Risky traffic environments for children: A comparison between objective observations and subjective perception.

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1. Introduction

Although the absolute number of traffic accidents in which children were involved has been decreasing during the last 20 years in most developed countries, we can not conclude that roads became safer. The decrease in accidents could be explained by a decrease in child autonomous displacements (Diguiseppi C., 1997). Statistics show that children's free and autonomous movements decreased during the last 25 years. In most cases such movements are now restricted to safe locations such as schools, playgrounds, in-house… The transport between those safe islands is often supervised by an adult (Hillman M. et al., 1990; Zeiher, H., 2001). As a consequence children between 6 and 12 years old are consequentially more often transported in the backseat of the car. This phenomenon has been described for various case-studies in Northern America and Europe (Mackett R.L., 2001 ; Hillman M. et al., 1990; Karsten et al., 2001; O'Brien et al., 2000; Kaesemans, 2002; Carlin J.B. et al., 1997; McMillan T.E., 2006; Ewing R. et al., 2004, OVG-Vlaanderen, 1996; OVG-Vlaanderen, 2001). Despite from this general trend there is still a huge variation of children's participation in traffic between different countries and regions which is related to cultural, social and economic settings (Robert I. et al., 1997). The increase of car dependency of young children can be explained by different factors: (1) increasing car ownership, (2) greater complexity in lifestyle, (3) increasing time pressure, and (4) parental concern about children's safety, both because of traffic and possible abuse by strangers (Mackett R.L., 2001; Prezza M. et al., 2006).

Although all factors play an important role and some are closely related, parental concern about traffic safety seems to be the most significant factor that explains the increase of children's car dependency (Fotel T. and Thomsen T., 2004; Ewing R. et al., 2004). Several studies pointed out that parental concern about traffic safety is highly correlated with principal travel mode of their children (Kerr et al., 2006; Fotel T. and Thomsen T., 2004; Prezza M. et al., 2006). Such parental concern is typically based on their perception of the traffic environment and more specifically on the perception of the potential risk for traffic accidents. This finding raises the question whether the perceived risks correspond with the real risks? Jensen and Hummer (2002) reported that road safety campaigns and campaigns for bicycle helmet use may have had a counter effect resulting in an increasing parental risk perception and consequentially the decrease of children's autonomous displacements. Such effects are more generally observed and object of many academic discourses on whether our behavior is guided by real or perceived risks (Giddens, 1999; Beck, 1992; Luhmann, 1991; Rasborg, 2002).

This implies that in order to understand parent's choices with respect to the traffic mode of their children two issues must be addressed: (1) what is the risk perception of the traffic environment by parents? And (2) is this traffic risk perception correct? Lam (2001) pointed out that parental perception of traffic risk is correlated with gender of the parent, age of children, gender of children, education rate, economic status, previous accidents and residential location. At present, however, little is known about the accuracy of this traffic risk perception by parents.

Such an accuracy assessment is relatively complex because both real and perceived risks have to be measured in a reliable manner in order to be able to compare them. Moreover different methods have to be applied to measure real risk on the one hand and perceived risk on the other hand. For the assessment of perceived risks qualitative measures need to be adopted, while for measuring real or objective risks quantitative data mining techniques are applied. In the specific case of traffic risk assessments the risk assessment procedures are further complicated by the definition of risk and safety. 'Safety' is a debatable concept and will always be subject to interpretation (Adams J., 1988). Traffic safety statistics typically list occurrences of accidents. A 'safe' could for example be defined as a road with a low number of accidents or as a road with a low number of fatal accidents. Additional uncertainty is introduced by the inaccuracy, completeness and representativeness of traffic safety statistics. Traffic data are often subject to over- or underrepresentation of certain accident types. Especially child related accident statistics are often

underrepresented (Leonard P. et al., 1999, Adams J., 1988) mainly because in most cases police reports are the base of national accident statistics. Minor accidents with children are often not officially reported. Finally, exposure to risk is a very important element that should be taken in consideration when perceived and real traffic risks are analyzed (Robert I. et al., 1997; Posner J. et al., 2002; Routledge DA. Et al., 1974; Macpherson A. et al., 1998; Carlin J.B. et al., 1997). It is however very difficult or work intensive to obtain exposure measurements.
Despite all these difficulties there is a strong need for a better understanding of parents motives for not exposing their child autonomous into traffic. A better understanding of their motivations and interpretation of safety would allow creating better and more suitable environments where children are allowed to move independently, and allows for better targeted bicycle and walking stimulus campaigns. Self-employed travel behavior has indeed advantages on their motor development, development of their social identity, physical condition (Timperio A. et al., 2004; Cooper A. et al., 2005; Mackett R.L. et al., 2003), spatial skills and reducing traffic volumes during rush hour (Meire and vleugels, 2004).

Therefore the objectives of this paper are:

(1) To analyze the travel behavior of children between 6 and 12 years old and its possible correlation with the age of the child, the socio-economic background, the travel distance and type of destination (school, leisure, friends, family…...).
(2) To analyze the role of the traffic infrastructure towards the traffic risk perception of parents and this in a spatial context.
(3) To detect possible correlation between the increasing concern of parents about current traffic safety and accident statistics.

Multiple studies investigate the effect of infrastructure on traffic injuries, but limited amount of studies focuses on the effects of current infrastructure on children. Flanders which is characterized by a high population density and a highly fragmented urbanized or semi-urbanized landscape was selected as a case-study.

2. Methods and materials

2.1. Materials

Out of 3963 elementary schools (for children between 6 and 12 years old) in Flanders 150 were selected ad random and asked to co-operate by distributing a questionnaire among parents. The questionnaire asked parents about their children's autonomous travel behavior and there own perception of the traffic infrastructure in their environment. The questionnaire existed of two parts. The first part aimed at the detection of controlling factors of parental perception of traffic safety with a focus on traffic infrastructure, such as the role of road types. The second part aimed at mapping children's travel behavior by asking them to keep a diary of every displacement on Monday, Wednesday and Saturday. For every displacement, starting point, destination, travel mode, travel distance and level of guidance was recorded. This diary data were used to (1) describe statistical distribution of children's travel modes and (2) to group children by similar travel behavior. Objective assessments of traffic safety were derived from national accident statistics of Flanders (Mobgis, 2006). The available database was compiled from official police reports which implies an underestimation of the total number of accidents (Leonard et al.,1999; Adams, 1988). In this study only statistics from 2002 till 2005 were used because data from before 2002 were not fully georeferenced and data 2006 onwards were not yet available. Accidents were assigned to segments of the Flemish road network, which is a geo-database made available by the Flemish government (AGIV). This road network is attributed with speed limits, vehicle restrictions and the distance of every road segment.

2.2. Methods

2.2.1. Children's Travel behavior
Children's travel behavior was analyzed using the answers from the children's travel diaries. For every trip travel mode, travel distance, starting point, destination and level of guidance was recorded as a qualitative variable with multiple possible answers which were recoded into natural numbers. Descriptive statistics

point the general trends in current travel behavior of Flemish elementary school children out. Chi-Square tests indicate the possible associations between the qualitative variables. The results can be seen in sequence to the Flemish Travel Surveys of 1996 and 2001 (OVG, Vlaanderen, 1996, 2001)

2.2.2. Parental traffic risk perception

Measuring traffic risk perception can be subject of discussion because every individual has his own definition of traffic risk mainly influenced by experience of accident losses one's own and others and potential rewards of risk-taking (Adams j., 1988). Therefore it is useful to use 'balancing behavior' to measure subjective risk perception. These are behavioral measures that address both concern for children's safety and concern that they recover the individual freedoms that they need. According to Adams J., (1988) 'proportion of children of various ages who are allowed on a certain road type' is such a 'balancing behavior measure' and this is indeed the measure used to quantify parental risk perception here.

2.2.3. Accident statistics

Distinction of age, severity, travel mode and road type is made when describing Flemish child injuries related to traffic using general descriptive statistics. The general characteristics of injury sites are compared with allowance to those sites to describe the real and perceived traffic risk. It is unfortunately not easy to interpret the accident statistics because of the lack of exposure data. The closest estimate for child's exposure per road type is the allowance index and this is exactly to be compared with injury data. Only bicycle injuries are used in the comparison, because data on pedestrian injury are not accurate enough.

3. Results

3.1. Survey response

In total 25,000 parents were addressed via the 150 selected schools. The response rate was 34% (N=8600). In every child's age group there were more then 1000 responses with an increase with age equal to the demographic structure of children in Flanders. Only the group of 12 year old children was underrepresented (N = 600) and the category girls was slightly overrepresented, compared with the demographic structure of Flanders. Responses are equally distributed over the area resulting in circa 1500-1800 survey responses per Flemish province.

3.2. Children's travel behavior

Figure 1 and table 1 show some general characteristics of the travel behavior of Flemish children between 6 and 12 years old. The data show that travel mode changes with age. The decrease of car use is compensated by an increase in bicycle use at later age. Both modes cover 89% of all children's travel trips. There are as many 6 year olds as there are 12 year olds who walk, the guidance level showed in figure 2 however, makes clear that there exists a large difference between them. More then 80% of the young children are escorted when being road users (cyclers or pedestrians), while only 15% till 30% of the older ones are escorted. Zwerts E. et al. (2009) came to a similar conclusion that a shift in age leads to a shift in mode use and more particularly, to a shift towards more independent travel modes.

Mode-use differs significantly between school trips and the total of trips made by children. Car use is 13 % less for school trips and especially bicycle use increases when travelling to school. This observation can be explained by the average travel distance for school trips compared to the average travel distance for leisure or family trips, this was also observed by Meire and Vleugels (2004). Only 14% of the school trips are more then 5km while 42% of the leisure trips and 48% of the family trips are more then 5km. A Chi-square test between travel mode and travel distance shows a significant dependency between the two variables (P=0.000). It should be noticed that the questionnaire was held in November, so leisure trips and family trips are mostly carried out during darkness, which may also be a reason for the difference in travel mode choice between school and other trips. Although travel distance is a significant factor (ranked third) in the decision making process of travel mode choice, parents put traffic safety and age at numbers one and two in the list of key factors that determine the travel mode.

Regarding gender, only significant differences exist for older children. Within the age group 6-9 no differences in travel mode for all trips can be observed (t = 1.88; p > 0.05), within the 10-12 group the difference in travel mode for all trips is significant *(t* = -2.95*; p* < 0.05) with boys travelling more by bike than girls (+5%), but girls walking more than boys (+1.8%). For school trips this trend is even more pronounced with 9% more boys travelling by bike and 3% more girls who walk. The same trends were observed in Zwerts E. et al. (2009) for Flanders, in Fyhri A. and Hjorthol R. (2009) for Norway and in O'Brien et al. (2000) for Great Britain.

Compared to previous reported figures (OVG Vlaanderen, 1996, 2001), a decrease of children as road users is observed during the last 20 years (table 1) and this mainly in favor of car use. Large international differences exist however between children's travel modes and consequentially the exposure to risk (Roberts I., et al., 1997; Posner J.C., 2002; Carlin J.B., 1997). Compared to other countries, Flanders has a cycling culture; especially when considering school trips (23% in total and more then 40% children aged 11 or 12 cycle to school). Although 20 % of all trips are less than 1km, Flemish children don't walk much (9%), even not to school (13%), where more than 30% of the children have to travel less than 1km.

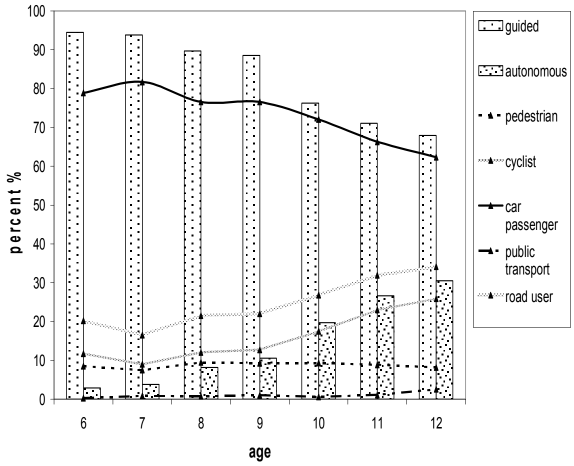

fig. 1 travel modus and guidance by age for all child displacements

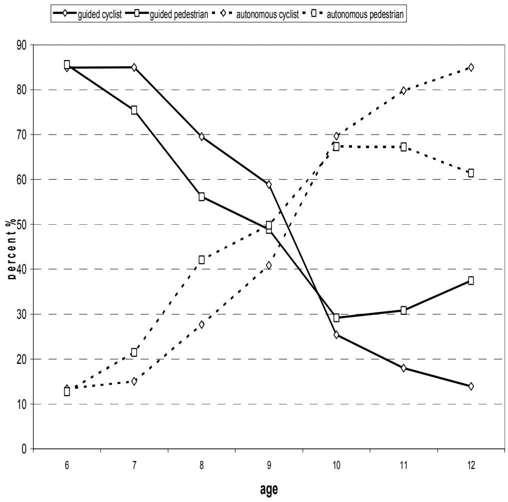

Figure 2: guidance level for cyclists and pedestrians

Year	2008 %	2000 %	1994 %
pedestrian	9	14	19
pedestrian	***12***	***18***	***28***
cyclist	16	23	23
cyclist	***23***	***34***	***29***
car passenger	73	58	55
car passenger	***61***	***39***	***38***
public transport	1	3	2
public transport	***2***	***6***	***3***
solo	8		
with friends	6		
guided	83		

Italic and bold = travel mode for school trips only

2000 and 1994 source = ovg Vlaanderen

Table1: children's travel behavior during last 20 years in Flanders

3.3. Parental risk perception

3.3.1. General parental perception

In the questionaire parents were asked to record wether they would allow their child to travel autonomous on a certain road type. The 8 road type categories are summed in table 2. This classification is based on maximum speed and infrastructural measures (cycling or pedestrian lanes). A cycling lane is defined as a separate strip where no motor vehicles are allowed (except certain types of motorbikes). The separation can be an augmentation, a barrier or a white painted dashed line.

vr: vehicle restricted
vr cl: vehicle restricted with a cycling lane
30: zone where the speed limit is 30 km/h
30 cl: zone where the speed limit 30 km/h with a cycling lane
bua: road within the build up area (speed limit is 50 km/h)
bua cl: road within the build up area with a cycling lane
obua: road outside the build up area but with speed limit 70 km/h
obua cl: road outside the build up area, speed limit 70 km/h with a cycling lane

When cl is pl, cycling lane is replaced with pedestrian lane.

When the parents answered 1, they allowed their children autonomous on that road type, when they answered 2, they didn't allow it. An allowance index was calculated for every road type:

$$Ai = \frac{\sum Ap}{Np} \qquad (2)$$

With Ai the allowance index, Ap the answers parents gave (1 or 2) and Np the total number of questionnaires This results in a number between 1 and 2, meaning that every parent allowed their child to travel autonomously on that type of road if the result is 1 and no parent would allow it if the result equals 2. If 50% of the parents allow autonomous travelling the result is 1.5. The general results of parental perception are shown in figures 3a and 3b.

As expected, large differences exist between the allowance index for different ages (figure 3a) and this for every road type. The difference reaches on average 0.6 or 60%, meaning that 60% more parents allow 12 year old children on a specific road then they allow 6 year olds. Roads with a cycling or pedestrian lane are perceived safer in comparison to roads where the speed limit is higher but cycling or pedestrian lanes are absent (figure 3b). This difference in perception between speed and infrastructure measures is more pronounced for pedestrian lanes than for cycling lanes. As expected the allowance index both for pedestrians and cyclist increases when speed limit increases. For roads with a cycling lane or a pedestrian lane the difference in allowance index between cyclist and pedestrians is larger then for roads without them. This means that the presence of a pedestrian lane is perceived less dangerous then the presence of a cycling lane and that, especially on roads with lower speed limits, walking is perceived safer than cycling. Figure 4 shows that this observation is particularly applicable for younger children, as they get older the differences between cycling and walking decrease. Figure 4 also shows that walking on a pedestrian lane is always perceived less dangerous then cycling is on a cycling lane for all speed limits and all ages. When there is however no pedestrian or a cycling lane, cycling is perceived less dangerous for older children compared to walking and especially on roads with speed limits 30 or 50 km/h.

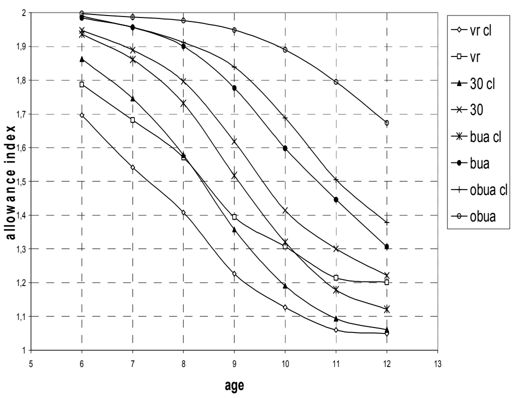

Figure 3a: allowance index for both cyclist and pedestrians by age.

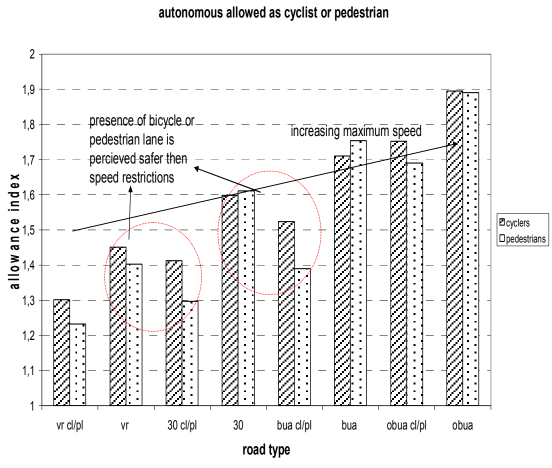

Figure 3b: allowance index for autonomous trips as a pedestrian or a cyclist.

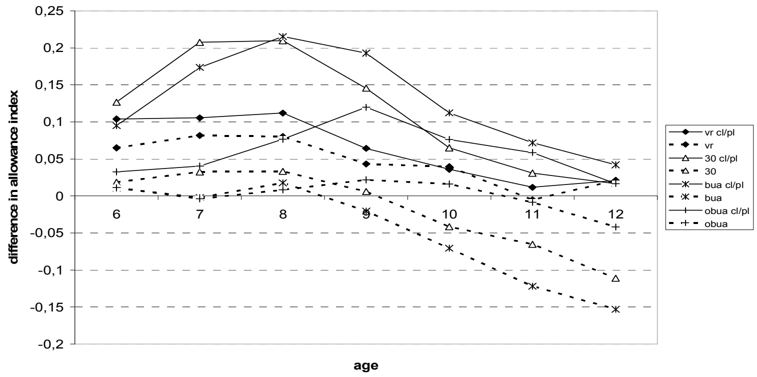

Figure 4: diffence is allowance index between cycling and walking (cyclist al.Ind. – Walking al.Ind.)

3.4. Accident statistics

The accident risks of children between 6 and 12 years old were calculated using accident statistics of the Flemish government between 2002 and 2005 (mobgis, 2006) and the travel behavior of the children.

$$P(A_{mat}) = \frac{A_{m,at}}{Nc_m} *100$$

$P(A_{mat})$ is the risk of having an accident per travel mode and accident type (fatal, major or minor) over a period of 4 years. $A_{m,at}$ is the total number of accidents per travel mode *(m)* (car passenger, cyclist, pedestrian) and per accident type *(at)*. *Nc* stands for the absolute number of Flemish children between 6 and 12 that use a certain mode *(m)* for their trips. Nc_m is based on the percentages presented in table 1 and the demographic statistics of Flanders (NIS, 2008). Table 2 shows the results and figure 5 shows the results of equation 2 but now per age *(a)* instead of accident type *(at).*

In figures 6, 7 and 8 the number of accidents of a group is expressed relative to the total number of accidents. The numbers are always differentiated by road type and specific by gender (figure 6), accident type (figure 7) and age (figure 8), only bicycle accidents are included because of the lack of accurate pedestrian accident statistics. Unfortunately no exposure data are available and the total length of every road type can not be calculated within an acceptable accuracy interval, therefore comparing risks between the different road types becomes nearly impossible.

Table 2 and figures 5 show that traveling as a car passenger is far most the safest way to travel as a child. Not only is the chance of having an accident circa 3 times lower than as a pedestrian or a cyclist, the chance of having a fatal or major accident is circa 7 to 11 times lower (table2). Older children have more chance of being involved in an accident as a cyclist while younger children have more chance as a pedestrian. The accidents as a car passenger are equally distributed by age (figure 5). Although no risks can be compared, some interesting trends become clear from the other figures. 1) On every road type, the number of accidents is significant larger for boys than for girls, with the largest differences on roads without cycling lanes. 2) Considering accident type, the observed pattern over the different road types is similar for all three injury types. 3) The accidents of different age group are also similar distributed over the different road types. 4) When comparing roads with the same speed limitations it is clear that more accidents happen on roads without a cycling or a pedestrian lane.

	an accident	**fatal accident (1/10000)!!**	**major accident**	**minor accident**
pedestrian	2,04	1,66	0,35	1,68
cyclist	2,74	1,34	0,24	2,49
car passenger	0,79	0,21	0,03	0,75

Table 2: chance of having a bicycle accident by accident type

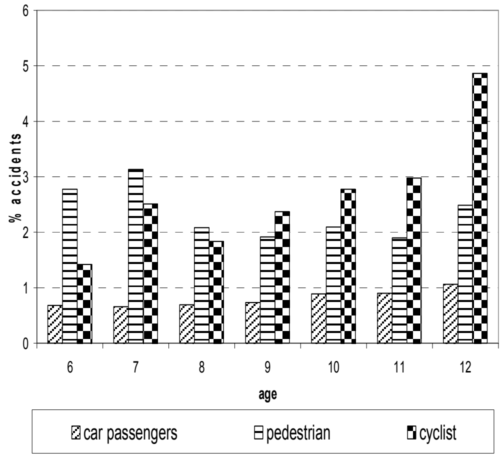

Figure 5: chance of having a bicycle accident in 4 years by age.

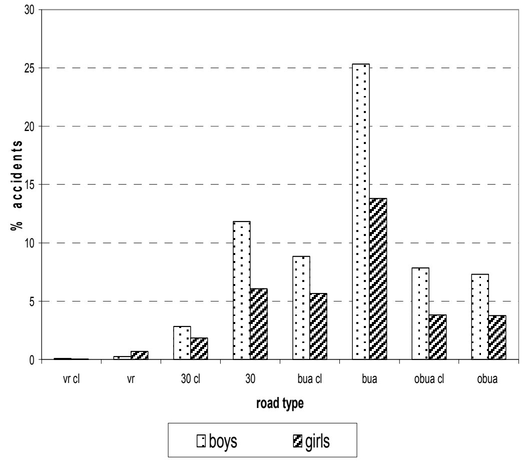

Figure 6: relative number bicycle accident by gender

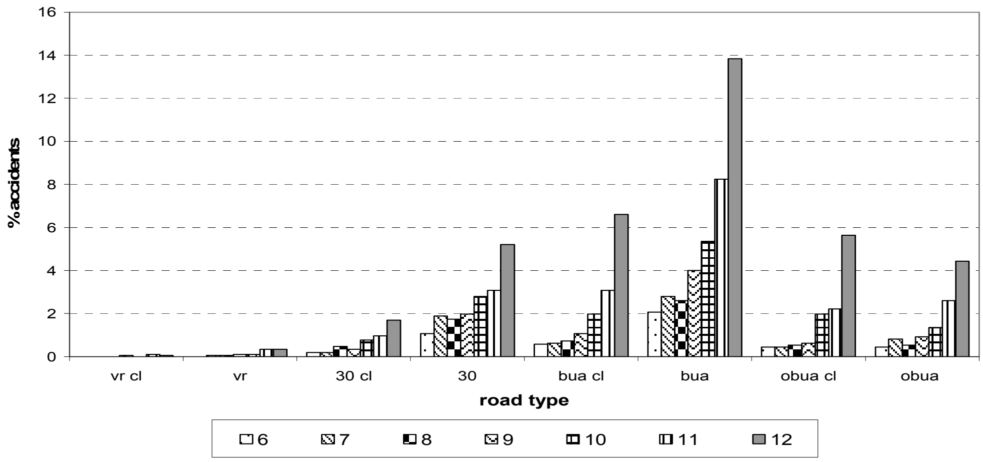

Figure 7: relative number of bicycle accident by road type

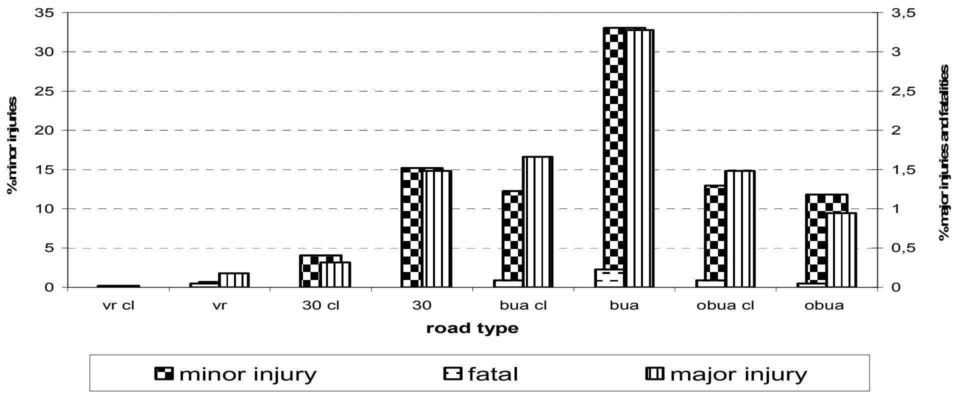

Figure 8: relative number of bicycle accident by accident type

4. discussion

As suggested by other studies like ovg Vlaanderen (2002); Kaesemans G. (2001); Mackett R.L. et al. (2001); Dicuiseppi C. (1997) autonomous traveling by children is still decreasing and this mainly in favor of car use. To increase independent traveling by children, it is necessary to create a traffic infrastructure that both protects the child and keeps the consequences of an accident limited. Infrastructural measures as such are however inadequate because the benefits of those measures will only become visible when they are useful for a lot of children. Because children's travel behavior is mainly influenced by parental perception of the traffic environment, is it important to understand parent's view on current traffic infrastructure and the factors that determine that view. This was also observed by Fyhri A. and Hjorthol R. (2009) who concluded that measures aiming to increase walking and cycling via improved traffic safety only will be effective if parents 'experience of traffic safety' is improved. Noland R. (1995) even found that there is evidence that perceived safety improvements in bicycle transportation have an aggregate elasticity value greater than one (i.e. a 10% increase in perceived safety results in greater than 10% increase in the share of people commuting by bicycle). Allowance on a certain road type is used as a proxy for parental safety perception. In general this perception differs by age of the child, road type and travel mode (cycling or walking). The results show a decrease of the allowance index with age, so belief and trust in children's traffic skills increases much during elementary school evolution (Yarmey A.D. and Rosentein S.R., 1998). So apparently allowance and related to that, parental safety perception, do play an important role in the travel mode decision. Indeed the same evolution of travel mode by age is observed in the travel behavior of Flemish children with an increase of bicycle use by age. No increase of walking is however observed although the allowance index for walking also decreases with age. The reason for this status quo in walking can be explained by the observation that the difference between cycling and walking decreases with age, and cycling even becomes the safer perceived mode choice when age. So the general shift from dependent mode (car passenger) to independent mode (walking or cycling) with age is mainly expressed by an increase in cycling. All these observations support to the conclusions of Fyhri A. and Hjorthol R. (2009) that only a positive safety perception of parents leads to a mode shift.

Descriptive numbers of the allowance index by road type show that the presence of a bicycle or pedestrian lane is perceived safer than speed limitations. Physical separation of child and motor vehicles is perceived more important than lowering speed limits which is a call for targeted measures instead of the more general speed lowering measures. This discrepancy is also found in the accident statistics for bicycle injuries. More accidents happen on roads without a cycling lane and this for every speed limit category (besides the 70 km/h category), both for boys and girls and within every accident type category. It is even so that more accidents happen on roads without a cycling lane with a lower speed limit than on roads with a cycling lane but with a higher speed limit. So there seems to be an inverse between autonomous allowance and number of accidents. Although this inverse as such doesn't confirm a dependency between perceived and real traffic risk because neither exposure data nor road length data are available to calculate accurate real traffic risk, it suggests that parental safety perception of different road types is influenced by the number of accidents that happen there. There are however three observations between autonomous allowance and number of accidents that contradicts the hypothesis that parental safety perception is influenced by the number of accidents. First there is a clear difference in number of accidents between boys and girls. Boys are more involved in accidents on every road type and the difference is larger on roads without cycling lanes. The same pattern is found in the travel mode of the children and the autonomous allowance. Especially within the older age groups, boys travel more by bike than girls and they are systematically more allowed to travel on all the different road types and the difference increases on roads with higher speed limits and increases slightly on roads without cycling lanes. Secondly the chance of having a bicycle accident increases with age, for walking the chances stay quiet steady. Again this is observed in both the travel mode and autonomous allowance. Older children travel more by bike and are more allowed on any road type than younger ones, on top of that biking is seen as the safer travel mode for roads without a cycling lane as the children get older. Thirdly the inverse relation of lower allowance with higher accident numbers is not observed for 70 km/h roads. The three observations suggest the opposite of the first hypothesis, namely that it is parental safety perception that determines the travel mode and consequently the number of accidents, and not the other way around. This result suggests that a decrease of child autonomous travelling is the best way to reduce the number of child accidents. On top of that is the observation that traveling as a car passenger is the least dangerous both in absolute numbers and in chances of having major or fatal injuries.

In reality however the relationships are probably more complicated by other factors which are not included in this study. So was it only possible for age to express accident numbers as risk chances. When looking at the absolute numbers of that, an increase in bicycle use of 15% between 6 and 12 years, only results in a chance increase of 3% of having an accident. For gender and road type, exposure data are not available so no risk chances could be calculated. The difference between boys and girls is probably determined by other factors besides parental safety perception. So found Zwerts E. et al. (2009) not only a difference in travel mode between boys and girls but also a difference in travel activity, boys are more active than girls which has precautions for exposure. If we assume that allowance is a proxy for exposure, the inverse relation between allowance and number of accidents is suggesting lower exposure on roads without cycling lanes and thus result in a more pronounced difference between roads with or without cycling lanes, which supports more the first hypothesis that it is the accident distribution that determines the safety perception.

5. Conclusion

No direct conclusion could be drawn regarding the relation between parental safety perception and real traffic risk from our data, yet some indications became clear for Flanders. As observed by Johansson M. (2006) in Sweden, the relation between infrastructure and parental safety perception is present. This safety perception plays an important role in the travel mode decision of parents for their children. Although there are indications that a relationship between safety perception and the number of accidents exist, it is not convincingly clear which of the both influences the other. It is however clear that when safety measures are taken to support increasing child autonomous travelling, it is necessary to address the parents because they eventually influence travel behavior of their children. The measures as such should best be targeted safety measures more in the domain of direct separation of children and motor vehicles and less in general measures like speed limitations.

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