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Gruden, Chiara; Ištoka Otković, Irena; Šraml, Matjaž

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Pedestrian safety at roundabouts: a comparison of the behavior in Italy and Slovenia

Chiara Gruden [1], Irena Ištoka Otković[2], Matjaž Šraml [1*]

[1]*Faculty of Civil Engineering, Transportation Engineering and Architecture, University of Maribor, Smetanova ulica 17, 2000 - Maribor*
[2]*Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek, Vladimira Preloga 3, 31000 Osijek, Croatia*

Abstract

Due to their ability to reduce conflict points, roundabouts are considered one of the safest infrastructure typologies for motorized traffic. While the increase in drivers' safety was largely demonstrated, and some efforts were spent on the side of cyclists, pedestrian safety was not extensively analysed. The present paper analyses pedestrian safety at roundabouts set in two different locations, Italy and Slovenia. This research highlights differences and similarities in pedestrian behavior at the same infrastructure typology, considering the effects risen by diverse road habits. Starting from footages recorded at the two locations, behavioral analysis and a proactive safety analysis are run. Statistical tests are developed to compare the two data samples. Behavioral results show for both locations faster pedestrian paces than expected. As for safety, the surrogate safety measures' percentages overcoming the thresholds for dangerous events underline the need to find solutions from both the infrastructural side and pedestrian safety awareness.

Keywords: roundabout; pedestrian behavior; road safety.

1. Introduction

The use of roundabouts is increasing in whole Europe. This kind of road infrastructure is considered by technicians an efficient way of improving road safety level, since they let speeds decrease, avoid direct conflict points among motorized users and permit a more fluent road flow (Persaud et al. (2001), Montella (2019), Lenters (2005)).

The study of roundabout's way of functioning from the point of view of motorized users has been focus of many authors (Di Stefano et al. (2018), Macioszek (2017), Pulvirenti et al. (2021)), and various researchers are making a lot of efforts in individuating new and better roundabout configurations (Tollazzi (2015), Fortujin (2009), Giuffre' et al. (2017)), but still little attention has been kept by the point of view of vulnerable road users, specifically, pedestrians.

* Corresponding author: Matjaž Šraml (matjaz.sraml@um.si)

The aim of this paper is to focus on pedestrian behavior and highlight the impact on roundabout intersection safety by analyzing video footages to investigate near misses and surrogate safety measures, as a means to achieve proactive safety solutions.

In this work, particular behaviors of pedestrians crossing on this kind of infrastructure are investigated in two different locations - Italy and Slovenia - in order to understand if there are different behaviors and how these differences effectively influence pedestrian safety. The advantage of the developed method is the preventive study of human behavior, which allows to analyze the problem before a fatal situation occurs (Laureshyn et al. (2010)).

The paper is organized as follows: the first section reviews the current state of-the-art on pedestrian behavior and safety at roundabouts, the second section summarizes the data collection methodology, the third section shows the results obtained by behavioral and safety data, and finally conclusions are drawn.

2. Related works

Recently vulnerable road users' behavior at roundabouts has gained interest and byciclists' behaviour has been extensively studied (Poudel, and Singleton (2021)). The design, safety and perception of this kind of infrastructure are themes, that has been tackled. Standing to (Poudel, and Singleton (2021)) 49 articles dealt with bicycle safety at roundabouts, of these 32 are crash data studies. Bicyclists' perception of roundabouts was tackled by 8 studies (Arnold, et al. (2010), Campbell, et al. (2006), Hydén and Várhelyi (2000), Møller and Hels (2008), Parkin et al. (2007)), which investigate their comfort, risk, danger and avoidance of this kind of infrastructure, while design characteristics have been investigated by five research works (Brüde and Larsson (2000), Daniels, et al. (2010), Turner et al. (2009)).

Pedestrian safety at roundabouts has also been identified as an important issue. Nevertheless, little work has addressed it and conflicting results have been obtained. Two studies have emerged in America, one as part of an NCHRP project (Harkey and Carter (2006)) and one for Federal Highway Administration (Carter, et al. (2006)). The latter (Carter, et al. (2006)) conducted data collection in three American cities, Miami, Philadelphia and San Jose, and linked different types of intersections to pedestrian, cyclist and motorist behavior. The authors developed indices for each type of infrastructure surveyed to rank intersections based on pedestrian safety. The former (Harkey and Carter (2006)) developed an observational study of 10 approaches at 7 roundabouts in America. It examined pedestrian risk and found that it increased for pedestrians crossing on roundabout exit legs and on two-lane pedestrian crossings; it also found a range of pedestrian speeds that was similar for all typologies of analyzed crossings, 1.22 m/s to 1.52 m/s. In contrast to (Harkey and Carter (2006)), (Jordan (1985)) and (Tumber (1997)) pointed out that more accidents occur at roundabout entries and that controlling this part of the infrastructure would lead to an improvement in safety at exits as well (Jordan (1985)).

As can be seen from the previous review, the issue of pedestrian safety at roundabouts remains an open one and opposing opinions can be found in the literature.

One fact on which most research studies agree is that of perceived risk: although roundabouts may be safer than other intersections, they are typically perceived by pedestrians as more dangerous (Lenters (2005), Stone et al. (2002), Gruden et al. (2021a)).

Finally, it should be noted that, unlike for vehicular traffic, for which the improvement in safety is clearly stated, for pedestrian safety an improvement is suspected by various authors, but without any certain data being given. According to (Stone et al. (2002)), converting conventional signalized intersections to modern roundabouts could reduce the number of accidents involving pedestrians and improve safety due to reduced speeds and fewer conflict points. Nevertheless, the authors also mention some additional open issues to be considered: the need for pedestrians to properly assess gaps to cross, the longer crossing distances, the usually higher traffic flows, and the constantly moving vehicles.

Ultimately, there is no clear and accepted framework for pedestrian behavior and safety at roundabouts, so new research studies may provide additional useful knowledge about this. Aim of this research is to provide new information about the behavior and safety of pedestrians at roundabouts. Three main research goals can be stated:

- to initiate the study of pedestrian behavior and safety in the European contest: as it was highlighted by literature review, the majority of the studies were developed in America;
- to identify if different nationalities and traffic habits can affect the behavior and the safety level of pedestrians at roundabouts;
- to give insights about safer design solutions for pedestrian crosswalks at roundabouts.

To reach them, a comparison and contrasting between two European locations is worked out, by analysing real-world recordings and obtaining from them both behavioral parameters and surrogate safety measures, which can lead to the proactive assessment of the safety level at the considered locations.

3. Methodology

The aim of the study is to highlight differences and similarities in pedestrian behavior on the same type of infrastructure but in different locations, and to consider the safety implications of the different traffic habits typical of the two countries. The following subsections introduce the two studied locations and explain how the data was collected and elaborated.

3.1 Case study locations.

Two sites with similar characteristics were selected for this study: both are pedestrian crossings located on the entry-leg of a two-lane roundabout, one is set in Italy and one in Slovenia. Figure 1 displays the locations and configurations of the two studied crosswalks as well as the positions of the cities where they are set, in relation to other known European destinations. In both cases, a pedestrian crossing at the entry-leg of a two-lane roundabout was studied.

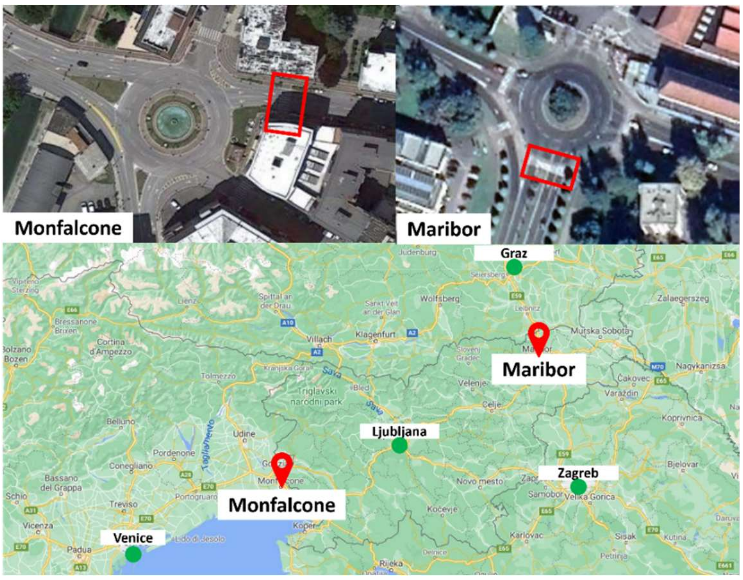

Figure 1: Geographical framework and identification of the two studied crosswalks.
Source: author’s elaboration of Google Maps images.

The first location is in the northeastern part of Italy, more specifically in Monfalcone, a medium-sized town of Friuli Venezia Giulia. The roundabout where recordings took place is still part of the urban area of the city, and it links the city centre with all the possible destinations of the nearbies. 3 of the 5 roundabout legs are designed for only one type of manoeuvre, i.e. they are only entry or exit legs, while the remaining two are suitable for both entering and exiting the roundabout. Pedestrian crossings are present on each of the legs: 4 out of 5 crossings are unsignalized, while the last one is a signalized crossing on the main exit leg. Pedestrian crossing under study crosses two unidirectional lanes and is frequented by both vehicular traffic and pedestrians. Indeed, many offices, cafes and other commercial activities are located in its vicinity. The pedestrian flow is mixed: children, adults and elderly were observed, though adults and young adults represent the majority of recorded people.

The second site under study is located in the northeastern part of Slovenia, more precisely in Maribor. Also in this case it is a medium-sized city and the chosen roundabout, similarly to the Italian one, belongs to the urban area of the city and distributes traffic from the city center to all possible destinations and viceversa. Also in this case, the roundabout is located near many cafes, houses and offices. An important element of the area is the student campus: from here, many students cross the road on the selected pedestrian crossing to reach their faculties. This explains the large number of young adults aged 19-26, although some adult and older individuals were also observed. The only difference between the two crossings is that at the Italian site, pedestrians finish their crossing action directly on the pavement of the opposite side, while at the Slovenian site they reach a pedestrian refuge island and then cross a single-lane exit leg. Considering the size of the refuge island, the width of the last exit leg and the observed behavior, no great influence of this geometrical feature has been recognized. Table 1 summarizes the geometric and flow characteristics of the two sites under study.

Table 1: Geometrical and flow characteristics of the two pedestrian crosswalks under study.

	Italy	*Slovenia*		Italy	*Slovenia*
Crossing length	10.25 m	12.50 m	Pedestrian flow	300 ped/hour	360 ped/hour
Crossing width	4 m	4 m	Vehicular flow	960 veh/hour	1080/hour

3.2 Data collection and elaboration approach.

The method used to develop this study consisted of 5 steps that were carried out in parallel at the two sites (Figure 2). First, video recordings (Figure 2-I.) were taken at both locations, in Italy and in Slovenia. An action cam mounted on a signal pole was used to record the scene: at both locations it captured the entire width of the road, the crosswalk and the entry leg of the roundabout. In this way it was possible to collect data about the whole pedestrian crossing action, as well to have information about the oncoming vehicular flow, and to identify the approaching behavior of both pedestrians and vehicles. The footages were taken during the month of February, on cloudy and dry days, from Monday to Friday, from 8am to 10am. The second step consists of data extraction (Figure 2-II.): this passage was developed thanks to the semi-automatic detection and tracking software T-Analyst, which allows obtaining both behavioral variables, such as speed and acceleration, and surrogate safety measures, such as Time-To-Collision and Time Advantage. The process for obtaining valuable data is to visually identify events of interest, such as near misses, which are automatically stored by T-Analyst in shorter 14 s-videos. On these shorter recordings, each road user involved in the event should be manually tracked by the researcher, it means a shaped box should be drawn around each road user involved in the detected event, at each defined frame-step, and their trajectories smoothed. The coordinates, speed, and acceleration data are then automatically calculated by the software. Finally, for each event of interest, the two involved road users should be labeled so that the software can automatically calculate the surrogate safety measures: Time-To-Collision (TTC), Time Advantage (TAdv), and relative speed (Vrel). At the end of data extraction two databases with a total of 253 observed pedestrians (139 individuals for the Italian location and 114 people for the Slovenian site) were obtained. For each individual the same information typology was collected and saved at both locations. It is: pedestrian ID, gender, age range, trajectory, average speed, average acceleration, average crossing time, Time-To-Collision, relative speed and Time Advantage. All data collected was then checked and filtered in order to eliminate possible outliers, by comparing them to normally accepted ranges (e.g. for pedestrian speed, values over 3 m/s were considered outliers). On the filtered data the subsequent analyses were developed: the third step was the analysis of the behavioral data (Figure 2-III.), by developing statistical tests on crossing time, speed and acceleration samples to infer the distribution and correlation of the datasets and by comparing the results with literature values.

The fourth step consists in investigating the surrogate safety at the two chosen locations (Figure 2-IV.) by analyzing the retrieved quantities, TTC, TAdv and Vrel. A comparison with the main thresholds found in the literature was elaborated in order to highlight the safety level of this type of infrastructure. At the end, a comparison and contrast of the two sites (Figure 2-V.) was carried out to highlight the differences in pedestrian behavior and their impact on safety.

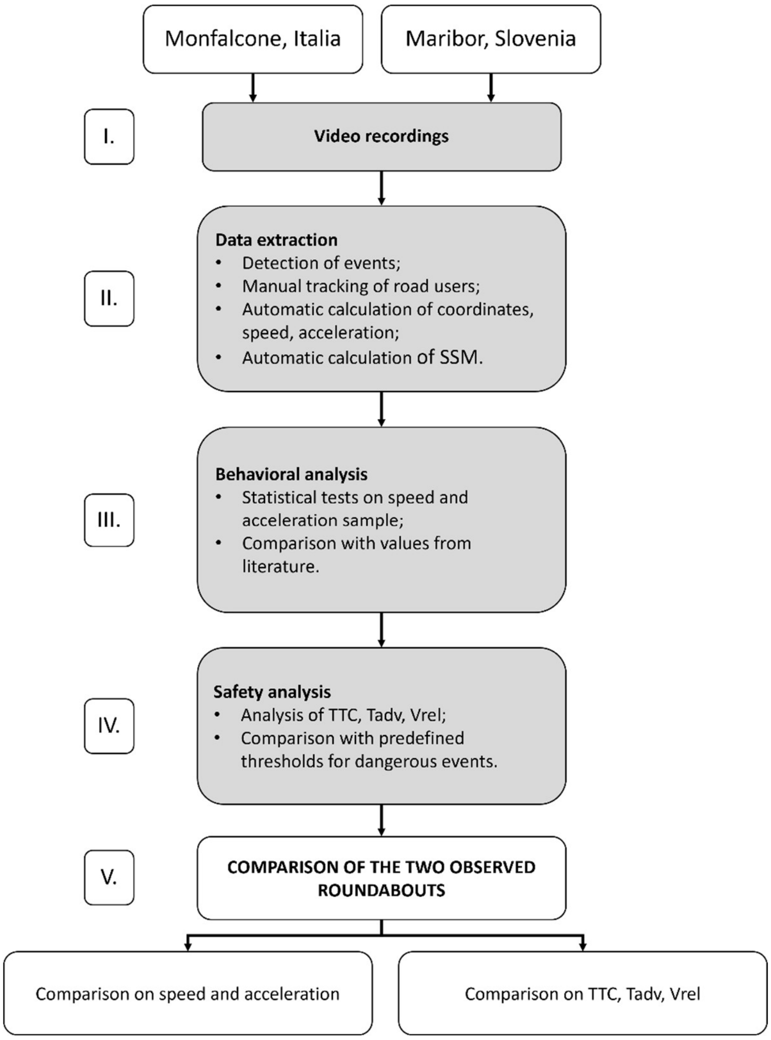

Figure 2 Schematic representation of the data collection and elaboration approach.
Source: authors.

4. Analysis and results

This section presents the two analyses developed and the comparison between the two locations. For better readability, two subsections have been created: the first refers to the behavioral variables, the last to surrogate safety.

4.1 Behavioral analysis

Behavioral analysis consists of separately elaborating crossing time, velocity, and acceleration data for each location studied.

Crossing time is defined as the time it takes a person to complete the crossing, from the moment they leave the sidewalk to the moment they reach the opposite safe side, and for both locations, it is measured in seconds. It was found that Italians have a mean crossing time of 8.27 s, while Slovenians cross the street in 5.94 s on average. It is interesting to note that the Slovenian crossing time is lower for a 2 m longer path compared to the Italian one. This is confirmed by the higher speed of Slovenians compared to Italians, with a mean value of 2.42 m/s and 1.55 m/s, respectively, and by the average acceleration of the speed of Slovenians compared to Italians, who are slightly slowed down. Table 2 summarizes the descriptive statistics of the three variables for both sites.

Table 2: Comparison of the descriptive statistics for the two locations under study.

	Crossing time (s)		*Crossing speed (m/s)*		*Crossing acceleration (m/s²)*	
	Italy	*Slovenia*	*Italy*	*Slovenia*	*Italy*	*Slovenia*
Mean value	8.27	5.94	1.55	2.42	-0.01	0.01
Standard error	0.13	0.09	0.03	0.03	0.02	0.01
Standard deviation	1.54	0.91	0.32	0.35	0.24	0.15
Variance	2.38	0.84	0.10	0.06	0.06	0.02

The difference in means and the restrained standard errors and deviations between the two datasets on all three variables suggest that this difference may also be statistically significant. To determine if this is the case, a normality test was first conducted for crossing time, speed, and acceleration in order to choose the appropriate further analysis. Anderson-Darling normality test was chosen. This test is based on the assumption that the tested population is normally distributed (null hypothesis) and it confirms or rejects this statement depending on the calculated p-value. If the p-value is less than the selected confidence level, the null hypothesis should be rejected. P-value is calculated in function of the test statistic AD as:

$$AD \geq 0.60 \qquad p = \exp(1.2937 - 5.709(AD) + 0.0186(AD)^2 \tag{1}$$

$$0.34 \leq AD^* \leq 0.60 \qquad p = \exp(0.9177 - 4.279(AD) - 1.38(AD)^2 \tag{2}$$

$$0.20 \leq AD^* \leq 0.34 \qquad p = 1 - \exp(-8.918 + 42.796(AD) - 59.938(AD)^2 \tag{3}$$

$$AD \leq 0.20 < \mathrm{AD}^* < 0.34 \qquad p = 1 - \exp(-13.436 + 101.14(AD) - 223.73(AD)^2 \tag{4}$$

where:
AD is the Anderson-Darlin statistics, calculated with formula:

$$AD = -n - \frac{1}{n}\sum_{i=1}^{n}(2i-1)[lnF(X_i) + \ln(1 - F(X_{n-1+1})] \tag{5}$$

AD* is the adjusted AD statistics and should be considered for small samples. It is obtained by:

$$AD^* = \mathrm{AD}(1 + \frac{75}{n} + \frac{2.25}{\mathrm{n}^2}) \tag{6}$$

n is the sample size;
F(x) is the cumulative distribution function for the normal distribution;
i is the i-th sample, calculated when data is sorted in asceding order (D'Agostino and Stephens (1987)).

Figure 3 and Table 3 show the results of the Anderson-Darling test for all variables considered at both sites, for a confidence level of 95.0%

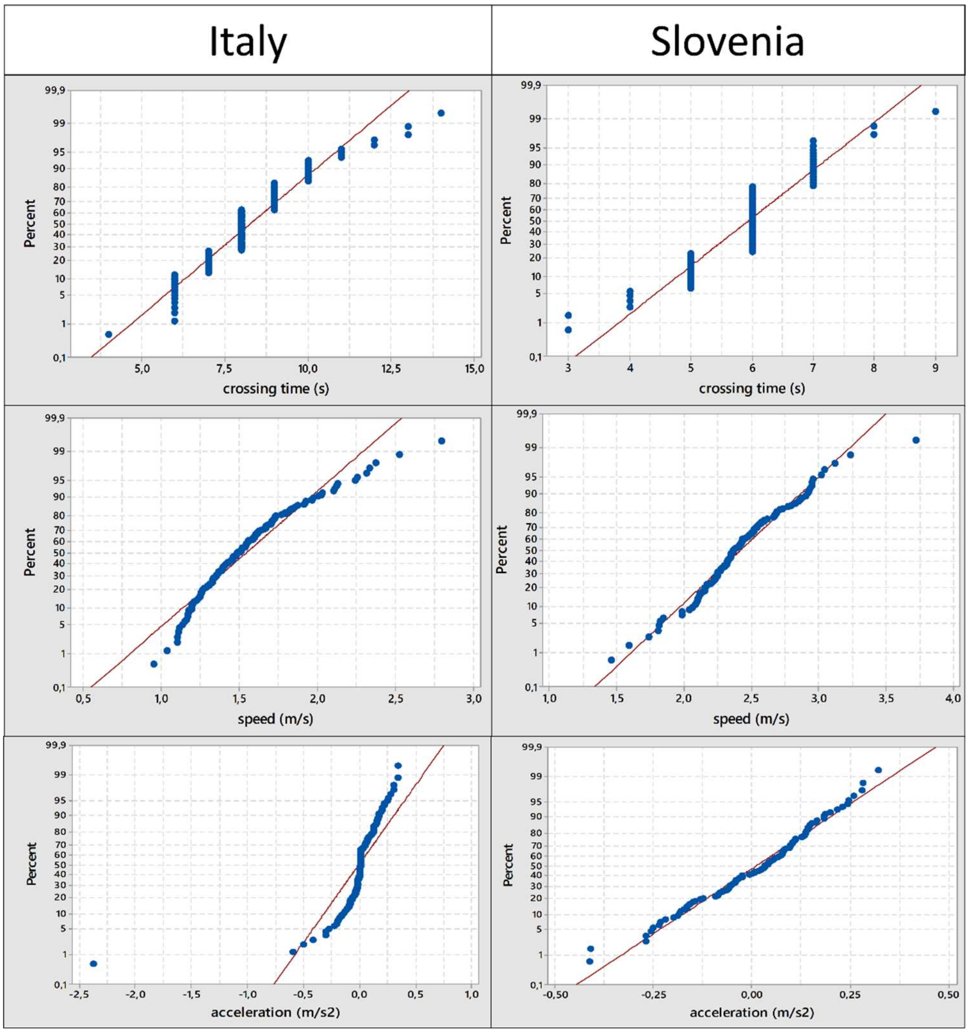

Figure 3: Graphical results of Anderson-Darling normality tests for crossing time, speed and acceleration in Italy and Slovenia.
Source: authors.

Table 3: Statistical results of Anderson-Darling normality tests for crossing time, speed and acceleration in Italy and Slovenia.

	Crossing time (s)		*Crossing speed (m/s)*		*Crossing acceleration (m/s^2)*	
	Italy	*Slovenia*	*Italy*	*Slovenia*	*Italy*	*Slovenia*
p-value	< 0.005	< 0.005	< 0.005	0.019	< 0.005	0.070
α-level	0.05	0.05	0.05	0.05	0.05	0.05

As can be seen from Figure 3 and Table 3, none of the variables can be assumed to follow a normal distribution. Therefore, the nonparametric test Mann-Whitney (Perme and Manevski (2019)) was performed to determine if the two populations of each behavioral variable are statistically different. This test compares the medians of the two populations and it tests if they are different for the chosen confidence level. Therefore, it can be reliably applied to non-normally distributed independent samples. The confidence level chosen for this study is 95.0%.

From Table 4, it can be seen that for all magnitudes, the difference between the medians of the two samples is different from zero. The confidence interval for this difference indicates whether there is a statistical difference between the two samples. For crossing time and crossing speed, this can be established beyond doubt, as they have a confidence interval not containing zero, whereas it cannot be confirmed for acceleration. This is also to be expected, since the acceleration values in the considered case are very restrained and variable within each sample. Finally, comparing the calculated p-values with the chosen confidence level $\alpha=0.05$, it can be seen that the statistical difference is confirmed for the two samples of crossing time and crossing speed, while the acceleration populations cannot be treated as statistically different.

Table 4: Results of Mann-Whitney's test.

	Slovenia (η_1)	*Italy (η_2)*	*Difference of the medians*	*CI for η_1-η_2*	*p-value*
Crossing time (s)	6.00	8.00	-2.00	(-2.00; -1.99)	< 0.0005
Speed (m/s)	2.37	1.49	0.89	(0.81; 0.96)	< 0.0005
Acceleration (m/s^2)	0.03	0.01	0.01	(-0.03; 0.04)	0.64

4.2 Safety analysis

In addition to the previous behavioral analysis, the safety of pedestrian crossings at roundabouts is evaluated using surrogate safety measures, specifically Time-To-Collision, Time Advantage, and relative speed. These measures, which have the advantage of proactively assessing the safety level of a defined location, are well defined in the literature (Hayward (1971), Laureshyn and Varheyi (2018)) and some thresholds for the same are provided to identify potentially risky situations. (Hayward (1971), Laureshyn and Varheyi (2018)) proposed a definition of the Time-To-Collision, and identified specific thresholds for this factor. They defined TTC as the time needed to cause a collision if the two involved road users continue on their current course at the current speed. Often, the minimum value of TTC is used to evaluate the safety level: Aliaksei et al. in (Fortujin (2003)) suggested a safety threshold for TTC_{min} of 1.5 s, with values below this indicating potentially dangerous situations. Time Advantage, TAdv, is also defined as a continuous Post-Encroachment Time (PET) and indicates the time interval between the moment the first road user leaves the path and the moment the second road user reaches it (Fortujin (2003)). Fortujin (2003) set the threshold value of TAdv for detecting dangerous situations to 1 s.

Based on these definitions, an evaluation of the two pedestrian crossings was conducted. Table 5 summarizes TTC descriptive statistics obtained for the two locations. Both the Italian and Slovenian pedestrian crossings appear to have a high safety level, with TTC mean values of 3.11 and 4.52 s, respectively. Nevertheless, it can be noted that Italy has a higher percentage of cases where the TTC was lower than 1.5s - 20.75%, than Slovenia - only 2.41%.

Table 5. Basic statistics about TTC (s).

	Italy	*Slovenia*
Mean	3.11	4.52
Standard Deviation	1.22	0.49
Minimum	0.97	0
Maximum	9.94	11.27
Percentage <2.5 s	26.38	9.64
Percentage < 1.5 s	20.75	2.41

Similar to TTC, TAdv was also analysed based on the thresholds defined in literature (Table 6). Although, also in this case, generally high average values of this measure for both sites indicate an adequate level of safety, 43.61% of the recorded situations in Italy show a value below 1.0 s. In contrast, the Slovenian crossing shows only 1.55% of situations with a TAdv value below 1.0 s.

Table 6. Basic statistics about TAdv (s).

	Italy	*Slovenia*
Mean	5.12	7.35
Standard Deviation	9.68	7.04
Minimum	0	1.56
Maximum	168.19	30.80
Percentage < 1.0 s	43.61	1.55

Finally, an essential element when considering pedestrian safety is the speed difference between the motorized vehicle and the pedestrian. Various studies have shown how the rate of pedestrian fatalities increases by slightly increasing vehicular speed (Leaf and Preusser (1999), Rosén and Sander (2009)): by increasing vehicle velocity from 40 km/h to 50 km/h fatality risk more than double, and by increasing speed from 30 km/h to 50 km/h it is five time higher.

Interestingly, the mean values of the relative speed between the crossing pedestrian and the arriving vehicle at the studied sites are 7.12 m/s in Italy and 3.39 m/s in Slovenia, which are 25.6 km/h and 12.2 km/h, respectively. Moreover, in Italy, 58.65% of the recorded encounters had a speed higher than 10 m/s, i.e. 36 km/h, and 87.22% had a speed higher than 5 m/s, i.e. 18 km/h (Table 7). Considering the reported statistics on pedestrian injuries and fatalities, it can be concluded that Slovenia has a safer intersection than Italy, and probably the design of the infrastructure contributes to the improvement of the safety level. Nevertheless, for relevant conclusions, it is necessary to observe and statistically process a much larger database of collected data at a large number of different roundabouts in both States.

Table 7. Basic statistics about Vrel (m/s).

	Italy	*Slovenia*
Mean	7.12	3.39
Standard Deviation	4.94	0.54
Minimum	1	2.62
Maximum	25.4	4.43
Percentage > 10 m/s	58.65	0
Percentage > 5 m/s	87.22	8.35

5. Discussion

In previous sections the crossing actions at two different crosswalks, one set in Italy and one in Slovenia, were compared. Both a behavioral analysis and a safety analysis of pedestrians' movements in interaction with traffic were worked out. The goal of this initial research was to obtain the main characteristics of this kind of action at the two locations and to highlight contrasts and similarities. The crossing action can be divided into two main parts: an approaching period, when the pedestrian reacts with his/her specific reaction time to the vehicular presence and judges the available gap time, and the effective crossing action, when the individual leaves the sidewalk to cross the street and reaches the other safe side. This last part and its features were tackled in this research from both a behavioral viewpoint – when the movement characteristics of each single pedestrian are considered, and from a safety point of view – when the interaction with the vehicles effectively occurs. The results of the behavioral analysis at the two observed roundabouts show different mean values of crossing time and speed between Italy and Slovenia, the latter being on average 0.87 m/s higher than the former. Two observations could explain this difference: firstly, although pedestrian flows are mixed at both sites, with younger and older people crossing the road, in Slovenia the vast majority of pedestrians are students, who have usually an accelerated pace; secondly, he different vehicular behavior at the two sites may also be a reason for the higher speed at the Slovenian site. In Slovenia, drivers are used to yield at crossing, and usually the yielding distances are large, encouraging pedestrians to accelerate when crossing. In Italy drivers behave differently: yielding distances are much shorter and pedestrians usually prefer to stop and wait before crossing the road. This different approach to the crosswalk is also reflected in the slight deceleration found in the Italian sample and the acceleration reported for Slovenian pedestrians.

Since few efforts have been made to define pedestrian speed when crossing on roundabout legs, and due to the reliability of this variable to compare users' behavior at different intersections, it was decided to compare the results of this study with the values this variable has at signalized intersections, and those found in the literature for unsignalized intersections (Table 7).

Table 7. Comparison of pedestrian crossing speed (m/s) on different types of crosswalks.

Authors of the study	*Location of the study*	*Speed [m/s]*
Gruden et al.	Roundabout crossing, Italy	1.55
Gruden et al.	Roundabout crossing, Slovenia	2.42
Gruden et al. (2021b)	Signalized crossing	1.61
Lam and Cheung (2000)	Signalized crossing	1.44
Lam and Cheung (2000)	Unsignalized crossing	1.26
Knoblauch et al. (1996)	Signalized crossing, youngers	1.46
Knoblauch et al. (1996)	Signalized crossing, olders	1.20

As can be seen from Table 7, in both cases the speeds are higher than at signalized and unsignalized intersections. This may lead to the confirmation of the statement of some authors, that pedestrians feel less comfortable crossing roundabouts and therefore try to leave the crossing as soon as possible. Of particular interest is the high value of pedestrian speed at the Slovenian site, which is higher than the value reported by (Knoblauch et al. (2010)) for young Americans, who seem to walk even slower than pedestrians of Italian mixed flow, and also for Slovenian pedestrians at signalized intersections.

From a safety point of view, it is valuable to note the positive results obtained for the Slovenian site in terms of TTC and Tadv, although both pedestrian and vehicle speeds are much higher than at the Italian site. Also, the relative speed between pedestrians and motorized users near the crosswalk is much lower than the relative speed in Italy. This could also be related to the different observed yielding behavior.

6. Conclusions

The developed research worked out a behavioral and a safety analysis of pedestrian crossing action at two selected locations. Firstly, it compared the behavior of pedestrians at the two observed roundabouts and found that Italians have higher crossing times and lower crossing speeds compared to Slovenians, the latter having an average accelerated gait, while a slightly slower gait characterized the Italian behavior. This different behavior can be explained by the overall different relationship established between oncoming car drivers and crossing pedestrians: while in Slovenia car drivers are used to slow down and give way to pedestrians already at a fairly large distance from the crosswalk, which causes pedestrians to accelerate, in Italy car drivers usually slow down when they are in the immediate vicinity of the crosswalk, so that the pedestrian who wants to cross often does not know whether he/ she will be given way until the vehicle stops.

Secondly, the study developed a surrogate safety analysis, which showed that although there are no serious safety issues at either location, the Slovenian intersection has safer conditions, with a lower percentage of TTC and TAdv values below the defined thresholds for risky situations, and with relative speeds between the involved vehicle and pedestrians much lower than at the Italian intersection.

The reasons for these differences may be manifold: on the one hand, the different vehicular yielding behavior certainly has an important influence; on the other hand, the different design of the two roads and pedestrian crossings may affect safety. In fact, although the two locations have similar geometric features, there are some design differences that should be considered. Interestingly, the road where the crosswalk is set in Slovenia has a much straighter geometry than the one in Italy. This also suggests higher speeds and consequently higher relative speeds between the two types of users involved.

Nevertheless, the design of the whole road and the partition of the elements at the borders of the same make the road environment clear for drivers and the crosswalk very visible. In contrast, visibility at the Italian site is not adequate, due to various obstacles and parked cars at the roadside. Finally, it should be highlighted a limitation of the study: in this research work a comparison of only two locations is run. A higher number of intersections could undoubtedly be beneficial for the research and highlight even more, hidden aspects. In further studies authors will tackled many different aspects, among which they also aim to compare a larger number of crosswalks as well as other intersection typologies and the behavior of pedestrians on the same. Besides that, an aspect that could add value to the research, is considering different road modes driving on roundabouts, such as long vehicles, e.g. buses in urban area. Indeed, as it was highlighted in (Barabino, B. et al. (2021)), the more difficult maneuvers such vehicles should take to pass roundabouts could increase the risk of accidents with other road users, especially pedestrians, due to the strict relationship between these two transport modes and, consequently, reduce the safety level.

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