of lanes	1	L1
	2	L2
Inscribed circle diameter (D)	$D \leq 40$ m	D1
	40 m $\leq D \leq 60$ m	D2
	$D \geq 60$ m	D3
Circulatory roadway width (W)	$W \leq 7$ m	W1
	7 m $\leq W \leq 9$ m	W2
	$W \geq 9$ m	W3
Right-turn bypass lane	Present	B1
	Absent	B2
Traffic flow	Low	T1
	Medium	T2
	High	T3
Risk of accidents perceived	Low	R1
	Medium	R2
	High	R3

3. Results and discussion

Multiple Correspondence Analysis was applied to the data collected. To define the correspondence between the categories of each variable, the statistical software SPSS version 24 was used. Output of MCA is a two-dimensional graph. The MCA graphical representations help simplify the process of interpreting the relationships among variables.

The model resulted in two dimensions with eigenvalues >1, explaining 64.17 per cent of the variance (Table 5).

Figure 4 illustrates the MCA plot. The MCA plot shows the distribution of the coordinates of all categories. This plot gives us an idea of the variable categories' positions on the two-dimensional space based on their eigenvalues. In this study, in order to easily comment on the results of Multiple Correspondence Analysis, we wanted to proceed with a two-step discussion of the influence on the risk perceived by young users due to the various variables considered. First, we analyzed the socio-demographic variables (age, gender, travel mode) and later, the geometric and traffic variables (number of lanes, inscribed circle diameter, circulatory roadway width and right turn bypass lane).

Table 5: Model summary resulting from the MCA

Dimension	Cronbach's Alpha	Variance accounted for total (Eigenvalue)	Inertia	% of Variance
1	0.788	3.343	0.371	37.142
2	0.662	2.432	0.270	27.024
Total		5.775	0.642	64,166
Mean	0.735[a]	2.887	0.321	32.083

[a]. Mean Cronbach's Alpha is based on the mean Eigenvalue.

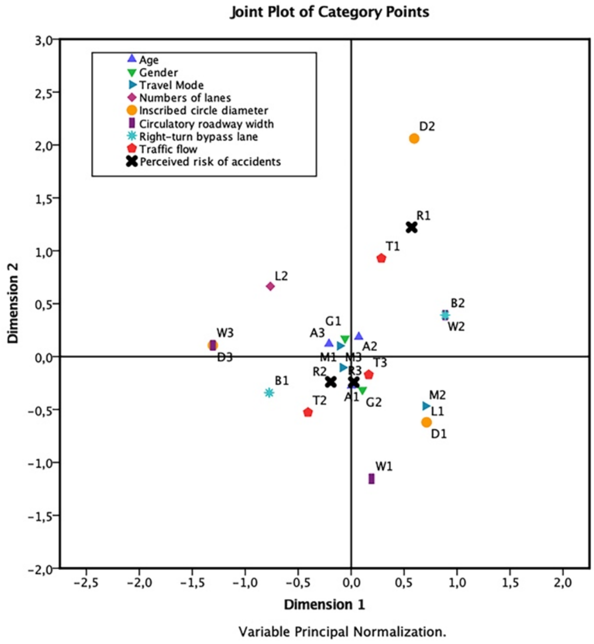

Figure 4: MCA Plot - All categories

Therefore, starting from the initial MCA plot, two MCA plots were generated: a) the MCA plot illustrated in figure 5 shows the influence of the socio-demographic variables on risk; b) the MCA plot illustrated in figure 6 describes instead how the geometric and traffic variables influence the risk perceived by young people using the roundabouts.

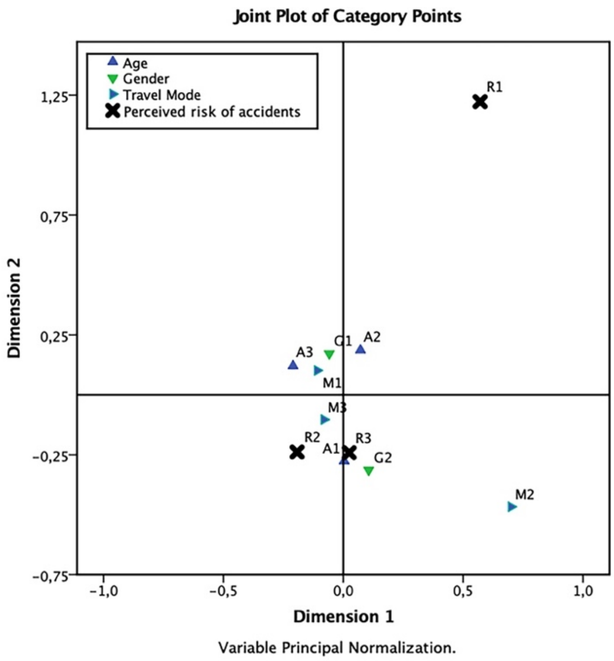

Figure 5: MCA Plot – Categories: a) socio-demographic characteristics; b) perceived risk

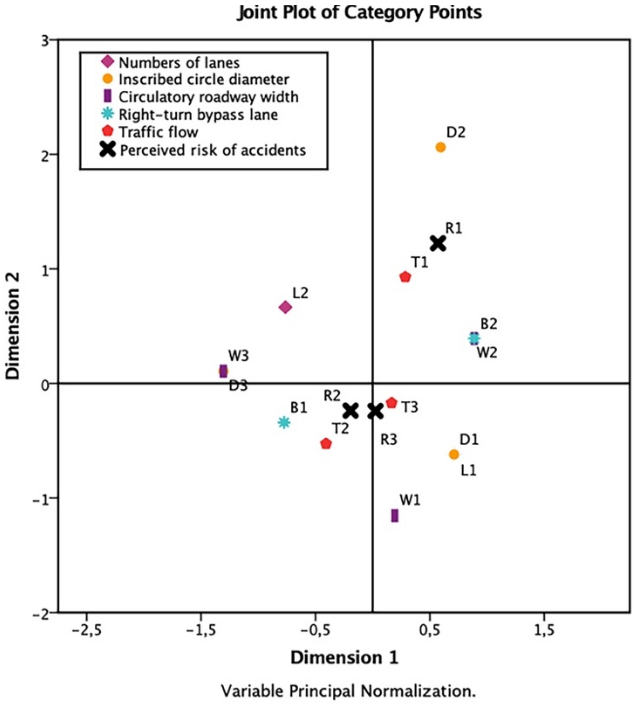

Figure 6: MCA Plot - Categories: a) geometric characteristics; b) traffic conditions; c) perceived risk

3.1 Risk perceived by young users on roundabouts: influence of socio-demographic variables

The MCA plot illustrated in figure 5 shows the distribution of the coordinates of all the categories related to the socio-demographic variables and the perceived risk.

First of all, we observe that the two categories representing the greatest risk perception (medium and high risk, i.e. R2 and R3) are associated with two points of the MCA plot that are very close to each other and very close to the origin of the axes. This shows that most of the young respondents always show a not negligible perception of risk in the roundabout.

We must also note that the age of respondents has not a significant influence on the risk perception of roundabouts. Indeed, the points relating to the three categories associated with the "age" variable are all concentrated at the origin of the MCA plot axes. This is probably due to the fact that all respondents are young and so there are not great differences among the three groups considered (18-21, 22-25 and 26-35 years-old).

Also, the gender has not a significant influence on risk perceptions of roundabouts. Females perceive a slightly higher risk than males. Indeed, the two categories G1, G2, although represented by diametrically opposed points in the MCA plot, are both very close to the origin of the axes. The "women" category is close to the "High Risk" category, while the men category is closer to the "Medium Risk" category. These findings support previous research that has shown no difference in roundabouts public opinion with respect to gender (Retting et al., 2002; Retting et al., 2006; Retting et al., 2007).

The travel mode shows interesting results as for the different risk perception among users: pedestrian perceive roundabouts more dangerous compared to drivers and motorcyclists. Indeed, the point of the MCA plot representing the “pedestrian” category is very close to the R3 category (High Risk). The category "motorcyclists" is represented in the MCA plot from a point further away than those associated with the other two categories related to the "travel mode" variable, but, in any case, closer to the risk category R3. The motorcyclists, therefore, are users who perceive a high level of risk in the roundabouts. This is similar to findings from other studies (Hydén and Várhelyi, 2000; Savolainen et al., 2012).

3.2 Risk perceived by young users on roundabouts: influence of geometric and traffic variables

The MCA plot illustrated in figure 6 shows the distribution of the coordinates of all the categories related to the geometric and traffic characteristics of the roundabouts and to the perceived risk. In this study, three significant cloud combinations were chosen (Fig. 7). Each of the combinations identified groups the categories of the variables that are most likely to condition the risk perceived by young users.

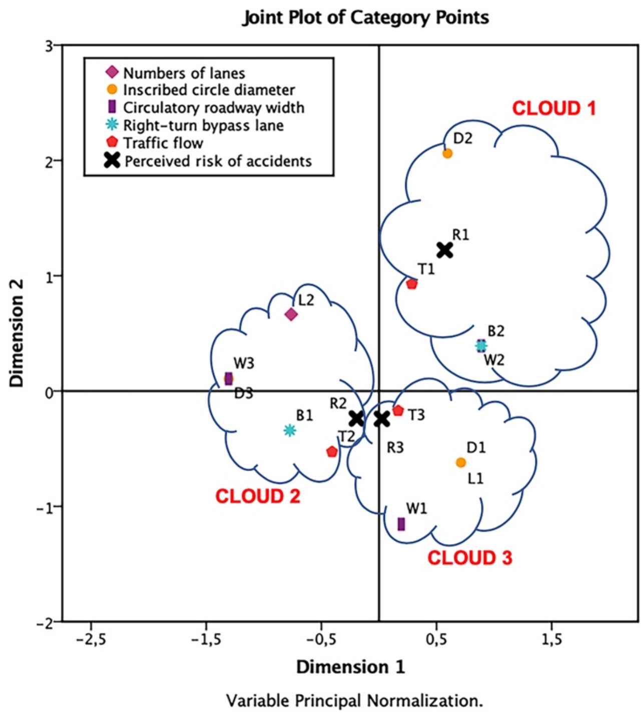

Figure 7: MCA Plot with cloud combinations – Categories: a) geometric characteristics; b) traffic conditions; c) perceived risk

In particular:

- Combination Cloud 1 combines five categories: Low Risk; Inscribed circle diameter: 40 m ≤ D ≤ 60 m; Circulatory roadway width: 7 m ≤ W ≤ 9 m; Right-turn bypass lane: absent; Traffic flow: low;
- Combination Cloud 2 combines six categories: Medium Risk; Number of lanes: 2; Inscribed circle diameter: D ≥ 60 m; Circulatory roadway width: W ≥ 9 m; Right-turn bypass lane: present; Traffic flow: medium;
- Combination Cloud 3 combines five categories: High Risk; Number of lanes: 1; Inscribed circle diameter: D ≤ 40 m; Circulatory roadway width: W ≤ 7 m; Traffic flow: high.

The geometric parameters associated with the overall and transversal dimensions of the roundabouts (i.e. diameter and width of the circulatory roadway), are perceived as dangerous both in the case of “configurations of minimum dimensions”, i.e. $D \leq 40$ m and $W \leq 7$ m (High Risk), which in the case of “configurations of maximum dimensions”, i.e. $D \geq 60$ m and $W \geq 9$ m (Medium Risk). In the first case (small roundabouts), young people probably perceive the danger of being involved in road accidents resulting from those operating conditions in which, also because of the high vehicular flows, the vehicles are forced to move in reduced spaces without maintaining the appropriate safety distances. In the second case (large roundabouts), there is a significant perception of the danger because the vehicles have too large spaces available that can also encourage hazardous or irregular maneuvers by other users.

As regards the presence of one or two lanes on the geometric elements of the roundabouts, it was found that young people perceive single-lane roundabouts more dangerous than double-lane ones. It should however be noted that the two categories (L1 and L2) associated with this variable are both equidistant from the center of the MCA plot and almost equidistant from the two categories R2 and R3 representative of medium and high risk conditions. It can be stated, therefore, that the variable "number of lanes" is not the most influential in the perception of the risk of accidents by young people; the sensation of risk seems to be directly linked to the fact of having to enter the circulatory roadway, regardless of whether the entry to the roundabout is organized with one or two lanes.

The presence of the right turn-bypass lane influences the perceived risk, although it does not lead to the perception of the highest risk in the young respondents. The respondents perceive a low risk of accidents in roundabouts without right turn-bypass lane and a medium risk in roundabouts with right turn-bypass lane.

Finally, traffic conditions strongly affect the risk of accident perceived in roundabouts. It is clear that risk perception grows with traffic congestion. In fact, as evidenced by the position of the T1, T2 and T3 categories in the MCA plot, the fluid traffic conditions are perceived at low risk, the medium ones at medium risk and those of congested traffic at high risk. These findings are consistent with previous studies regarding the relationship between roundabout geometric design, traffic conditions, and crash rates. A lot of researches showed, for example, that that variations in crash rates at roundabouts are mainly driven by the traffic (e.g. Daniels et al., 2010; Pecchini et al., 2014; NCHRP, 2010) and that an increase in the circulatory roadway width increases the total crashes in roundabouts (e.g. NCHRP, 2010; Farag and Hashim, 2017).

3.3 Definition of a ranking of roundabouts in relation to perceived risk

The results of the MCA analysis applied to the collected data showed that roundabouts risk perception for young people is weakly affected by the socio-demographic characteristics, and it arises mainly from geometric characteristics and traffic conditions affecting the safety offered to the different type of users (drivers, motorcyclists and pedestrian).

With the aim of a better understanding of the role of these variables in the roundabouts risk perception for young people, the “Discrimination Measures” obtained by the MCA analysis (Figure 8) were used to determine the Weighting Factors (WF_i) of the variables associated with the geometric and traffic characteristics; this is to quantify the influence of these variables on the “Perceived Risk of Accidents” variable.

From the diagram shown in figure 8 it is even more evident that the traffic flow is that which contributes the most to influencing the risk perceived by young users. Conversely, the diameter of the roundabout and the width of the circulatory roadway have the least influence on the perception of risk.

The Weighting Factors (WFi) deduced from Figure 8 are shown in Table 6.

Table 6: Weighting Factors of the variables associated with the geometric and traffic characteristics.

	Number of lanes	*Inscribed circle diameter (D)*	*Circulatory roadway width (W)*	*Right-turn bypass lane*	*Traffic flow*
Weighting Factors (WF_i)	*2.2*	*1.0*	*1.4*	*2.90*	*21.3*

Furthermore, from the MCA plot, the distances of all the categories associated with the geometric and traffic variables from the three risk categories (Low, Medium, High) were evaluated. Table 7 shows these distances ($Dist_i$) using conventionally:

- the number 1, to indicate the distance of the geometric or traffic category from the furthest risk category;
- the number 3, to indicate the distance of the geometric or traffic category from the nearest risk category;
- the number 2, to indicate the distance of the geometric or traffic category from the risk category other than those defined in the previous points.

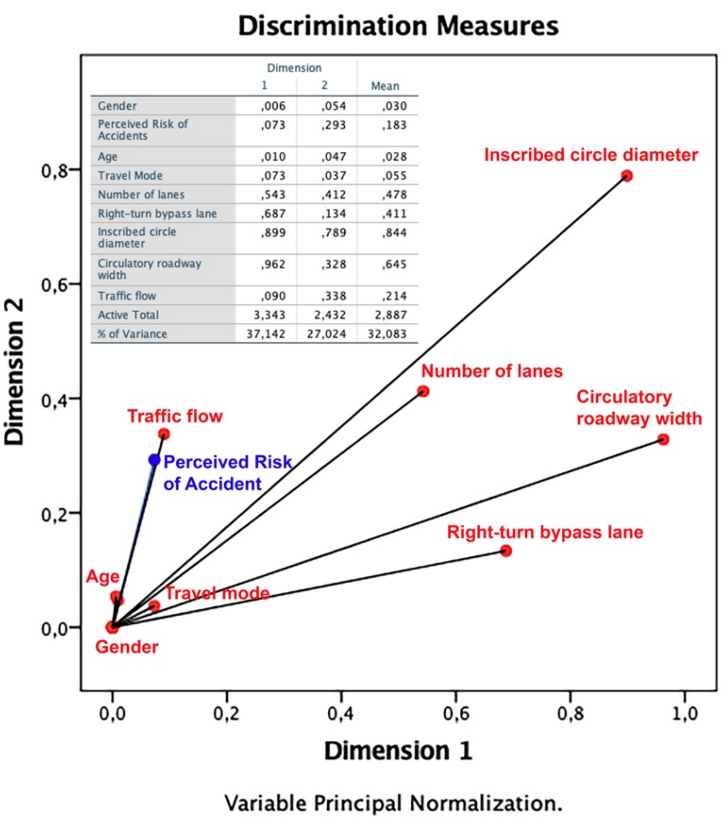

Figure 8: Discrimination measures

Table 7: Conventional distances of geometrical and traffic categories from risk categories

	Conventional distances ($Dist_i$)												
	Number of lanes		*Inscribed circle diameter (D)*			*Circulatory roadway width (W)*			*Right-turn bypass lane*		*Traffic flow*		
Perceived risk of accidents	L1	L2	D1	D2	D3	W1	W2	W3	B1	B2	T1	T2	T3
Low (R1)	1	1	1	3	1	1	3	1	1	3	3	1	1
Medium (R2)	2	3	2	1	3	2	1	3	3	1	1	3	2
High (R3)	3	2	3	2	2	3	2	2	2	2	2	2	3

The level of risk perceived for a specific configuration of roundabout was defined by the weighted average, using the Weighting Factors (WF_i), of the distances ($Dist_i$) associated with the geometrical and traffic categories that fully define the configuration of the analyzed roundabout. Dividing all the values of the risk level to the minimum value, that is the one associated with the perceived less dangerous configuration by the young respondents, the "Relative Risk Levels (RRL)" shown in Table 8 were obtained. The combination of the geometric variables (number of lanes, inscribed circle diameter, circulatory roadway width and right turn-bypass lane) and of the traffic conditions gave rise to 11 different configurations of roundabouts (configuration A to K in Table 8). In order to find the combinations of geometric factors and traffic conditions in roundabouts preferred by young users, a ranking of the 11 configurations of roundabouts was defined. The ranking was defined based on the RRL values for the 11 configurations of roundabouts. The configurations were ordered by decreasing order starting from the highest value of the Relative Risk Level.

Table 8: Relative Risk Levels (RRL) values for 11 configurations of roundabouts

	N. of lanes	*Right turn-bypass lane*	*Circulatory roadway width*	*Inscribed circle diameter*	*Traffic flow*	***Relative Risk Level***
Configuration A	1	Yes	$W \leq 7$ m	$D \leq 40$ m	Low	1,006
Configuration B	1	Yes	$W \leq 7$ m	$D \leq 40$ m	Medium	1,203
Configuration C	1	Yes	$W \leq 7$ m	$D \leq 40$ m	High	1,360
Configuration D	1	No	$7 \text{ m} \leq W \leq 9$ m	$40 \text{ m} \leq D \leq 60$ m	Low	1,003
Configuration E	1	No	$7 \text{ m} \leq W \leq 9$ m	$40 \text{ m} \leq D \leq 60$ m	Medium	1,199
Configuration F	1	No	$7 \text{ m} \leq W \leq 9$ m	$40 \text{ m} \leq D \leq 60$ m	High	1,357
Configuration G	2	Yes	$W \geq 9$ m	$D \geq 60$ m	Low	1,001
Configuration H	2	Yes	$W \geq 9$ m	$D \geq 60$ m	Medium	1,198
Configuration I	2	Yes	$W \geq 9$ m	$D \geq 60$ m	High	1,355
Configuration J	2	No	$7 \text{ m} \leq W \leq 9$ m	$40 \text{ m} \leq D \leq 60$ m	Low	1,000
Configuration K	2	No	$7 \text{ m} \leq W \leq 9$ m	$40 \text{ m} \leq D \leq 60$ m	Medium	1,197

The radar chart in Figure 9 provide a graphical representation of this ranking: it shows the risk perceived for the 11 configurations of roundabouts in decreasing order, from the one perceived as the most dangerous to the one perceived as the safest. Therefore, in this chart the 11 configurations of roundabouts analyzed were placed in descending order according to their level of risk perceived, clockwise starting from the most dangerous at the top center. The configurations have been exemplified through schematic drawings representing their geometric characteristics and traffic flows, in order to have an immediate view of them. In the different drawings, high traffic flows are represented with red cars, medium traffic flows are represented with blue cars and low traffic flows are represented with green cars.

From Figure 9 it can be immediately observed that the variable mostly affecting the risk perception is the traffic: indeed, the configurations perceived to be the most dangerous (i.e., configurations C, F and I) despite having different geometric characteristics, are exactly those with high traffic flows. Conversely, the configurations perceived as the safest (i.e., configurations A, D, G and J) are precisely those with the lowest traffic flows. The configurations B, E, H and K, positioned in the radar chart between those perceived as the most dangerous and those considered to be the safest, are all those characterized by medium traffic flows. Therefore, the radar chart shows three groups of roundabouts characterized, in order of decreasing perceived risk, by high, medium and low traffic conditions.

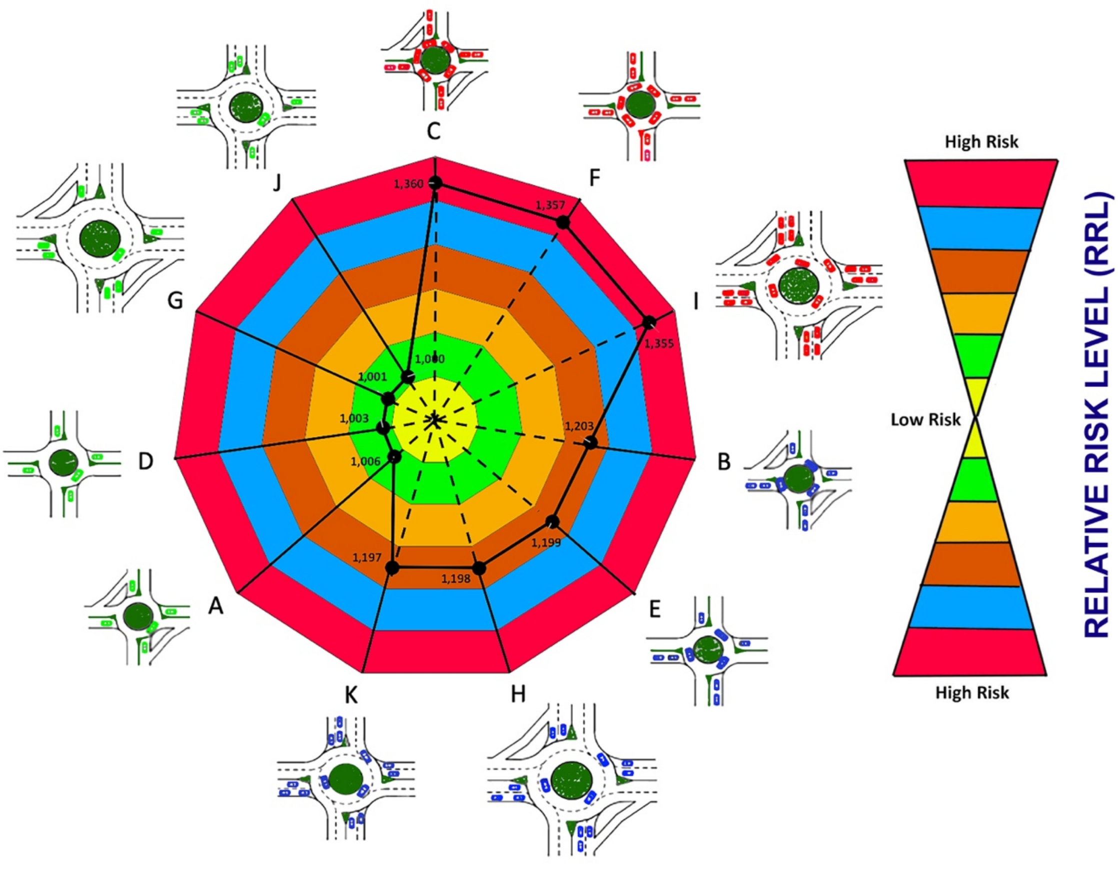

Figure 9: Risk perception radar chart for the 11 configurations of roundabouts

The three groups of roundabouts, highlighted by the radar chart, therefore are homogeneous from the point of view of traffic conditions, but not homogeneous as regards the geometric characteristics of the roundabouts. With regard to the geometric parameters, the following considerations have therefore been deduced, valid for each of the three groups mentioned above:

- the greatest risk is perceived on small roundabouts, with the single lane on the legs and on the circulatory roadway;
- the minor risk is perceived on medium / large roundabouts, with the double lane on the legs and on the circulatory roadway;
- the right turn-bypass lane seems to have little influence on the perception of risk. Indeed, in the roundabouts included in each of the three analyzed groups, this lane is alternately present and absent and, therefore, there is no clear influence of this geometric element on the level of risk perceived by young users.

3. Conclusions

This study investigated the risk perception of roundabouts for young people in order to identify the major factors which influence such perception. A road users survey was developed to obtain young people feedback on roundabouts. Multiple Correspondence Analysis (MCA) was used in order to understand how the young people features, the geometric characteristics and the traffic conditions of roundabouts affect the respondents' risk perception. Finally, a risk perception scale was defined for the configurations of roundabouts identified. From the radar diagram representative of the risk perception scale for the configurations of roundabouts related to the geometric characteristics and to the traffic flow considered, the following results were found:

1. traffic conditions strongly affect risk perception of roundabouts. On a sample of 11 configurations of roundabouts, all three perceived as the most dangerous are characterized by high traffic flows;
2. the roundabouts with small circulatory roadway (smaller than 7 m), with a diameter less than 40 m and with one lane on the legs and on the circulatory roadway are generally perceived as more dangerous than those with a medium/large circulatory roadway (larger than 7 m), with a diameter longer than 40 m and with two lanes n the legs and on the circulatory roadway;
3. the right-turn bypass lane affects the respondents risk perception, but not in a clear and unambiguous manner.

It is well known that roundabouts are safer than other forms of intersections. However, driving behavior is continuously changing. It is therefore important to understand how roundabouts design could be improved to make them safer for their actual users. The authors believe that the results presented on this paper provide updated findings which may be useful to improve roundabouts design. The results of this study are based on a certain sample of young people and on certain configurations of roundabouts. Further studies will focus on overcoming the above-mentioned limitations. Sample sizes could be larger and other several geometric configurations of roundabouts could be considered. The results presented in this research along with future extensions would provide a complete comprehension of the young drivers' behavior for the optimum design of roundabouts. This type of study could also be extended to other categories of users (such as the elderly, the pedestrians, the motorcyclists, etc.) in order to understand the roundabouts risk perception for different type of users.

References

Al-Madani, H.M.N. (2003). "Dynamic vehicular delay comparison between a police-controlled roundabout and a traffic signal". *Transportation Research Part A: Policy and Practice,* 37 (8), pp. 681-688.

Anjana, S., Anjaneyulu, M. V. L. R. (2015). "Development of Safety Performance Measures for Urban Roundabouts in India". *Journal of Transportation Engineering,* 141 (1), art. no. 04014066.

Arndt, O. K., Troutbeck, R. J. (1995). "Relationship between roundabout geometry and accident rates". *International Symposium on Highway Geometric Design Practices*, Vol. 28, Transportation Research Board, Washington DC, pp. 1-16.

Begg, J., Langley, J.D. (2001). "Changes in risky driving behavior among young adults". *Journal of Safety Research*, 32, pp. 491-499.

Bie, J., Lo, H.K., Wong, S.C. (2008). "Circulatory markings at double-lane traffic roundabout: comparison of two marking schemes". *Journal of Transportation Engineering,* 134 (9), pp. 378-389.

Bingham, R.C., Shope, J.T. (2004). "Adolescent problem behavior and problem driving in young adulthood". *Journal of Adolescent Research*, 19, pp. 205-223.

Borowsky, A., Shinar, D., Oron-Gilad, T. (2010). "Age, skill, and hazard perception in driving". *Accident Analysis and Prevention,* 42, pp. 1240-1249.

Chen, Y., Persaud, B., Sacchi, E., Bassani, M. (2013). "Investigation of models for relating roundabout safety to predicted speed". *Accident Analysis and Prevention*, 50, pp. 196-203.

Cheng, A. S. K., Ng, T. C. K., Lee, H. C. L. (2011). "A comparison of the hazard perception ability of accident-involved and accident-free motorcycle riders". *Accident Analysis and Prevention*, 43, pp. 1464-1471.

Daniels, S., Brijs, T., Nuyts, E., Wets, G. (2010). "Explaining variation in safety performance of roundabouts". *Accidents Analysis and Prevention*, 42, pp. 393-402.

Distefano, N., Leonardi, S., Pulvirenti, G. (2018). "Factors with the greatest influence on drivers' judgment of roundabouts safety". An analysis based on web survey in Italy. *IATSS Research,* DOI: 10.1016/j.iatssr.2018.04.002

Easa, S.M., Mehmood, A. (2006). "Optimizing geometric design of roundabouts: multi-objective analysis". *Canadian Journal of Civil Engineering,* 33 (1), pp. 29-40.

Elvik, R. (2003). "Effects on Road Safety of Converting Intersections to Roundabouts Review of Evidence from Non-U.S. Studies". *Transportation Research Record*, 1847, pp. 1-10.

Elvik, R. (2017). "Road safety effects of roundabouts: A meta-analysis". *Accident Analysis and Prevention*, 99, pp. 364-371.

Farag, S.G., Hashim, I.H. (2017). "Safety performance appraisal at roundabouts: Case study of Salalah City in Oman". *Journal of Transportation Safety & Security,* 9, pp. 67-82.

Ferguson, S. A. (2003). "Other high-risk factors for young drivers: How graduated licensing does, doesn't, or could address them". *Journal of Safety Research*, 34, pp. 71-77.

Giuffrè, O., Granà, A. (2013). "Crash modeling for urban roundabouts: A case study". WIT Transactions on Ecology and the Environment. Vol. 179, pp. 1001-1011.

Grayson, G., Maycock, G. (1988). “From proneness to liability”. In J. A. Rothengatter & R. A. de Bruin (Eds.), *Road user behavior*, pp. 234–241. Assen, Netherlands: Van Gorcum.

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

Hatfield, J., Fernandes, R. (2009). “The role of risk-propensity in risky driving of younger drivers”. *Accident Analysis and Prevention,* 41, pp. 25-35.

Highway Capacity Manual (2010), Transportation Research Board, Washington, D.C.

Horswill, M. S. (2016). “Hazard Perception in Driving”. *Current Directions in Psychological Science,* 25 (6), pp. 425-430.

Horswill, M. S., Anstey, K. J., Hatherly, C. G., Wood, J. (2010). “The crash involvement of older drivers is associated with their hazard perception latencies”. *Journal of the International Neuropsychological Society*, 16, pp. 939-944.

Horswill, M. S., Hill, A., Wetton, M. (2015). “Can a videobased hazard perception test used for driver licensing predict crash involvement?” *Accident Analysis and Prevention*, 82, pp. 213-219.

Horswill, M.S., McKenna, F.P. (2004). “Drivers’ hazard perception ability: situation awareness on the road”. In S. Banbury, S., Tremblay, S. (Eds.), *A Cognitive Approach to Situation Awareness: Theory and Application*, pp. 155-175.

Hull, M., Christie, R. (1992). “Hazard perception test: The Geelong trial and future development”. *Proceedings of the National Road Safety Seminar*, Wellington, New Zealand. Dublin, Ireland: Institution of Engineers of Ireland.

Hydén, C., Várhelyi, A. (2000). “The Effects on Safety, Time Consumption and Environment of Large Scale Use of Roundabouts in an Urban Area: A Case Study”. *Accident Analysis & Prevention*, Vol. 32, pp. 11-23.

ISTAT (2017) *Incidenti Stradali*, Anno 2016. Report of ISTAT*,* Italy.

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

Kennedy, J., Peirce, J., Summersgill, I. (2005). “Review of accident research at roundabouts”. *National Roundabout Conf.*, Transportation Research Board, Washington, DC.

Kim, S., Choi, J. (2013). “Safety Analysis of Roundabout Designs based on Geometric and Speed Characteristics”. *KSCE Journal of Civil Engineering*, 17 (6), pp. 1446-1454.

Lakouari, N., Oubram, O., Ez-Zahraouy, H., Cisneros-Villalobos, L., Velásquez-Aguilar, J.G. (2018). “Traffic flow behavior at a single-lane urban roundabout”. *International Journal of Modern Physics C*. Vol. 29, Issue 3.

Lim, P. C., Sheppard, E., Crundall, D. (2013). “Cross-cultural effects on drivers’ hazard perception”. *Transportation Research Part F,* 21, pp. 194-206.

Ma, W., Liu, Y., Head, L., Yang, X. (2013). “Integrated optimization of lane markings and timings for signalized roundabouts”. *Transportation Research Part C: Emerging Technologies*, 36, pp. 307-323.

Mahdalova, I., Krivda, V., Skvain, V. (2013). “Influence of roundabout inscribed circle diameter to the traffic safety”. *Applied Mechanics and Materials*, 409-410, pp. 1122-1125.

Mauro, R., Cattani, M. (2012). “Functional and economic evaluations for choosing road intersection layout”. *Promet – Traffic & Transportation*, 24 (5), pp. 441-448.

McKenna, F. P., Crick, J. L. (1991). *Hazard perception in drivers: A methodology for testing and training.* Report No. CR313. Berkshire, UK: Transport Research Laboratory.

McKenna, F. P., Crick, J. L. (1997). *Developments in hazard perception*. Report No. TRL297. Berkshire, UK: Transport Research Laboratory.

Meneguzzer, C., Rossi, R. (2010). "Analysis and control of the interaction between vehicular and pedestrian flows on roundabout approaches". *European Transport - Trasporti Europei.* Issue 53.

Montella, A. (2010). "Analysis of Crash Contributory Factors at Urban Roundabouts". *Proc, 89th Transportation Research Board Annual Meeting,* Washington, D.C., USA, January 10-14, 2010.

National Cooperative Highway Research Program (NCHRP). (2010). *Roundabouts: An information guide*. NCHRP Rep. 672, Transportation Research Board, Washington, DC.

Olsen, E. C. B., Lerner, N., Perel, M., Simmons-Morton, B. G. (2005). "In-car electronic device use among teen drivers". *Proc., 84th Annual Meeting of the Transportation Research Board*, Transportation Research Board, Washington, D.C.

Pecchini, D., Mauro, R., Giuliani, F. (2014). "Model of Potential Crash Rates of Rural Roundabouts with Geometrical Features". *Journal of Transportation Engineering, 140.*

Persaud, B.N., Retting, R.A., Garder, P.E., Lord, D. (2001). "Safety effect of roundabout conversions in the United States: Empirical Bayes observational before-after study". *Transportation Research Record*, 1751, pp. 1-8.

Pilko, H, Šarić, Š. (2018). "Vehicle Speed Impact on the Design of Efficient Urban Single-Lane Roundabouts". *Lecture Notes in Networks and Systems*. Vol. 21, pp. 3-15.

Pilko, H., Mandžuka, S., Barić, D. (2017). "Urban single-lane roundabouts: A new analytical approach using multi-criteria and simultaneous multi-objective optimization of geometry design, efficiency and safety". *Transportation Research Part C: Emerging Technologies*. Vol. 80, pp. 257-271.

Pollatsek, A., Narayanaan, V., Pradhan, A., Fisher, D. L. (2006). "Using eye movements to evaluate a PC-based risk awareness and perception training program on a driving simulator". *Human Factors*, 48, pp. 447-464.

Retting, R.A., Luttrell, G., Russell E. (2002), "Public Opinion and Traffic Flow impacts of Newly Installed Modern Roundabouts in the United States". *ITE Journal*, Vol. 72, No. 9, pp. 30-37.

Retting, R.A., Mandavilli, S., Russell, E.R., and A.T. McCartt (2006), "Roundabouts, Traffic Flow and Public Opinion – Evidence from the US". *Traffic Engineering and control*, Vol. 47, No. 7, pp. 268-272.

Retting, R.A., McCartt, A., S.Y. Kyrychenko (2007), "Long-Term Trends In Public opinion Following Construction of Roundabouts". *Journal of the Transportation Research Board.* No. 2019, pp. 219-224.

Sabey, B. E., Taylor, H. (1980). *The known risks we run: The highway*. Supplementary Report SR 567. Transport and Road Research Laboratory, Crowthorne.

Sacchi, E., Bassani, M., Persaud, B. (2011). "Comparison of safety performance models for Urban roundabouts in Italy and other countries". *Transportation Research Record.* Issue 2265, pp. 253-259.

Savolainen, P. T., Kawa, J. M., Gates, T, J. (2012). "Examining Statewide Public Perceptions of Roundabouts through a Web-Based Survey". *Transportation Research Record*, 2312, pp. 25-33.

Shope, J.T. (2006). "Influences on youthful driving behavior and their potential for guiding interventions to reduce crashes". *Injury Prevention,* 12, pp. 9-14.

Šurdonja, S., Deluka-Tibljaš, A., Babić, S. (2013). "Optimization of roundabout design elements". *Tehnički vjesnik*, 20 (3), pp. 533-539.

Underwood, G., Phelps, N., Wright, C., Van Loon, E., Galpin, A. (2005). "Eye fixations scanpaths of younger and older drivers in a hazard perception task". *Ophthalmic Physiological Optics,* 25, pp. 346–356.

Vujanić, M., Antić, B., Pešić, D., Savićević, M. (2016). "Safety effectiveness of converting conventional intersections to roundabouts: Case study in the city of niŠ". *Promet – Traffic & Transportation*, 28 (5), pp. 529-537.

Wallis, T.S.A., Horswill, M.S. (2007). "Using fuzzy signal detection theory to determine why experienced and trained drivers respond faster than novices in a hazard perception test". *Accident Analysis and Prevention*, 39, pp. 1177-1185.

Williams, A. F. (2003). "Teenage drivers: Patterns of risk". *Journal of Safety Research*, 34, pp. 5-15.

World Health Organization (WHO), (2017). *World Report on Road Traffic Injury Prevention*. Report of Wold Health Organization, Geneva.