The Effect of Reconstruction and Code Changes at Pedestrian Crossings to Traffic safety for Children, Grownups and Elderly

Results from a case study in Borås

Charlotta Johansson, Lars Leden[1]

Luleå University of Technology SE-971 87 Luleå Sweden
[1]and *VTT Communities and infrastructure, P.O. Box 1901, FIN-02044 VTT Finland*

1 INTRODUCTION

Our traffic environment is designed to fit grown-up people rather than children. According to the UN Convention about Children's Rights, what is best for children should be the target for all governmental decisions affecting children. The Swedish National Road Administration has therefore initiated research as a base for developing guidelines "towards a safe environment for children". It should be noted that a traffic environment that is safe for a child as a vulnerable road user typically is safe for people of all ages. When designing roadways, it should be remembered that children of different ages have different needs and abilities. The very youngest may in most environments be under adult supervision, whereas preteens typically are allowed to move around freely even outside their immediate neighbourhood. These children are often shorter; and sight, hearing, intellect and understanding are not fully developed. Older teenagers may have the same ability to judge situations as adults, but their attitude is often different—they not only take higher risks, they sometimes also want to seem 'cool' and therefore do not scan before crossing or wait for adequate gaps. And obviously, they have less experience with traffic.
One of the main principles of the Swedish Vision Zero states: The level of violence that the human body can tolerate without being killed or seriously injured shall be the basic parameter in the design of the road transport system.
The following hierarchical division of roads and streets is suggested to fulfil this:

1. Through traffic route (70-km/h-road or shorter 70-road) with only grade separated crossings
2. 50/30-km/h-street or shorter 50/30-street. 30 km/h at pedestrian and cycle crossings. 40 - 50 km/h elsewhere **(**Main street/Urban arterial road)
3. 30-km/h-street or shorter 30-street **(**Residential Street/Wohnstrasse/Rue Residentielle)
4. Walking speed street (Woonerf)
5. Car-free areas such as pavements, footpaths, squares, cycle-tracks, cycle-lanes etc.

Above other things this means that in built-up areas the standard 50-streets are changed to 50/30-streets or 30-streets depending on if pedestrians and cyclists need to cross at certain points with specific safety features or anywhere they like along the street. The carriageway on a 50/30-street normally has two lanes for ordinary car traffic, one lane in each direction. The 50/30-street also has wide cycle-tracks and wide pedestrian pavements, affording pedestrians and bicyclists good accessibility, safety and security. An intersection between two 50/30-streets always has marked pedestrian and bicyclist crossings. These crossings are designed so that a car will not be driven through them at speeds exceeding 30 km/h. The pedestrian and cycle crossings should be designed to meet the needs of children, elderly, and disabled persons (Wramborg, 1998). Children find intersections to be appreciably more troublesome than sections of road, providing the speed is kept low. Therefore it is favourable for them if pedestrian crossings are located mid block rather than at intersections. Excellent sight conditions at these locations are also important. (Leden, 1988). However, it should be kept in mind that crosswalks at intersections may have to be provided as well if there are substantial pedestrian flows along the street. This is typically the case in older neighbourhoods where separate walkways away from the street network do not exist.

The law concerning car drivers giving way to pedestrians was strengthened May 1, 2000 in Sweden. Now the car drivers must give way to pedestrians that intend to cross the street at zebra crossings. Before, the law stated that the car driver should if possible give way to pedestrians. The rule of giving way also says that the car driver must by his or her way of driving show the pedestrian that he intends to stop by decreasing the speed and slow down and stop. Still the pedestrian has the responsibility to cross the street safely. The law of car drivers giving way at zebra crossings does not concern giving way to people going by bike. People going by bike crossing the street at cycle lanes have to give way to vehicles. A person walking with the bike at a zebra crossing is regarded as a pedestrian.

At Luleå Technical University a methodology is being developed based on before and after studies of children's behaviour and safety. Places that are to be rebuilt are filmed simultaneously from different angels to capture the different road-users' behaviour. Close-up pictures of vulnerable road users and overviews of the traffic environment are filmed.
The results from five different intersections in Borås are presented here. The first from Hultagatan and the second from Sjöbotorggatan that were reconstructed. Two are from Tranderedsgatan where two intersections near the Trandered School were rebuilt a long time ago. These studies examine differences between children's, grownups' and elderly people´s interactions with motor traffic at zebra crossings. A fifth intersection in Borås where no changes are made, Källbäckrydsgatan, is used as a control point. The sites were studied before changes of the traffic environment, after changes before the new law and after changes and the new law.

Test site Hultagatan

Hultagatan is a major street with approximately 5000 vehicles per day and about 3 km from the centre of Borås, see Figure 1.1. The speed limit was 50 km/h before reconstruction, after the reconstruction the limit is 30 km/h at the intersection. To the north of the road, above the zebra crossing, is an open park area with trees. To the south is Hulta Centre with a housing area, supermarket and a school named Ekerängskolan. People of all ages are crossing Hultagatan on foot or by bike at the zebra crossing on their way to Hulta Centre. After the reconstruction the intersection has a refuge to narrow the street and speed cushions specially designed for bus trafic for decreasing the speeds of the vehicles.

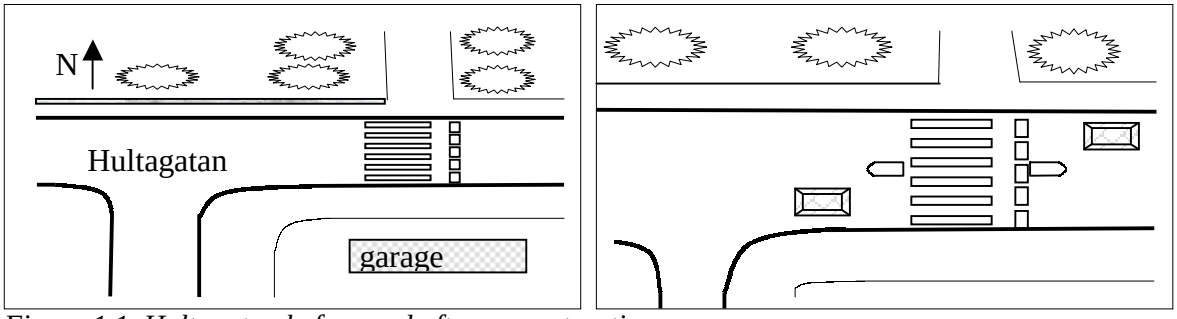

Figure 1.1. Hultagatan before and after reconstruction

Test site Sjöbotorggatan

The Sjöbotorggatan site is a T-intersection with about 3000 vehicles per day, see Figure 1.2. The speed limit was 50 km/h before reconstruction. After reconstruction the limit is 30 km /h. On the south side of the street is a square with small shops. The square and the shops are Sjöbo Centre. The school is situated on the north side of Sjöbotorggatan. After the reconstruction the intersection is elevated with paving stone and one zebra crossing is left at the west side near the school.

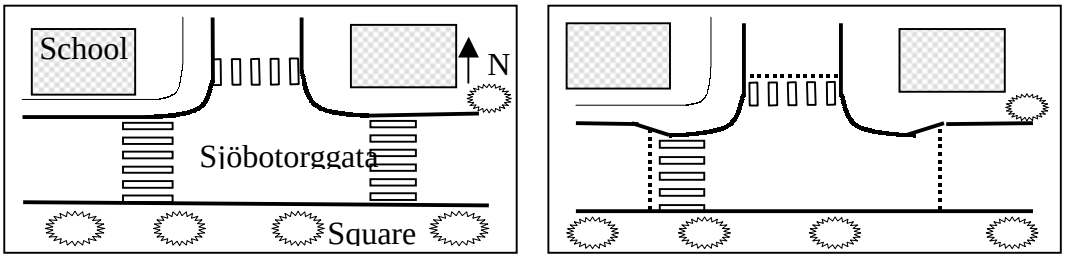

Figure 1.2. Sjöbotorggatan before and after reconstruction

Test site Trandaredsgatan

At Trandaredsgatan two T-intersections are studied, one is situated on the upper side of the Trandared School and the other on the lower side of the school, see Figure 1.3. At both intersections the speed limit is 30 km/h. The upper intersection has a refuge and zebra crossing and is elevated with paving stones. At the lower intersection the area at the zebra crossing is elevated and it has a refuge.

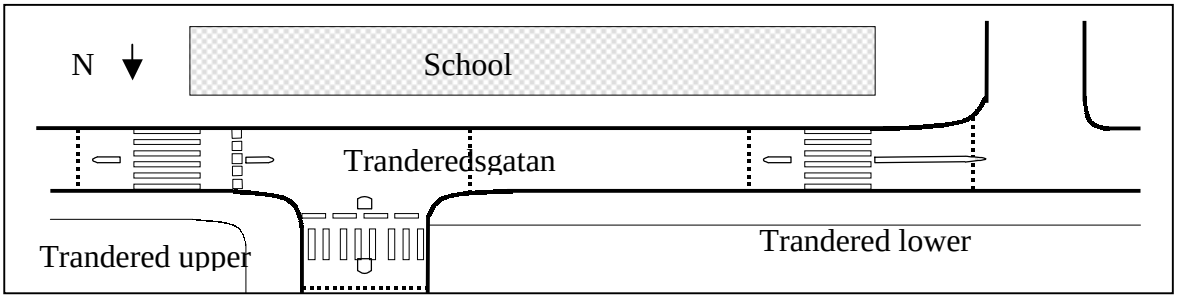

Figure 1.3. Trandaredsgatan, the upper and the lower intersections.

Test site Källbäcksrydsgatan

At the studied site at Källbäcksrydsgatan a pedestrian- and bicycle path is crossing the street mid block. The path goes parallel with the street on the north side. The speed limit at the street is 50 km/h.

2 METHOD

Video filming

The intersections were filmed with video cameras. Sony's Hi8 system was used. The advantages with these cameras are that they are light in weight and small in size. Most important is that the quality of the picture is better than conventional VHS system. When filming traffic situations it is most important that road users do not easily detect the cameras. If the road users detect the cameras it might influence their behaviour. Therefore the cameras are placed on posts and walls of the houses hopefully invisible to drivers as well as pedestrians and cyclists. Up to four cameras are used to capture all road users' behaviour. Figure 2.1 shows the placing of the cameras at the intersection. One or two camera is used for filming close ups of the pedestrians crossing and the road at the zebra crossing. One or two cameras are used for overview pictures of the intersection.

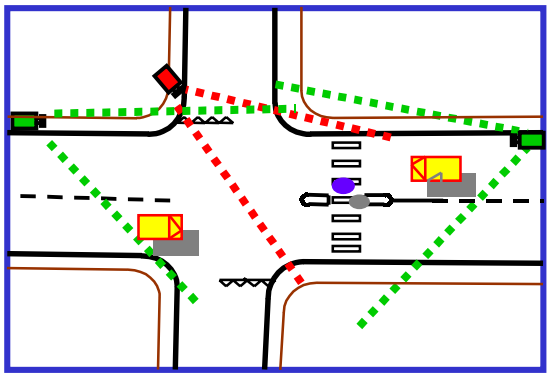

Figure 2.1. Placing of cameras.

It is important to include vehicles coming in both directions to the intersection. That is why it often is necessary to use two overview cameras. This enables us to see whether the brake lights of the vehicles are activated. The overview cameras must be placed high otherwise it is not possible to get a good picture of the traffic situation. The filming periods are chosen to capture the hours of the day when children are travelling to and from school. This is also the time of day when other vulnerable road users are travelling. The flow of children on their way to school is strongly directed in the morning and in the afternoon. In the morning this coincides with the peak hour for the traffic. School often starts at 8.10 –8.30 a.m. The morning filming period is therefore chosen to be 7.30 to 9.00 a.m. In the afternoon the situation is a little bit different, dependent on the age the children their school day ends at different hours. Therefore the filming period in the afternoon is longer, between 1.30 and 4.30 p.m.

Speed measurement with radar

The speeds of free cars are measured with radar at the intersection, just before the zebra crossing, the hypothetical point of collision. It is important that the drivers do not understand that their speeds are measured, otherwise they might change their behaviour. As mentioned before the flow of children on their way to school is strongly directed in the morning and in the afternoon. The speeds of the car drivers with the children coming from the drivers right side are therefore if possible measured, these drivers have the shortest time to detect the vulnerable road users. If not possible the speeds of the drivers in the other direction is measured.

The Swedish conflict technique
Conflicts are studied at the different sites using the Swedish Traffic Conflict Technique (Almqvist & Ekman, 1999). One or maximum two persons are handling the video filming, speed measurement and conflict study at each site. The advantage with this is that it is lowering the costs of the field work, the disadvantages is that speed measurement can not be done parallel with conflict studies and when checking and taking care of the video cameras speed measurement and conflict studies can not be done.

Coding of parameters, behavioural studies
The traffic situations with the vulnerable road users stored on videotapes are manually analysed and coded. The coding is based on Øvstedals and Ryengs (1999) work where they studied the behaviour of children and car drivers at intersections. Some adjustments are made to better describe the traffic situation in question. The studied parameters are:

- Gender
- Age
- Means of transport
- Number of people in the group
- Gender of oldest in group
- Age of oldest in group
- Crossing behaviour, stops at kerb
- Stops at refuge
- Crossing behaviour
- Straight angle across
- Tempo, before intersection
- Tempo first lane
- Tempo second lane
- Tempo after intersection
- Look around before kerb
- Look around at kerb
- Look around when passing first lane
- Look around at refuge
- Look around when passing second lane
- No. of cars passing before kerb
- No. of cars passing at kerb
- No. of cars passing before refuge
- No. of cars passing at refuge
- Interaction, if car give way
- Which car stops, no. of
- Traffic situation, first vehicle / interaction
- Type of vehicle
- Overtaking at intersection at zebra crossing
- Overtaking of vehicle standing still
- Vehicle from the left
- Vehicle from the left stops
- Vehicle from the right
- Vehicle from the right stops
- Time gap accepted car-car
- Time gap accepted starts to cross-2.nd car
- Waiting to cross, time
- Time for crossing
- Comments

Interactions of higher severity
Very few conflicts are likely to occur at the studied traffic environments. Another detailed way to measure how the traffic situation has changed besides the conflict technique is to analyse the interactions when a car from the left or right is close oncoming to a vulnerable road user. These interactions of higher severity are most often less severe than a serious conflict but can still give important clues to describe the traffic situation, see e.g. Svensson (1998). The interactions that are coded “a car closely oncoming to a vulnerable road user” are therefore specially analysed.

3 RESULTS

Data were collected two or three days for each condition in Hulta and Sjöbo. In the two crossings in Trandered and the control point Källbäcksrydsgatan data were collected one day each. The amount of data analysed at each site are presented in Table 3.1. One person corresponds to one passage (person crossing at or close to the zebra crossing).

Table 3.1. Data analysed at each site

	Hulta	Sjöbo	Trandered upper	Trandered lower	Källbäcksryd Control crossing
Before reconstruction	990504, 990505 4.5 h, 271 persons	990421, 4.5 h 242 persons	-	-	990505, 4.5 h 61 persons
After reconstruction, before change of law	000320, 4.5 h 322 persons	-	000322, 4.5 h 193 persons	000323, 4.5 h 265 persons	-
After reconstruction, after change of law	000509, 4.5 h 352 persons	000509, 3 h 302 persons	000510, 4.5 h 236 persons	000508, 4.5 h 241 persons	000511, 3 h 46 persons

Some of the strongest parameters to see if the traffic safety has increased are the speeds of the cars and the giving way frequency to vulnerable road users. After the new law the car drivers are strongly forced to give way to pedestrians. It is of special interest to see how the car driver behaviour towards children has changed. These parameters from the five sites in Borås are presented below.

Encounters

It is of special interest to study if the behaviour of drivers, pedestrians and cyclists in encounters between pedestrians and motor vehicles have changed after the intersections have been reconstructed and after the new law concerning car drivers giving way to pedestrians was enacted. It is also of interest to see if the new law influence the habit of giving way to people going by bike. In the first table below are the encounters pedestrians – cars presented. For all places except the control crossing the percentage of pedestrians given way to by car drivers have increased. In Sjöbo the frequency of given way has increased with only 5 %. This is mainly explained by the fact that after the reconstruction only 28% of the pedestrians cross the street at the zebra crossing. The share of passages with car present is also lower in the after situation than in the before situation. In Hulta the reconstruction of the intersection increased the given way frequency with 32 % and after the new law the frequency again increased with 15 %. There are now not any known reasons why the frequency of encounters has decreased in Hulta after the reconstruction but it is likely that the flow of cars has decreased. There are alternative faster roads in the area that are not reconstructed. At the two intersections at Trandared the frequency of pedestrians given way to has increased with 28 % and 9 % respectively. Why the frequency of given way has decreased at the control crossing is not known but the numbers of passages are so low that it is difficult to draw any firm conclusion from them. At Sjöbotorggatan and the two intersections at Trandared School there are few people going by bike. At Sjöbotorgatan most people are from the Sjöbo housing area visiting the Sjöbo Centre travelling short distances by foot, or school children walking to school. In Trandared many children walk to school. At all places the frequency of people going by bike that are given way to has increased, both after the reconstruction and after the new law, see Table 3.3. It has increased even at the control crossing where more people are going by bike than walking.
The giving way frequency from the driver point of view is also presented in the two tables below. At all sites but the control crossing more car drivers are giving way to pedestrians after reconstruction and after the new law was enacted. At the control crossing the percentage of car drivers giving way stays the same. More car drivers are also giving way to cyclists except at the lower Trandared intersection, but still more cyclists are given way after the new law at the intersection. This means that they are given way but more car drivers are passing them before they are let way.

Table 3.2. Encounters pedestrians - car

		Hulta	Sjöbo	Trandered upper	Trandered lower	Källbäcksryd Control crossing
Before	Total no of passages	199	220	-	-	22
recon-	Encounters (passages with car	*88*	*65*	-	-	*59*
struction	present) (%)					
bef. law	Passages using zebra crossing (%)	*75*	*68*	-	-	*81*
	Car drivers that give way (%)	*5*	*10*	-	-	*5*
	Enc. were pedest. are given way (%)	*17*	*15*	-	-	*15*
After	Total no of passages	263	-	169	260	-
recon-	Encounters (passages with car	*75*	-	*70*	*66*	-
struction,	present) (%)					
bef. law	Passages using zebra crossing (%)	*90*	-	*97*	*81*	-
	Car drivers that give way (%)	*25*	-	*28*	*35*	-
	Enc. were pedest. are given way (%)	*49*	-	*54*	*59*	-
After	Total no of passages	221	264	198	226	18
recon-	Encounters (passages with car	*49*	*41*	*70*	*76*	*67*
struction,	present) (%)					
after law	Passages using zebra crossing (%)	*86*	*28*	*81*	*79*	*79*
	Car drivers that give way (%)	*37*	*12*	*50*	*40*	*5*
	Enc. were pedest. are given way (%)	*64*	*20*	*82*	*68*	*8*

Table 3.3. Encounters bike - car

		Hulta	Sjöbo	Trandered upper	Trandered lower	Källbäcksryd Control crossing
Before	Total no of passages	72	19	-	-	39
recon-	Encounters (passages with car	*60*	*74*	-	-	*59*
struction	present) (%)					
bef. law	Passages using zebra crossing (%)	*73*	*41*	-	-	*40*
	Car drivers that give way (%)	*4*	*0 of 13*	-	-	*0 of 77*
	Enc. were cyclists are given way (%)	*7*	*0*	-	-	*0*
After	Total no of passages	58	-	10	5	-
recon-	Encounters (passages with car	*67*	-	*70*	*100*	-
struction,	present) (%)					
bef. law	Passages using zebra crossing (%)	*72*	-	*70*	*40*	-
	Car drivers that give way (%)	*17*	-	*14*	*40*	-
	Enc. were cyclists are given way (%)	*38*	-	*4*	*40*	-
After	Total no of passages	131	38	38	14	28
recon-	Encounters (passages with car	*47*	*24*	*61*	*79*	*61*
struction,	present) (%)					
after law	Passages using zebra crossing (%)	*78*	*21*	*82*	*75*	*75*
	Car drivers that give way (%)	*36*	*17*	*34*	*32*	*11*
	Enc. were cyclists are given way (%)	*54*	*22*	*48*	*55*	*21*

Is there a change in car speeds?
At Hultagatan the average speed of the vehicles before the intersection were reconstructed was 52 km/h ± 8 km/h (with standard deviation 8 km/h) for the whole sample and the 85 percentile was 61 km/h in the morning traffic. For the afternoon traffic the average speed was 49 ± 7 km/h with 85 percentile 54 km/h. In March 2000 after the reconstruction of the intersection the average speed in the afternoon was 30 ± 5 km/h with 85 percentile 35 km/h. This is a significant difference from the before situation. In may 2000 after reconstruction of the intersection and after the new law the speeds was in the morning traffic 28± 5 km/h with 85 percentile 34 km/h and in the afternoon 29± 5 km/h with 85 percentile 34 km/h. The average is a little bit lower than before the new law was enacted.
The speed measurements at Sjöbotorggatan also show a significant decrease between the before and after situation. In the before situation the average speed in the morning was 40 km/h with standard deviation 6 km/h for the whole sample and the 85 percentile was 47 km/h. The average speed in the afternoon was 39 ± 7 km/h and 85 percentile 45 km/h. In the after situation the average speed in the morning was 28 ± 6 with 85 percentile 33 km/h and in the afternoon 22 ± 5 km/h with 85 percentile 26 km/h. In Trandared the speeds were only measured in May 2000 after the new law was enacted. At the upper zebra crossing the average speed of the vehicles in the afternoon was 33 km/h with standard deviation 5 km/h for the whole sample. The 85 percentile was 37 km/h. At the lower zebra crossing the average speed was 29 ± 2 km/h with 85 percentile 31 km/h. When comparing the three different sites after two of them were reconstructed and the third since before, they have an average speed less than or around 30 km/h. For Sjöbotorggatan the 85 percentile is less than 30 km/h. At the control crossing Källbäcksrydsgatan the average speed in the afternoon in the before situation was 52 km/h with standard deviation 7 km/h for the whole sample and 85 percentile 59 km/h. After the new law was enacted the average speed was 47 km/h with standard deviation 8 km/h and 85 percentile 53 km/h. The average speed decreased by 5 km/h and the 85 percentile by 6 km/h.

Pedestrians that are given way to by car drivers - from the pedestrians point of view

It is of interest to see how the encounters between pedestrians and car drivers have changed for different age groups. Below are the data presented for the five different sites expressed in number of encounters for each age group. The different colours in the bars represent a car driver give way to the pedestrian (grey) and pedestrian stops at the kerb and wait but no car driver stops (dark). The third colour (white) represents encounters when the pedestrian never has to stop and wait at the kerb (maybe he adapts his pace) but the oncoming cars do not give way.
In Figure 3.1. below showing data from Hultagatan the magnitude of children are low but one can see that the frequency of giving way to children has increased at least after the reconstruction (the legend for the figure is shown on the next page). It is clear that the giving way frequency towards youth and adults has increased both after the reconstruction and after the new law was enacted. The magnitude of elderly is low but the given way frequency for elderly has increased after the reconstruction.

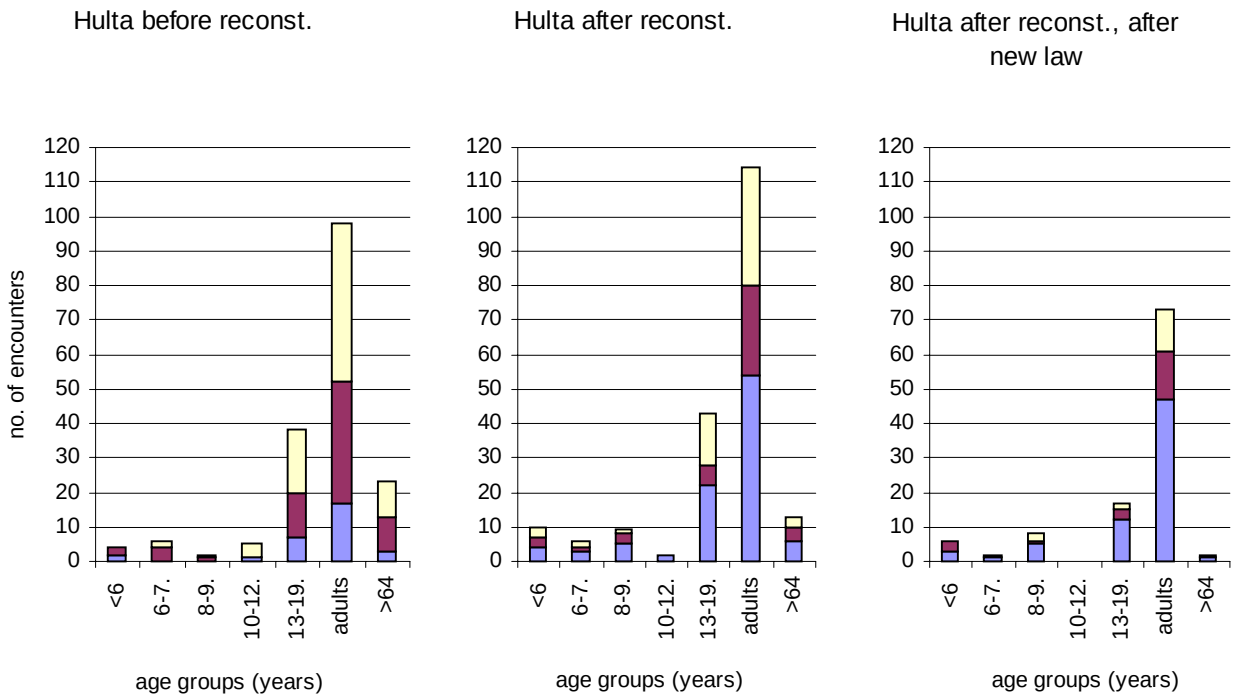

Figure 3.1. Encounters at Hultagatan divided in age groups.

In Figure 3.2 showing data from Sjöbo the magnitude for children also is low and the given way frequency has not clearly increased. The youth and the adults are given way to to a somewhat higher extent after the reconstruction and the new law. The elderly are not given way to at all in the after situation. This low frequency of pedestrians given way to by car drivers after the reconstruction is most likely explained by that less pedestrians use the zebra crossing after the reconstruction than before.

The given way frequency is very high at the upper intersection in Trandared compared with the other sites, see Figure 3.3. All the youth are given way to after the new law. No elderly people had an interaction with a car in the after situation. At the lower intersection in Trandared Figure 3.4 it is clear that the given way frequency has increased for all ages but the youngest, younger than 6 years. All these children were walking with an adult. If the child groups together (12 years or younger) are compared with the adults no differences in frequencies of given way to between the two groups are shown for the two intersections at Trandared. Before the code changes the frequencies of given way to for children were 45 % for the upper intersection and 63 % for the lower intersection. After the code change the frequencies were 78 % and 65 % respectively for children. For the adults the figures were 55 % and 52 % respectively before the code change and 71 % and 70 % after the code change.

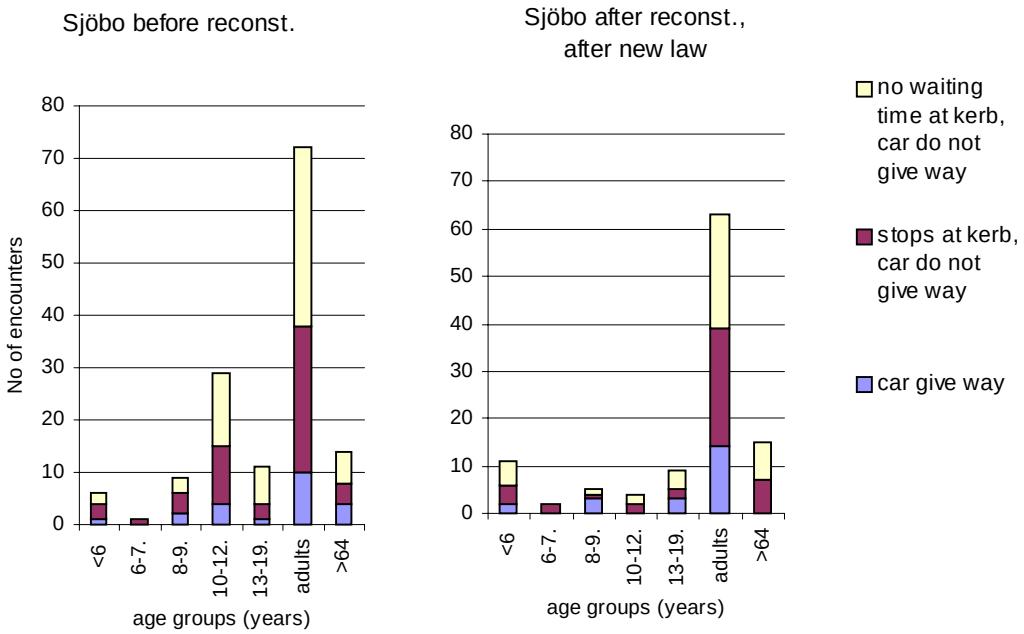

Figure 3.2. Encounters at Sjöbogatan divided in age groups.

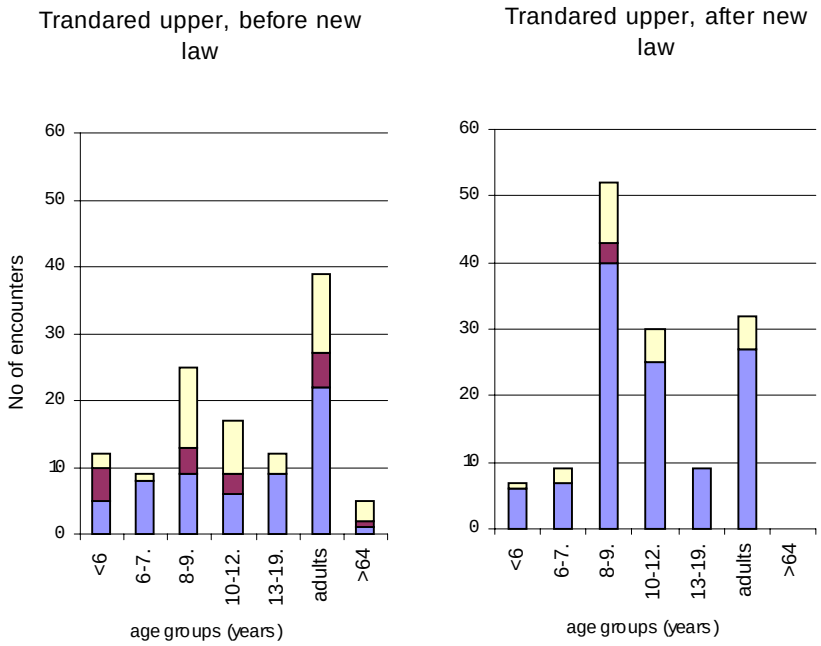

Figure 3.3. Encounters at Trandered upper divided in age groups.

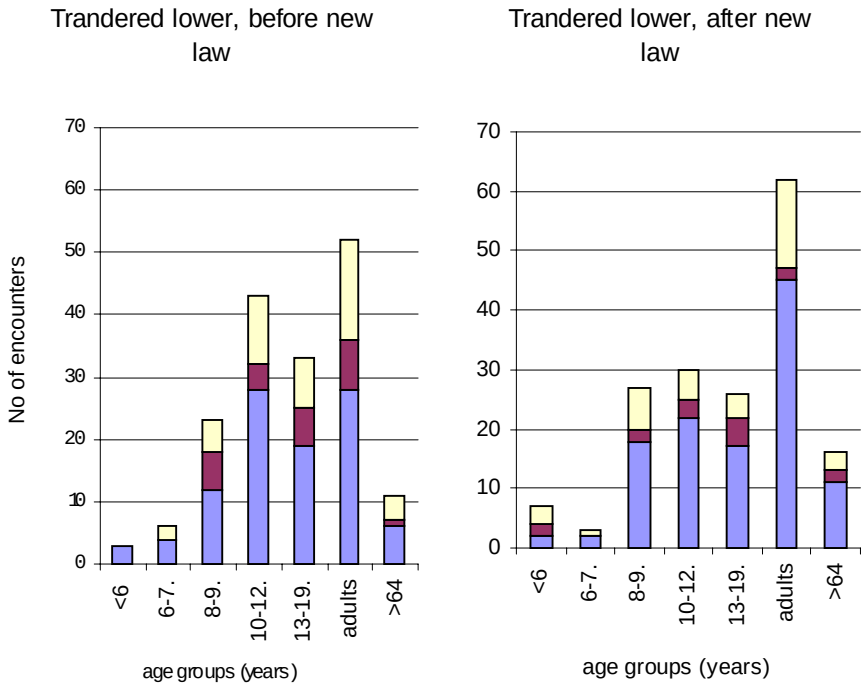

Figure3.4. Encounters at Trandered lower divided in age groups.

Because of the few number of pedestrian passages at the control crossing no figure is shown. Those that were given way before the new law were youth and adult. After the new law those given way were adult. In the before situation four 8-9 years old crossed the street and none of them were given way. The other persons in the before situation crossing the street were all youth and adults. In the after situation only youth, adults and elderly crossed the street.

The interactions between bicyclists and car drivers are not presented divide in age groups because of the low number of passages in each age group, especially in the child groups.

Interactions of higher severity and conflicts

Below are number of interactions of higher severity presented for each site based on the analysed data. Interactions of higher severity are those passages when a car from the left or right is closely oncoming to a vulnerable road user. Table 3.4. show the number of interactions of higher severity before reconstruction, before change of law after reconstruction and after code change. As numbers are low no firm conclusions can be drawn

Table 3.4. No. of interactions of higher severity, (No. of people involved)

	Hulta	Sjöbo	Trandered upper	Trandered lower	Källbäcksryd Control crossing
Before reconstruction	2(4)	5(9)	-	-	0(0)
Before code change, after reconstruction	1(1)	-	6(9)	4(5)	-
After code change (after reconstruction)	3(4)	1(1)	0(0)	1(1)	1(1)

4 SUMMARY AND DISCUSSION

At Hultagatan the frequency of car drivers giving way to pedestrians has increased significantly. The original frequency was 17 %. It increased to 49 % after the reconstruction using speed cushions and went to 64 % after the new law was enacted. The giving way frequency towards cyclist has also increased from 7 % to 38 % after the reconstruction and went to 54 %after the new law was enacted. The giving way frequency is 10 % less towards cyclist than pedestrians at all studied time periods. The average speed of the vehicles has decreased from just below 50 km/h to around 30 km/h. The pedestrian usage of the zebra crossing has increased with 10-15 % after the reconstruction. The giving way frequency towards children has increased. If there is a difference compared to adults is difficult to tell because of the low number of children.

At Sjöbotorggatan the giving way frequency towards pedestrians increased with only 33 % or 5 percentage points from 15 % to 20 % after elevating the intersection and after enacting the new law. This is mainly explained by the fact that only 28 % of the pedestrians walked on the zebra crossing after the reconstruction. Before the reconstruction 68 % used the zebra crossings. The giving way frequency towards cyclists increased from 0 % to 22 %, more of a change than towards pedestrians. However the figures for cyclists are based on rather low numbers of passages. The elevated intersection has slowed down the average speed of the vehicles from 40 km/h to 28 km/h for the morning traffic and from 39 km/h to 22 km/h for the afternoon traffic.

At the two intersections at Trandared's School the giving way frequency has increased after the new law to 82 % and 68 % respectively for all ages, the two highest frequencies observed in this study. Before the new law the frequencies were 54 % and 59 %, respectively. These rather high starting figures might be related to the fact that the two intersections are very close to the school and that the intersections have been elevated many years ago. No differences between giving way frequency towards children and adults were shown. The zebra crossings are also used by the pedestrians to a large extent. The number of interactions of higher severity did decrease after the new law. In combination with the new law the intersections seem to be designed in a successful way.

At none of the studied reconstructed intersections the speeds of the cars have reached the aim that no cars shall exceed 30 km/h at the zebra crossings. However, few cars now clearly exceed 30 km/h and the overall safety effect is expected to be notable.

The code change concerning car drivers giving way to pedestrians had also a positive influence on car drivers giving way to cyclists.

Acknowledgement
First of all we would like to thank Prof. Per Gårder, University of Maine for fruitful advice and the National Swedish Road Administration for financial support, especially Mr Urban Lindqvist, Mr Jan Moberg, Mr Per Nettelblad, Ms Anette Rehnberg, Ms Margitta Schelin and Mr. Per Wramborg. We would also like to thank Mr Elmer Kärrman and Mr Jörgen Fors at Borås kommun for introducing us to the traffic environment in Borås and helping us find the test sites.

Litterature
Ekman, L., Almqvist, S., 1999. The Swedish Traffic Conflict Technique Observers Manual. Lund University, Department of Technology and Society, Traffic Engineering.
Leden, L., 1988. The safety of cycling children. Effect of the street environment. Technical Research Centre of Finland. Publications 55.
Svensson, Å., 1998. A method for analysing the traffic process in a safety perspective. University of Lund, Department of traffic planning and engineering, Bulletin 166.
Wramborg, P., 1998. On a New Approach to Traffic Planning and Street Design in Sweden. Bahrain, SORIC – 98.
Øvstedal,L. , Ryeng, E. Registrering av barns atferd på skolevei. SINTEF rapport STF22A99556, Trondheim, 1999.