A method for analysing the traffic process in a safety perspective

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1 Aim

The aim of the work behind this paper is to extend the traffic safety assessment concept to also include normal road user behaviours, thus not only exceptional behaviours such as accidents and serious conflicts. The goal is to provide a framework for a more thorough description and analysis of safety related road user behaviour in order to better understand the traffic safety processes i.e. the course of events towards accidents. The traffic safety process is used for describing the relationship(s) between encounters, serious conflicts and accidents - to establish whether these events belong to the same severity continuum – a continuum where events can be ordered with regard to their serious injury accident potential.

2 Background

2.1 Interaction

Traffic is interaction - all events in traffic 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 environment. The interaction between road users contains communication. The level of unsafety is closely linked to the quality of the interactive behaviour and the communication. If there is a total breakdown in the interaction between the road users or between the road user and the road environment, the situation must be considered as being unsafe. Accidents and serious conflicts indicate such total breakdowns in the interaction. These are often due to breakdowns in the communication.

2.2 Accident data analysis

The traditional way of approaching traffic safety has mainly been concerned with the occurrence of traffic accidents and their consequences. This approach implies that accident data analysis can be regarded as a valid method for estimating unsafety. This implication is
quite natural as we equate reported accidents with traffic unsafety. There are, however, disadvantages with the use of accident data analyses and these have been discussed extensively in several papers, e.g. Englund et al. (1998), Grayson & Hakkert (1987).

- Accidents are, for example, rare events and are therefore associated with the random variation inherent in small numbers. For the local everyday traffic safety work, it is not sufficient to use accident data only.
- Not all accidents are reported and the level of reporting is unevenly distributed with regard to e.g. type of road users involved, location, severity of injuries etc. Vulnerable road users are for instance heavily underrepresented in the police accident statistics compared to what hospital registrations and other studies show (Berntman, 1994).
- The behavioural or situational aspects of the events are not covered by police accident data. Being involved in an accident is often a traumatic event and is also often connected with the feeling of guilt by at least one of the involved parties.

These aspects make it very hard to understand the connection between behaviour and safety by only reading the accident record, or even by making an in-depth analysis of accidents. In the latter case a major complication is that it is very expensive to obtain data that will be representative enough to allow conclusions to be drawn regarding safety e.g. at a certain type of intersection or on any other more detailed level.

2.3 A method to collect and analyse near-accidents

The need for surrogate or complementary methods for accident analysis is consequently high. There is a need to get a more complete picture of the relationship between behaviour and safety; the development of the Traffic Conflicts Technique (TCT) can be seen as a first attempt in this direction. With the TCT, events that almost end up as accidents, serious conflicts, are collected and analysed.

'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.'

The basic hypothesis is that there is a close relationship between conflicts and accidents. The interaction between road-users can be described as a continuum of safety related events. These events can be looked upon as different levels in a pyramid; the accidents are found at the very top and the "normal" passages at the bottom. The different levels in the pyramid can in other words be seen as a severity scale. In the Swedish TCT, this severity scale is accomplished by applying the TA/Speed dimension i.e. the Conflicting Speed and the Time to Accident value (TA value), which presupposes a collision course. The severity scale in the Swedish TCT implies that the probability of a police reported injury accident is constant within the level and increases towards the top.

The **Conflicting Speed** is the speed of the road user taking evasive action, for whom the TA value is estimated, at 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 if they had continued with unchanged speeds and directions.

Besides having a severity scale based on the TA / Speed presumption, the Swedish TCT is also characterised by the elaboration of conflicts with different severity. When developing the Swedish TCT it was found essential to distinguish the serious conflicts from the rest of the conflicts, as the serious conflicts were found to more strongly possess the quality of being an indicator of a breakdown in the interaction – a breakdown that could correspond to the breakdown in the interaction preceding an accident. A serious conflict is also, like the accident, a situation that nobody puts him/herself into deliberately.

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

In the validation of the Swedish TCT, analyses show that at lower accident frequencies it is preferable to use conflicts instead of accidents in estimating the expected number of accidents (Svensson, 1992)

In the process validation work of the Swedish Conflicts Technique, Hydén (1987) has compared the processes preceding injury accidents to those preceding conflicts. Analyses showed big similarities between accidents and conflicts when the comparison was based on TA values and conflicting speed. Accidents and conflicts were continuously distributed with a tendency for the accidents towards lower TA values and higher speeds. At least one of the alternative definitions for serious conflicts (for further information see Hydén, 1987) produced both logical and relevant severity distributions for conflicts and accidents; severity increased continuously and logically. This is very much in line with the hypothesis that accidents and conflicts are events in a time based continuum.
3 How to extend the concept?

Many of the shortcomings in accident data analyses are provided for with the use of TCT, but not all. Sometimes the serious conflicts are also too few to establish significant results. The analyses of serious conflicts do also have the same angle of approach as the accident data analysis i.e. the primary focus is set on rather exceptional events. Experience with the TCT has, nevertheless, shown that it is possible to include less severe events than accidents, serious conflicts, and reach better understanding of the traffic safety process.

If we once more take a look at the relationship between events in traffic, Figure 1, it is quite astonishing how few and exceptional those events are that we usually base our safety estimates on i.e. the accidents and sometimes also the serious conflicts. Why do we hardly ever regard all the other, so much more frequent events in traffic, for safety assessment? We cannot neglect the fact that all these other events with less severity also are part of traffic. It would, thus, be logical to assume that they also contribute, to some extent, to the traffic safety process. I assume that there is a resistance against including events that must be characterised as quite normal road user behaviour as it is perhaps not so very obvious that these events are associated with accidents or serious conflicts. If we, however, turn the discussion the other way around and state that it is safety, in the correct meaning of the word, we would like to obtain then it is quite obvious that most events in traffic, and especially the safe ones, would contain valuable traffic safety information.

The basic hypothesis of my work is that we are forced to widen the scope of traffic safety and relevant safety related events, if we ever will come close to explaining the relationship between road user behaviour and safety. Therefore, I think, a logical continuation of research is to extend the traffic safety concept towards less severe events thus to include “more normal” road user behaviour. This would enable us to better explore the pre-conditions for safe/unsafe road user behaviour and increase the possibility of working with safety estimates on a more detailed level. Then the next issues arise; As it is not possible to include all events in traffic we must define what events to include and decide on how to estimate the severity of those events. Before elaborating with these issues I would like to introduce and define two terms; the safety hierarchy and the severity hierarchy.

Safety hierarchy
All events in traffic are more or less related to safety and it is logical to assume that encounters between road users can be described as events in a safety hierarchy. If a safety hierarchy was to be set up on the basis of road users’ and society’s conceptions of unsafety and the severity of an event, the serious injury accident would be located at the top of the hierarchy as the most severe event. The events located next to the serious injury accidents in the safety hierarchy must be those events that almost end up as serious injury accidents. And so on.

Severity hierarchy
To be used for practical applications the safety hierarchy has to be made operational. The operational version of the safety hierarchy is here called the severity hierarchy. The aim must be to construct a severity hierarchy for traffic events so that for each event a severity
can be estimated. The severity should be related to the probability of serious injury accident. This probability is linked to the dynamics of the event, and should relate to any event with similar characteristics occurring for the same entity (intersection, road user group etc.).

3.1 Events in the traffic safety process

Which traffic situations should be included in the chain of continuum events that build up the traffic process: events that according to the severity hierarchy have some serious injury accident potential?

As I stated earlier, all events have some kind of relation to safety. If we choose to tackle this problem by analysing every single event in traffic in order to find relations to those events resulting in injury accidents, we would soon find ourselves having problems constructing a clear picture of the relations. There are too many events, and every single event is unique in some way. An other approach could be to start with looking at the accidents and, from those, state what should characterise an accident related event, in order to be called ”accident-like” i.e. to have some injury accident potential. If we were to follow this approach it is very easy to see that we would soon be in the position of analysing accidents and perhaps claiming that events that were not “accident-like” enough had no safety content. My opinion is that both approaches might very well be correct and the best approach is perhaps a compromise. On an overall level, it is important to draw some general conclusions from the accidents in order to find “accident-like” situations. Then, on a more detailed level, it might be appropriate to look at all those single events that comply with the basic standards of an “accident-like” situation, in order to be able to say something about the safety situation e.g. at an intersection.

3.2 The severity of the events in the severity hierarchy

When it comes to providing the events with different severity, this can be done with respect to different presumptions. Here are a few of what I regard as the most relevant examples. (The severity hierarchies here deal only with encounters between road users.)

1) Closeness in time – time margins between the road users
2) Closeness in space – space margins between the road users
3) Closeness in time and space
4) Collision impact – the relative speeds, the masses of the involved road users, the fragility of the road users etc.

Depending on the different presumptions, it is possible to consider correspondingly different severity hierarchies. The reason for setting up a severity hierarchy based on certain presumptions is the belief that there is a correlation between the severity, defined by these presumptions, and safety.
4 A behaviour based framework for exploring the traffic safety process

4.1 Relevant accident-like events

The common denominator for all collisions is that two road users, due to unfortunate circumstances, end up in the same spot at the same time. A collision presupposes a collision course.

Collision course: Unless the speed and/or the direction of the road users changes, they will collide.

The duration of the collision course may, however, differ. If the road users have been on a collision course for a long period before they actually collide, there must have been several opportunities to avoid the collision. If the road users enter a collision course just before the collision, the possibilities of avoiding the collision have diminished. The conclusion is, thus, that the common denominator for events to be included in the “accident-like” chain, i.e. to be included in the severity hierarchy, are those events where the road users move on a collision course.

4.2 Severity scale

Most interactions where road users move on a collision course do however not result in a collision; at least one of the road users takes evasive action. Interactions where the collision course diminishes at an early stage must have much less injury accident potential than interactions where the evasive action is taken at such a late stage that a collision just about is avoided. When the concept of the traffic safety process is to be extended it seems to be appropriate to adopt the Swedish TCT severity scaling; the severity of the process is described by the Time-to-Accident and Speed values. According to the definition of the severity hierarchy an event with a certain severity cannot be classified as an injury accident or a conflict etc. Severity does not refer to the known outcome after the evasive action but to the severity of the event an infinitesimal unit of time before the evasive action. The outcome in the form of an accident or not then depends on the success of the evasive action. What we can say is that an unknown event with a certain location in the severity hierarchy has a certain probability to be an injury accident as an outcome.

5 Data collection

The study includes interactions between vehicle drivers and pedestrians. Only manoeuvres where the vehicle driver either drives straight ahead or makes a right turn, and interacts with a pedestrian are included. Road user behaviour is studied at two signalised
intersections and at one non-signalised intersection with right hand rule. The interactions are studied from video-recordings. At one of the signalised intersections accidents have also been studied from video. For the other intersections this was not possible and the severities of the accidents are based on estimates. The interactions are positioned in the hierarchy, Figure 4:2, with the estimated TA/Speed value obtained at the moment of evasive action, Figure 4:1. The different shapes of the hierarchies are then analysed.

Figure 2  
TA/Speed graph defining the different severity levels. There is a continuation towards lower severity levels. Severity level 1 (not shown) intersects the X-axis at TA=13.0 seconds.

Figure 3  
Severity hierarchy with severity levels corresponding to the ones defined in Figure 2.
6 Shape of the hierarchy

The relationship between the number of events of different severity (defined by the Time-to-Accident/Speed value from the moment of evasive action for interactions with a collision course) can be analysed through the shape of the hierarchy. The shape is affected by different factors influencing the evasive behaviour of the road users, such as type of road users and type of manoeuvres involved, speed of the road users involved, traffic flow, intersectional design, etc.

In this paper I have chosen to present the interactions and their corresponding severity hierarchies for two, from a traffic engineering point of view, totally different solutions; a signalised intersection and a non-signalised intersection with right hand rule, see Figure 4. The interactions, in Figure 4, involve straight ahead driving vehicles and pedestrians, where it is the pedestrian taking evasive action. Due to the fact that these analyses only are based on two specific intersections and for specific manoeuvres, the results are of course fairly uncertain and we have to be very cautious when trying to make any generalisation. There are, nevertheless, indications of differences in the shapes of the hierarchies due to differences in the road user behaviour at a signalised and at a non-signalised intersection.

![Figure 4](image-url)  
Distribution of interactions with regard to severity at a signalised intersection (solid line) and at a non-signalised intersection (dotted line). Interactions between straight ahead driving vehicles and pedestrians taking evasive action.
6.1 Traffic engineering interpretations

The two hierarchy shapes in Figure 4 differ in many respects. There is a difference regarding the existence of events at the highest severities. The location of the convexity i.e. the part of the hierarchy where most events are located, is also different for the two hierarchies. Furthermore, the extension of the convexity has different shapes in the two hierarchies. There might be several different interpretations of the safety implications of different shapes of the hierarchies.

Events at the highest severities
A location with observations at the highest severity levels in the hierarchy indicates a high injury accident potential. The events at the highest severity levels are found to consist of police reported injury accidents and serious conflicts. Due to the low occurrence rate of these events and the random variation inherent in low numbers, the shape at the highest severity levels is difficult to verify statistically. The indication is, however, that the signalised intersection seems to more occasional events at the highest severities than the non-signalised intersection. What we can learn from this is that in the attempt to get information about the most severe levels of the hierarchy, additional information must be sought on the lower levels.

Events at fairly high severities
If there are many interactions at fairly high severities this could a) mean something good like that there is behavioural feedback regarding the necessity of increasing the awareness at interactions with fairly high severity or b) mean something bad like that it is always associated with an element of surprise to have interactions at these high severities. The non-signalised intersection seems to have a more distinct location of events around the fairly high severities compared to the signalised intersection.

Events at less severities
If the majority of events are located at the region of less severity, this could also have different interpretations. One interpretation could be that this is good for traffic safety as the normal road user behaviour is to divert from collision course at an early stage. The other interpretation could be that this is not good for traffic safety as it makes the road users less prepared to handle an interaction safely once there is an interaction which is close in time and space. The signalised intersection seems to have most of its interactions at less severity.

Convexity
The convexity of the severity hierarchy i.e. the part of the hierarchy where most events are located, describes normal road user behaviour at a specific location for a certain type of road user involved, for a certain type of manoeuvre etc. It is the normal evasive behaviour when two road users move onto a collision course. The convexity can be interpreted as the distribution of individual safety margins - safety margins that differ due to each individual’s unique acceptance of comfortable margins in time and space at interactions, and due to time of detection. These margins also depend on considerations other than safety, such as the wish to maintain a certain speed or the wish to conserve energy and comfort.
The form of the convexity can evidently range from being narrow with regard to the extension over severity levels, as for the non-signalised intersection, to being more widely spread over several severity levels, the signalised intersection. The latter could be an indication of road users’ difficulty to interpret and decide upon signs of possible threat. It can also be seen as a confirmation of the safe effect of signalisation; the priority rules are clear and the intention of the pedestrians is to stop but due to differences in the individual safety margins the adaptation of speed differ from individual to individual.

**Conclusion**

The interactions at the signalised intersection (solid line in Figure 4) do at first sight seem to be the result of safe behaviour – most interaction are handled in due time before they become critical. At the same time we do, however, have the information that pedestrians do get killed and seriously injured at this type of intersection – the narrow peak up to the highest severities. The shape of the interactions at the non-signalised intersection (dotted line in Figure 4) gives certainly the analyser the feeling of unsafety – most interactions are located at fairly high severities. Accident statistics do, however, show that pedestrians do not as likely get killed or serious injured at this intersection compared to the signalised intersection. According to the poor accident statistics available the conclusion is that the shape of the hierarchy at the signalised intersection indicates an unsafe location with unsafe road user behaviour as the shape of the hierarchy at the non-signalised intersection indicates a safe location with safe behaviour.

**6.2 Traffic safety strategies**

By analysing the shape of different severity hierarchies, the traffic safety process for different conditions can be studied. The shape of the severity hierarchy can be used:
- in describing differences in road user behaviour
- for predicting the frequency of more severe events from information about less severe events
- for formulating traffic safety strategies

When formulating traffic safety strategies I think some of the findings in this work might be well worth to consider. Like the suggestion of
- not regarding interactions as such as being an altogether bad thing for traffic safety – it is not always an indication of unsafety that interactions are rather close in time and space
- promoting communication and interactive behaviour, on condition that requirements are taken in such a way that failure or erroneous behaviour do not imply imminent danger to any of the involved road user, e.g. by enforcement of low speeds at the location
- not only focusing on the occurrence of accidents in traffic safety work
- seeing the normal interactive behaviour as a natural complementary source for traffic safety information
- keeping an eye on locations, manoeuvres etc. where the potential for unexpected interactions can be regarded as high due to a low interaction frequency

are suggestions that can be applicable in many types of studies.
7 Potential use of the method

Validation assessment of the severity hierarchy concept must be one of the logical continuations of this work. The severity hierarchies analysed and discussed here are still only estimates of the “true” hierarchies. The ”true” hierarchy shape is the shape we would get if we were able to make observations during an infinite time and with a perfect registration method.

If the method proves to be scientifically valid the concept could be very useful in future traffic safety work, especially in connection with an image processing application. If we look ahead, say 5 years, then we could very well be able to record a site for a week or two and then, with help of the image processing, analyse all the different severity hierarchies with regard to type of road users involved, type of manoeuvres etc. Decisions like safety strategies, what safety measures to introduce etc. would then have a firmer foundation.

For traffic safety research, the concept will hopefully serve as a possible framework for exploring different traffic safety theories by taking the whole severity hierarchy into consideration. The theory of safety margins and its potential border differentiating events with a substantial difference in injury accident potential, could for instance be very interesting to apply to the severity hierarchy. The theory of describing road users’ behaviour and decisions with regard to level of mental control (Englund et al., 1998) could also be interesting to apply to the severity hierarchy concept. Where in the severity hierarchy will the interactions characterised by knowledge-based and skill-based decisions be located? And what does this mean for the work of promoting safety? These are very interesting issues that could be further elaborated on in an attempt to make some of the traffic safety theories operational according to this framework.

REFERENCES:


