Identification of unsafe traffic environments for children as autonomous road user in Flanders (Belgium)

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1. Introduction

Statistics show that the number of victims in traffic has decreased in most European countries compared with 20 years ago. Also the number of accidents with children between 6 and 12 years of age shows a decline. These facts, however, do not imply that the safety of European roads have increased because child mobility may have been decreased. De Groof (2004) and Mackett (2001) reported that children are more and more transported on the backseat of the car - the so called *'backseat generation'* - and as consequence are less exposed as active road users.

One of the consequences of the decreased participation of children in traffic is that the road infrastructure is in the first place designed for car drivers while the needs of weak road users including children are in some cases not taken into account. A poor design of road infrastructure may result in unpleasant and unsafe environments for children to travel autonomously, leading to even more car use, since parents do not find it safe for their children to travel alone.

The parental concerns about the safety and security in traffic restrict the independent exploration of the local environment by the child. Children don't get the opportunity to exercise in real traffic situations, so they can't develop the necessary decision-making skills to safely participate in real traffic situation (Mackett, 2007). This partly explains why the number of accidents in which 12 year old children are involved is exceptionally high: children that make the transition from elementary to secondary school are often exposed to traffic situations as autonomous road users but lack sufficient training in real traffic in the earlier years (OECD, 2004).

This finding pleads for an early participation of children in traffic. If young children participated more in traffic by bike or on foot they would develop the necessary safety skills.

Research (Zeedyk et al., 2001 & Helsen et al., s.d.) showed that theoretical traffic education in school alone is not sufficient to increase safe behaviour of young children in traffic. A large part of the traffic safety of young children depends on the quality of the traffic environment which should be self-explaining, homogeneous, functional and forgiving (Theeuwes, 1995 & Wegman & Aarts, 2005).

There are several ways to improve the traffic safety and decrease the number of victims through the 3 E's of prevention: education, enforcement and engineering (Lammar, 2005b). In this paper the focus is on the engineering part.

At present, however, it is not fully understood, to what extent a traffic environment controls the behaviour of young children. Moreover, it is not known how a road infrastructure should be designed to maximise their safety. A first insight in these research questions could come from an analysis of recorded traffic accidents with children. The identification of risk locations could then be used to formulate interventions, measures, and policy strategies to improve existing traffic environments.

In this paper a database with traffic accidents in Flanders in which young children where involved was analysed in order to (i) detect the temporal evolution of the number of traffic accidents with children and (ii) to identify unsafe traffic environments for children 6 to 12 years old. To identify risky traffic environments for children, the locations of accidents where children were involved were compared with the “mean accident location”.

2. Temporal evolution of traffic safety for children as road users in Flanders

When people talk about traffic safety, the risk of having an accident is often the topic of their conversation; roads and traffic are considered to be unsafe, because the perceived risk of having an accident is rather high. It is at present, however, not clear whether the real risk of having an accident for Flemish children has been increased or decreased. Therefore a database with traffic accidents from 2000 to 2005 in which children from 6 to 12 years old were involved was analysed. The database was derived from a national accident statistics database.

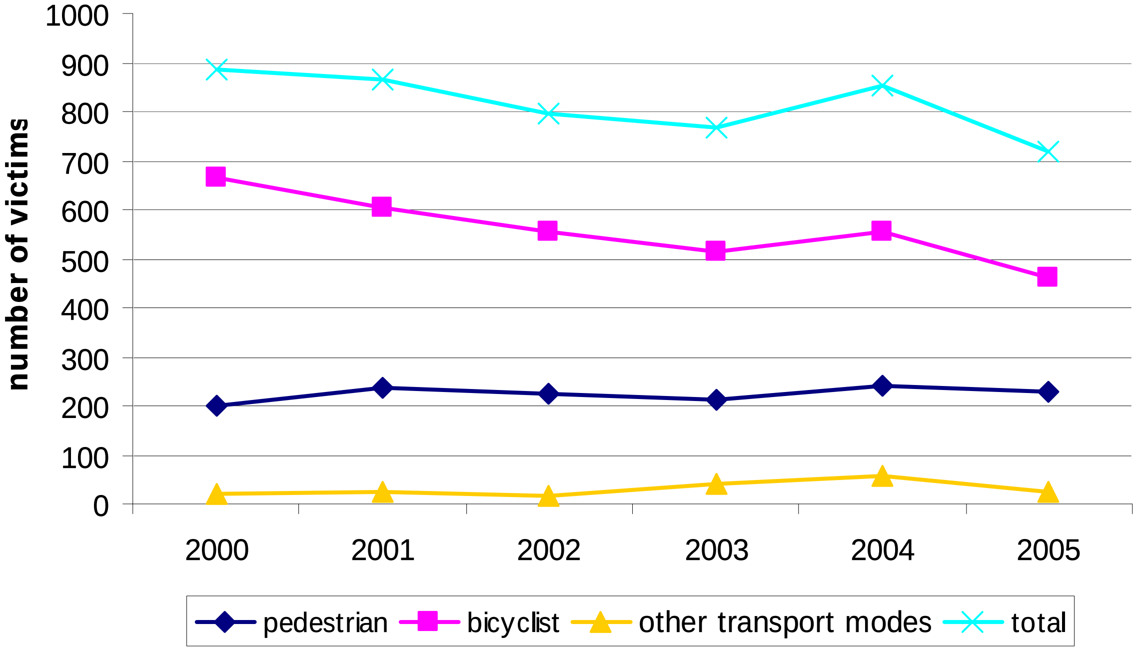
In principle, risk should be calculated by dividing the number of victims by the total travel distance or time spent in a traffic environment. This risk can be specified for different travel modes and age categories (Hermans, s.d., Schepers & Methorst, 2005). If possible, the number of victims should be compared with exposure time in order to quantify risk levels. For example, a small number of victims in a certain age category does not necessarily mean that this group is relatively safe in a traffic environment. It might well be possible that this specific group is hardly exposed to traffic.

Since exposure data of Flemish children as road users in traffic are not available, the total number of victims was used as an indicator for traffic safety.

Figure 1 shows the evolution of the number of child traffic victims as road user for the years 2000 until 2005. The total number of road user victims between the age of 6 and 12 decreased steadily from 886 victims in 2000 to 718 victims in 2005 (-19%), with an exception in 2004 were an increase occurred (853 child victims).

The evolution of the bicycle victims shows the same trend, with a decrease in number of victims from 666 in 2000 to 513 in 2003 and an increase in 2004 (557 bicycle victims), followed by a decrease a year later, leading to the lowest number of child bicycle victims (463 victims). The temporal evolution of pedestrian victims, however, does not show a clear trend. From 2000 until 2005, the number of pedestrian victims slightly increased from 201 to 229. The most remarkable increase was found in 2004, when 240 child pedestrians where injured in traffic, in comparison with 212 in 2003.

Figure 1: Evolution of total amount of child road user victims by travel mode (2000-2005)



Source: own data processing based on the national accidents statistics (http://statbel.fgov.be/figures/d364_nl.asp#3)

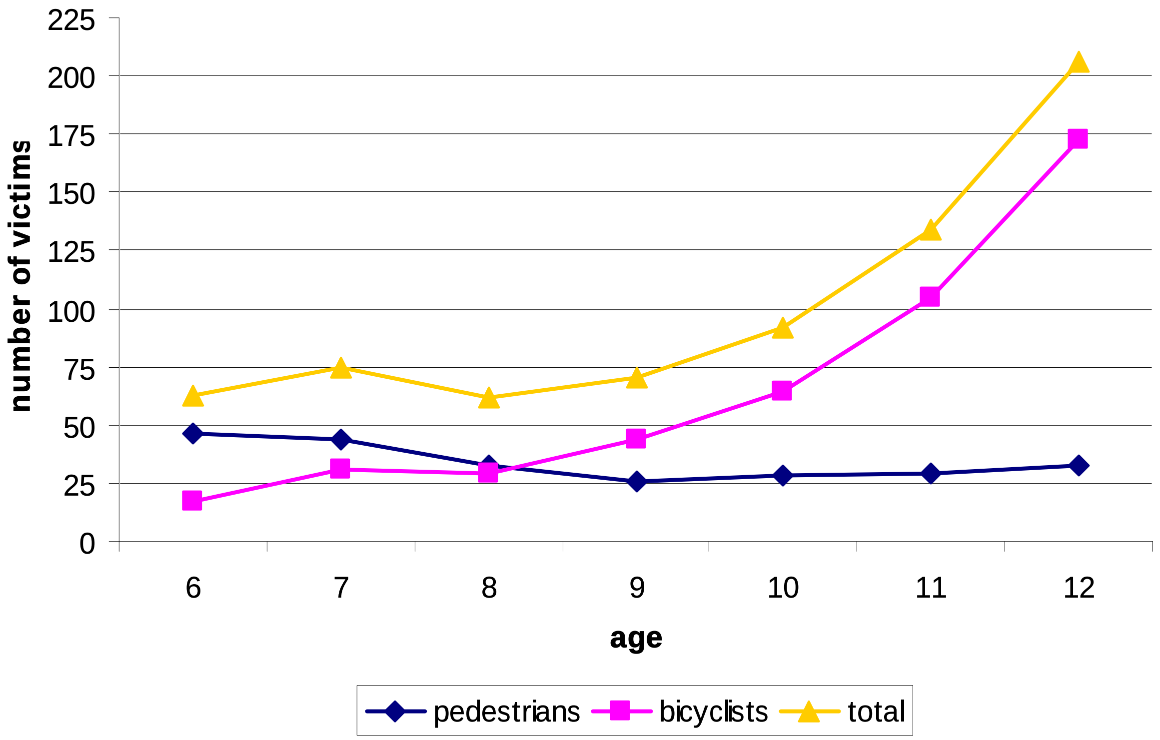
Hubert & Toint (in Lammar, 2005a) reported that the total number of child bicyclists in Flanders did not change significantly between 1991 and 1999. Under the assumption that this trend was still valid from 2000 till 2005 it can be concluded that the risk of having an accident as a child bicyclist dropped significantly since the same exposure led to a decrease in number of victims.

The slight increase in number of pedestrian victims, on the other hand, is alarming, since the research of Hubert & Toint (1999) found that there was a significant decrease in the relative number of child pedestrians in traffic. This implies that the risk for children as pedestrians in traffic increased.

Figure 2 shows the number of traffic victims by age and transport mode. The older the child gets, the higher the number of bicycle victims. This correlation can be explained by the higher number of bicycle victims with increasing age, with the highest number at the age of 12 (Pearson $r = .906$, $p<0.01$ for the year 2005; a significant correlation was also found for the other years). The high number of bicycle victims at the age of 10 to 12 can be explained by the high exposure time of this age category in comparison with younger children, who often aren't capable enough to ride a bike on the street.

For the pedestrian victims no significant correlation between the number of victims and their age could be found. The slightly negative trend suggests that younger children (6-7 years old) more than teenagers are involved in an accident as a pedestrian. A possible explanation for the relative high number of very young children who were injured as a pedestrian in traffic could be their more impulsive behaviour in comparison with older children.

Figure 2: Number of child road user victims by age and transport mode (2005)



Source: own data processing based on the national accidents statistics (http://statbel.fgov.be/figures/d364_nl.asp#3)

3. Identification of unsafe traffic environments

3.1 Traffic accident database

Roberts et al. (1995), Agran et al. (1996), Petch & Henson (2000) and Lammar (2005a) pointed out that environmental factors have an important impact on the level of risk for children in traffic (as pedestrians). Their research results showed that traffic volume, traffic speed, and number of parked cars on curbs were correlated with the risk children run in traffic. Agran (1996) and Mayr et al. (2003) found that most of the accidents with child pedestrians happened at midblock (44.2 - 53%), followed by intersections (34.6 – 28%) and driveways or parking lots (18.4 – 19%). Carlin et al. (1995) reported that children as a bicyclist had an elevated risk in traffic which was associated with sidewalk riding and playing on the street rather than with using the bike for transportation.

In this paper a Flemish database based on the registration of the location of accidents by the police was used to evaluate the impact of some of these environmental characteristics.

The database that was analysed consists of information on the location characteristics of the accidents that happened in Flanders from 2000 until 2004. The database was compiled on the basis of the accident registration by the police. This means that minor and unregistered accidents are not taken into account. Therefore our results should be interpreted with care.

Firstly some descriptive statistics (frequencies, Chi-statistics) were drawn from the database to get an idea of the place and conditions where accidents with children aged 6 to 12 years happen. Next the correlation between age of the victim and location of the accident were analysed.

The database contains 2929 records of road user victims between 6 and 12 years. The coordinates of each accident location were registered. A comparison with the national traffic accident database shows that of the 2929 reported road user victims, 1997 involved a child bicyclist (68.2%) and 764 involved a child pedestrian (26%). 56 road users were injured while driving a motorised vehicle – a moped or a car – (1.8%). This number is quite surprising, since children under the age of 12 aren't allowed to drive a motorized vehicle. This number might be the result of inaccurate registration. The travel mode for the other 4 percent of the victims was unknown, i.e. not registered.

When these numbers are compared with the total number of road user victims from 2000 until 2004, a different distribution over the different travel modes can be noticed. Almost 85% of all victims were injured while driving a motorized vehicle. Only 10% were bicycle victims, 3% of the total number of victims was injured as a pedestrian (table 1).

Table 1: Number of road user victims by travel mode (2000-2004)

Travel mode	# child victims	Total number
Cyclist	1997 (68.2%)	22462 (10.1%)
Pedestrian	764 (26%)	7152 (3.2%)
Motorized vehicle	56 (1.8%)	189198 (84.9%)
Unknown	112 (4.0%)	4010 (1.8%)
Total	**2929 (100%)**	**222822 (100%)**

Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

In the further analysis of the location and the conditions of the accidents with children only the accidents which involved a bicyclist or pedestrian are taken into account. because these two travel modes are most often used by children when travelling autonomously.

First, the location of the accident with child victims is described and compared with the "mean accident location", based on all the registered victims independent of their age. The following location indicators were analysed: (i) on or off a crossroad, (ii) in or outside the built-up area, (iii) while crossing a street, (iv) occlusion of visibility, (v) on or off the cycle path, (vi) properties of the cycle path. Secondly the time distribution of the accidents is analysed, since for most victims the date and the hour of the accident was registered.

3.2 Location of the accidents

3.2.1 Accidents with child bicyclists

The database contains 1997 records of accidents in which children were injured riding a bike. 50% of these injuries took place on or nearby a crossroad. The other half of the accidents did not occur nearby a crossroad (table 2). These results are in agreement with the findings of Lammar (2005a) who reported similar percentages for Flanders.

A similar analysis using all recorded accidents with bicyclists, including adults, showed that 52% of the total bicyclist population was injured on a crossroad out of which may be concluded that children have relatively more chance of being injured at non-crossroads locations. However, this difference didn't appear to be significant (Chi-test: p=.704, n.s. at .05).

An age specific analysis showed that very young children are injured more off a crossroad than nearby a crossroad. Only 30 to 40% of the 6 year olds and 7-8 year olds respectively were injured near a crossroad, compared with 53% of the 11-12 year olds. With increasing age, the relative number of accidents on a crossroad increases (Pearson r = .958, p<0.01, 1-tailed) (table 2). This could be explained by the fact that very young children are often not allowed to travel in complex traffic environments. Their exposure at crossroads is therefore much lower.

Table 2: Cross tabulation age of the child bicyclist – crossroad

Age	**Number of accidents**		
	Near a crossroad	Not near a crossroad	**Total**
6 years	19 (30.6%)	43 (69.4%)	62 (100%)
7 years	39 (39.7%)	59 (60.3%)	98 (100%)
8 years	47 (40.5%)	69 (59.5%)	116 (100%)
9 years	78 (48.4%)	83 (51.6%)	161 (100%)
10 years	141 (48.0%)	153 (52.0%)	294 (100%)
11 years	220 (53.0%)	195 (47.0%)	415 (100%)
12 years	456 (53.6%)	395 (46.4%)	851 (100%)
Total children	**1000 (50.1%)**	**997 (49.9%)**	**1997 (100%)**

Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

Table 3 shows that 74.3% of the registered bicycle victims between 6 and 12 years old were injured inside the built-up area. The other 25.7% of child bicyclists were involved in an accident outside the build-up area. This distribution differs slightly from the distribution of an average bicyclist where 67.4% of the accidents occurred in the build-up area. The difference is, however, not significant. (Chi-test: p=.141, n.s. at .05).

The higher number of accidents inside the built-up area should, in our view, not be contributed to a higher risk, but rather to a higher exposure. Travelling outside the built-up area is more dangerous for the weak road user, since the speed difference between the different travel modes (i.e. between a car and a bicyclist) is very high (Wegman, 2005). The higher number of accidents in the built-up area should therefore be attributed to differences in exposure.

An age-specific analysis of the data shows a significant decrease in the relative number of accidents inside the built-up area with increasing age (Pearson r = -.849, p<0.05, 2-tailed) (table 3). Again, this can be explained by differences in exposure of the different age categories.

Table 3: Cross tabulation age of the child bicyclist – built-up area

Age	**Number of accidents**		
	Inside built-up area	Outside built-up area	**Total**
6 years	51 (82.3%)	11 (17.7%)	62 (100%)
7 years	83 (84.7%)	15 (15.3%)	98 (100%)
8 years	88 (75.9%)	28 (24.1%)	116 (100%)
9 years	129 (80.1%)	32 (19.9%)	161 (100%)
10 years	226 (76.9%)	68 (23.1%)	294 (100%)
11 years	315 (75.9%)	99 (24.1%)	414 (100%)
12 years	591 (69.4%)	260 (30.6%)	851 (100%)
Total	**1483 (74.3%)**	**513 (25.7%)**	**1996** (*) **(100%)**

Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen),
(*) For one victim the variable 'built-up area' not code

For most child victim records (1939) additional information was available on the exact location of the accident: on or off a bicycle path, on an elevated or marked cycle path, and on a one or two directional bicycle path.

Similar X^2-analysis as presented above showed that child bicyclists have fewer accidents on than off a cycle path (63% vs. 37%). This distribution is significantly different from the distribution of the average cyclist (52% vs. 48%) (Chi-test: p=.018, sign. at .05).
Possible explanations are (i) it's safer for children to ride on a bicycle path than on the road or (ii) children ride more on the street than they do on bicycle paths – because they have to (lack of sufficient bicycle paths) or they want to (lack of correct behaviour) –, so their exposure on streets is higher, as a consequence also the risk of having an accident increases.
Of all the children that were injured on a bicycle path 53% was injured on a 'marked' bicycle path, while 47% was injured on an 'elevated' bicycle path, separated from the road. The distribution of all victims over these categories shows relatively more (57.2%) victims on 'marked' bicycle paths. However, this difference was not found significant (Chi-test: p=.363, n.s. at .05)

2/3 of the child victims was involved in an accident on a one directional bicycle path, 1/3 of the victims was injured on a two directional bicycle path. The same distribution was found for the "mean" bicycle accident location. This finding corresponds with the results of the research of Lammar (2005a) who found that 72% of children aged 5 to 14 years got injured on a one directional bicycle path, 28% on a two directional bicycle path.

3.2.2 Accidents with child pedestrians

Only 21% of the child pedestrians (n=159) who were involved in an accident were injured near a crossroad. The majority of child pedestrians were involved in an accident where there was no crossroad nearby (table 4). An analysis of the distribution of the average pedestrian over these categories showed that 29.3% of all pedestrian victims were involved in an accident near a crossroad. This is a significant higher proportion than the accident location of the child pedestrian (Chi-test: p=.036, sign. at .05). Again differences in exposure could be the cause of these differences.

This trend is confirmed by the age-specific analysis: a significant increase in the relative number of accidents near a crossroad with increasing age can be noticed. It seems that older children are relatively more involved in an accident near a crossroad, compared with younger children (Pearson r = .901, p<0.01, 1-tailed).

Table 4: Cross tabulation age of the child pedestrian – crossroad

Age	**Number of accidents**		
	Near a crossroad	Not near a crossroad	**Total**
6 years	16 (13.4%)	103 (86.6%)	119 (100%)
7 years	19 (17.3%)	91 (82.7%)	110 (100%)
8 years	17 (15.7%)	91 (84.3%)	108 (100%)
9 years	24 (22.2%)	84 (77.8%)	108 (100%)
10 years	21 (18.6%)	92 (81.4%)	113 (100%)
11 years	25 (26.3%)	70 (73.7%)	95 (100%)
12 years	37 (33.3%)	74 (66.7%)	111 (100%)
Total	**159 (20.8%)**	**605 (79.2%)**	**764 (100%)**

Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

Table 5 shows the distribution of accidents in and outside the built-up area. The distribution of accidents with child pedestrians in and outside the built-up area shows a similar trend as the distribution of the average accident location with pedestrians. Both for the child pedestrian as the “average” pedestrian, most of the accidents occurred inside the built-up area. 82% of all victims and almost 86% of the child pedestrian victims were injured inside the build-up area. Again, as was the case with the bicycle accidents, this finding can be explained by the higher exposure of pedestrians inside the built-up area. Especially kids have a high exposure in the built-up area, near their home and on local streets (Petch & Henson, 2000). Age-specific analyses couldn’t however detect a significant trend in the location distribution of child pedestrians.

Table 5: Cross tabulation age of the child pedestrian – built-up area

Age	**Number of accidents**		
	Inside the built-up area	Outside the built-up area	**Total**
6 years	101 (84.9%)	18 (15.1%)	119 (100%)
7 years	94 (85.6%)	16 (14.4%)	110 (100%)
8 years	97 (89.8%)	11 (10.2%)	108 (100%)
9 years	97 (89.8%)	11 (10.2%)	108 (100%)
10 years	101 (89.4%)	12 (10.6%)	113 (100%)
11 years	83 (87.4%)	12 (12.6%)	95 (100%)
12 years	83 (74.8%)	28 (25.2%)	111 (100%)
Total	**656 (85.9%)**	**108 (14.1%)**	**764 (100%)**

Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

For most child victim records (706) additional information was available on the exact location of the accident: (i) while crossing and (ii) with and without occlusion of visibility.

Of the 706 children who were injured as a pedestrian, 520 (73.7%) were injured while they were crossing the street. This finding corresponds with international research, which found that most child pedestrian casualties occurred when the child was crossing the street (U.K. Department of Transport, 1997 in Petch & Henson, 2000).

In comparison with the “average” pedestrian victim, this percentage is rather high; only 65.5% of the total number of pedestrian victims was injured when crossing the road. This difference (8.2%), however, was not found to be significant (Chi-test: p=.478, n.s. at .05); the difference can be due to chance.

Most accidents with child pedestrians happened while crossing the street where there was no zebra crossing available within 30 metres (40.4%) or on a disorganized zebra crossing, i.e. with no traffic lights or police man (35%). These locations were also the most dangerous when taking all pedestrian victims into account: 40.1% of the victims were involved in an accident while crossing a disorganized zebra crossing, 31.3% while crossing the street where there was no zebra crossing available within 30 metres. As well for the child as for the “average” pedestrian, streets without a zebra crossing or with a disorganized zebra crossing are most dangerous.

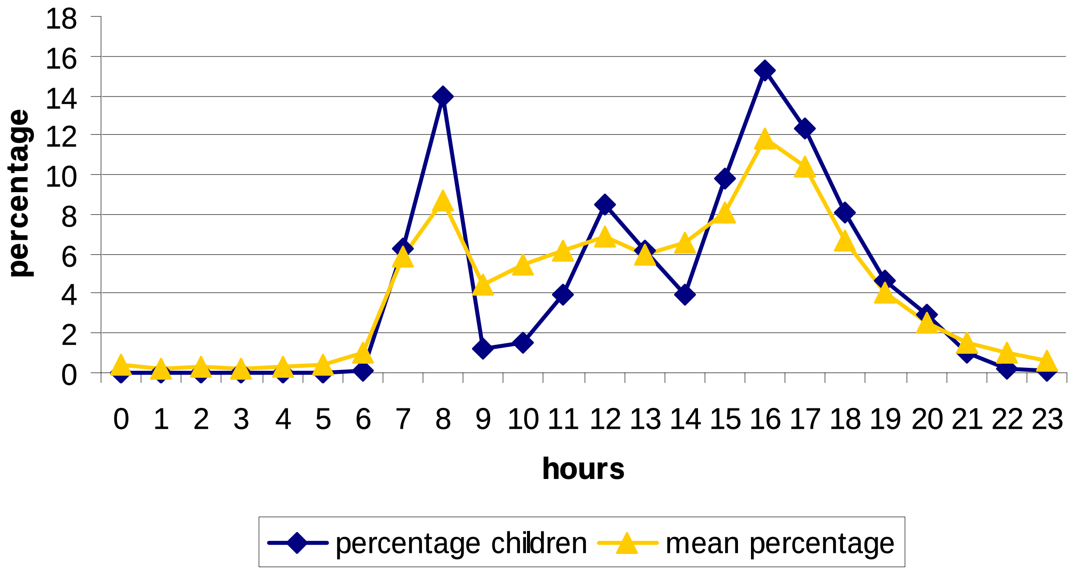
Another important parameter when crossing the street is the visibility of the pedestrian. Considering the accidents where a child was involved, 48.9% of the child pedestrians were not visible for the driver. 39% of the child pedestrians were visible for the driver. For the other 12.1% the specific conditions were unknown. A different distribution was found for the total population of pedestrian victims; only 27.7% of all the pedestrian victims were not visible for the other road user involved in the accident. This is a significant lower percentage than for the child pedestrian victim (Chi-test: p=.000, sign. at .05). Children appear to run a higher risk when crossing the street, because of their lower visibility (i.e. smaller body length).

3.3 Time distribution of the accidents with children

Apart from specific environment characteristics, also the hour of the day can influence the risk children run in traffic. As well for the bicyclists as for the pedestrians, the number of child victims shows a peak between 7 and 9 a.m., at 12 a.m. and between 3 and 6 p.m. (figure 3 and 4). This pattern is less explicit for the mean percentage of victims.

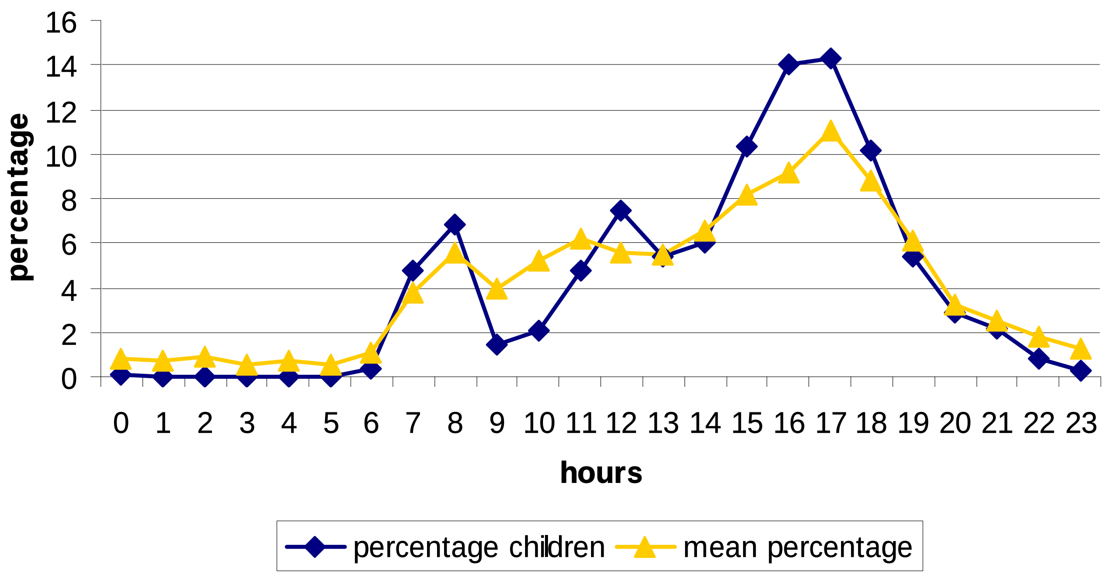
The timing of the accidents in which a child was involved, corresponds with the school hours.

Figure 3: Percentage of bicyclist victims by hour of the day



Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

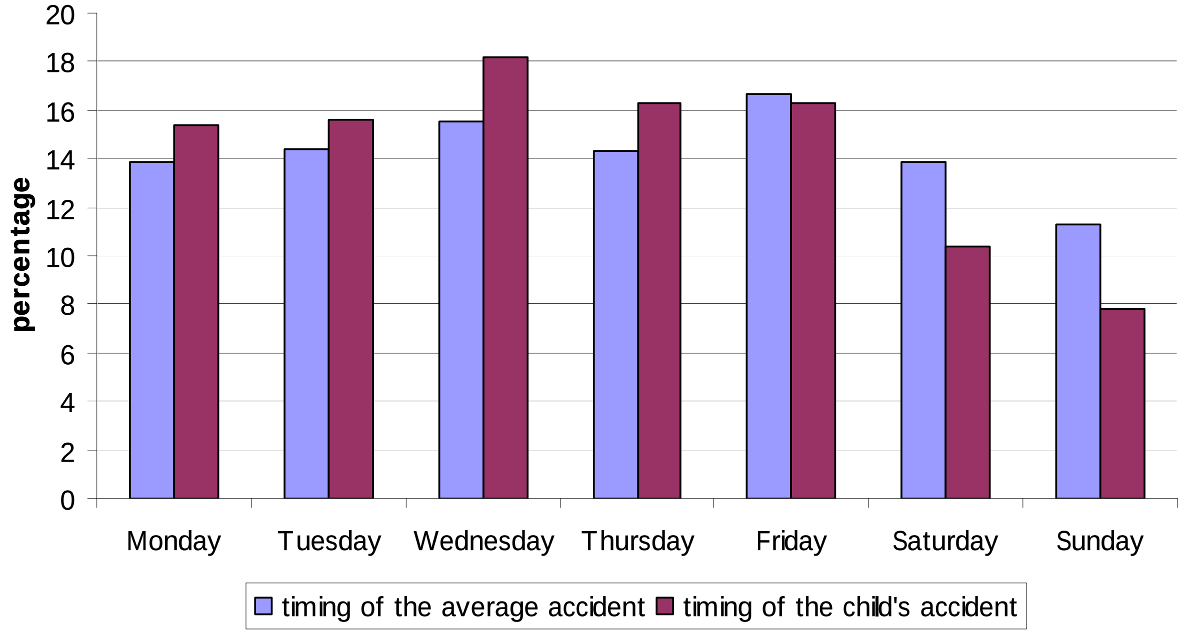
Figure 4: Percentage of pedestrian victims by hour of the day



Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

Considering the day of the week that the accident happened, it is remarkable that on all weekdays, except Friday, the percentage of child accidents was higher than average; during the weekend less children were involved in an accident. The difference is most explicit for Wednesday; 18.2% of all accidents where a child was involved as a pedestrian or a bicyclist happened on a Wednesday, in comparison with 15.5% of all accidents, independent of the age of the road user (figure 5). An explanation for the higher involvement of children in an accident on a Wednesday can be the higher exposure of children on the streets on Wednesday afternoon when there is no school and a lot of children spend their time travelling to recreational, sport or other facilities (music school, library ...) or playing on the street.

Figure 5: Distribution of the average and child accident over the week



Source: own data processing based on the accident database (Mobiliteitscel Vlaanderen)

On average 64.3% of the child accidents happened during the week (Monday till Friday), the other 35.7% happened during the weekend (Saturday and Sunday). This distribution differs significantly from that of the average accident. On average 54.3% of the accidents happened during the week, 45.7% happened during the weekend (Chi-test: p=.037, sign. at .05). Children are relatively more injured during a weekday, especially on a Wednesday, in comparison with the average road user.

4. Discussion and research recommendations

An analysis of the accident database that was available for this study showed that infrastructural factors can have a significant impact on the distribution of accidents with children. For each factor the distribution of an average road bicyclist or pedestrian was taken as the reference. Table 6 shows all environmental factors for which a child has a significantly different risk of having an accident than an average road user.

Table 6: Identification of unsafe traffic environments for children

		Pedestrian	Bicyclist
Infrastructural factors			
	On local, straight roads	+	n.s.
	Inside the built up area	n.s.	n.s.
	On streets without a zebra crossing	n.s.	
	On streets with a disorganized crossing	n.s.	
	Presence of elements which could hinder the visibility of the child - trees or bushes - parked cars - poles - ...	+	
	Streets without a cycle path		+
	On marked cycle paths		n.s.
	On a one-directional cycle path		n.s.
Time distribution			
	During school hours: between 7 and 9 a.m., at 12 a.m. and between 3 and 6 p.m.	+	+
	During the week, especially on Wednesday	+	+

Source: own data processing

+ : significant higher risk than average

- : significant lower risk than average

n.s.: not significantly different from average

A key problem for the interpretation of the results presented above is the lack of exposure data of the child in different traffic environments. As a consequence it is very difficult to draw hard conclusions form table 6. A higher number of accidents in a specific environment or location can be easily explained by a larger number of children passing. On the contrary it is possible that locations with relatively less accidents with children are in reality very dangerous for children and are therefore being avoided.

A second factor that has to be taken into account is that accidents are rare events. Based on national accident statistics alone, where only accidents are reported and no near-accidents or conflict situations are mentioned, it is impossible to have a complete overview of all the locations where children run a risk in traffic. Moreover, the numbers of records in official databases are underestimations because the traffic statistics don't register off-street events such as driveways and parking lots and accidents while playing, which are not reported to the police.

An identification of unsafe traffic environments is therefore only a first indication of risky traffic environments. It does not include all (or most dangerous) locations where children run a high risk. Future research should therefore compare the results of table 6 with experiences of stakeholders such as parents, police men, and experts in the field of traffic safety and engineering in order to get a clearer and more detailed idea and define additional parameters of risky traffic environments. A typology of risky traffic environments could then be used in the further research to select relevant locations for the observation of the behaviour of children by foot or on bike and their interaction with the environment and other road users. The traffic conflict technique as proposed by Almqvist & Hydèn (1994), Chin (1997), Svensson (2006) could be used to define near-accidents and conflict situations.

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