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Comparative Analyses of Parameters Influencing Children Pedestrian Behavior in Conflict Zones of Urban Intersections

Aleksandra Deluka-Tibljaš [1,*], Irena Ištoka Otković [2,*], Tiziana Campisi [3] and Sanja Šurdonja [1]

1   Faculty of Civil Engineering, University of Rijeka, 51000 Rijeka, Croatia; sanja.surdonja@uniri.hr
2   Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek, 31000 Osijek, Croatia
3   Faculty of Engineering and Architecture, University of Enna KORE, 94100 Enna, Italy; tiziana.campisi@unikore.it
*   Correspondence: aleksandra.deluka@uniri.hr (A.D.-T.); iirena@gfos.hr (I.I.O.)

Abstract: Children pedestrians make up 30% of the total number of children injured in road traffic in the EU. Research shows that children are injured more often in the urban areas, in residential areas near schools and parks, often at intersections and pedestrian crossings. In this study, children's traffic behavior was analyzed by observation of signalized pedestrian crosswalks. According to the same methodology, the research was conducted in three cities in two countries (Enna, Italy, Osijek and Rijeka, Croatia) with different urban and traffic characteristics. A total of 900 measurements were analyzed, 300 in each of the cities at 18 pedestrian crosswalks located in an urban setting in the vicinity of primary schools. A detailed statistical analysis of the influence parameters shows that, as general influence parameters, pedestrian crosswalk length, movement in a group and the age of children can be distinguished. Factors that have proven to have a significant influence on the movement of children in two of the three cities observed are gender, supervision by adults, running and cellphone use. The result can serve as a valuable input for interventions in traffic education as well as a basis for the improvement of traffic conditions at intersections where children are regularly present.

Keywords: child pedestrian; children traffic behavior; pedestrian speed; crosswalk infrastructure

1. Introduction

In the last ten years (2008–2018) 8100 children died in traffic accidents in the European Union and 30% were pedestrians [1]. At the world level, the statistics are even worse. According to the WHO data [2] in high-income countries children account for 5–10% of all road traffic deaths of pedestrians and in low and middle-income countries the percentage is 30–40%. Most at risk are children between the ages of 5 and 14 [1,2] and boys rather than girls. Data show that boys are involved in road traffic accidents almost twice as much as girls and this tendency grows with their age. The overall death rate is 13.8 per 100.000 for boys and 7.5 per 100.000 for girls [2].

Traffic accident statistics for Croatia for the period 2009–2018 show a decrease in the total number of deaths by 42.2% (from 548 deaths in 2009, the number of deaths in 2018 was reduced to 317, which is 8 deaths per 100,000 inhabitants). In the same period, an average of eight children died each year, among whom the share of children fatally injured as pedestrians was diverse (from 22% in 2015 when nine children were killed, to 2016 in which the least number of children were killed—two, both as pedestrians). At the same time statistics show that in 2009 children represented more than 10% of all victims while in 2018 there was not a single child pedestrian victim in Croatia. During the same time the percentage of heavily injured children pedestrians was about 20% of all heavily injured pedestrians (in 2018 the total number of injured pedestrians in Croatia was 426), the same as it was 10 years ago [3]. Croatian children, as a positive consideration, are able to become

mobility independent in city traffic at an earlier age and, among the EU countries, Croatia has one of the highest percentages of children that walk alone to school [1]. Part of the data collected in this study also proved that fact.

Considering the data from the Italian National Institute of Statistics [4], although the EU's strategic goal is to reduce the number of road fatalities for children between the ages of 0 and 14 by 50% from 2010 to 2020, in Italy that number has not yet decreased. The age groups with the highest number of deaths are those between 0–5 years and 11–14 years. In addition, most at risk of traffic accidents are boys aged from 11 to 14 years. In Italy, many children are accompanied by their parents on daily travel to and from school [5]. On average only one third of children go to school without adult company when the walking distance is up to 1 km—precisely 33.2% of children up to 14 years of age. Among them 41.7% of children are between 11 and 13 years of age and 17.3% are aged 8–10 [6]. According to an extensive study carried out in 16 EU countries (including Italy) it was established that Italian children practice independent mobility on average at a later age, compared to the other countries included in the research. The most independent children, according to the results of the research, come from Finland [7].

Different studies have been carried out in recent decades to establish factors influencing children's traffic behavior such as age, gender, environment, distractions, and others, in order to mitigate potential traffic risks for child pedestrians [8]. Even if they all come to similar conclusions regarding the influence of children's age on their traffic behavior, other parameters show differences over time and depend on the global location of the study. The results of the study carried out in the UK, regarding children's perception of safety and danger on the road, suggest that children up to nine years of age do not have the ability to recognize a location as dangerous and that children's gender does not play a role when it comes to recognizing dangerous traffic situation [9]. Results from an extensive study carried out in Israel where, by means of field observation, children's behavior at three types of crosswalks (signalized, un-signalized and with divided roads) was recorded and analyzed, demonstrated a wide range of risky behavior of children and adolescents [10]. The statistical analyses of factors associated with unsafe behavior of the total sample of 2930 young pedestrians shows that probability of crossing on red is higher for older children (over the age of 9) and particularly for adolescents; gender and distractions do not affect this behavior. The research based on simulated roads carried out in the USA where 85 children and 26 adults were observed in the same traffic conditions while crossing the road, pointed out that younger children, boys and children with less behavioral control engaged in risker behavior [11]. Recently, studies regarding the influence of children's age and gender on their traffic behavior were carried out also in China [12,13] and Estonia [14]. Results from the study [12] suggested that male adolescents reported riskier behaviors than female and showed significant age difference—older adolescents demonstrated riskier behavior than younger; however, the other study established that there is no statistically important difference between male and female population regarding risky traffic behavior [13]. In a study carried out in Estonia, the gender factor was important, and on average 13-year-old boys take more risks as pedestrians than girls [14].

The type of urban environment influences children's pedestrian safety in different ways, and children are far more at risk in highly populated and high traffic density urban areas than in less populated [13]. The results of the analysis carried out by [15] indicate that the priority for traffic intervention programs regarding children's safety should be residential areas with curb parking and large numbers of pedestrians. It was also established that perception of crash risk is increased in areas with low density and non-mixed land use. What is also interesting is that increased perception of risk in these areas reduces crash rates because of behavior changes. [16]. In [17], risk for children pedestrians was strongly associated with traffic volume and speed. It was established that children are more injured at locations with higher volume and that risk increased with increased traffic volume and with speeds over 40 km/h. Analyses of locations at which most of the traffic accidents involving children pedestrians occur show that nearly 35% of accidents involving school-

aged children occurred at intersections or so-called "buffer zones" around schools [18]. The data base of 793 accidents involving children pedestrians analyzed in Canada showed that 65.1% of all traffic accidents involving children happened at intersections and 22% of all accidents on intersections with traffic lights, while 20% happened on non-signalized mid-block crosswalks, mainly during daylight (72.6%) and in dry pavement surface conditions (70.1%) [19]. A similar study done in the USA on the basis of data from six cities suggests that children pedestrian fatality rates are significantly higher in areas around a school or parks rather than in other locations [20]. A study done in Bucarest, Romania pointed to the fact that the number of accidents, because of unsafe crossing and car drivers not giving priority to pedestrians, constantly increased until the age of 15, after which traffic accidents involving school-aged children decreased continuously [21]. These data are confirmed with the statistics from the EU project [22] about age and gender influence on safety. It was established that at age 14 the number of road fatalities amongst children rises steeply and strong gender differences are visible. Almost three quarters of all children who die at the age of 14 are boys. There is also evidence that during teenage years there is a rising tendency toward risky behavior and, consequently, the number of fatalities that involve teenagers.

The analysis of available papers shows different approaches and different influence parameters determining the causes of child injuries in road traffic. In all of the analyzed studies [9,12,13,23] children's age has been shown to be an important element of risky behavior which leads to child injuries, while in recent studies gender also results as a risk factor [14]. The limit for "safe behavior" of children in traffic is stated to be 15 years of age, and boys in childhood, including teenagers, exhibit a higher proportion of risky behavior than girls. Existing research also points to the need for additional interventions to improve the safety of children in certain parts of the city's transportation network: in residential and mixed-use zones [15,16,18,24,25] at intersections and/or at pedestrian crosswalks [18,19,21] and expectedly near schools and parks where children move around regularly and very often independently [20,21]. What can be also concluded is that studies selected in this review from different regions globally (USA, Canada, China, Estonia, Israel) pointed some common, but also many different, parameters that influence children's traffic behavior.

According to the results of available studies and research, the idea of this study was to analyze the influence of selected parameters that were already established as significant when considering children's pedestrian traffic safety at the point of the road network detected as potentially dangerous—crosswalks at intersections in the buffer area of primary schools. The analyzes of the impact of different parameters on children's pedestrian speed while they are in the critical area of the intersection, where there is a risk of collision with motorized vehicles, while crossing the road was performed. In the study we seek to determine what influences the speed of children pedestrians at crosswalks on signalized intersections, how this speed depends on the characteristics of the children observed (age, gender, physical disabilities), manner of movement (alone, in a group, accompanied by an adult), risky behaviors (running, distractions) and infrastructure (length of pedestrian crosswalk, width of pedestrian crosswalk, length of cycle and green pedestrian time). The study was carried out simultaneously in three different cities located in two countries, Croatia and Italy, based on the same methodology—children were recorded on their way to school without their knowledge. The results were compared to detect similarities and differences in children's traffic behavior in different countries.

The main goal of the study was to establish the influence of selected independent variables, input parameters, on the observed dependent variable, crossing speed. The results suggest which of the analyzed parameters can be defined as local, as they are significant for just one of the analyzed sites, and which are common to all three sites, so they can be used as a basis for traffic safety analyzes of vulnerable road users in other countries. Analyzes also pointed out which of the parameters need more detailed elaboration to be considered generally applicable. Comparison of the results with already existing studies on children traffic behavior and safety was done.

The results can help to define general and specific strategies for improving the safety of children, aged 6–15, in urban areas as it points out the possible impact parameters that affect children's behavior and their safety in three different environments and can be seen as general. The used methodology can be applied to select local parameters influencing children's behavior in different traffic environments.

2. Materials and Methods

2.1. Methodology of Field Measurements

This study was carried out in a similar manner in three different cities located in two EU countries: Enna in Italy and Osijek and Rijeka in Croatia.

The cities of Rijeka and Osijek, despite being in the same country, can be seen as different urban settlements due to very different space and traffic conditions. Both Rijeka and Osijek have around 130,000 inhabitants but very different densities; Rijeka is the most densely inhabited city in Croatia with a density of around 2900 inh/km^2 while Osijek has 650 inh/km^2 [26]. At the same time Rijeka is situated unfavorably while Osijek has a very pleasant topographic location.

Observations were made under similar conditions in urban settlements with different urban typology and size in countries/regions that have different traffic habits and cultures. In this way it was possible to establish locally influenced and more widely applicable parameters that influence children's pedestrian speed while crossing the street.

Analysis of data on children's executive functions was approved by the Ethics Committee of the Josip Juraj Strossmayer University of Osijek, Faculty of Humanities and Social Sciences, dated 11 April 2017 (reference number: 1/4/2017) within the framework of the project: Croatian Science Foundation Problems in the Behavior of School-aged Children: The Role of Executive Functions, Individual, Family and Genetic Factors-ECLAT, project leader Asoc.prof. Silvije Ručević, HRZZ-IP-2016-06-3917. Research done in this project is part of the international bi-lateral Croatian–Slovenian project "Development of prediction model of pedestrian children behavior in the urban transport network", financed by the Ministry of Science and Education of Croatia.

The study was conducted by video recording the children, without them being aware, in real traffic conditions at signalized pedestrian crosswalks within intersections. Then the movements of each child were analyzed from the recordings and estimation of their age and gender was done. Basic statistical analysis was performed to establish children's pedestrian speed for different groups (age, gender, walking in a group or alone).

In every city 300 crossings were selected from recorded material for further analyses, and crossings that were not recorded clearly were excluded. The recordings were made during working days in May and June 2019. For every location measurements were done during one or two days during the same period of the day, in the morning, from 7.15–9.00 a.m., depending on schools' start times. Days with clear and dry weather conditions were chosen for the measurements. Sites in all three cities were selected at collector or primary urban roads in the buffer area of primary schools. The idea was to record children's behavior in familiar circumstances, on their way to school and at the crosswalks that they use regularly. In this way, it was presumed to record reliable children's traffic behavior which can serve as valuable input for future interventions in traffic systems or infrastructure.

2.1.1. Site Selection

Field measurements were made at a total of 18 signalized pedestrian crosswalks located on primary roads near primary schools on corridors that are, on a daily basis, used by children. In the City of Enna, 4 crosswalks were observed, 8 in the City of Osijek and 6 in the City of Rijeka.

The crosswalks' lengths were from 7 to 16 m, and the width from 2 to 4.5 m. At each pedestrian crosswalk, the duration of the total traffic cycle was measured as well as the duration of the pedestrian green light. The elected cities do have some significant differ-

ences in number of inhabitants, urban (space) organization and traffic system organization, which are described in the following part of this paper.

The city of Enna is located in the central part of Sicily, Italy and has 30,000 inhabitants. The crosswalks considered in this study in Enna were located in the city center, in a compact mixed-use area where there is intensive traffic. Recordings and analyses were made for 4 crosswalks, all located at the same intersection (Table 1). The intersection is located in front of a kindergarten and primary school where more than 400 children are enrolled, and less than 200 m from the intersection there is another primary school with around 200 children. The intersection is used daily by pupils and people who work and live in the neighborhood. In addition, this intersection is a transit point during weekdays and holidays for the flow of buses and minivans that reach the bus terminal (500 m away).

Table 1. Basic characteristics of crosswalks in Enna, Italy.

	Length (m)	Width (m)	Cycle Length (s)	Pedestrian Green Time (s)
Crosswalk 1, 3	12.5	3	84	49
Crosswalk 2	9.5	2.5	84	49
Crosswalk 4	10	2.5	84	49

The city of Osijek is situated in the eastern part of Croatia in a topographically very favorable area that enables favorable urban space organization and organization of its traffic system. It has 108,000 inhabitants with a density of 640 inh/km² [26]. The crosswalks analyzed in Osijek are situated at two intersections on collector and primary roads in a mixed-use area. They are both in the buffer zone of a primary school, app 250 m (first intersection) and 300 m (second intersection) from the school building. In total, measurements were made at 8 crosswalks situated at two different intersections (Table 2).

Table 2. Basic characteristics of crosswalks in Osijek, Croatia.

	Length (m)	Width (m)	Cycle Length (s)	Pedestrian Green Time (s)
Crosswalk 1	7	3	90	50
Crosswalk 3	9.3	4.5	90	50
Crosswalk 2, 4	10.5	3.1	90	20
Crosswalk 1, 3	14	3.1	90	13
Crosswalk 2	9.2	2.5	90	52
Crosswalk 4	9.2	2.2	90	52

In Rijeka, city measurements were made at 6 crosswalks situated at three different signalized intersections on a primary road passing through a residential area with mostly multi-story buildings. The pedestrian crosswalks are located in the buffer zone of primary schools, approximately 100–500 m from the school buildings. School children were the dominant pedestrians on all analyzed crosswalks during the recording period. The intersection and position of crosswalks in Rijeka are shown in Table 3.

Table 3. Basic characteristics and positions of crosswalks in Rijeka, Croatia.

		Length (m)	Width (m)	Cycle Length (s)	Pedestrian Green Time (s)
	Crosswalk 1	16	4	80	12
	Crosswalk 2	16.5	4	80	12
	Crosswalk 1	7	4	100	13
	Crosswalk 2	10	4	100	13
	Crosswalk 1	10	4	80	9
	Crosswalk 2	10	4	80	9

2.1.2. Observational Method

The video recording of selected pedestrian crosswalks was made from a point that was not visible to children pedestrians. All recordings were made in the morning when children were on their way to school, in the Croatian cities (Osijek, Rijeka) from 7.15–8.00 a.m., because the schools start at 8.00 a.m., and in Enna from 8.15–9.00 a.m., as the schools there start at 9.00 a.m.

In the second phase, the video material was examined, and it was possible to measure the crossing time of every child (a few times if necessary) and note all other important parameters—walking in a group or with adults. As risky behavior, running and walking outside the marked area was considered. These are circumstances which can provoke unexpected events (e.g., fall while running), unconsciousness of the traffic situation, and increase in time spent in the conflict area of the crosswalk. Images served also to estimate children's gender and age.

2.1.3. Input Parameters

On the basis of the analyses of existing studies and parameters influencing traffic safety for children pedestrians (explained in detail in the Introduction) a set of possible parameters that can influence children pedestrians' speed at crosswalks was defined. The database was formed with two groups of parameters: input parameters defined as general, related to infrastructure, and a second group of parameters related to children, Table 4.

The parameter that was measured from the recorded material is the time spent in the conflict area of the pedestrian crosswalk. For every child, the time (in seconds) was measured from the first step on the traffic lane to the first step on the sidewalk, expressed in seconds. The speed for every pedestrian was then calculated on the basis of the measured time and crosswalk length, measured on the site. For movement in a group, the speed of every group member was established, from the fastest to the slowest member.

2.2. Data Analyses

To assure reliable comparison of data in all three cities, 300 measurements, i.e., 300 recorded crossings done by children, individually or in a group, from Enna, Osijek and Rijeka were included in the analyses. The sample was analyzed by inspection of video recordings. Main features of the collected data are shown in Table 5.

<div align="center">**Table 4.** Parameters description.</div>

	Parameter–Independent Variable	Explanation/Measure	Type of Variable
I-1	length of pedestrian crosswalk	measured from curb to curb meter [m]	numerical
I-2	width of pedestrian crosswalk	width of white marked crossing lines meter [m]	numerical
I-3	green time for pedestrians	seconds [s]	numerical
I-4	traffic signal cycle length	seconds [s]	numerical
I-5	number of children on pedestrian crosswalk	for every pedestrian green light cycle	numerical
I-6	total number of pedestrians on pedestrian crosswalk	for every pedestrian green light cycle children included	numerical
I-7	age groups	AG1 $\leq$ 7 years old AG2 8–11 years old; AG3 $\geq$ 12 years old.	categorical
I-8	gender	girl$\rightarrow$0, boys$\rightarrow$1, for mixed groups (number of boys/total number of children)	categorical
I-9	children with special needs	no$\rightarrow$0, minor interference$\rightarrow$0.5 yes$\rightarrow$1	categorical
1-10	movement in a group	movement of 2–5 children together	categorical
1-11	supervision by adults	children in company of parents or other adult no$\rightarrow$0; yes$\rightarrow$1	categorical
I-12	mobile-messages/internet	occupying visual attention no$\rightarrow$0; yes$\rightarrow$1	categorical
I-13	mobile–talking	not occupying visual attention no$\rightarrow$0; yes$\rightarrow$1	categorical
I-14	running	it implies movement when both legs are above pavement level no$\rightarrow$0; yes$\rightarrow$1	categorical

Table 5. Main features from analyzed samples.

Location	Gender	Crossing in a Group/Alone	Supervised by Adults	Children Age (Years)		Talking on a Mobile Phone	Using Mobile Phone
Enna	54% W 46% M	89% alone 11% group	45% NO 55% YES	AG1 (<7) AG2 (8–11) AG3 (12–15)	27% 31% 42%	94% NO 6% YES	91% NO 9% YES
Osijek	47% W 53% M	75% alone 26% group	94% NO 6% YES	AG1 (<7) AG2 (8–11) AG3 (12–15)	8% 29% 63%	94% NO 6% YES	93% NO 7% YES
Rijeka	51% W 49% M	64% alone 36% group	89% NO 11% YES	AG1 (<7) AG2 (8–11) AG3 (12–15)	6% 39% 55%	99% NO 1% YES	97% NO 3% YES

E—Enna, O—Osijek, R—Rijeka.

From Table 4 it can be seen that in all three cities, boys (M) and girls (W) are almost equally represented in the samples. As for the age groups, younger children are less represented in Croatian cities, probably because children enter the school program at an older age than in Italy.

Data also show that children on their way to school tend to go more often in a group in Croatia but far more children are supervised by adults in Enna, Italy. It is also interesting to see that use of and talking on mobile phones is not present among school children, neither in Croatia nor in Italy.

2.2.1. Children Pedestrian Speed Analyses

Analyses of children's speed is based on mean speeds, calculated from time spent crossing the street and crosswalk length, for different groups of children. In Tables 6 and 7, mean children's speed depending on their characteristics, gender and movement in groups or individually, are presented. Mean speeds for chosen age groups are also presented, but these results have to be considered with caution as age in two of the cities (Rijeka, Enna) was estimated only from the video recordings, and in Osijek partially via personal contact with the children, during previous research considering children pedestrians. Together with mean speed value, the number of analyzed crossings (*n*) are shown as well as standard deviation (SD) for all groups of data with more than 30 measurements. This number was adopted as a basis for reliable statistical analyses.

All children that moved in a group in Enna were supervised by adults, and in Osijek 6% and in Rijeka 11% of children walk with parents and are not included in the Individual movement or Crossing in group columns in Table 6. The mean children speed for different age groups is presented in Table 7.

Children's pedestrian speed calculated in this study show that there is no clear correlation between gender and pedestrian speed. As for the age influence, it is evident that children up to 7 years old in Rijeka and Osijek tend to walk more slowly than older ones, but the difference between the other two groups is not so evident. In Enna children up to 11 years have very similar average speed on crosswalks, and older children walk a little faster.

2.2.2. Children's Pedestrian Speed Depending on Infrastructural Parameters

Children's pedestrian speeds in the conflict zone of the intersection, depending on the length of the zone (pedestrian crosswalk), are presented in Table 8. This parameter was included in the analyses because it significantly affects children's exposure to a potential conflict with motorized vehicles. The results are shown for all three sites and the duration of green pedestrian time is also indicated.

Table 6. Children pedestrians' speed–depending on gender and walking in a group.

	Children Pedestrian Speed (m/s)						
	Whole Sample		Individual Movement		Crossing in Group		
	Male	Female	Male	Female	Male	Female	Mixed Group
Enna	0.79 SD = 0.14 (*n* = 162)	0.83 SD = 0.13 (*n* = 138)	0.86 SD = 0.14 (*n* = 123)	0.84 SD = 0.12 (*n* = 144)	0.73 - (*n* = 7)	0.64 - (*n* = 10)	0.71 - (*n* = 16)
Osijek	1.39 SD = 0.30 (*n* = 152)	1.35 SD = 0.29 (*n* = 148)	1.45 SD = 0.29 (*n* = 117)	1.41 SD = 0.27 (*n* = 90)	1.14 SD = 0.19 (*n* = 31)	1.17 SD = 0.27 (*n* = 34)	1.096 - (*n* = 10)
Rijeka	1.57 SD = 0.43 (*n* = 140)	1.60 SD = 0.39 (*n* = 160)	1.70 SD = 0.43 (*n* = 83)	1.75 SD = 0.43 (*n* = 81)	1.35 SD = 0.22 (*n* = 25)	1.40 SD = 0.37 (*n* = 49)	1.38 - (*n* = 29)

SD—standard deviation.

Table 7. Children pedestrians' mean speed–depending on children's age.

	Age Group Mean Speed		
	AG1	AG2	AG3
Enna	0.78 SD = 0.14, *n* = 82	0.76 SD = 0.11, *n* = 93	0.86 SD = 0.14, *n* = 125
Osijek	1.23 SD = 0.24, *n* = 23	1.37 SD = 0.36, *n* = 88	1.37 SD = 0.26, *n* = 189
Rijeka	1.45 SD = 0.288, *n* = 19	1.62 SD = 0.44, *n* = 116	1.58 SD = 0.40, *n* = 165

SD—standard deviation.

Table 8. Mean children's pedestrian speed–depending on crosswalk length.

		Pedestrian Crosswalk Length (m)					
		7 m	9.2–9.5 m	10–10.5 m	12.5 m	14 m	16–17 m
Enna	Speed [m/s] gt [s]		0.74 49 (*n* = 57)	0.77 49 (*n* = 124)	0.88 49 (*n* = 119)		
Osijek	Speed [m/s] gt [s]	1.12 50 (*n* = 46)	1.35 50 (*n* = 106)	1.35 20 (*n* = 73)		1.53 13 (*n* = 75)	
Rijeka	Speed [m/s] gt [s]	1.47 13 (*n* = 20)		1.59 9 (*n* = 211)			1.6 12 (*n* = 69)

gt—pedestrian green time.

The data show that children in all three locations cross more quickly at longer pedestrian crosswalks.

3. Results

3.1. Statistical Analyses of Data Base

Statistical analyses of calculated data (crossing speed) based on the measured data (crossing time, crosswalks length) included the Anderson-Darling test to check the normal distribution of data for every location (city). Test for two variances, Levene's and Bonett's methods, was performed in order to establish if there is statistically significant difference among data for every possible pair of cities in which the study was conducted. Levene's and Bonett's method is accurate for the distribution of data that does not fit the normal

distribution [27–30]. Bonett's method proved to be more reliable in cases where the distribution is not extremely skewed; however, for extremely skewed and heavy-tailed distributions, Levene's method is usually more reliable [31]. In this case both tests were applied.

For each city separately, on the basis of 300 data sets, an analysis of the influence of independent variables (described in Section 2.1.3) on the dependent variable (crossing speed) was made by application of the non-parametric Kruskal-Wallis test [32].

3.1.1. Basic Statistical Analyzes of Observed Databases

Basic statistical analyses for each group of crossing speeds (m/s) data are presented in Table 8. The normality of the data measured for each group (each city included in the study) was tested by performing the Anderson-Darling test (Table 8—columns AD, *p*-value). The Null hypothesis of the test is that data follow a normal distribution and a significance level of 0.05 was set.

Anderson-Darling test results showed that for all three groups (Enna, Osijek, Rijeka), data do not follow normal distribution (Table 9).

Table 9. Descriptive Statistics of Databases and Anderson-Darling test results.

	N	Mean	SD	Median	Min	Max	Variance	AD	*p*-Value
Rijeka	300	1.59	0.41	1.53	0.82	3.24	0.17	8.114	<0.005
Osijek	300	1.36	0.30	1.35	0.53	2.37	0.09	0.913	0.020
Enna	300	0.81	0.14	0.79	0.44	1.23	0.02	1.798	<0.005

SD—standard deviation, AD—Anderson Darling test results, *p*-values of AD test.

3.1.2. Comparison of Databases

The differences between the results in the crossing speeds of children pedestrians in three different urban transport networks were analyzed using the Test for two variances. Significance level of $\alpha = 0.05$ was set.

The results of the Test for two variances showed that there is a statistically significant difference between the results in the crossing speeds of children pedestrians in the three different urban transport networks (Table 10).

Table 10. Comparison of variances and standard deviations for pairs of analyzed cities.

	Enna Rijeka	Enna Osijek	Rijeka Osijek
Ratio of St. Dev.	0.340	0.467	1.376
Ratio of variances	0.116	0.218	1.893
Bonett's method	80.36	97.57	12.48
p-value	0.000	0.000	0.000
Levene's method	98.35	138.65	5.15
p-value	0.000	0.000	0.024

The above confirms the justification of the further analysis for the three analyzed cities separately and enables determination of the influence parameters that are important for all three locations and that can be applied widely, and those locally significant parameters that are only important in one or in two of the selected cities.

3.2. Influential Parameters' Analysis

Finally, an analysis of the influence of selected parameters, independent variables, on the dependent variable, crossing speed, was made for each city separately.

Taking into account that the measured data do not follow the normal distribution, analysis of the selected influential parameters was made using the non-parametric Kruskal-Wallis test, and a significance level of $\alpha = 0.05$ was set.

According to the results of Kruskal-Wallis test shown in Table 11, bold *p*-values for different urban networks confirm the influence of the specific independent variable (parameter) on the dependent variable (crossing speed).

Table 11. Influence of specific independent variable on dependent variables based on the Kruskal-Wallis test.

Independent Variable	Description	Rijeka		Osijek		Enna	
		H	**P**	**H**	**P**	**H**	**P**
I-1	length of pedestrian crosswalk [m]	18.47	**0.004**	57.95	**0.000**	52.35	**0.000**
I-2	width of pedestrian crosswalk [m]	-	-	6.79	0.147	-	-
I-3	green time for pedestrians [s]	3.11	0.212	37.05	**0.000**	-	-
I-4	traffic signal cycle lengths [s]	0.00	0.99	-	-	-	-
I-5	number of children on crossing	-	-	27.06	**0.000**	-	-
I-6	total number of pedestrians	-	-	23.89	**0.001**	-	-
II-7-1	age group 1	4.33	**0.037**	7.71	**0.005**	10.15	**0.001**
II-7-2	age group 2	0.93	0.335	0.10	0.718	14.32	**0.000**
II-7-3	age group 3	0.00	0.997	3.36	0.067	41.34	**0.000**
II-8	gender	0.34	0.557	1.27	0.259	6.75	**0.009**
II-9	children with special needs	-	-	7.87	**0.005**	16.69	**0.000**
II-10-1	movement alone	53.54	**0.000**	63.54	**0.000**	28.71	**0.000**
II-10-2	movement in a group of 2	8.09	**0.004**	16.46	**0.000**	24.15	**0.000**
II-10-3	movement in a group of 3	19.47	**0.000**	36.00	**0.000**	4.82	**0.028**
II-10-4	movement in a group of 4	27.47	**0.000**	5.75	**0.016**	-	-
II-10-5	movement in a group of 5	-	-	1.75	0.186	-	-
II-11	supervision by adults	8.14	**0.004**	3.02	0.082	15.23	**0.000**
II-12	Mobile—occupies visual attention	1.43	0.231	6.46	**0.011**	0.11	0.741
II-13	Mobile—does not occupy visual attention	0.55	0.458	4.24	**0.040**	12.99	**0.000**
II-14	running	73.38	**0.000**	32.17	**0.000**	-	-

H—H value, result of Kruskal-Wallis test, *P*—*p* value, result of Kruskal-Wallis test, bold—*p* value < 0.05

Empty cells in Table 11 are those for which it was not possible to reliably establish the influence of the selected parameter on pedestrian crossing speed because there was not enough variability of collected data (e.g., green times in Enna, crossings' width in Rijeka and Enna, traffic signal cycle lengths in Osijek and Enna) or no data at all (e.g., running in Enna, children with special needs in Rijeka, number of pedestrians/children).

4. Discussion

The study was conducted in two European countries (Croatia and Italy) in three different cities (Enna in Italy and Osijek and Rijeka in Croatia)—urban environments with different space, traffic and cultural characteristics, in order to determine how much the parameters that affect the traffic habits of children are common and can be applied widely around the world and how much they depend on local specifics.

Children were recorded on their everyday way to school and without being aware of the observer as this methodology was previously noted as objective because it was established that children tend to walk faster when they are aware of being recorded [33]. What can be seen as positive in this approach is that children behaved completely spontaneously so it was possible to notice all kind of risky behaviors and measure pedestrian speed in non-forced circumstances. The main problem of this approach was the estimation of children's age because the age was estimated from the recorded material. Children were recorded at crosswalks near primary schools, as analyses of locations where most traffic accidents involving children happen pointed to mixed-used zones [15,16,18,24,25] and intersections as critical points in the urban road network where children pedestrian safety is considered [18,19,21]. Altogether more than 900 children were observed, around 300 in every city, aged from 5 to 16, and 300 measurements in every city were selected for the analyses.

In this study the difference in children's traffic behavior is evident not only in cities of different states, but also in different cities of the same state. The results of this study, when children's pedestrian speed is considered, are similar in part to that presented in

the paper [33] that was carried out by Toor et al. with the aim of calculating children's pedestrian speed at crosswalks. Results of both studies suggested that walking in a group decreases mean children's pedestrian speed. When it comes to children's age, [33] confirmed its influence on children's walking speed, but in this study a difference is visible only between children aged up to 7, who walk more slowly than the other two analyzed age groups. Research into and comparison of children's pedestrian speed in Germany, USA and Australia [34] pointed out gender, age, height and weight to be influencing factors when children's walking speed is considered. In this research it was established that gender influenced children's pedestrian speed in just one of the analyzed locations (Enna, Italy), thus proving that traffic habits do have very local specifics that cannot be associated with any country, but only locally [35].

The study also reinforced an already established fact that Italian children gain independent mobility during school years to a smaller extent than children in the rest of Europe, in this case Croatia [5,6]. While in Rijeka and Osijek respectively 6% and 11% of children were supervised by an adult while crossing the street, in Enna the percentage of supervised children was 55%. This fact does not contribute to traffic safety data for Italy, so it suggests the need to promote traffic education among school aged children in Italy in order to enhance their traffic independence and safety.

Analyzed infrastructural parameters (crossing lengths, pedestrian green time) were not sufficiently common in all three cities to enable detailed comparison of mean speeds, but the results of available data show that when crossing longer crossings children tend to walk faster.

The main analysis of this study was dedicated to establishing statistically significant parameters that have influence on children's traffic behavior—in this case represented as crossing speed.

Analyses of factors influencing children's crossing speed was performed separately for three data bases, because a comparison with the data base of the whole sample confirmed that pedestrian traffic behavior in this case shows regionally conditioned characteristics. This confirms the need for this kind of analysis to be done locally. As collected data for neither of the cities followed normal distribution, a non-parametric Kruska-Wallis test was conducted to establish parameters (general parameters and parameters connected to children) that do have influence on children's traffic speed, and the level of their significance.

Conducted statistical tests confirmed the strong influence of the length of pedestrian crosswalk and walking in a group on children's pedestrian speed in all three cities, while the influence of one age group parameter was also confirmed as significant. Comparison of results with previous studies considering children and young pedestrians suggested that children's age has influence on their traffic behavior (9–11) but in the case of this study it was proved only for younger children (up to 7 years old). For children older than eight, other parameters influence their behavior at crosswalks more significantly. As for the gender influence, the results of available studies came to different conclusions [12,13] and the same happened in this study; gender resulted as an important influencing parameter only in one of the analyzed cities (Enna), while in the other two (Osijek and Rijeka) gender was not established as an influencing parameter. Supervision of adults is also indicated in only two of three cities (Enna, Rijeka) as well as the use of a mobile phone while crossing the street (Enna, Osijek). Although the influence of mobile phones as attention distractors showed significance in the two observed environments, the results show a small percentage of mobile phone use in the observed population of children. A mobile phone that occupies visual attention was used by 6% of children in the entire database in Enna and Osijek and 1% in Rijeka. The use of mobile phones that do not occupy visual attention (talking, listening to music, etc.) was observed for 9% of children in Enna, 7% in Osijek and 3% in Rijeka. For all three data bases, walking in a group was established as more of an influencing distractor than use of mobile phones.

The width of the pedestrian crosswalk and the traffic signal cycle length in this case were evaluated as parameters that did not have a statistically significant influence on the

crossing speed of children pedestrians. The influence of both of these parameters should be further investigated since in the existing databases these parameters are not sufficiently diverse for determination of their influence. Even though there is not enough data to establish correlation between children's pedestrian speed and traffic signal duration, the results suggest that children pedestrians tend to walk faster if they are aware of a shorter pedestrian green light which is the case in Rijeka where the pedestrian green times are minimal and enforce pedestrians to walk 1 m/s if they start walking with the green light, and far more quickly if they do not.

5. Conclusions

The study, conducted in two European countries (Croatia and Italy) in three different cities (Enna in Italy and Osijek and Rijeka in Croatia), urban environments with different space, traffic and cultural characteristics, aimed to determine how common are the parameters that affect the traffic habits of children and can be they be applied widely in other countries, and how much they depend on local specifics.

Children were recorded while crossing the street at signalized intersections on their everyday way to school and without being aware of the observer.

Altogether more than 900 children were observed, around 300 in every city, aged from 5 to 16, and 300 measurements in every city were selected for the analyses. The results of statistical analyses confirmed that the traffic behavior of children pedestrians is regionally conditioned because significant differences in children's pedestrian speed were established for each pair of cities.

Input parameters that were statistically significant for all three urban areas are:

- length of pedestrian crosswalk
- age group
- moving in a group.

Differences between the means are statistically significant for two urban areas for these input parameters:

- children with special needs
- supervision by adults
- mobile—not occupying visual attention
- running.

Partly unexpectedly, gender was established as a significant parameter in only one of the analyzed sites–the city of Enna in Italy; in other cities the importance of other parameters was stronger.

The presented results can serve as valuable input for definition of traffic safety measures, interventions on infrastructure and policy actions in each of the analyzed cities. Traffic education at an early age should take into consideration differences in children's behavior that influence their safety while crossing the street such as visual distraction and lower speed when walking in a group. Special emphasis should be placed on education and other activities to increase traffic safety of children aged 5–7 years which is usually the age when they enter school, as this group was detected as the most vulnerable. For infrastructural interventions it is important that pedestrian paths, including crosswalks, that are regularly used by school children, are designed using standards that can assure their safety, for example, longer green times and shorter crossings or implementation of pedestrian refuge islands.

The methodology, i.e., children not being aware of the recordings, enabled objective observation of their behavior so it can be suggested as an effective tool for the establishment of local specifics when children's pedestrian behavior is analyzed. The main problem of this approach was the estimation of children's age because it was mainly estimated from field observation and inspection of recorded material, and it was not possible to identify exact age with precision.

Even though 900 crossings were analyzed at 18 different locations, for some of the parameters there was not enough variability of data to establish relevant statistical influence on children's behavior. Further research will be focused on enlargement of the existing data base in order to better establish the influence of the infrastructural parameters on children's traffic behavior and to propose some precise design elements that can improve their safety.

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