A method to analyse the traffic process in a safety perspective

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1. Introduction

This research has its basis in the Swedish Traffic Conflicts Technique (TCT) developed at the Department of Traffic Planning and Engineering in Lund, Sweden (Hydén, 1976). Validation studies have shown a clear relationship between serious conflicts and police reported injury accidents. The work with serious conflicts is a big step forward towards more satisfactory analyses of traffic safety problems. The analyse of serious conflicts can however not claim to be the universally prevailing tool when it comes to describing all safety related aspects. It has therefore become necessary to expand the conflict concept and look into the whole traffic process in order to find parameters explaining the occurrence of risky situations. If we would be able to find these parameters in the "normal" traffic process then we would have a more favourable and efficient situation when making safety evaluation studies and proposing measures. Taking into consideration the possibility of using a more automatic method to collect traffic data, this approach would be very attractive.

2. Traffic process

What do I mean by *the traffic process in a safety perspective*? The traffic process can be seen as a continuum of events. A continuum of events that build up the whole traffic system. These events are all more or less related to safety. Traffic is interaction. All events in the traffic process contain some kind of interaction but of course to varying extent. There is interaction between road users and there is interaction between the road user and the road and vehicle environment. The interaction contains communication. The quality of the interactive behaviour depends on the quality of the communication. The level of communication is influenced by factors like;

- expectancies: a priori knowledge and situational information
- attitudes, etc.

A safe traffic environment presupposes good interactive behaviour and good communication. The opposite, in an unsafe environment, the interactive behaviour and the communication are bad. Accidents indicate serious breakdowns in the interaction between road users or between the road user and the road and vehicle environment. It is therefore quite natural to approach traffic safety by analysing the occurrence of the traffic accidents and their consequences, in order to find clues to prevent future accidents.

There are however many problems connected to the use of accident data for traffic safety evaluation. Accidents are rare events. For the local everyday traffic safety work, it is not sufficient to use accident data only. To produce reliable estimates of traffic safety; very often additional information is needed. There are also difficulties with the recording of accidents. Not all accidents are reported and the level of reporting is unevenly distributed with regard to type of road users involved. Vulnerable road users are for instance heavily under represented in the police accident statistics compared to what hospital registrations and other studies show. The behavioural or situational aspects of the events are not covered by accident data. It is for example very hard to determine underlying factors causing the accident only by reading the accident record, or even by making in-depth analysis on accidents. In the latter case a major complication is that it is too expensive to obtain data that will be representative enough. The need for surrogate or complementary methods to accident analysis is consequently high.

Work with the Swedish TCT has shown that one type of unsafe interaction called serious conflict, exactly like the accident, contains a breakdown in the interaction. The serious conflicts have furthermore an established relationship to accidents. It has also been possible to distinguish the serious conflicts from other types of interactions, in terms of closeness in time. If we believe in the continuum of safety related events, then there must be many more interactive events, besides the accidents and the serious conflicts, that have a correlation to safety.

The following hypothesis were set up:

- There is a continuum of safety related events

- i.e. some of the factors that make a situation turn out as an accident or a serious conflict might also be found in more normal interactions. There is safety information to be found in "normal" interactions

- That these interactions will give us information about the behaviour pattern and characteristics of comfortable, safe passages and the contradiction - passages that are less comfortable, more unsafe

- That there might be a boarder of how close (in time?, in space?, in both time and space?) it is comfortable, safe, to pass other road users (depending on types of road users involved).

- That there is a relationship between the quality, in some dimension, of the interactions and accidents / serious conflicts

The conclusive hypothesis is therefore that the quality of the interactions is the basis if we really want to talk about traffic safety and how to induce proper traffic safety work. Today, traffic safety work lack theories that connect behaviour to safety. Or more correctly, there are many theories but most of them have never been validated with regard to safety. Speed is an exception. Studies have shown a firm relationship between speed and safety (Pasanen, 1992). On the other hand there are for example no theories about how changed level of vehicular speed changes the crossing behaviour among pedestrians and by that the safety situation. This is due to lack of principles for safe interactions. The future challenge, where my work hopefully can be a part, is to define and study the principles of safe interaction. The outcome will hopefully be a help towards more qualified traffic safety work.

3. The safety pyramid

In Oslo 1977, 33 researchers from 12 nations agreed upon a common definition of a conflict: 'a conflict is an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged'. When describing the relationships between different safety related events in the traffic process the pyramid concept was introduced (Hydén, 1987), see Fig 1. According to this concept the different levels in the pyramid can be seen as a severity scale i.e. the probability for an police reported injury accident is constant within the level and increases towards the top. This severity scale is accomplished by applying the TA / Speed-dimension i.e. the Conflicting Speed and the Time to Accident-value (TA-value). The Conflicting Speed (here after just called speed) is the speed of the road user taking evasive action, in the moment just before the start of the evasive action. The Time to Accident (TA-value) is the time that remains to an accident from the moment that one of the road-users starts an evasive action with the assumption that they otherwise had continued with unchanged speed and direction. The ICTCT calibration study in Malmö (Grayson,1984) showed that all calibrated TCTs work according to the same severity scale even if they in other dimensions differ.

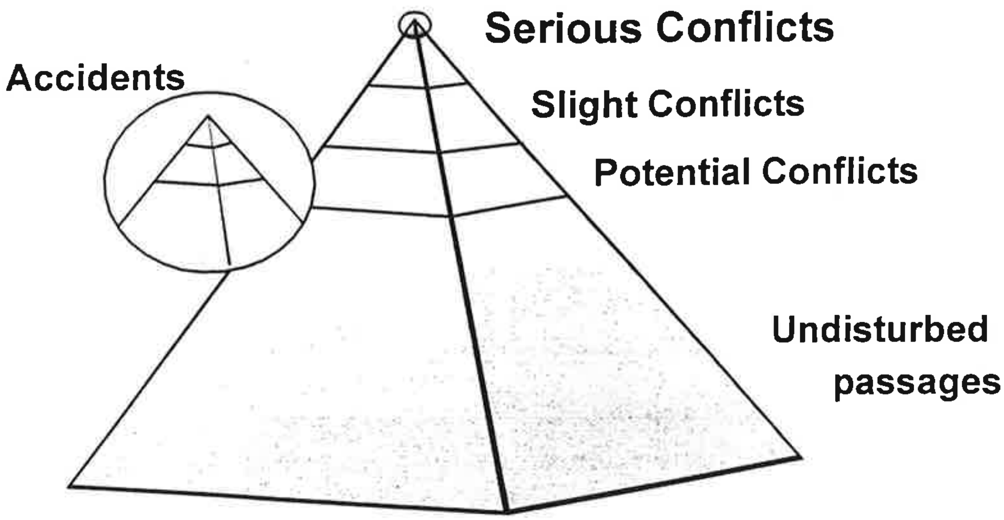

Figure 1 The pyramid - the interaction between road-users as a continuum of events (Hydén, 1987)

The validation studies carried out have shown a relationship between police reported injury accidents (the very top of the pyramid) and serious conflicts (the level beneath the property only accidents). The question is now what happens if we go to the levels below the serious conflicts and look at the traffic process. The levels below the serious conflicts are called slight conflicts and potential conflicts. These are conflicts with much higher TA-values than the serious conflicts. If we go all the way down to the base of pyramid, we'll find the "undisturbed" passages. What do we include in this term? If the rest of the pyramid is based on TA / Speed values, it is logical to assume that this is true for the "undisturbed passages" as well. Is there a limit in the TA / Speed - graph that separates the potential conflicts from the "undisturbed passages"?

If we have a safety pyramid based on the TA / Speed concept, where do all the other TCTs fit, that work according to other concepts? It is quite easy to accept that for instance the PET situations with very low margins also have safety relevance even though there is never collision course. (The PET-value is the time measured from the moment the first road-user leaves the potential collision point to the moment the other road-user enters this point.) There might be a possibility that we actually are talking about a number of severity scales based on different concepts / safety principles. Perhaps if all these severity scales were put together we would obtain the whole continuum of safety related events. What I am trying to say is that there are other safety dimensions in traffic that are not necessarily based on the TA / Speed concept. I do however stick to the TA / Speed concept since I believe that the first approach towards better knowledge about the safety content in "normal" interactions must go through the relationships that we do know something about. What we do know is as I mentioned before that there is a relationship, on the basis of TA / Speed, between accidents and serious conflicts. My approach is to follow this concept down in the pyramid and analyse whether I am able to find other situations that have a connection up in the pyramid.

An other reason for keeping to the pyramid concept is the finding in a validation study of the Swedish TCT (Svensson, 1992). The basis for that validation study is a report by Hauer and Gårder (1986) where they "define safety of an entity to be the expected number of accidents (by severity) occurring on the entity per unit of time". "Thus when the validity of the TCT is questioned, one is in fact asking whether the estimate of the aforementioned expected value in some sense is 'valid'". Hauer and Gårder suggest the following operational definition of what 'validity' means: "A technique (method, device) is 'valid' if it produces unbiased estimates the variance of which is deemed to be satisfactory". In the validation study by Svensson it was found to be better, it produced lower variances, when the expected number of accidents for a unit was based on three days of conflict studies than on one year of accident data. The registration procedure of conflicts in the Swedish TCT has changed a bit over the years. At that time when the data for the validation study was collected, there was a subjective severity rating for the conflict observers to fill in for each registered conflict. The subjective severity rating represents the observers personal estimate of the probability that the conflict could have ended up in an injury accident. A subjective rating in the interval 3 to 6, indicated a serious conflict or an accident. A subjective rating of 2 indicated a potential conflict and the subjective rating of 1 indicated some kind of closeness. The best results for the Swedish TCT were achieved when conflicts with subjective rating 2 to 6 were included. That is when the more serious potential conflicts also were included. We had previously anticipated that the most favourable results for the Swedish TCT would come about when only serious conflicts were included in the data set. Why didn't it turn out this way then? There are two possible answers to this question. 1) The simple fact that the increased data also improved the results 2) The content in the additional data, conflicts with subjective rating 2, correlated to safety. The "truth" could very well be found in both answers. To clear up the concept an additional analysis was carried out - all registered conflicts, also those with subjective severity rating 1, were included. That is the data increased and the severity of the conflicts decreased. Now the variance in the expected number of accidents increased. The conclusion could be that the potential conflicts, subjective rating 2, also contain safety related information but that there is a limit when the interactions start to be less safety relevant. But the conclusion could also be that since the intention never was to collect interactions of subjective type 1, this type might be incomplete in the set of data. The finding however suggests that it might be wise to move down in the safety pyramid, below the serious conflicts. How far down in the pyramid it is reasonable to go, further research hopefully will give us clues about.

Studies with the Swedish TCT show that the accident to conflict ratio differ between types of intersections and between road user categories. The accident to conflict ratio is for instance different in signalised and non-signalised intersections. Depending on road user types involved, the accident to conflict ratio is about 1.5 times higher in signalised intersections compared to non-signalised intersection. This implies different shapes of the safety pyramid depending on type of intersection. Thus, the pyramid in the signalised intersection have a more pointed top compared to the non-signalised intersection. Which pyramid shape would be optimal for safety? When we are talking about optimal traffic safety solutions we imagine solutions that neither produce injury accidents nor serious accidents. This implies that the top of the pyramid is cut off. The hypothesis about a safety continuum will still exist even without the accidents and the serious conflicts. But what will the rest of the pyramid then look like?

4. Interactions

Definition of interaction

In my case an interaction involves two road users. Interaction with the road and vehicle environment as such is excluded i.e. single interactions are excluded. In a way it can still be seen as an explanatory variable to why the interaction between road users perform in a certain way. If, for instance, it comes to explaining why the severity distribution of the interactions differ between two intersections, the variable ”interaction with the road and vehicle environment” might be an interesting variable.
An interaction is a situation with collision course. Collision course = the road users would have collided if the they had continued with unchanged speed and direction. This implies that there is some kind of noticeable evasive action, like in the conflict definition. The evasive action is not necessarily always as dramatic as in the serious conflicts. It can also have the character of adaptation i.e. evasive action to avoid ”something more serious”.

The procedure to register interactions is the following:

The evasive behaviour is analysed for each vehicle or pedestrian approaching the beforehand selected part of a site. At the point when the road user starts to slow down or accelerate, the road user is projected with the speed it had just before. For each road user taking evasive action there is only one counterpart. On the other hand may one road user be counterpart to several different road users taking evasive action.

With the Dutch TCT (Risser&Tamme, 1987; van der Horst&Kraay, 1985) there is found to be a significant correlation between PET and speed of the oncoming car, that has right of way and safety. A situation with a certain PET and a higher speed is more severe than a situation with the same PET and lower speed. So both the ICTCT Calibration study in Malmö (Grayson, 1984) and the definition in DOCTOR of a recordable event suggest that events that are close enough in time and space ought to be included when describing severity. The ICTCT Calibration study found MTTC (Minimum Time To Collision - a continuos measuring during the duration of a conflict) to be the most important factor in explaining common severity for the different Traffic Conflicts Techniques. The second most important factor was found to be the minimum distance between the road users. The DOCTOR both includes PET (Post Encroachment Time) situations and situations with TTC (Time To Collision). This implies content of safety information in situations that are close enough in time and space without necessarily having collision course.

What is registered?

At the department we are traditionally very concerned with the traffic safety of vulnerable road users. It was therefore quite clear from the beginning that I wanted to look at interactions involving vulnerable road users. It was also very tempting to try to include the Kaivokatu-Keskuskatu - intersection in Helsinki, Finland where accidents have been video-recorded (Pasanen, 1993). By including this intersection I would get the opportunity to describe the relation between accidents and interactions. Since the focus in the Kaivokatu-Keskuskatu - recording was set on pedestrians, I chose to concentrate the interaction studies to pedestrians / motor vehicle situations. I consequently decided to register all situations between motor vehicles and pedestrians having collision course. Besides these situations, due to the above mentioned reasons, I also wanted to include some situations where there is no objective collision course. The criteria for these situations are:

Evasive action - might be interpreted as having subjective collision course. The road user takes evasive action as if there was a real collision course.

Closeness in time and space - might be interpreted as PET situations with small margins.

How to make sure that all these interactions are included in the registration?

One possibility would have been to enlarge the footprint for the vehicle and/or the pedestrian: If I had used the semi-automatic image processing system developed at the Department then I could have enlarged the footprint. The footprint is a rectangular box projected from the road user to the road surface. The size of the footprint is set at the beginning of each analysis. The footprint then keeps the size in terms of road length units but changes in image length units as it moves around in the picture. The size of the footprint is set manually and could accordingly be reduced or enlarged in relation to the true size. With an enlarged footprint, situations with no, but just about, collision course would be registered as if there were collision course. Depending on how much the footprint was enlarged it would have been possible to decide how big the margins would be for a situation to be detected as one with collision course. This presupposes though that both road users are followed through the intersection and that the coordinates are picked for both road users every 0.08 seconds. This process is fairly time demanding and was not thought to be justified in my study.

What I have done instead is to further analyse situations without collision course but where the TA- value is up to 0.2 seconds from being a collision course. The first estimate is based on pedestrian speeds like 4.0, 5.0, 6.0 km/h. If I then get a close hit, PET, then I go back and see if it would have been collision course if the pedestrian had walked 0.5 km/h faster or slower. On top of this I have analysed as if the vehicles fill up the whole lane, from the kerb to the lane marking. If the pedestrian had just stepped out from the kerb when the vehicle had passed then it would have been collision course.

The major drawback with this way of analysing is that these values are speed dependent and I haven't taken that into account so far. Situations involving vehicles with higher speeds and that are close in time and space will to a higher extent not be detected compared to situations with slower driving vehicles. The situations including slow driving vehicles will be over represented in the sample. The reason is that the time for being in collision course decreases with both vehicle speed and pedestrian speed.

5. Shape of the safety pyramid

Now we have arrived to the part where I will try to justify the new approach. All interaction studies are carried out from video recordings, recorded during daytime, about 10 a.m. to 1 p.m.

I have looked at the following vehicle / pedestrian situations:
- Pedestrians crossing on a pedestrian crossing and straight on driving vehicles
- Pedestrians crossing on the same pedestrian crossing and right turning vehicles

At the following sites and times

- Kaivokatu-Keskuskatu- a signalised intersection in Helsinki, Finland (Pasanen, 1993). Video-recordings from the accident tapes and from recordings in connection to conflict studies 1995 - A total of 7 hours.
- Värnhemstorget - a signalised intersection in Malmö, Sweden, similar to the Helsinki intersection. Video-recordings from 1996 and 1997 - A total of 13.5 hours.
- Djäknegatan-Baltzarsgatan - an intersection with obligation to give way to the right, in Malmö, Sweden. Video-recordings from 1996 - A total of 12 hours.

The first analyse was to see if the two situations, vehicles driving straight on and vehicles turning right, would produce different distributions with regard to TA / Speed. That is, would these situations produce different shapes of the safety pyramid. This analyse is from one pedestrian crossing at the signalised Kaivokatu-Keskuskatu intersection in Helsinki. The pedestrian crossing chosen is independent of recent changes in the intersection (as far as I can tell) and is furthermore the pedestrian crossing closest to the camera. The latter is very important since the camera is placed very high up in a building and I must be able to register also small evasive actions. The two situations compared are:
SF/P - Straight forward driving vehicles and the pedestrians taking evasive action
T/P - Turning vehicles and pedestrians taking evasive action

The TA / Speed graph is divided into 22 severity sections (numbered 1 to 22 in Fig 2). The sections are parallel to the curve that sets the border between serious conflicts and potential conflicts. According to the Swedish TCT all events within the same section have the same severity. Situations in section 1 have the highest severity and then the severity decreases as the section-number increase. Section 1 to 5 are serious conflicts and 6 to 22 are slight and potential conflicts. The border between serious conflicts and potential conflicts is consequently between section 5 and 6 i.e. at TA=0.5 sec (on the X-axis) when the Conflicting speed=0 (on the Y-axis).

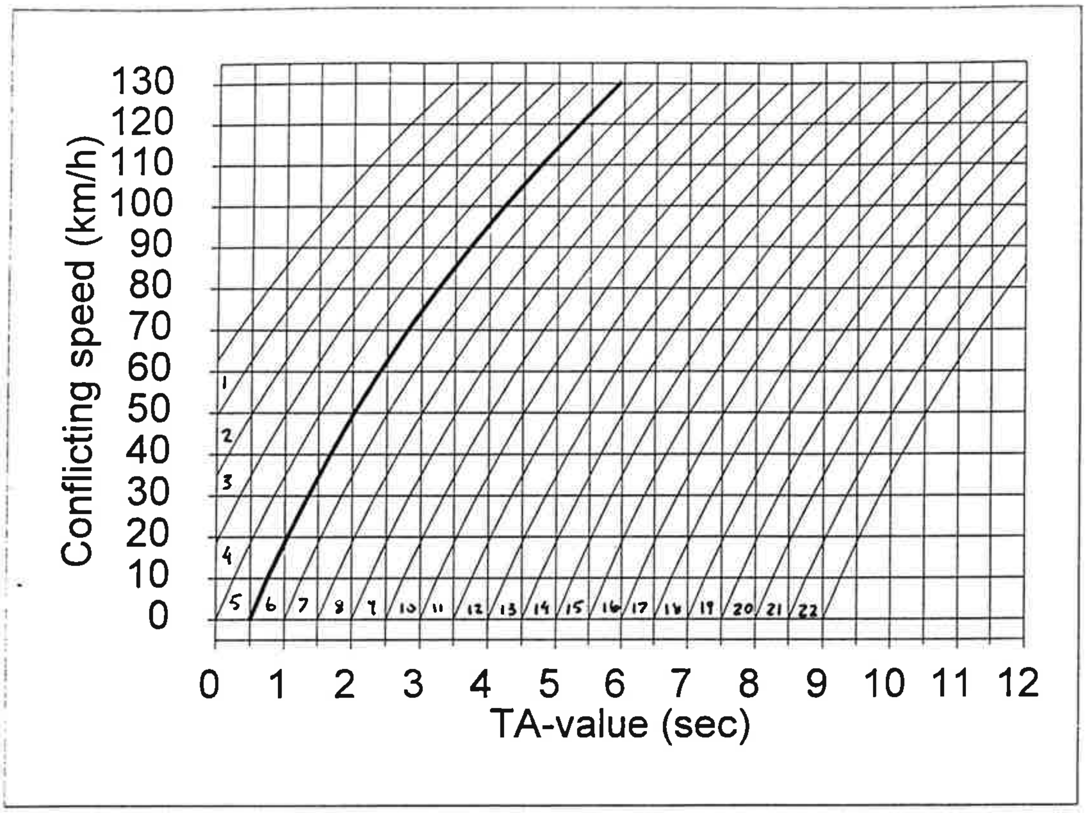

Figure 2. The TA / Speed graph divided into 22 parallel sections, numbered 1 to 22.

The TA / Speed values of the T/P interactive situations (see Fig 3) start in severity section 5, that is this type of situation contains serious conflicts. There are no serious conflicts registered for the SF/P situations (see Fig 4). The TA / Speed values of the SF/P situations start to appear in section 7. The number of interactions in the severity sections then increase as the severity decreases and reach a breakpoint in section 9 for T/P and in section 12 for SF/P. After the breakpoints the number of interactions in the sections start to decrease.

The similarity in the distributions of the T/P situations and the SF/P situations was tested with the Kolmogorov-Smirnov test (Marascuilo & McSweeney, 1977). The null hypothesis is that the distributions are identical. With a two-sided test, KS(maximum difference)=0.31 > KS(132,168;0.99)=0.19, i.e. the null hypothesis was rejected on the 99% significance level. The test showed that the distributions are not identical.

The finding suggests that there is a difference in the shape of the safety pyramid for the T/P and SF/P situations. From the accident recordings in this intersection (that I'll come back to further down) I know that injury accidents of both types have occurred. If I didn't have that information I would faulty assume that SF/P situations are safer since the interactions produce higher TA-values than the T/P situations. I could have drawn the completely misleading conclusion that the very top of the pyramid (injury accidents and serious conflicts) is cut off in the SF/P pyramid. But since I do know that there are injury accidents at the top of both pyramids the conclusion should instead be that the SF/P pyramid should be more pointed at the top compared to the T/P pyramid. The accident to conflict ratio should be higher for the SF/P situations that is these situations are more unsafe.

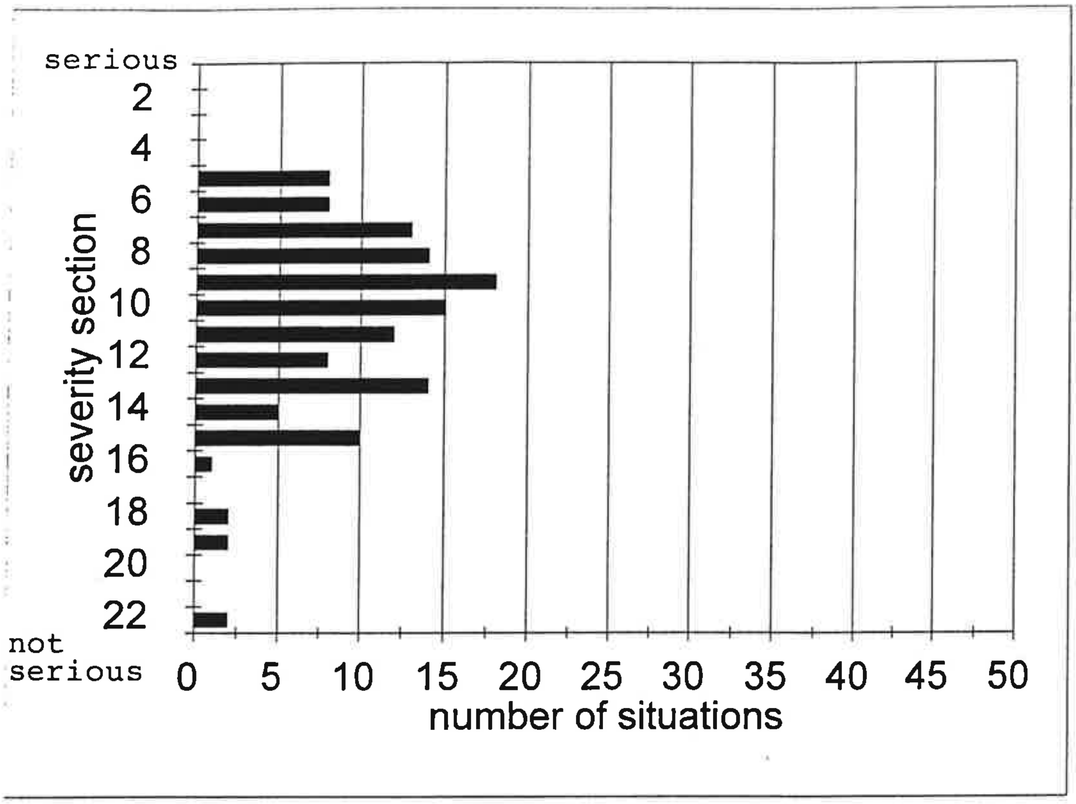

Figure 3. Interactions belonging to T/P = Turning vehicles and pedestrians taking evasive action. The distribution of interactions in the 22 TA / Speed related sections.

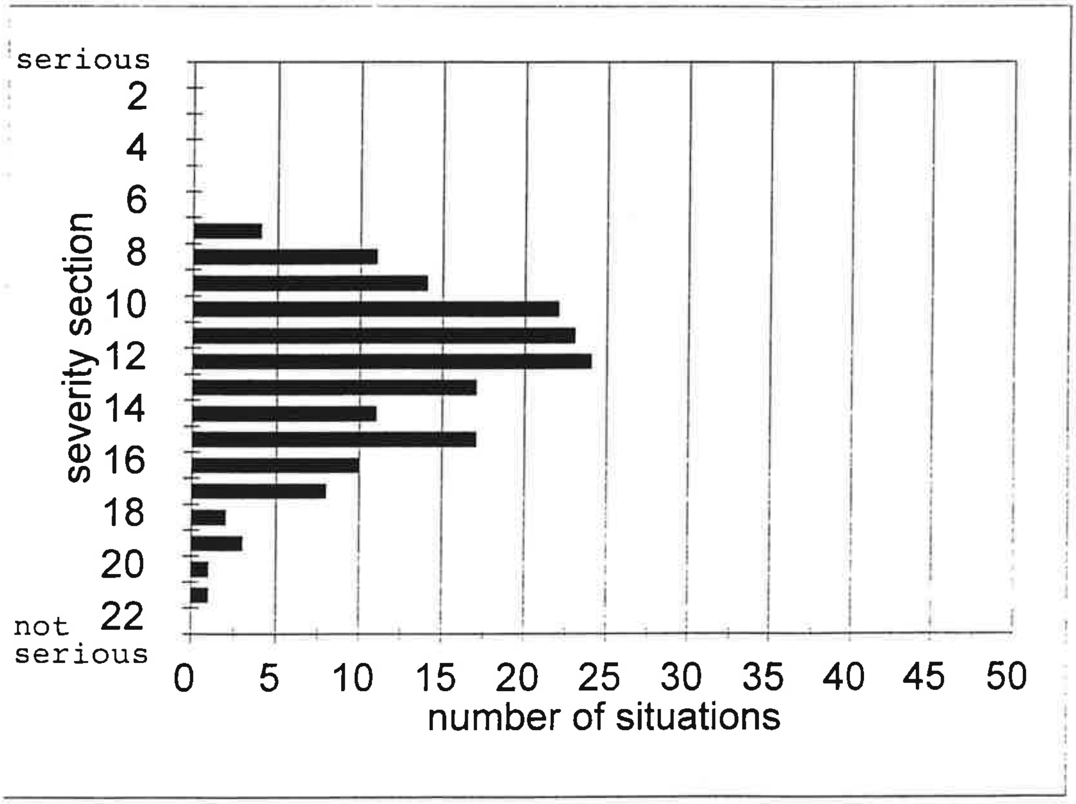

Figure 4. Interactions belonging to SF/P = Straight Forward driving vehicles and pedestrians taking evasive action. The distribution of interactions in the 22 TA / Speed related sections.

The total lack of serious conflicts in the SF/P situations is quite interesting. One explanation could be that the serious conflicts in SF/P interactive situations do exist but are very rare. If the SF/P situations just were studied long enough the serious conflicts would also start to appear. An other explanation could be that the safety outcome of this type of situation can not be explained by the TA / Speed concept. A third explanation could be that the SF/P situations to a higher extent occur at other times of the day than I have observed .

The search for an explanation reminded me of an other study where we during one week in the summer of 95 video-recorded the Kaivokatu-Keskuskatu intersection. The aim was to conduct conflict studies from these recordings. The intersection was video-recorded during 19-20 hours per day, starting at 7 a.m. and finishing at 2 or 3 a.m. the following morning. So far 39 hours, two "day-and-night periods", have been analysed with regard to conflicts. The result was 9 conflicts of the type turning vehicle at conflict with crossing pedestrian, out of which 6 were regarded as serious. They were evenly distributed over the registration period. Conflicts of the type straight forward driving vehicle in conflict with crossing pedestrian were 4 in number. "All" occurred during the night, i.e. 11 p.m. to 3 a.m., and were regarded as serious conflicts.

The four years of accident data, that I so far have access to, include 2 accidents of type turning vehicle and pedestrian crossing and 2 accidents of type straight forward driving vehicle and pedestrian crossing. In both accidents with the turning vehicle, the pedestrian and the vehicle proceed when the signal is green. It is worthwhile to note that the vehicles here have an obligation to give the pedestrians right of way. The 2 accidents with the straight forward driving vehicles include a pedestrian crossing at red. 3 of the 4 accidents occurred during the night, in this case between midnight and 2 a.m.

The issue why I seem to lack the serious conflicts in the interactive data set for SF/P situations must be sorted out thoroughly when this paper is written. But from the discussion above there seems to be more information to achieve if it was possible to conduct interactive studies during longer periods and during other times of the day. The main problem with this approach would be that it is almost impossible to register interactions during the night. Small deviations in speed and direction are not observable due to the poor quality of the pictures. It is considerably easier with the serious conflicts since the evasive actions are so much more distinct. The most important task right now is to combine all information about accidents, conflicts and interactions for the Kaivokatu-Keskuskatu intersection. Information like speed, TA-value and severity in terms of injury. From this it would be possible to determine likely shapes of the whole safety pyramids, ranging from injury accidents at the top to interactions with low severity at the bottom.

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