CODEN:LUTVDG/(TVTT-1018-174)/1998

Bulletin 166

Department of Traffic Planning and Engineering
Lund Institute of Technology
Lund University

A method for analysing the traffic process in a safety perspective

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Lund 1998

Acknowledgement

First of all I want to thank my supervisor, professor Christer Hydén. I appreciate the great enthusiasm in your support and guidance. Thank you for being the generous person you are and for not showing too much annoyance with my slow pace.
Thank you Risto Kulmala, my second supervisor for your heavy commitment and inspiration and great sense of humour. I will certainly miss the great laughs.

I am of course also very grateful for the financial support from the Swedish Transportation Research Board, KFB, enabling this work to come true.

Thanks Karin Brundell-Freij, Hans-Erik Pettersson and Richard van der Horst for taking your time last summer to get together and discuss the work with me. Especially thank you Karin for being the never-ceasing source of inspiration.

Thanks Eero Pasanen, for providing me with all the data from Helsinki.

Thanks Magnus Eriksson, for doing such an excellent work with the observations. I wish you all luck with future tasks.

Thanks Mia Sinclair, for helping me out when finalising my work and for being a warm and close friend.

Thank you all at my Department at Lund University. I would like to especially mention my colleagues at the Ideon office for being so concerned even at times when I have locked my door and refused to have coffee-break. Lars Ekman for always encouraging me but also for helping out with computer issues. Thomas Jonsson, for solving many of my acute computer problems and Klas Odelid for providing me with computer programs.

A big advantage with my Department is the sympathetic attitude when a thesis is to be finalised; colleagues always offer a helping hand. Thank you all and especially thank you András Várhelyi, Magda Draskóczy, Birgitta Åkerud and Georg Siotis.

Finally, I want to thank my dear family. Your support has, as always, been very essential to me. Thank you Richard for your encouragement and help with red X's and thank you Rasmus and Lovisa, my lovely children, for always standing by me. Thank you Lena, for believing in a thesis despite your daughter taking her ample time. I also owe a great deal to Benkt-Ingvar, my father who is not with us any longer, for among other things providing me with the right ticket to the Department.

Lund, September 1998

Åse Svensson

Glossary of terms

Accident	An interaction where two road users have collided.
Adaptive situation	An interaction with lower severity than an accident or a serious conflict.
Collision course	Unless the speed and/or the direction of the road users changes, they will collide.
Conflicting speed	Speed at the moment just before evasive action
Encounter	A meeting between two road users.
Evasive action	Action taken to diverge from a collision course by changing speed or direction
Event	Any kind of incident or occurrence in traffic.
Expectation	What the road user expects from the environment; an environmental feed back loop.
Interaction	A traffic event with a collision course where interactive behaviour is a precondition to avoid an accident.
PET value	Post Encroachment Time. Time measured from the moment the first road-user leaves the potential collision point to the moment the other road-user enters this conflicting point.
Safety hierarchy	Conceptions of unsafety and severity of an event. The serious injury accident is at the top.
Serious conflict	An interaction where the evasive action starts late and the impression is such that the situation easily could have ended up in an accident instead.
Severity hierarchy	The safety hierarchy transferred into measurable parameters based on certain presumptions.
Severity level	Level in the severity hierarchy
TA value	Time to Accident at the moment of evasive action when two road users are moving on a collision course.
TA/Speed value	Position in the hierarchy based on TA value and Conflicting speed
TCT	Traffic Conflicts Technique(s)
Traffic safety process	Continuum of events with different severity describing the relationship(s) between accident related events.
TTC value	Time To Collision. A continuous function of time as long as there is a collision course; the time required for two road users to collide if no evasive action is taken.

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Summary

A method for analysing the traffic process in a safety perspective

The aim of this study 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.

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 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.).

My approach

The severity hierarchy can be used for analyses of the traffic safety process, i.e. describing the relationship between accident related events. The traffic process can be seen as a continuum of events with different severity. Relevant events in the traffic safety process are called interactions and are characterised by a collision course. The severity of the process is described by the Time-to-Accident and Speed values. Time-to-Accident is the time that remains to an accident from the moment one of the road user takes evasive action calculated assuming that they otherwise had continued with unchanged speeds and directions. The severity in the operationalised severity hierarchy refers 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.

Study design
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.

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. 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

Hypotheses on factors possibly affecting the shape of the severity hierarchy
A) Similarities between the severity shapes, i.e. the frequency of events with different severity, even though the data is collected during different time-periods.
B) Similarities between the severity shapes at similar types of intersections.
C) Type of control at the intersection influences the severity shape.
D) Type of manoeuvre at the intersection influences the severity shape.
E) Type of road user taking evasive action influences the severity shape.

Interactional data, conflict data and accident data are collected for the three different sites with regard to the hypotheses set up and with regard to the manoeuvre and the road user taking evasive action.

Results of analyses
The general conclusions are:

1) All distributions decline in both ends; towards the high and towards the low severities. There is however a difference with regard to where the declination is located, and to the degree of declination.
2) The pattern of the convexity, i.e. the part of the hierarchy with most interactions between the declining top and the declining bottom, differ to varying extent between the distributions.

- There seem to be similarities between distributions of interactions involving turning vehicles irrespective of whether the intersection is signalised or not and irrespective of whether the turning interactions take place at different signalised sites.
- For the interactions involving vehicles driving straight ahead, however, there seems to be a difference between the distributions with regard to whether the intersection is signalised or not. At the non-signalised intersection the convexity of the distribution is located towards higher (but not the highest) severities as compared to the signalised intersection. The convexity of the distribution at the non-signalised intersection is more narrow, restricted to extend over only a few severity levels as compared to the more widely spread convexity covering several severities at the signalised intersection. (See example in Figure 0:1 below)

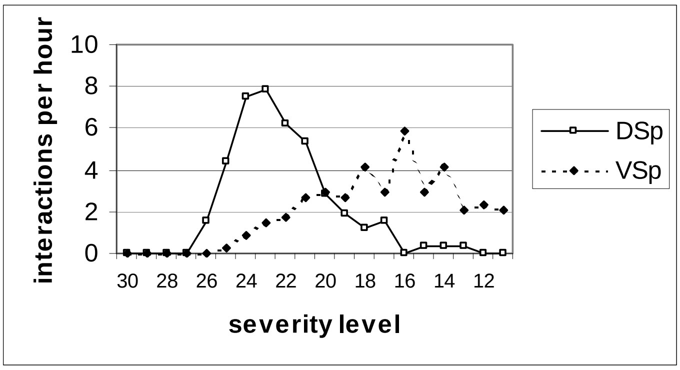

Figure 0:1 An example of different shapes with regard to severity. VSp, vehicles driving straight ahead at a signalised intersection. DSp, the same manoeuvre at a non-signalised intersection.

- From the analyses it has not been possible to unambiguously describe the importance of the type of road user taking evasive action.

Discussion

The results suggest a border in the severity hierarchy above which a high occurrence rate of interactions is a sign of unsafety and beneath which a high occurrence rate of interactions is a sign of safety. This could be of help when differentiating between locations with mainly safe road user behaviour and locations characterised by unsafe road user behaviour.

It is, however, to be noted that a location with a high interaction frequency at low severity levels seems to produce the conditions for occasional events with high injury accident potential. The convexity of these interactions with less severity was in this study widely spread over several severity levels. The opposite pattern, a narrow convexity at reasonably high severities, seems to be the insurance for preventing the most severe types of events from occurring. This is probably due to the learning process, i.e. the increased awareness of the road users brought about by involvement in interactions with reasonably high severity. It is, therefore, from a safety perspective not only interesting to analyse the part of the hierarchy with the most severe events, but also to take the convexity of the distribution into consideration. Hence, the shape of the hierarchy as such includes valuable safety information.

The severity concept will hopefully prove to be useful in ordinary traffic safety work. 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.

1 Introduction

Road traffic is an intense social system in which individuals with different means of transport move around. On average, each individual in society spends 70-80 minutes per day just for transportation (Holmberg & Hydén et al., 1996). In the long run this makes the traffic system a somewhat tiring and boring system, at the same time as it is a very demanding system. Road users have to consider the presence of other road users, as they often have to share the same space, even as they have to focus on managing their own movements, keeping on the road and keeping upright (most valid for pedestrians and cyclists). As it is not an automatic system, the success of such a system depends on the behaviour of the road users in it; how well they adapt to prevailing traffic rules, how well the road and vehicle environment explains the forthcoming traffic situation, how road users perceive the information and how they actually react, interact etc. Moving in traffic implies, at least in dense traffic, an almost continuous interaction with other road users.

According to Finnish and US data, a driver faces on average 5 pieces of traffic information per second in traffic or, with another measure, 300 per km, see Table 1:1. During the average 70-80 minutes of transportation per day, a driver would face more than 20 000 pieces of traffic information! Many of these concern encounters with other road users. Considering the great number of encounters in traffic, it is quite remarkable that most of them actually are solved satisfactorily. This is what we often refer to as the ordinary, normal traffic condition. The opposite, the extraordinary traffic condition, is associated with accidents, as they are such rare events. But accidents do happen. On average, a driver is involved in one accident per 7.5 years or one accident per 150 000 km, see Table 1:1.

Table 1:1 The number of events an average driver faces in traffic, per unit of time or per km. The figures are based on an average speed of 60 km/h and an annual mileage of 20 000 km. The figures are gathered from US and Finnish data (Häkkinen & Luoma, 1991).

	number of events in a unit of time or per km	
Traffic information	5 in 1 sec	300 per km
Driver observations	2 in 1 sec	120 per km
Driver decisions	40 in 1 min	40 per km
Driver actions	30 in 1 min	30 per km
Driver errors	1 in 2 min	1 per 2 km
Risky situations	1 in 2 hours	1 per 120 km
Near-accidents	1 in 1 month	1 per 2 000 km
Accidents	1 in 7.5 years	1 per 150 000 km
Injury accidents	1 in 100 years	1 per 2 000 000 km
Fatal accidents	1 in 2 000 years	1 per 40 000 000 km

1.1 A safety hierarchy

The scope of this thesis is to study the traffic safety process. The more correct term should of course be the traffic unsafety process, as safety is characterised by the absence of unsafety, the absence of accidents, risky situations etc. The aim is, nevertheless, to study the relationship between traffic events in terms of safety. From the figures in Table 1:1, it is logical to assume that encounters in traffic can be described as events in a safety hierarchy. The most severe events are found at the top of the hierarchy and then, as the events become less and less severe, they are found further and further down in the hierarchy. The frequency of the events also seems to be in inverse proportion to the severity of the event.

The terms safety and severity have varying meanings depending on who defines them and for which circumstances. Different parties the society, the traffic engineer and the road user might use different expressions of what characterises an unsafe event, an event with high severity. Nevertheless, most of us associate safety with accidents, or rather the absence of accidents. What characterises an accident then? An accident is an event where the road users have not managed to react in time to avoid a collision. They are either so close in time or space when they detect the danger that the possibilities to avoid a collision have vanished, or they do not detect each other until having collided. An accident is, for the road users involved, an event that happens ‘all of a sudden’. The proximity is sudden. The road users are most often totally unprepared to handle the situation. The situation is not under control. Accidents are, fortunately, very rare events. Usually accidents with the most severe consequences are also the most rare, see Table 1:1. One way of explaining accidents is to say that an accident is the result of an unhappy realisation of many small probabilities. The more, simultaneous, occurrences of “unexpected” probabilities that are required, the fewer are the realisations and the more rare become the events. Accidents range from damage-only accidents to fatal accidents. Thus, it is not reasonable to regard all types of accidents as equally unsafe or equally severe.

To explore road users’ estimates of the discomfort of suffering from traffic accidents with different consequences, the “willingness-to-pay” concept is used (Lugnér Norinder et al., 1995). Subjects are asked questions like “how much are you prepared to pay to get a reduction in the probability of having your arm broken in a traffic accident?” Such studies show that road users’ willingness to pay for a reduction in the probability to suffer from different injuries is associated with the consequences of the accident. The willingness-to-pay increases with the seriousness of the injury. For the road user the event with the highest severity is the serious injury accident. The Swedish Parliament has passed a proposal (SNRA, 1996), which says that the foremost aim of the national traffic safety work in Sweden is to prevent fatal accidents and accidents with severe injuries. This approach is called the Vision Zero and the vision is that nobody should get killed or seriously injured in traffic.

If a safety hierarchy was to be set up on the basis of the road users' and the society's conception of unsafety and 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. These could be other types of accidents with injuries or no injuries but also those events that almost end up as accidents; near-accidents. The near-accidents are also characterised by very small margins in time and space. These margins are too small for the road user to consciously put oneself into such a situation. The road users either detect each other and the imminent risk of colliding just in time to avoid the collision, or end up passing each other with very small margins. The circumstances around the near-accidents and the accidents are very similar, but yet a bit different. Despite the similarity regarding the closeness in the situations, there is an obvious difference in severity between almost colliding and colliding. One type of near-accidents are called serious conflicts (Hydén, 1987). Serious conflicts do, nevertheless, according to Hydén's definition also include accidents. Most often, however, when serious conflicts are mentioned it is in connection with serious conflicts other than accidents. Henceforth, serious conflicts will be associated with near-accidents, if nothing else is stated. The serious conflicts, as near-accidents, are much more frequent events than accidents. Serious conflicts are 1 000 to 30 000 times as frequent as police reported injury accidents (Hydén, 1976, 1987), (Linderholm, 1981, 1992), (Svensson, 1992). The serious conflict is also like the accident an unexpected event, but here the participants (or at least one of them) are able to take a successful evasive action.

In the same way as there are events that almost end up as accidents, it is very logical to assume that there are events, risky situations, that almost end up as near-accidents. Some of these are for instance very similar to serious conflicts but the involved road users detect each other at an earlier stage and avoid the imminent risk of colliding in a more controlled way. Here the involved road users are more prepared - things do not happen 'all of a sudden' anymore. In the safety hierarchy these situations are found at a lower level than the serious conflicts. For some of these risky situations the severity lies in the fact that the road users are fairly close in time and space without actually interacting.

Further down in the safety hierarchy there is the 'almost almost near-accident', at an even lower severity level etc., all the way down to the events that are solved in a proper, safe, way at a very early stage and even further down to the events where the road users pass each other with satisfactorily safe margins. At the bottom of the safety hierarchy we find the events where both road users are very determined to solve the situation in a controlled and safe way. They detect each other at a very early stage and adapt their speeds and directions well in advance. Here we also find the events where the road users pass each other with margins of very good size.

The safety hierarchy should thus be a continuum from the top, the serious injury accidents, down to safe events characterised by early behavioural adaptation by the road users involved

1.2 Severity hierarchies based on different requirements

How can the safety hierarchy be made usable for practical applications, for instance to be used in safety assessment studies? The safety hierarchy has to be made operational. The operational version of the safety hierarchy is here called the severity hierarchy. I must try to aim at a severity hierarchy that with acceptable probability produces the sequence of events described by the safety hierarchy. In such a severity hierarchy an observed injury accident will more likely be located high up than far down in the hierarchy, i.e. an observed injury accident must with a fairly high probability to be regarded as a severe event. The most severe events are found at the top of the hierarchy, and then as the events become less and less severe, they are found further and further down in the 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 deal with encounters between road users.)

1) Closeness in time – time margins between the road users, before, during or after the encounter.
2) Closeness in space – space margins between the road users, before, during or after the encounter. The space margin can be measured either between distinct points, defined beforehand, of the road users or between the two nearest points of both 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. One encounter that is assigned a severity in one hierarchy might for instance not be included at all in another hierarchy. One and the same encounter might be assigned different severities, depending on the way in which the severity is estimated, i.e. with regard to for which severity hierarchy the encounter is estimated. The different hierarchies do, thus, presumably have some parts more or less overlapping while other parts could differ substantially. The reason for setting up a severity hierarchy based on certain presumptions is the belief in a correlation between the severity, defined by these presumptions, and safety.

1.3 The hierarchy concept used to connect behaviour and safety

It is most likely that the relation between the frequency of different events in the severity hierarchy depends on a number of factors like geometrical design, environmental factors etc., and human factors like road user behaviour. The understanding of the behaviour linked to different levels of severity of events, the connection between behaviour and safety, is however still fairly small. The fact is that traffic safety work and research often 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. It has been very difficult to prove statistically significant correlations between behaviour and injury accidents, first of all because the relationship is not deterministic, but rather probabilistic. Incorrect road user behaviour does not necessarily lead to a traffic injury accident, unless it coincides with other circumstances (e.g. overtaking when the sight distance is insufficient leads to collision only if there is an oncoming car, and the parties cannot find any way to avoid the collision), but the frequency of incorrect behaviour at a specific place or by a specific road user is correlated with the probability of an accident. There are, however, empirical behavioural studies which attempt to relate behaviour to safety in different situations (Draskóczy, 1990).

In this context, speed is in some respects an exception. Studies have shown a firm relationship between speed and safety (Nilsson et al., 1991), (Baruya & Finch, 1994), (Baruya, 1997). This relationship is primarily only valid for mean speeds; how the individual speed affects the safety outcome is still not fully elucidated. There are, for example, no theories about how a changed level of the individual vehicular speed, speed adaptation, changes the safety situation. At what moment in the course of events and to what extent does the vehicle speed need to be adapted in order to, for instance, change the crossing behaviour among pedestrians and thereby give the pedestrians a chance to cross safely?

1.3.1 Traffic engineering safety work

In traffic engineering, road user behaviour is, with the exception of speed, if not overlooked, at least not given primary attention. Solutions to traffic safety problems are often chosen among different geometrical designs. By modifying the environment, the road user behaviour is influenced and the safety situation is changed. We engineers are of course fully aware of the fact that factors like expectancy and quality of the communication are important when it comes to explaining changes in behaviour and safety. But, nevertheless, we often skip the behaviour part and try to make a direct link between introduced measure and safety outcome. This is not by any means wrong, but I think the understanding of the safety outcome by different measures could increase considerably, and the design of the measures would probably be improved towards the optimum, if we were to understand how and why road user behaviour changes and how the behaviour change is linked to any injury accident change observed.

More detailed analyses

Traffic safety assessment is often very difficult due to the fairly small data sets. It is almost exclusively only the information from the most severe events in the severity hierarchy that is used. The basis for estimating the consequences of traffic safety measures is almost always police-reported injury accidents, in exceptional cases extended to also include police-reported damage-only accidents. Here the main interest is focused on accident frequencies and accident consequences. When making an estimate of the safety effect of an introduced measure, accidents are studied before and after its introduction. Today, this is the knowledge that traffic engineering safety work is based upon. There might, however, be traffic safety information to obtain while studying less severe traffic events – not to clarify if an accident will happen or not but to clarify how the road users generally behave under different conditions. Studies show that more thorough knowledge about different measures' safety effect is achieved when the before and after studies also include conflict and other behavioural studies. In one such study, Towliat & Ekman (1997), pedestrian safety problems when pedestrians are to cross a road with more than one lane in each direction, at a pedestrian crossing, are analysed. The safety problem arises when a vehicle has stopped to let a pedestrian cross and this vehicle is overtaken by another vehicle in the adjacent lane. To promote safety, a buffer zone before the pedestrian crossing was created. The hope was that this measure would induce the vehicles to stop before the buffer zone and also increase the willingness to give way to a crossing pedestrian. Conflict studies before and after the introduction showed no change in the number of serious conflicts. Other behaviour studies, such as speed measurements and observation of vehicles stopping to let pedestrians cross, supported this result by not finding any change between the before and after period. This study gave a quick answer to the question of possible safety effects. Instead of putting resources into a measure that "might have promoted safety" these resources can now be put into finding more promising solutions to the still-existing problem.

The analyses of the results in the study above were improved by complementing the conflict studies with other types of behavioural studies. The conflict studies themselves could however also be developed in order to become more effective. Often the conflicts are analysed and used in a very aggregated way. The details of the behaviour are seldom revealed. If the before and after studies, generally, were to be based on an even larger data set, by also including even less severe events from the severity hierarchy, analyses could be performed on a more detailed level. It is very probable that we could then achieve an even better understanding of the behaviour changes involved and how that influences a measure's safety effect.

Examples of traffic engineering measures

An example of a traffic engineering measure in the road environment which produces a dramatic change of behaviour and safety is the elevated zebra crossing. It reduces speed and improves communication between the road users; more drivers stop and let pedestrians cross (Trafikkontoret i Göteborg, 1994). It has been found that the frequency of the less severe events decrease when the crossing is elevated. According to Elvik et al. (1997), there are results that indicate that the frequency of the most severe events also decline. Why does this happen? Speeds are reduced – but how is the behaviour in other respects changed? Has the relationship between the severe and the less severe events remained unchanged or is there a shift in relations?

Traffic signals are installed with the partial aim of improving safety. At signals the numbers of primary conflicts are reduced considerably; the numbers of accidents, however, are not reduced to the same extent. This is partly due to red-driving and red-walking. Furthermore, unconscious red-walking quite consistently turns out to be more dangerous than deliberate red-walking (Linderholm, 1987). If all encounters for both types of red-walking could be studied, would a study of the differences in the severity hierarchies produce explanations of how a difference in behaviour might result in a difference in safety?

1.3.2 Psychological and sociological traffic safety research

In psychological and sociological traffic safety research there are many general theories about the correlation between behaviour and safety (accidents). The theories are, however, very seldom linked to traffic engineering factors such as intersectional design, regulation, characteristics of the vehicles etc. The theories are often described in very general terms and therefore difficult to validate against safety. According to Summala (1996) the problem is not the theories as such but that they often lack testable hypotheses - ”to explain changes in accident loss adequately, the related behavioural changes should also be found”. Over the years, many different theories to explain why road users (with emphasis on drivers) behave as they do in traffic have been proposed. Thus, to obtain a relation between these theories and safety consequences, the theories must be converted into testable (measurable) variables in terms of behaviours.

Summala mentions for instance Wilde’s risk homeostasis theory, which is based on the assumption that a driver adapts his/her driving behaviour in such a way that a balance between what happens on the road (the perceived risk) and the level of risk that the driver can accept (accepted risk) is achieved. To gain knowledge about the correlation to safety, it is vital, according to Summala, to ask questions like - What mechanisms give the individuals their experience of risk? What is it in the traffic environment that informs the driver about the risk?

Summala also mentions the zero risk theory (Näätänen & Summala, 1976) which, in contrast to Wilde’s risk homeostasis theory, presumes that risk is not the only motivational module. Other motives to satisfy are for instance hurry, maintaining speed and conservation of effort. The zero risk theory says that risks normally are avoided by staying within certain safety-margin thresholds and that behaviour is corrected when the safety-margin threshold is violated. Here Summala emphasizes the necessity of getting knowledge about this unknown mechanism that sees to it that the safety margins are not exceeded. I see a clear connection between this 'safety-margin threshold' and the safety margins implied in the severity hierarchy. The first is a subjective, individual, safety margin and the latter probably an objective one, measured by physical parameters. There is, however, a possibility that the two might meet. It has, for instance, been possible to objectively discriminate between serious and non-serious conflicts at the same time as involved road users characterise a serious conflict as a situation they do not want to participate in voluntarily, i.e. there is a lack of both safety margins (Hydén & Ståhl, 1979). On the whole it might be possible to operationalise traffic safety theories (both traffic engineering and psychological and sociological) to make a connection between behaviour and safety by using the severity hierarchy, i.e. by studying relationships between events of different severity.

1.4 A need for behaviour-based framework in exploring traffic processes

To round off this introduction to my thesis work, I would like to stress the necessity to make a first move towards taking interactive road user behaviour into consideration in order to more comprehensively understand the processes in traffic; processes that sometimes result in accidents but so much more often go no further than to 'normal' traffic events. In order to discuss these processes it seemed very relevant for me to analyse events of different severity and try to understand how different relations between these events might produce differences in safety. This approach presupposes the existence of a continuum of safety related events, a hierarchy with regard to safety. The aim of my work should be seen as an attempt to provide a framework for exploring different traffic safety theories by taking the whole hierarchy of severity related events into consideration.

2 Attempts towards a severity based hierarchy

2.1 Background

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 and vehicle environment. The interaction between road users contains communication. The quality of the communication is influenced by the perception of the current situation by the road users. Depending on the norms, attitudes, a priori knowledge about similar situations, information regarding this specific situation etc., different expectations among the different road users are created. These expectations then set the scene for individual behaviour regarding choice of speed, level of attention etc. The communication between the road users can be said to be good or bad depending on how well the expectations, and the thereby derived behaviours, are in accordance with the actual prevailing situation. 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 and vehicle environment, the situation must be considered as being unsafe. The most severe events in the severity hierarchy indicate such total breakdowns in the interaction. These are often due to breakdowns in the communication.

Accident data analysis

The interest in the whole safety hierarchy is a fairly new approach. The traditional way of approaching traffic safety has mainly been concerned with the occurrence of traffic accidents and their consequences. The disadvantages of accident data analyses have been discussed extensively in several papers, e.g. Englund et al. (1998), Grayson & Hakkert (1987). The problems connected to the use of accident data for traffic safety evaluation have made it quite obvious that there is a need to widen the scope. Accidents are, for example, 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, additional information is very often 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 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). But most importantly, the behavioural or situational aspects of the events are not covered by police accident data. As pointed out in the previous chapter, it is for example 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.

Sometimes, for various reasons, accident data do not exist at all. This is for instance the case in countries with no established routines for collecting accident data in a structured way. Or when a totally new measure is to be introduced, there is no historical accident data to indicate possible safety effects of the measure. Before introducing such new measures on a larger scale it is, of course, desirable to know their safety effect. This demonstrates the need for quick and valid results from perhaps many different small-scale trials. Accident analysis is presumably not the most relevant tool to use in such circumstances.

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 whole safety hierarchy. As a first step towards including less severe events than injury accidents in the hierarchy, the following requirements can be set up:

- The events in traffic that are to be complements to accident data have to be much more frequent than the accidents.
- These events have to be observable in traffic.
- The utmost requirement is that the complementary events have to have a correlation to accidents. Not only a statistical relationship but also a very clear causal relationship to accidents.
- These events must be characterised as being almost accidents. When these events get a location in the severity hierarchy they must be placed right next to the accidents with regard to severity.

The events that fulfil all these preconditions are called traffic conflicts. The development of the Traffic Conflicts Technique (TCT) has been the first attempt to explore and utilise the severity hierarchy.

2.2 Traffic Conflicts Techniques

2.2.1 Definitions and some operational techniques

The first (known) conflict technique was presented in 1968 by Perkins and Harris at General Motors Laboratory in the USA (Perkins & Harris, 1968). The task was to study intersections and see whether GM cars performed differently in comparison to other makes of car with regard to safety. This first definition of a conflict was mainly based on brake light indications. Since then a number of different conflict techniques have been developed in different countries. The first International Traffic Conflicts Workshop was held in Oslo in 1977. Here a group of researchers assembled from many parts of the world decided upon a general 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.'

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 (previously referred to in Chapter 1). 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 pyramid based on the TA/Speed concept can be seen as one of the severity hierarchies (other severity hierarchies are based on other presumptions).

> 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.

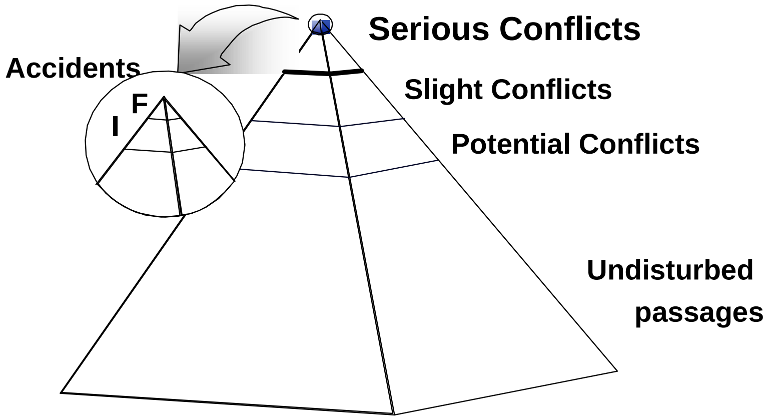

Figure 2:1 The pyramid - the interaction between road users as a continuum of events (Hydén, 1987)

Hydén's definitions of the different events in Figure 2:1:

Undisturbed passage - The road users pass independently of each other

Potential conflict - The road users are closer and have to cross each other's routes. There is a smooth and very early interaction.

Slight conflict - A situation where the road users have a collision course and start an evasive action. The situation is characterised by being under control and the evasive action is not the type of emergency breaking.

Serious conflict - The evasive action starts late and the impression is such that the situation easily could have ended up in an accident instead.

Accident - The evasive action started too late, or there is no time for an evasive action at all - a collision is unavoidable.

DOCTOR, the Dutch TCT, is developed by the Institute for Road Safety Research SWOV and the TNO Institute for Perception in the Netherlands (van der Horst & Kraay, 1986). The definition of a conflict in DOCTOR is a combination of the probability of an accident and the expected loss (injury etc.) in the case of the resulting accident. According to DOCTOR,

> ‘A conflict is a critical traffic situation in which two or more road users approach each other in such a way that a collision threatens, with a realistic risk of injury or material damage if their course and speed remain unaltered. The available space for manoeuvre is less than needed for normal reaction.’

The probability of a collision, in DOCTOR, is determined by the TTC (Time-To-Collision) and/or PET (Post-Encroachment-Time). TTC is a continuous function of time as long as there is a collision course; the time required for two road users to collide if no evasive action is taken. (Note that the TA value (Time-to-Accident) in the Swedish definition is the TTC value at the moment an evasive action is started.) TTC_{min} is the lowest value of TTC in the approaching process of two road-users on a collision course. Analyses show that TTC_{min} values less than 1.5 sec indicate a potential dangerous situation in urban areas. 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 conflicting point. A PET situation measures the closeness in time by the time margins between the road users after the encounter, in contrast to the TTC where the time margin is measured before and during the encounter. Since a slight disturbance in the process causes an imminent risk of collision it is understandable to also include this kind of event in the definition of a conflict. For built up areas PET values less than 1 sec are critical. In DOCTOR the observer estimates TTC_{min} or PET.

Work with DOCTOR (Risser & Tamme, 1987; van der Horst & Kraay, 1985) has shown that there is 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. This implies content of safety information in situations that are close enough in time and space without necessarily having a collision course.

A calibration of eight different traffic conflict techniques in Malmö, Sweden, (Grayson, 1984) showed that all calibrated TCTs work according to the same severity scale even if they differ in other dimensions. Analyses of the study found the TTC_{min} to be the most important factor in explaining common severity for the different TCTs. The second most important factor was found to be the minimum distance between the road users. The minimum distance was measured between the two nearest points of both road users before, during or after the encounter. The correlation between severity score and conflict type, i.e. type of road users and type of manoeuvre, was also found to be high.

2.2.2 Reliability and validity

Reliability and validity are two issues strongly connected to the usability of TCT. The external reliability of observers answers the question if the observers are able to distinguish serious conflicts from other events in the same way among themselves and in accordance with the conflict criteria. In the Malmö international calibration study, there was an opportunity to check the subjective estimates with objective measures (analyses by Hydén (1987) from results of Grayson(1984)). The Swedish conflict observers' estimate of TA values were just about as often an overestimate as an underestimate. On average, however, the observers' estimates were somewhat biased with a 0.05 second difference from the objective evaluation. There was a tendency to underestimate high objectively measured TAs and overestimate low objectively measured TAs. When comparing the figures on speed, there was also found to be a small bias. The estimates of the speeds were on average 3 km/h lower than the objectively measured speeds. The analysis also showed that the observers failed to score about 26% of the conflicts that should have been scored. These results are generally very encouraging and the conclusion is that human observers are able to detect serious conflicts and make satisfactory estimates of the speed and TA value.

Validity in this context means to what extent conflicts describe the phenomenon in traffic that they are intended to measure. Some state that the validity of TCT depends on how well it can predict accidents. This is sometimes called product validity, i.e. to what extent serious conflicts can be used in order to predict the number of accidents. Hauer and Gårder (1986) have looked into the issue of validity and they state "some will regard the TCT as valid if it proves successful in predicting accidents; others will judge validity by the statistical significance or the magnitude of the correlation between conflicts and accidents". There is in other words some confusion. They try to overcome this problem by defining safety for some part of the transportation system (for example an intersection) as expected number of accidents per unit of time. They continue that "the proper question to be asked is: how good is the TCT in estimating the expected number of accidents". In this sense the TCT should be compared to other methods, e.g. accident data or exposure, and comparisons should be made between the variances of the estimates. Hauer and Gårder conclude, in their attempt to make a final definition of 'validity', that "A technique (method, device) for the estimation of safety is 'valid' if it produces unbiased estimates, the variance of which is deemed to be satisfactory."

Both the Swedish TCT and the US TCT have been validated following this theory. 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 validation of the US TCT, the expected accident frequencies estimated by conflicts and accidents proved to be very close to the actual observed accident frequencies (Migletz D J et al., 1985). The conclusion from this work is that traffic conflicts of certain types are good surrogates of accidents in that they produce estimates of average accident frequencies nearly as accurate, and just as precise, as those produced from historical accident data.

Process validity means the extent to which conflicts may be used for describing the process that leads to accidents. The process is here understood as the events preceding the accidents. In the process validation work of the Swedish Conflicts Technique, Hydén (1987) has compared the processes preceding injury accidents to those preceding conflicts. The greatest problem here has been to get information about the pre-crash phase in accidents. It was, however, possible to compare the last part of the pre-crash phase of accidents and conflicts, from the moment that one road-user takes evasive action.

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. It also showed that the distributions of different types of evasive action were very equal for accidents and conflicts. The conclusion of this validation study is that conflicts work satisfactorily as substitutes for accidents in this respect. It is quite possible to clarify, at the same time as collecting the conflict data, the events preceding the conflicts and thereby the accidents. These events are the ones that lead to the breakdown in the interaction.

2.2.3 Conflicts as part of the process

The approach here (to see the hierarchy of severity as a continuum with conflicts as a part of the continuum) is not approved by all researchers according to Gηttinger (1984) and Rajesh (1995). The opposing argument is that after knowing the result of the evasive action the possible outcomes are either an accident, a conflict or normal traffic continuation. The conclusion is that a conflict can’t lead to a collision. The conflict is an event parallel to the collision, a substitute to the collision.

As I see it the main differences between the two approaches are a) if the conflict is the precondition for an evasive action or the outcome of an evasive action b) if conflicts and accidents are substitutes (part of the same traffic process describing traffic unsafety) or if they are parallel events. An argument that often has been raised in connection to the approach that the conflict is to be seen as an event parallel to the collision, is how we, from a serious conflict where there evidently never was a collision, can say that there is a probability of an accident. They didn’t collide - even if they repeat the same situation over and over again - they will never collide. The conflict is a conflict and could be very nasty but it is not a collision.

Yes, this particular serious conflict, with this particular setup of preconditions, is not a collision. And from only one serious conflict it is not reasonable to try to estimate the probability of an accident. Instead we analyse this serious conflict together with a number of similar serious conflicts at the same site, with collision course as the foremost important common precondition, but also with the same type of manoeuvre and same type of road users involved etc. If the conflict observation is carried out during a "very" long period of time, then it is also more likely that a serious conflict with the highest severity, an accident with serious injuries, will be recorded. Traffic can be viewed as a dynamic set of probabilities of various occurrences. An accident is the product of the simultaneous realisation of different probabilities of failure as two road users move towards each other and end up on a collision course and collide. Any conflict where at least one of the probabilities for failure does not materialise is an accident-related conflict. In other words, from the serious conflicts, with slightly different preconditions and therefore slightly different severity, it is possible to estimate what types of collisions could occur if the prevailing preconditions were a bit less advantageous.

In the validation work referred to earlier (Hydén, 1987) there was a rather big overlap between accident plots and conflict plots when compared in the TA/Speed dimension. Thus, there are events with the same position in the TA/Speed graph that sometimes result in an injury accident and sometimes result in a serious conflict. This overlap indicates that injury accidents and serious conflicts are events in a common continuum. If we agree upon the continuum of events, then it is logical to assume that this continuum is continuous towards events with less injury accident potential as it is continuous towards situations with higher injury accident potential.

2.2.4 Conclusions

When the interest now is to extend the scope of safety analyses, to also cover parts of the severity hierarchy with less severity, the conflict concept is a good basis. Research is always more advantageous if it builds on already established knowledge, instead of beginning from scratch and, so to say, inventing the wheel all over again. Experience with the TCT has shown that it is possible to include less severe events in the safety hierarchy, serious conflicts, and achieve better understanding of the process and the relation between events with different severity in the severity hierarchy. The TCT is, however, restricted to the very top of the severity hierarchy, where the probability of locating an accident with serious injuries is high. The safety estimates from conflict studies are also primarily used on an aggregated level. The conclusion is that it might be very feasible to extend the concept towards less severe events in the severity hierarchy and thus increase the possibility of working with safety estimates on a more detailed level.

2.3 Extension of the concept towards the whole traffic process

Work with the Swedish TCT has played an important role in describing the traffic process as a severity based hierarchy. The aim is now extended to include even less severe events, i.e. to move even further down in the hierarchy to get an even better picture of the shape of the hierarchy. To realise this attempt, the concept must be extended to also include more normal traffic behaviour, not only exceptional behaviour. Thus, there is an aim to also include those so much more frequent events, where the situation is solved at an earlier stage and where the injury accident potential is low due to better adaptive behaviour and a higher degree of control. At the same time as events with less severity are included, it is vital to maintain the link to the events with higher severity, i.e. to ensure that the continuum is maintained.

2.3.1 Traffic process

The meaning of the word "process", according to the dictionary, is equal to the expressions "course of events" or "development". Applied to traffic, the expression traffic process would, in a broad perspective, embrace all events and characteristics of the transport system, with the intention of describing the course of events. The traffic process would include movements of people, vehicles, cargo and encounters between road users, encounters between road users and the road and vehicle environment etc. in the transport system. To study the traffic process could be associated with the study of the course of events in the transport system, i.e. to study what happens in traffic, to study relationships between different events in traffic etc.

The traffic process can, however, be defined in different ways. In the context of this study, the aim is to examine the traffic safety process or, as stated before, it should more correctly have been called the process of unsafety as the aim is to study the course of events towards accidents, to study the relation between events with regard to unsafety. Anyway, if there is no connection, continuum, between the events then there is no possibility to talk about events in the traffic safety process. The traffic safety process can of course refer to the processes preceding all accidents, but here it is restricted to the processes preceding accidents between two or more road users. 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.

From an engineering point of view, the uttermost interest is to study the traffic process with regard to different traffic engineering measures. The traditional procedure, both in accident analyses and conflict analyses, is to select a location and there study the course of events in terms of accidents and serious conflicts. The interest lies within the scope of how, with the help of information from different individual road users with different individual behaviours, as a "collective", we can describe what happens in connection with different traffic engineering measures. Another possibility of studying the process is to follow individual road users for a certain time or along certain routes to describe the different interactive situations that he/she gets involved in. This method has been used for conflict observation by Gηttinger (1984) and was found well suited for comparison of larger environment units (e.g. neighbourhoods), for the detection of high risk spots within large areas or to trace the relative risks of routes or groups of pedestrians. There is also a method called Wiener Fahrprobe (Chaloupka & Risser, 1995) where car drivers follow certain routes and a conflict observer accompanies the driver in the car. This method has been developed in order to relate different types of interactions to different types of accidents.

2.3.2 Events in the traffic 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, the approach can be said to be Bottom-Up oriented. One advantage by the Bottom-Up approach would be that we would most probably find accident related events that we otherwise would have ignored as quite “normal behaviour”. It is however very difficult to follow this approach and construct a clear picture of the relations. There are too many events, and every single event is unique in some way. A perhaps more feasible way to go is 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. This could be called the Top-Down approach and is completely opposite to the Bottom-Up approach. If the Top-Down approach was proposed, 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 these 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.

2.3.3 Severity of the process

The severity of the events in the severity hierarchy, or the serious injury accident potential of the event, can be set up with regard to different criteria. This has already been mentioned in Chapter 1.2 “Severity hierarchies based on different requirements”. The different criteria are based on physical parameters in order to make the severity operational; closeness in time, closeness in space, closeness in time and space.

In the calibration studies in Malmö, Sweden (Grayson, 1984) and in Trautenfels, Austria (Risser & Tamme, 1987), the calibrated conflicts techniques were of both the quantitative and the subjective kind. All techniques did, however, agree upon the use of a severity scale. Once a conflict is detected and evaluated there seems to be a high agreement upon a common severity scaling. There are of course different ways of structuring the different presumptions that form the basis of the different severity hierarchies. Some of these ways apply quantitative and some subjective estimates of safety. The subjective estimates are, as I see it, estimates of physical parameters but expressed in qualitative terms like: the evasive action is started a long/moderate/ short time before the possible collision point; a subjective estimate of the power of the evasive action; a subjective estimate of the safety margin between the road users – if it is big/moderate/small; the degree of control in the situation etc. The quantitative estimates are in terms of: minimum distance (in meters) or time margin (in seconds) between the road users; time margin (in seconds) between the road users in relation to speed (km/h) when the evasive action starts; deceleration needed to avoid an accident etc. The classification can further be based on the necessity or not of a collision course between the road users and also on the necessity or not of evasive action. The different possibilities of defining the severity of a process can be illustrated as a tree that branches off:

Collision course needed or not needed
- Evasive action needed or not needed
  - Quantitative or subjective severity assessment
    - based on proximity during the approach or at a certain point during the approach, or
    - based on proximity at the collision point
    - based on proximity after the collision point, or
      * the proximity can be based either on the time or space margin or on both, or
    - based on collision impact

To exemplify the different possibilities of defining the severity of a process, I describe below the quantitative assessments: TA/Speed, TTC, PET and distance. All of these can of course also be subjective estimates.

Time to Accident / Speed (TA/Speed)

The TA/Speed value is based on the necessity of a collision course and evasive action. The proximity is estimated at a certain point during the approach; at the time of evasive action. The proximity is estimated from the time and space margin with the help of introducing Conflicting speed. An event with a low TA and a high Speed value indicates an event with high severity. Speed is a logical choice for a severity measure as it correlates with the collision impact in case of the realisation of the accident.

Time To Collision (TTC)
The TTC value is also based on the necessity of a collision course. The proximity is estimated during the approach. The proximity is estimated from a continuous estimate of the time margin. The TTC_{min} is a specific estimate of the TTC. It is the minimum TTC during the whole course of the event. A low TTC or TTC_{min} indicates an event with high severity.

Post Encroachment Time (PET)
For the PET value there is no necessity for a collision course or evasive action. The proximity is an estimate of the time margin after the collision point. A low PET value indicates an encounter with high severity.

Distance
The distance between the involved road users requires neither a collision course nor evasive action. The proximity is estimated from a continuous estimate of the space margin. The minimum distance is the minimum space margin during the approach or at the collision point. It is perhaps difficult to argue that distance in itself would indicate a certain level of severity, but if distance were analysed together with speed then it would perhaps be possible to say that an encounter where the distance between the road users is small and the speeds of the road users are high would indicate an encounter with high severity.

What does it now mean if we have different severity hierarchies based on different assumptions? It has partly to do with the assumption about what parameters would be the best indicators of severity; whether it is the safety margin measured by time, space or time and space etc.; whether the estimates must be objectively measured (either by a machine or by observers) or if there are advantages of having trained observers estimating the severity on a subjective severity scale. Then it has also to do with the assumption about in what phase of the process the severity of the event is best reflected. Is the severity of the event best reflected at the moment when the road users approach each other and at least one of them takes evasive action? Or is the severity of the event best reflected by how close the road users get in terms of minimum distance or minimum time as they approach each other or just pass each other? The very same event can, consequently, be assigned different severities, depending on by which criteria the severity is estimated, i.e. into which severity hierarchy the event is assigned.

Validation work with the Swedish TCT (see 2.2.2) has indicated a correlation between serious conflicts, where the severity has been assessed by using the TA/Speed value, and police reported injury accidents. There is a critical line in terms of TA/Speed values that separates the serious conflicts from the non-serious ones. This can be interpreted as a safety margin expressed in TA/Speed values that is recognised both as a threshold for the involved road users and for the trained conflict observers. The evasive action as such can therefore be seen as an action taken in order to keep within certain safety margins. When less severe events are to be included in the traffic safety process it seems to be important to assign the evasive action criteria to these events as well, in order to maintain the continuum.

2.3.4 Collision course

In the pyramid, Figure 2:1, the approach by Hydén (1987) was to build a relationship between safety related events but not necessarily with a collision course as a base. The events at the bottom of the pyramid ("the undisturbed passages") were, for instance, defined as situations where "one road user is passing the intersecting point without being at all influenced by the presence of any other road user". In the Swedish TCT, however, where the severity scale of the pyramid is accomplished by applying the TA/Speed dimension, i.e. the Conflicting Speed and the Time to Accident value (TA value), the collision course is a precondition.

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. There are of course situations where more than two road users are involved in an accident, but then it can be analysed as if they collide two at a time; first there is a collision between two road users, then there is a collision between a third road user and one of those who has already collided etc. A collision presupposes a collision course. 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 get into a collision course just before the collision, the possibilities of avoiding the collision have diminished.

Some emphasis has been put on the question whether an accident was preceded by an evasive action or not. The fact that some accidents occur without any previous evasive action somehow "proves" that there are types of accidents that do not have any corresponding "accident-like" situations (conflicts) as a result of the TCT concept. As I see it the most essential contributing factor to whether a situation will turn out as an accident or not, is not whether the situation included an evasive action or not, but if there was a collision course. No collision course - no possibility for an accident to occur. Relevant "accident-like" events in line with the TCT concept should therefore be situations that include a collision course.

Now the importance of the evasive action is revealed. Not as a primary factor - that is the collision course - but as a secondary factor. Without the evasive action, situations with a collision course would always end up as collisions. Accidents are situations with a collision course, either where the evasive action started too late in order to avoid the collision or where the collision occurred already before any of the road users had the time to begin evasive action. Theoretically the latter case is dealt with using negative TA values (Hydén, 1987). If there is no evasive action before the collision, then, according to Hydén, the TA value is set to 0. This must be interpreted as if the evasive action starts at the moment of collision. This can, however, not be true for all accidents with TA=0. In some situations the case must be that the threat was detected and the evasive action was under preparation and would have started some time after the collision. This implies negative TA values.

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[1].

2.4 Conclusions

To sum up the discussion on the events in the traffic process, the following synthesis can be presented:

- The traffic process can be seen as a continuum of events.
- One part of this process, a continuum within the continuum, consists of the events with the basic prerequisite for an accident - they have a collision course.
- These situations exist at all times everywhere in the transport system.
- Depending on how and when the fact that they are moving on a collision course is solved, the severity outcome differs.
- The severity ranges from situations where one or both road users adapt their speed and/or direction, consciously or for other reasons, in ample time to situations where the road users are so close in time and space that none of them has the time to even start an evasive action before they collide. That is, the events in this continuous process range from events with a low serious injury accident potential to events with a high corresponding potential.
- The severity scale for the events within the traffic process can be accomplished by different presumptions. The use of the TA/Speed value is a good way to assess the severity of situations having a collision course. With this approach it is possible to argue that a traffic event with a collision course is to be seen as a natural part of the continuous process that describes the safety continuum. Traffic events with a collision course where interactive behaviour is a precondition to avoid an accident, are henceforth called interactions.

This leads to the following definitions of the different events in the safety process chain. All events presuppose a collision course:

Accident - No distinct limit between serious conflicts and injury accidents. Serious conflicts include both serious conflicts as near-misses and serious conflicts as accidents. An accident is regarded as a serious conflict even if the evasive action doesn’t start before the collision. In theory, according to the distribution of the accidents, it would be possible to also find accidents in the area defined below as adaptive situations. On the whole, however, it is more likely to find the severe injury

[1] Definition of a collision course: Unless the speed and/or the direction of the road users changes, they will collide

accidents in the more severe layers in the severity continuum (higher speeds and lower TA values) and the damage-only accidents in the layers of lower severity (lower speeds and higher TA values).

Serious conflict - There is a distinct limit between the serious conflicts and the events beneath in the hierarchy, below defined as adaptive situations. This threshold is set in earlier validation studies.

Adaptive situations with higher severities – Compared with the adaptive situations with lower severities, the road users in these situations either detect the potential danger later or wait to take preventive action until the danger is more imminent. Another possibility is that the road users do not start to approach each other on a collision course until they are a bit closer in time and space as compared to the adaptive situations with lower severities. In these adaptive situations with higher severities the safety margin starts to decrease to an extent that is not comfortable to both road users.

Adaptive situations with lower severities - In this type of interaction at least one of the road users recognises the potential danger in the situation, if it is allowed to continue, and therefore takes a well-controlled evasive action in due time. The other road user(s) will perhaps never discover the potential threat in the situation or perhaps not even recognise that there is an interaction at all. The interaction is solved in a proper way before it develops into something that would require some kind of action from the other road user(s).

3 Shape

The events in the traffic process form a hierarchical order with regard to safety. As argued in the previous chapter, the severity of the hierarchy can be based on different presumptions. In the safety pyramid the events are defined in terms of a collision course, evasive action and TA / Speed value. The severity of the event is determined at the moment of the evasive action. The TA /Speed value at the moment of evasive action positions the event in the safety pyramid based on its severity. The relationship between the number of events of different severity can be analysed through the shape of the pyramid and also illustrated in terms of ratios. The Swedish TCT, for instance, works with the accident to conflict ratio or conversion factor, which for Swedish conditions is in the region of 1 accident per 1 000 to 100 000 conflicts, i.e. 1×10^{-5} – 100×10^{-5} . Most of what will be said in this chapter is valid for most severity hierarchies: that the hierarchy can be disaggregated; that there are ”true” hierarchies; what it is that makes the hierarchy shape interesting etc.

3.1 Formation of the pyramid’s shape

3.1.1 Estimates of the ”true” pyramid

Through observations of accidents, conflicts and other interactive situations we can make estimates of what the relationship, the shape of the pyramid, might look like. The observed relationship between events with different severity can never be anything but estimates of the ”true” relationship. The ”true” pyramid shape is the shape we would get if we were able to make observations during an infinite time and with a perfect registration method. The variance of the estimate will, thus, decrease the more data there are on which to base the estimate. The ”true” pyramid represents earlier interactions, current interactions and future interactions. The pyramids reflect the sum of the individual behaviours in the road user population at the location: the expectations, the choice of action, the choice of speed, the degree of control etc. Interactions are handled with different success with regard to safety. Depending on the prevailing situation, whether the road users at any time move on a collision course or not, the situation belongs to one or several severity pyramids or none at all. Once on collision course, factors like choice of speed, closeness in time and space, expectancy, level of awareness etc. determine where in the pyramid the event gets a position, its severity.

3.1.2 Getting a position in the pyramid

Probability of entering on a collision course

The probability of having an interaction with a collision course, i.e. of belonging to the pyramid, must be linked to the total number of possible interactions. The number of possible interactions is linked to the magnitude of the interacting (conflicting) flows. The magnitude of the interacting flows in turn depends on type of intersection, section, geometrical design etc. and of course exposure.

Irrespective of everything else, with larger interacting flows there will be a higher probability that two road users will happen to move on collision course. That is, everything else equal, intersections with larger interacting flows will have more interactions than intersections with smaller interacting flows. Then there are of course factors related to road, design and geometry, due to which the relationship between interacting flows and the number of interactions with collision courses is not straightforward. For the individual road user, the relation between the magnitude of the interacting flows and the total flow, is important for the probability of being involved in an interaction while passing a certain location. If the interacting flows are comparably high, the probability of entering a situation with a collision course is also high and vice versa.

The size of the pyramid for a specified location in a fixed period of time is interesting in the sense that it gives information about the volume of the interacting flows. But it is the shape of the pyramid, irrespective of size, that gives information about the probability of having an interaction of a certain severity, once there is an interaction.

Process of an event on a collision course

The formation of a pyramid’s shape is interesting as it makes it possible to describe the processes from where traffic events become interactions, where road users start to move on a collision course to where they eventually crystallise into events of different severity. That is, to describe the process of how the severity continuously increases, how the TA / Speed value becomes continuously more severe, as two road users proceed on collision course. The relatively large base of the pyramid would then reflect the many possibilities to still handle the situation safely, as in terms of control, freedom of action etc. The narrowing top of the pyramid would reflect the decreasing possibilities of handling the situation safely.

Shape as a pyramid?

Which is a probable ”true” shape as a result of describing the relationship between the interactions of different severity? As stated before, the events with the most severe safety consequences are also the most rare. Hence, the shape of the top of all pyramids must be more or less peaked. The rest of the pyramid will most probably not resemble much of a real ”pyramid” with a horizontal base etc. It is more likely that the number of interactions does not continuously increase as the severity of the interaction decreases. There is a lowest limit when there starts to be a probability of taking evasive action. Two road users moving on a collision course have no reason to take evasive action when they are 1 000 km apart. The interactions with the lowest severity can be interpreted as the lowest limit when it starts to be probable that one road user starts to take evasive action as he/she approaches, perhaps still being so far away that it is impossible to determine whether a collision course exists or not. It is an evasive action for something ahead. Below the limit with the lowest severity the probability of taking evasive action must be zero. So a bottom with a peaked shape must be more realistic than a straight line above which there are numerous interactions, as depicted in the traditional pyramid.

Due to the probably poor compliance between the shape as a pyramid and the shape of the interaction distributions, the relation between the events of different severity will henceforth be called severity hierarchy or simply hierarchy. The idea is to imagine the hierarchy being in two dimensions, not three, as with the pyramid. When the hierarchies are illustrated in this chapter the severity increases vertically and the interaction frequency at each severity level is shown horizontally.

The convexity of the distribution is the part of the hierarchy between the peaked top and the peaked bottom, i.e. the part with most interactions. The shape and position of the convexity could possibly reflect the typical road user behaviour for that location / manoeuvre / road user type. This part could perhaps even be related to the average speed on an intersection leg etc. It could very well be so that the convexity in any hierarchy reflects the typical behaviour based on the desire to maintain constant speed, to maintain sufficient safety margins, to maintain comfort etc.

The evasive action as part of automatized behaviour

The shape of the hierarchy is a description of the evasive manner at a location, of a certain manoeuvre, for a certain type of road user category etc. By only observing the evasive behaviour, there is no possibility to find out what the major reason for the evasive action was. This is very problematic when, for example, we want to differentiate conscious speed adaptation from unconscious speed adaptation. According to Ranney (1994), who has based his further reasoning on Rasmussen’s theories, the road user has to a great extent become automatized concerning decision making and action taking in traffic (Englund et al., 1998) . Many actions in traffic are taken routinely and more or less automatically depending on the nature of the task, and the ability and experience of the road user. Road users’ behaviours in traffic can be classified with regard to level of mental control and with regard to types of tasks (see Table 3:1). Thus, the behaviour consists of three levels depending on level of mental control. They are called the knowledge-based level, the rule-based level and the skill-based level. The different levels of mental control reflect the degree of learning how to handle different actions; the ability to solve problems. A skill-based behaviour consists of well-practised behaviours in familiar situations. These behaviours are automatized and are performed without being conscious about a decision having been taken. A rule-based behaviour means an automatized activation of well-practised rules which have been initiated in previous less familiar situations. The knowledge-based behaviour involves conscious decision making in situations where there is little or no previous knowledge to base the decision on. By far most behaviour occurs on the skill-based and rule-based levels; it is likely that drivers are rarely conscious of their decision making until knowledge-based problem solving is required.

Table 3:1 Classification of selected driving tasks by Michon's control hierarchy and Rasmussen's skill-rule-knowledge framework (adapted from A. R. Hale et al. 1990, Figure 1, p. 1383). Citing Ranney (1994) Figure 1 p. 743.

\ Task Level of \ mental control \	Strategic	Tactical / Manoeuvring	Operational/ Control
Knowledge	Navigating in unfamiliar area	Controlling skid	Novice on first lesson
Rule	Choice between familiar routes	Passing other vehicles	Driving unfamiliar vehicle
Skill	Route used for daily commute	Negotiating familiar intersection	Vehicle handling on curves

The types of tasks are also divided into three different levels. First there are the tasks with strategic characteristics like planning a journey, selecting routes. At the tactical or manoeuvring level there are the tasks that are handled during the journey like negotiating curves, interacting with other road users etc. The operational level consists of tasks that mainly have to do with the control of the vehicle like braking, shifting gears etc. Moving around in traffic implies that different kinds of decisions on different levels have to be taken at the same time as the road user has to handle different types of tasks. Most tasks are handled automatically and most tasks are handled on the tactical or operational level. Hence, the road user is rarely conscious of the decisions taken. When the decisions are taken on the strategic level and when there is no automated behaviour to rely on, the automatic behaviour has to be interrupted and the decision is made consciously.

Ranney suggests that there might for instance be an automation with regard to route selection which is independent of other day-to-day variations. ”Alternatively, the similarities among curves or intersections may be sufficient for development of automatic action patterns, despite geometric differences between individual intersections or curves.”

Here the point is first of all that behaviour in traffic is more a routine than conscious. It is therefore necessary to study routine-based normal behaviour in traffic and analyse to what extent parts of this automatized behaviour are correlated to behaviour involving accident risks. That is, whether the adaptation of the speed as the pedestrian approaches an intersection is conscious or not is perhaps of less importance as long as it reflects the normal behaviour as a part of the traffic process. So unless the different situations are disaggregated to a great extent, I will only be able to talk about general patterns of the severity hierarchy. The distribution of TA/Speed values will reflect the adaptation due to collision course but also the adaptation due to approaching an intersection of a special kind, and all those considerations that this brings about for the road user. In connection to the theory about level of mental control it could have been interesting to link the shape of the hierarchy to decisions made on the knowledge-based, rule-based and skill-based levels. In the time-based continuum it would perhaps be possible to relate the different levels to different safety margins, i.e. to different adaptive behaviour and hence to different shapes. Could it be that at the top parts of the hierarchy most decisions, evasive actions, are made on the knowledge-based level and that the convexity of the distribution reflects the skill-based behaviour?

3.2 Factors affecting the shape

Different types of interactions take place at different types of locations. The involved road users, the manoeuvres etc. are of different types. It must be assumed that the safety level at a location is dependent on a number of factors like whether vulnerable road users are present at the interactions or whether the majority of the interactions take place between vehicles driving straight ahead etc. Do different traffic engineering solutions produce different shapes of the hierarchies and in case they do, why? How is this related to road user behaviour? Please note that the hierarchies in this chapter refer to the ”true” hierarchies, the shape of the hierarchies that would be achieved if the interactions were observed during an infinite time period with a perfect observation method.

3.2.1 Factors of importance

Studies (Hydén, 1976; Linderholm, 1981) show that there is a stability in the relationship between the number of accidents and serious conflicts with regard to manoeuvre type. For perpendicular car / car interactions (the angle between the intersecting road users is ≥ 90^o), the ratio is quite stable around 1 police reported injury accident per 8 000 serious conflicts. This is to be compared with the ratio for parallel car / car interactions (the angle between the intersecting road users is < 90^o), which is around 1 per 36 000. Also factors such as type of road users involved and level of speed at the intersection have shown to be of importance for the accident to conflict ratio.

There are presumably many explanations for why an interaction under different conditions turns out with different severity. The traffic engineering factors that I expect to be of greatest influence are: flow, intersectional control, geometrical design and speed.

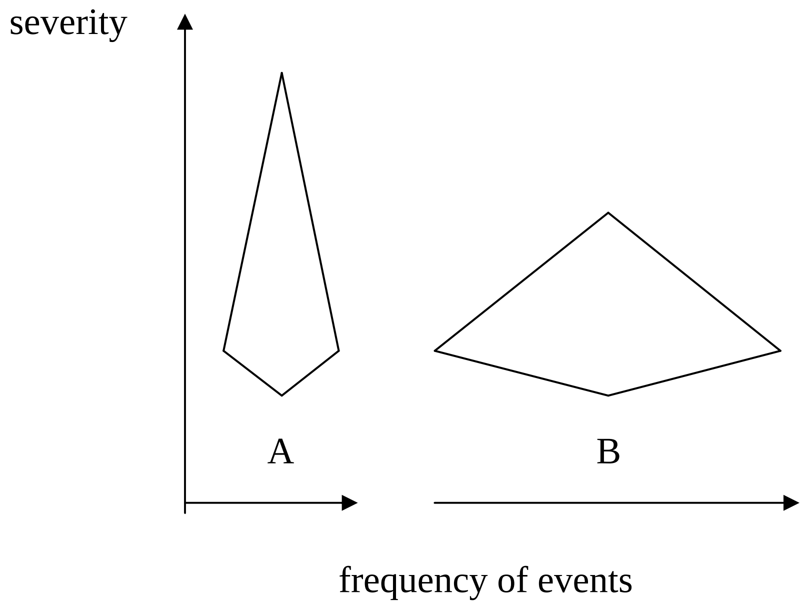

Figure 3:1 Severity shapes of two extremes

In the discussion below I talk about the hierarchies in extreme terms: comparably many events with high severity (the shape looks like A in Figure 3:1 above) or the reverse; comparably many events with low severity (the shape looks like B in Figure 3:1 above). Then there are of course the situations that give hierarchy shapes that are something in between A and B.

The concept of **flow** and its influence on the severity of the interaction is not so straight forward. According to Ekman (1996) the number of bicycle conflicts per bicyclist is twice as large at locations with low bicycle flow as compared to locations with higher flow. The conflict rate for bicyclists seems to be high at locations with a limited range of car flow. Thus, it is possible to argue that at larger flows there is an increased awareness of the fact that there are other road users around. This would prevent the situation from becoming too severe before action is taken. A hierarchy based on larger flows would then have comparatively few events with the highest severity (B). At very small traffic volumes there is hardly any expectancy among the road users that there might be interacting road users ahead. The road users are lulled into the notion that there is no need for increased awareness. If the road users, nevertheless, do start to move onto a collision course, the unpreparedness could lead to the collision course being maintained for a comparatively long period. In this case, the hierarchy showing interactions at small traffic volumes would reach high severities (A).

On the other hand, according to Ekman, the number of conflicts per pedestrian seems to increase with increasing car flow. That is, at higher flows there are more road users to keep track of and this could mean that the situation would be able to proceed into fairly high severities before the danger is detected. A hierarchy based on this assumption about larger flows would be comparatively small at the bottom and reach up to the highest severities (A).

Type of **intersectional** control can also be a factor contributing to whether the collision course is maintained for a longer or shorter period. At signalised intersections, for instance, the road users ought to expect simultaneous arrivals when both road users travel on green, as with the turning vehicle having green at the same time as the pedestrian is crossing at green. For these situations there ought to be a good potential for diverging from the collision course before the situation turns into too high severeties. A hierarchy for the signalised intersection, with the mentioned road users and manoeuvres involved, would have comparatively few events with high severity (B).

At the signal there is on the other hand less expectancy of simultaneous arrivals when one road user travels on green and the other surprisingly enough drives or walks against red. In this situation there could be a greater tendency for the situation to turn quite severe before action is taken. A hierarchy for this case would have the opposite shape, the top parts reaching up to high severities (A).

Factors like **geometrical design** could also contribute to whether the collision course is solved at an early stage or whether the situation proceeds into higher severity levels. Poor sight distances, for instance, can very well work in both directions. It can be negative in the sense that road users do not detect that they are on a collision course until the safety margins for handling the situation safely have (almost) diminished. A hierarchy with these assumptions, at a location with poor sight distance, would be comparatively small at the bottom and reach high severities (A).

Poor sight distance can, perhaps a bit contradictorily but nevertheless, also be somewhat positive in the sense that the road users could anticipate that another road user might move onto a collision course, even if the other road user still is not detected, and therefore is prepared to handle the collision course immediately. These assumptions would call for a hierarchy with comparatively few events with high severity (B).

Another factor that has to do with geometrical design is expectations about the **normal traffic function**. Let's say that a certain intersectional layout very often follows a certain pattern; then, if it diverges at one location, this is not expected. Road users can for instance appear at locations or in directions that are not normal. If two road users, on top of this, start to move on collision course, it is quite probable that the situation can turn into quite high severity levels before action is taken. A hierarchy at a location where road users do not expect each other's appearance could, according to this argumentation, reach up to high severities (A). An example of this is found in a report by Summala et al. (1996), where the connection between bicycle accidents and drivers' visual search at left and right turns is studied. This study is based on the findings in the Helsinki City accident data base (Pasanen, 1992a). Analyses indicated a higher accident risk between vehicles crossing a cycle path while entering the intersection to turn right and cyclists coming from the right, than for vehicles turning left. The study confirmed the hypothesis that right turning drivers scanned the left leg more frequently than the right leg, and thus failed to notice the cyclists coming from the right, an unexpected direction.

Speed can certainly also be a contributing factor for a collision course being maintained too long. When travelling at too high speed, the time and space margins for handling the situation safely decrease rapidly. Even if the interaction enters onto a collision course at a fairly low severity, the severity of the event could rapidly increase with high speeds. This suggests that a hierarchy from a location where the speeds of the road users involved in the interactions are high, would have a shape that reaches up to the higher severities (A). But if the road users approach each other with fairly low speeds there is still time to solve the situation in a controlled way before it turns too severe. A hierarchy with a rather different shape, comparatively few events with high severity (B), could be the result from observing interactions at a location with low speeds.

3.2.2 Disaggregation

The fact that there must be different factors influencing the shape of the hierarchy and the safety level calls for a disaggregation into sub-hierarchies. Depending on the established criteria it is of course possible to disaggregate to different degrees. With an assumption of a number of specific severity hierarchies, the whole severity hierarchy for that intersection or that section of the road could be described, if these were combined. The severity hierarchy can presumably be disaggregated into sub-hierarchies with regard to the different engineering factors mentioned above, but also with regard to type of road users involved, type of manoeuvre etc.

3.3 The importance of the shape

The shape of the severity hierarchy is interesting for several reasons. It can be used as a measure of the safety condition at a location: to visualise the relation between events of different severity. The shape of the hierarchy can also be used in **describing** differences in road user behaviour. The difference can be with regard both to the individual behaviour and to the accumulated behaviour at a certain type of location. The shape can be used for **predicting** the frequency of more severe events, based on the observation of less severe events in the hierarchy. It can also be of help when trying to formulate **strategies** for better traffic safety.

3.3.1 Explanation and prediction

In the previous section there was an example of how the type of manoeuvre affected the shape of the hierarchy. The question is of course what causes this pattern? One explanation is that the different ratios are linked to different police reporting rates for the different accident types (RWA, 1982). The reporting differences do not, however, account for the whole difference. How and to what extent do the behaviour(s) differ in the two different situations?

Let's take a hypothetical example to further emphasize the importance of the relationship between the events of different severity in the hierarchy. Let's say there is an intersection where the incoming flow in one direction is 6 000 vehicles per day. The perpendicular incoming flow is 10 000 vehicles per day. Let's say that with statistical probability calculation we have estimated the daily number of events where at least two road users are involved in a situation where they have to interact to be 4 000. We then of course could change this probability by changing the preconditions, like installing a signal. If, for the sake of simplification, we disregard that possibility, we have 4 000 interactions that depending on geometrical design, speed level etc., will end up in 4 000 different events of various severity. Now we have the unique possibility of trying out different solutions at this intersection. One solution perhaps produces a hierarchy (A), that is proportionally small at the base and goes high up to the most severe levels. Another solution will produce a severity hierarchy (B), that is very big at the base and the top does not reach up to the most severe levels. A third solution produces yet another possible shape (C). These three solutions could thus produce the three possible hierarchy shapes A, B and C, see Figure 3:2 below. What is it in these solutions that influences the shape of the hierarchy to produce such different results? In what way is the road user behaviour so different during these conditions?

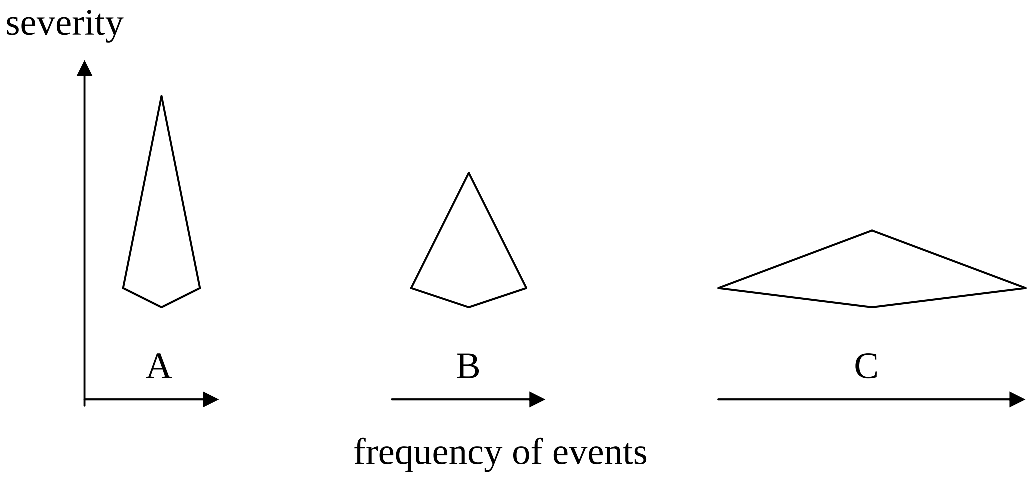

Figure 3:2   Different severity shapes with different solutions at an intersection

This example shows how different the shapes of the hierarchy might be when the same amount of interactions are to take place, but under different conditions. When we notice a change in safety, then we must ask if the total number of interactions has increased or decreased, or if it is, as here, a shift of events between severity levels. If the total number of interactions, events, has remained unchanged, then perhaps the hierarchy can resemble a soft ball – with a somewhat strange shape. If it is squeezed in one place then it has to expand somewhere else. If the total number of interactions differs to a great extent, this might explain why the shape of the hierarchy looks different under different conditions. The relationship between the different events in the hierarchy can, for instance, be assumed to be different for pedestrian / car interactions on motorways compared to interactions between these road user types in urban 30 km/h zones. If all vehicles were to drive at 30 km/h as a maximum, the number of fatal accidents will be very low (Anderson et al., 1997), (Pasanen, 1992b) compared to the so much more numerous interactions characterised by early detection, early speed adaptation, mutual communication etc. Pedestrian / car interactions would very seldom be found on motorways. If a pedestrian, for some reason, is to cross a motorway and is involved in an interaction with a vehicle, it is very likely that this interaction will turn out as a situation with a high severity. The vehicle speeds are high and the drivers do not expect to interact with pedestrians on a motorway. Here it is very obvious that the shape of the hierarchy for these two different situations must be different.

The main conclusion is, however, that the number of interactions, as well as the number of interactions in relation to flow and severity of the interactions, contain valuable information when describing possible relations to safety.

- **With regard to the severity of the interactions,** the shape of the hierarchy is the same as the ratio of interactions with different severity in relation to the total number of interactions. Therefore the ratio, i.e. the shape, in one sense can be said to be independent of the total number of interactions. It might however be interesting to relate the shape to the size of the hierarchy and to the flow.
- **As to the number of interactions,** the total size of the hierarchy must be interesting when it comes to estimating the frequency of interactions with a certain severity. Whether the total size of the hierarchy is small or large must be of importance when describing the safety situation at the location. It can also be the case that there is a dependency between the size of the hierarchy and the shape.
- **With regard to flow,** according to Ekman (1996) there is a correlation between conflict rate and flow. The number of conflicts per pedestrian is, for instance, largely unaffected by the pedestrian flow, while the car flow seems to be of great importance for the number of conflicts per pedestrian. The size of the hierarchy in relation to flow must therefore be of interest and, furthermore, also the relation between the shape of the hierarchy and flow.

No severe interactions

If the hierarchy does not contain any interactions of a higher severity, then both the formal and the informal traffic rules are approved and obeyed by the road users at the location. It must be concluded that road users do take their responsibility to solve the current interactions safely. This can be due to low speeds, which increase the possibility to handle the event safely well in advance before it turns into a severe event. It can also be due to a good road design inducing other safe behaviour. With a shape like this describing the relationship between the events with different severity, the probability of an interaction ending up as an event with high severity is very small. If this type of hierarchy shape is found, it could be worthwhile to study the interactions and the factors affecting them more thoroughly. Amongst other factors, analyses of the total number of interactions and flow could for instance be beneficial. This could be of great help in the attempts to achieve better understanding about safe behaviour, the preconditions for safe behaviour etc.

High ratio

A high ratio between severe and non-severe interactions indicates a high probability of a severe event once there is an interaction. In a hierarchy with this relationship, the top of the hierarchy is comparatively large in relation to the whole hierarchy, see Figure 3:3. Once the road users start to move on collision course, the probability that the interaction will turn out as an event with high severity is high. Too high speeds for the prevailing conditions could be one of the reasons for such a shape. It could also be a question of unexpectancy about each other’s appearance. It could also be interesting to analyse the shape in relation to the size of the severity hierarchy and to flow.

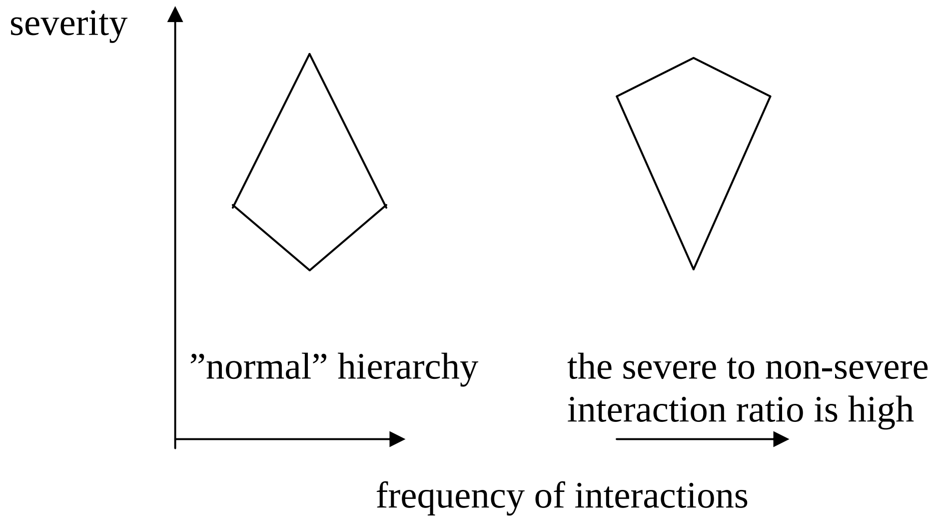

Figure 3:3 Severity shape of a high ratio between severe and non-severe interactions

Low ratio
A low ratio between severe and non-severe interactions indicates a small probability of a severe outcome once there is an interaction. If a situation presents a hierarchy with this type of shape, see Figure 3:4, it must indicate a much better traffic safety situation as compared to when the ratio is high. It can be a sign of a situation where the road users have mutual respect for each other’s movements. Perhaps the speeds are low and the road users are visible to each other all the time. It would, once more, be interesting to put this type of shape in relation to the size of the hierarchy and to flow.

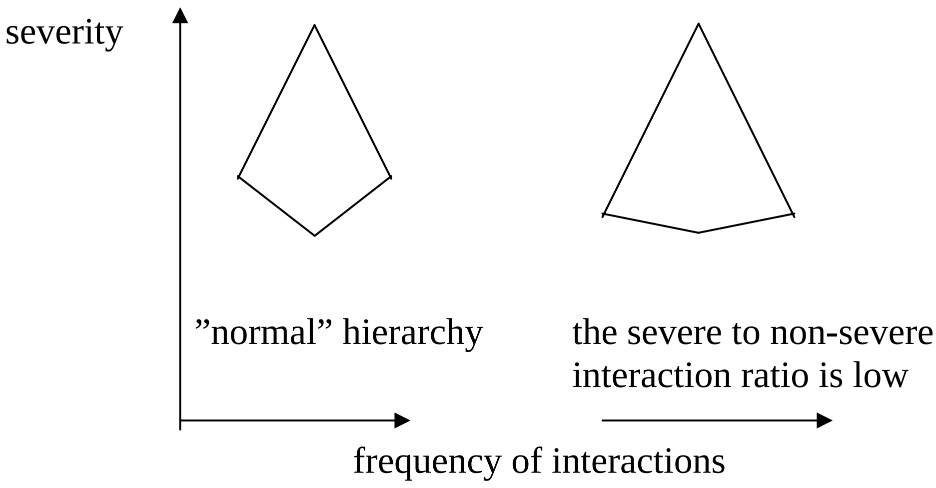

Figure 3:4 Severity shape of a low ratio between severe and non-severe interactions.

One shortcoming of accident analysis, and sometimes also of conflict analysis, is the limited amount of data. Sufficient data means that it is possible to get statistically significant estimates. To make estimates from, particularly, accident data, the data collection must be expanded over a relatively long period. If the events with less severity could be used for safety assessment, then sufficient data could probably be collected during a much shorter period. It would then, however, be necessary to have knowledge about the whole shape in order to be able to say something from an isolated, even if perhaps a major, part of it. So in order to be able to make a prediction about what the continuation upwards will look like, based on the shape of the less severe events, a number of different conditions must be investigated. If we can make a reliable estimate of the ”true” hierarchy, it would be very possible to use the less severe events for making predictions. Then of course the relation to traffic flow has to be taken into consideration in order to be able to make any quantitative predictions.

3.3.2 Strategy purposes

Another issue that makes the shape of the severity hierarchy so interesting, is the acceptance of safety margins. Conflict studies show that the individual road user has the strategy of not putting him or herself into situations with too low safety margins. Injury accidents and serious conflicts are considered to belong to this ”unwanted” group. In the ”zero-risk” theory, Näätänen and Summala (1976) also refer to a safety margin threshold that road users aim to keep within. How does the shape of the hierarchy, or of some other hierarchy based on other presumptions, look if it is to reflect the individual road user desire of safely being able to pass an intersecting point? From society’s traffic safety planning point of view, it also forces us to at least reflect upon how small safety margins we are willing to accept for interactions of different types. Or expressed in terms of the hierarchy, how severe events can be accepted and what severity distribution are we aiming at?

Increase of number of less severe interactions

One interesting safety implication of interactional studies is whether it would be possible to clarify whether it would be a successful strategy to increase the number of less severe interactions in order to reduce the number of interactions with the highest severity? In a study by Linderholm in 1992, it was concluded that cycle paths at intersections parallel to and a short distance from the street create safety problems. This intersectional design is especially dangerous for cyclists driving straight ahead compared to when these cyclists are mixed with other road users in the street. The interacting vehicles are vehicles making a turning manoeuvre at the intersection and thereby end up crossing the cyclist's direction of travel. Linderholm carried out conflict studies, behavioural studies and interactional studies, and measured the flows and conducted interviews. The risk (estimate of the injury accident frequency) per cyclist is lower for cyclists travelling on the road as compared to on the cycle path. With a presumption of an equal number of interactions, the severity hierarchy for the cyclist in the road does not reach the highest severities; most interactions are located at the less severe parts. The severity hierarchy for the cyclists on the cycle path is presumably thinner at the base and goes higher up into the higher severities instead. Even if the number of possible interactions is the same in the two situations, according to Linderholm, this is not perceived by the road users involved. The cyclists travelling on the road are more visible to the vehicles and the cyclists must be very aware of the fact that there are vehicles in their vicinity. For the cyclists travelling on the cycle path, every vehicle that appears is regarded as an unexpected event since they are not prepared to interact. It must be a similar situation for the vehicle making a turn at the intersection and all of a sudden being confronted with a crossing cyclist.

The optimal hierarchy shape

Applying the hierarchy concept to the traffic process proposes that we believe that the shape of the hierarchy will tell us something about the traffic safety situation. Which hierarchy shape would then be optimal for safety?

When we talk about optimal traffic safety solutions we perhaps imagine solutions that produce small probabilities for injury accidents. This implies that the top of the hierarchy, where the probability of injury accidents is the highest, is cut off. There is however a connection between the top and the rest of the hierarchy. The solution must be found by analysing the whole severity hierarchy, all interactions. Then it is of course of uttermost importance to concretise what the safety work is aiming at. Perhaps we do not accept interactions at all during certain conditions. The aim behind such a strategy is the knowledge about the existence of a high probability of injury accident at every probable interaction at the location. We should, on the other hand, not regard interactions as such as an altogether bad thing. The goal must be to reduce or to eliminate interactions with high severity. But interactions with less severity can be signs of good traffic safety and safe behaviour among the road users.

If the aim is to reduce the injury accident probability, then it is vital to get an understanding of the ”true” hierarchy and the injury probability at each severity level as well as the interdependencies between the various severity levels. It is otherwise very difficult to suggest strategies to reduce the interactions on the severity levels of greatest importance.

4 My own approach

In the previous chapters there has been a general discussion of;

- Different ways to describe the traffic process
- Different ways to study the traffic process
- Different presumptions about what events to include in the traffic process
- Different ways to set up the severity hierarchy.

To some extent it has been quite obvious where the standpoint of my work is positioned regarding these issues. In this chapter there is a conclusion of the hypotheses that my work aims at testing. Then there is a discussion about what kind of data is collected and how the data is collected in order to be able to make proper analyses and tests of the hypotheses.

4.1 Scope of the analyses

By analysing the shape of the different severity hierarchies, the traffic safety processes for different conditions can be studied. The traffic safety process is a continuum of events, all with a linkage to unsafety, the injury accident. The events in the traffic safety process are called interactions and are characterised by a collision course. The severity of the process is described by the TA/Speed value. In the severity hierarchy, as mentioned earlier, 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 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. The different severity levels in the hierarchy describe different probabilities for the occurrence of an injury accident. In analogy with the definition of severity; we can say that traffic safety is the probability of not being seriously injured in traffic.

The approach includes studying interactions, positioning them in the hierarchy, Figure 4:2, with the estimated TA/Speed value obtained at the moment of evasive action, Figure 4:1, and illustrating the shapes.

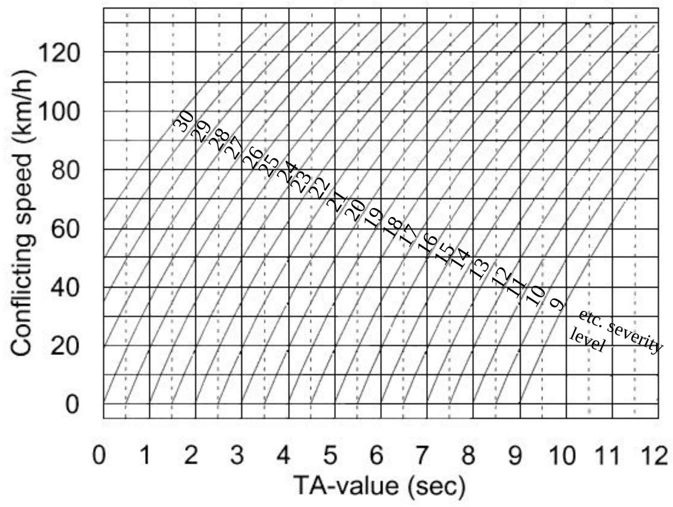

Figure 4:1 TA/Speed graph defining the different severity levels. There is a continuation towards lower severity levels. Severity level 1(not shown) intersects the X-axis at TA=13.0 seconds.

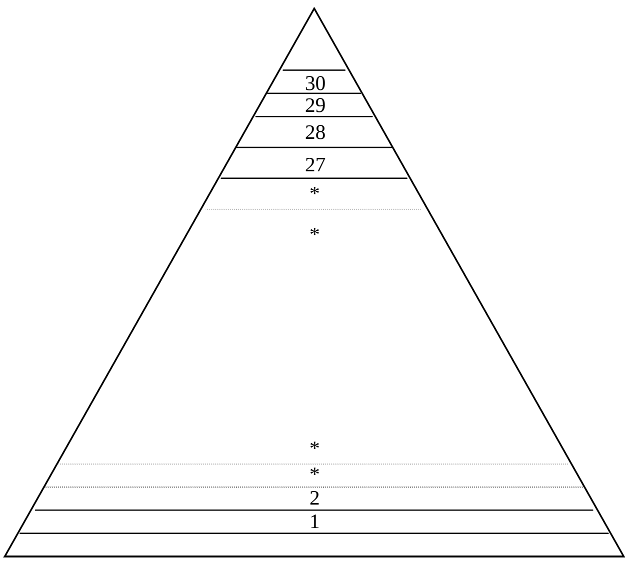

Figure 4:2 Severity hierarchy with severity levels corresponding to the ones defined in Figure 4:1.

Traffic safety work at Lund University is traditionally very concerned with the traffic safety of vulnerable road users. It was therefore quite clear from the beginning that I wanted to focus on interactions involving vulnerable road users.

At the Kaivokatu-Keskuskatu intersection in Helsinki, Finland, accidents have been video-recorded (Pasanen, 1993). By including this intersection I would get the opportunity to describe the relation between accidents, serious conflicts and adaptive situations. Since the focus in the Kaivokatu-Keskuskatu recording was on pedestrians, I chose to concentrate the interaction studies on pedestrians / motor vehicle situations and to only include intersections in the studies.

The traffic process, in my study, refers to individual road users' behaviours in connection to different traffic engineering parameters. The approach is therefore also to illustrate the effect of some factors on the shape of the hierarchy. In Chapter 3 ("Shape") different factors of importance for the shape of the severity hierarchy were listed: type of road users involved, type of section or intersection, type of regulation, type of manoeuvre etc.

4.2 Experimental design

4.2.1 Criteria and indicators of hypothesis testing

Type of road users
The interactions of interest are interactions between two road users, a motor vehicle driver and a pedestrian. Interactions with the road and vehicle environment as such are excluded, i.e. single vehicle/pedestrian interactions are excluded.

Type of manoeuvre
Manoeuvres of interest are vehicles driving straight ahead interacting with pedestrians and vehicles turning right interacting with pedestrians.

Type of intersection
Intersections of interest are signalised intersections and non-signalised intersections.

Type of situation
Situations of interest are interactions, i.e. situations involving a collision course. This implies the existence of an evasive action. For the adaptive situations, the evasive action is not as dramatic as with the serious conflicts. The evasive action, instead, more often has the character of adaptation i.e. evasive action to avoid ”something more serious”.

The ICTCT calibration study and the development of DOCTOR, mentioned earlier, suggest that events that are close enough in time and space ought to be included when describing severity. It was found, for instance, that for a given set of conflicts the minimum distance between the road users was an important factor when describing the severity of the conflict (Grayson, 1984). Even if this doesn't mean that all interactions with short distances are conflicts, it could imply existence of safety information in situations that are close enough in time and space without necessarily having a collision course. Taking evasive action can be interpreted as if the road users perceive a collision course. They behave as if they were moving on a collision course. If in addition the road users almost move onto a collision course, it was felt vital to include these events in the severity hierarchy as the safety margins in these situations are so small that it must be impossible for the individual road user to estimate whether there is a real collision course or not. In the definition of an interaction, events with evasive action and almost a collision course (explained in section 4.2.2) are therefore also included.

Situations that comply with the conditions above are registered. The TA value and the speed just before the evasive action are noted. Other conditions, such as whether the pedestrian arrives at the pedestrian crossing alone or in a group, and whether there are other pedestrians waiting at the kerb, are also noted. The speed of the counterpart, the party not taking evasive action, is also registered.

4.2.2 Study design

Cross-sectional

The study design is cross-sectional. Three different sites are selected and at each site a specific pedestrian crossing is chosen. As far as it has been possible to achieve, the main characteristics of the crossings are comparable. The vehicles driving straight ahead travel on the “main “ road. The vehicles turning right do so from the “minor” to the “main” road. The pedestrians cross the “main” road.

Observations from video

All analyses of the interactions are made from video recordings. At each site the camera has been mounted at least 8 meters up on a building. At each site four reference points are selected and their positions in the road and in the picture are settled. With the help of this data it is possible to convert road data in meters to picture data in pixels and vice versa (Szanto, 1989), (Horst, 1990).

I consequently decided to register all situations between motor vehicles and pedestrians having a collision course and those with evasive action and almost a collision course and where there is compliance with the conditions above in other respects (correct pedestrian crossing, correct type of manoeuvre). The registration procedure is as follows. For all road users approaching the pedestrian crossing studied, it is determined whether there is an evasive action or not. If there is an evasive action then the road user’s position is projected with the speed just before the evasive action, the earlier denoted conflicting speed, from the point of evasive action. Speeds and positions are determined with the help of a semiautomatic image processing, earlier developed at Lund University, Sweden, for partly other purposes (Odelid et al., 1991)(Odelid & Svensson, 1993). The speed is also estimated subjectively by the observer.

The image processing system is developed with the main purpose of determining collision course and the time remaining to collision. Every 0.08 seconds, corresponding to every second picture, the positions of two approaching road users are projected with the help of current speeds and directions. Here, however, only the positioning function and the speed function were used. If there was found to be a collision course with another road user the situation is registered as an interaction. The speed just before the evasive action and the TA value are recorded. If there is found to be an almost collision course, here defined as the TA value being 0.2 seconds or less from being a collision, the interaction is further analysed. In the further analysis there is an estimate of collision course based on an approaching speed of 0.5 km/h higher or lower as compared to the first speed estimate.

Furthermore, the interaction is analysed as if the vehicle fills 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 a collision course. The reason for these precautions, to calculate with some difference in speed and as if the vehicle fills up the whole driving lane, is first of all to make sure that all interactions with a real collision course are registered. Then as a secondary side effect, those situations where there objectively is almost a collision course and where the road user behaves as if there was a collision course, i.e. takes evasive action, are also registered. Another reason for analysing the interactions as if the vehicle fills up the whole lane is the considerable reduction in time spent on this analysis as compared to more detailed analyses.

Another possibility of making sure that all interactions with a collision course and those with almost a collision course really are detected would have been to employ the more sophisticated parts of the image processing system. The system works with a ‘footprint’ of the road user (Szanto, 1989). The footprint is a projection of the road user’s extension on the road surface with the shape of a rectangular box. The size of the footprint is set manually at the beginning of each analysis. Then as the footprint is moved around in the picture the size is adjusted automatically. The footprint keeps the size in terms of road length units but changes in image length units as it moves around in the picture. That is, the further into the picture the road user is positioned the ‘smaller’ is the footprint, and the closer the road user is positioned in the picture the ‘bigger’ is the footprint.

One possibility in this context would have been to enlarge the footprint for the vehicle and/or the pedestrian in relation to the true size. The amount of space occupied by the road users would become bigger compared to when it is set according to the normal size. With an enlarged footprint, situations with no, but just about, collision course would be registered as if there was a 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 an interaction with a collision course. This presupposes, though, that the counterpart to the road user taking evasive action is identified before the analysis and that both road users are followed through the intersection. This is a very time consuming procedure as there are many interactions and for each interactive pair of road users the positions must be picked every 0.08 seconds. In my study it was not considered justifiable to perhaps achieve an increase in accuracy at the cost of an increase in the time spent on analysing.

For each road user taking evasive action there might be several possible counterparts to have an interaction with. Here, however, only one interaction for each road user taking evasive action is analysed, and that is the first possible interaction. Considering that if no evasive action was taken the interaction would have ended up as a collision, it is logical to only register the first possible interaction, i.e. for each road user taking evasive action there is only one possible counterpart. On the other hand one road user, not taking evasive action, may be counterpart to several different road users taking evasive action. For all analyses it is the party taking evasive action that determines whether an interaction is to be further analysed or not. That one road user takes evasive action is independent of all other road users taking evasive action. Therefore is it here regarded as a totally new interaction when another road user takes evasive action even if the counterpart might be the same as in another interaction.

When pedestrians arrive at the pedestrian crossing as a group the TA/Speed value is estimated for the pedestrian who would have arrived at the collision point first. A whole bunch of people walking together are not always regarded as a group. In order to be regarded as a group the pedestrians must walk closely together as they approach the pedestrian crossing. If they are walking and talking with each other they are definitely regarded as a group.

4.2.3 Description of the three sites

The Kaivokatu-Keskuskatu intersection in Helsinki, Finland is a signalised intersection located in the central part of Helsinki, see Figure 4:3. Kaivokatu runs in the east-west direction. The Keskuskatu road is a one-way street with traffic only allowed in the south direction. The video is located at the top of the railway terminal which is situated at the north-west part of the intersection. There is a tram operating in the middle of Kaivokatu. The pedestrian crossing where the interactions have been studied is located on Kaivokatu in the north-west part. The vehicles driving straight on travel from east to west. The turning vehicles drive south on Keskuskatu approaching Kaivokatu and turn right into Kaivokatu. The Kaivokatu-Keskuskatu intersection was rebuilt in 1995. The stop line for the vehicles on Kaivokatu was pulled back, and therefore we did not choose either of the two pedestrian crossings on the Kaivokatu approaches. The chosen pedestrian crossing is instead located at the west exit of Kaivokatu. There is of course the possibility that the behaviour of vehicles and pedestrians at this pedestrian crossing has also been modified due to the change. If this were the case the behaviour can at least be anticipated to be less modified at the selected pedestrian crossing than at the two at the approaches. The speed limit at the site was 50 km/h in 1991. In 1994 and 1995 the speed limit had been reduced to 40 km/h. This will of course affect the results.

Figure 4:3 The Kaivokatu-Keskuskatu intersection.

The Värnhemstorget intersection in Malmö, Sweden, see Figure 4:4, is a signalised intersection with a bus terminal in the western part. Lundavägen approaches from the north-east ; Sallerupsvägen approaches from the south-east; Föreningsgatan approaches from the south-west and Östra Förstadsgatan approaches from the north-west. The pedestrian crossing of interest is located at the northern part of Föreningsgatan. The vehicles driving straight on travel from north-east to south-west, from Lundavägen into Föreningsgatan. The turning vehicles approach from the north-west on Östra Förstadsgatan and turn right into Föreningsgatan. The video camera is located in the southern part of the intersection.

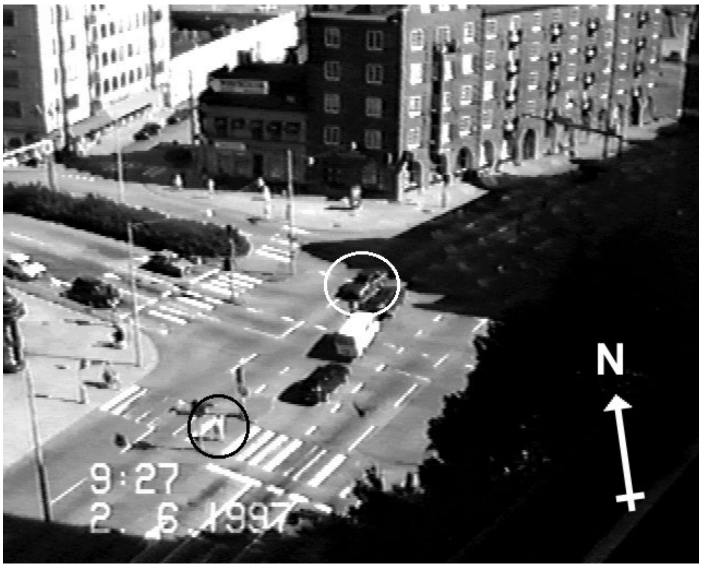

Figure 4:4   The Värnhemstorget intersection

The Djäknegatan-Baltzarsgatan intersection is a non-signalised intersection in the central part of Malmö, Sweden, see Figure 4:5. The official rule is to give way to the right. The more unofficial rule is to give way to the traffic on Djäknegatan which runs in the north-south direction. The pedestrian crossing of interest is located in the south-west part of Djäknegatan. Vehicles travelling straight ahead travel south on Djäknegatan. Turning vehicles approach on Baltzarsgatan from the west and turn right into Djäknegatan. The video camera is located in the south-east part of the intersection. In a smaller complementary study the video camera is located in the north-east part of the intersection.

Figure 4:5   The Djäknegatan-Baltzarsgatan intersection

4.3 Hypotheses on factors possibly affecting the hierarchy shapes

It is reasonable to assume that external factors affect the shape of the hierarchy. From the discussion in Chapter 3 (“Shape”) it will be interesting to have a look at how the hierarchy shapes vary with regard to the following factors:

A) **There might be similarities between the severity shapes even though the data are collected during different time-periods**. There is an assumption that the true shape of the hierarchy should reflect the sum of all road user behaviour at the location. If the intersection has remained unchanged and there is a “true” hierarchy then observations collected during different years should produce similar severity shapes. Here the collection of data from the Kaivokatu-Keskuskatu intersection in the years 1991, 1994 and 1995 provides an opportunity to test this hypothesis, although the conditions were not exactly the same during these years.

B) **There might be similarities between the hierarchy shapes at similar types of intersections**. There is every reason to believe that similar intersections with regard to type of control (signal / yield / yield to the right etc.) will produce similar hierarchy shapes when the same type of road users and the same type of manoeuvres are studied. This is analysed by making a comparison between the signalised intersection Kaivokatu-Keskuskatu in Helsinki, Finland and the signalised intersection Värnhemstorget in Malmö, Sweden. The greatest similarity between the intersections is the fact that they are both signalised. Then there are other circumstances that perhaps could turn out to make the two intersections different. The two intersections are located in different cities, even in different countries. Then there might of course be other more specific differences between the intersections such as difference in flow etc.

C) **Type of control at the intersection might influence the hierarchy shape**. The accident-to-serious conflict ratios differ, according to previous studies, at signalised intersections as compared to non-signalised intersections. It is therefore reasonable to believe that the whole shape of the severity hierarchy could look different at signalised intersections as compared to non-signalised intersections when the same type of road users and the same type of manoeuvres are studied. There is a possibility here to compare the hierarchy shapes at a signalised and at a non-signalised intersection in Malmö, Sweden.

D) **Type of manoeuvre at the intersection might influence the hierarchy shape**. The accident-to-serious conflict ratios differ here too according to previous studies, due to type of manoeuvre. It is therefore also here reasonable to assume that the whole shape of the hierarchy could look different for different types of manoeuvres at the same intersection. Here there is a possibility to compare interactions between pedestrians and vehicles driving straight on, and between pedestrians and turning vehicles.

E) **Type of road user taking evasive action might influence the hierarchy shape**. Among the few accidents analysed from the Kaivokatu-Keskuskatu intersection, it seemed as if it was more often the vehicle than the pedestrian that took evasive action. It would be very interesting to further analyse the influence of which party it is that takes evasive action and the shape of the hierarchy. Could it be so that the interactions where the vehicle takes evasive action are more severe than the interactions where the pedestrian takes evasive action, for the same type of manoeuvre at the same intersection? There is a possibility to compare interactions where the vehicle takes evasive action and interactions where the pedestrian takes evasive action in the same type of manoeuvre and at the same intersection.

4.4 Data collection

At Kaivokatu-Keskuskatu the accidents were collected for the period between January 1991 and June 1995. Fortunately enough, not only were the accidents themselves saved on the video recordings but also the recording from approximately one hour before the accident. From two of these accident tapes, one in 1991 and one in 1994, interactions were observed. From the other two accident tapes it was impossible to conduct interaction studies due to the poor quality of the picture caused by the fact that the accidents occurred in the middle of the night. The recordings from 1991 and 1994 were enough to cover the interactions with vehicles driving straight ahead and pedestrians taking evasive action. For the turning situations additional data were required. There was no other way than to study the turning interactions from the recordings in 1995. All conflict studies have also been conducted from the 1995 recordings.

At Värnhemstorget the interaction data was collected in May, June and July 1997. Conflicts were registered in April 1998 and the accidents were collected from police files, January 1991 to December 1995. No major changes regarding intersectional layout or speed limits have occurred at the intersection during this time period.

At Djäknegatan-Baltzarsgatan the interaction data were collected in May 1995 and March 1998. Conflicts were registered in March and April 1998 and the accidents were collected from police files, January 1991 to December 1995. No major changes regarding intersectional layout or speed limits have occurred at the intersection during this time period.

Apparatus

We have used a system where the video picture is laid on the computer screen. A computer program provides the observer with the positions of the road users in terms of coordinates and an accompanying time code. Then there is a calculation program where the time position of the evasive action, the speed just before the evasive action and the distance to a previously positioned point in the approach are input. The output data from this calculation is the position in time when the road user should have reached different locations of the intersection if the speed and direction had been maintained.

Procedure

The term “category cell” is used to distinguish the different categories of interactions. The aim has been to collect at least 100 interactions for each category cell or to make the observation during at least one hour. For two of the category cells, explained more in detail below, it turns out that the number of interactions is less than 100. The reason for this is that detailed studies of which party really takes evasive action in some doubtful cases resulted in cancellations of interactions for these two category cells. Altogether there will be 9 main category cells to work with.

Explanation to the notations in the category cells

K stands for	Kaivokatu-Keskuskatu, Helsinki, Finland.
D stands for	Djäknegatan, Malmö, Sweden.
V stands for	Värnhemstorget, Malmö, Sweden.
S stands for	Vehicles driving Straight ahead
T stands for	Turning vehicles
v stands for	Vehicle takes evasive action
p stands for	Pedestrian takes evasive action

Category cells

KSp =	Interactions at Kaivokatu-Keskuskatu, the vehicle driver drives straight on, the pedestrian takes evasive action.
KTp =	Interactions at Kaivokatu-Keskuskatu, the vehicle driver turns, the pedestrian takes evasive action
KTv =	Interactions at Kaivokatu-Keskuskatu, the vehicle driver turns, the vehicle driver takes evasive action
VSp =	Interactions at Värnhemstorget, the vehicle driver drives straight on, the pedestrian takes evasive action
VTv =	Interactions at Värnhemstorget, the vehicle driver turns, the vehicle driver takes evasive action
DSp =	Interactions at Djäknegatan-Baltzarsgatan, the vehicle driver drives straight on, the pedestrian takes evasive action
DSv =	Interactions at Djäknegatan-Baltzarsgatan, the vehicle driver drives straight on, the vehicle driver takes evasive action
DTp =	Interactions at Djäknegatan-Baltzarsgatan, the vehicle driver turns, the pedestrian takes evasive action
DTv =	Interactions at Djäknegatan-Baltzarsgatan, the vehicle driver turns, the vehicle driver takes evasive action
Number =	Year of data collection if the data is split in the analysis. 91=1991, 94=1994, 95=1995, 94/95=1994+1995

When it has been possible the different types conflicts and accidents have also been denominated with corresponding category cells.

Interaction data

More detailed information on the interaction data is found in Appendix 1.

Kaivokatu-Keskuskatu, Helsinki, Finland

The interaction observations are from recordings dated 1/6/91, 3/9/94, 6/6/95 and 7/6/95.

Table 4:1 Interactions and flow at Kaivokatu-Keskuskatu, Helsinki, Finland with regard to category cell.

Category cell	Number of inter-actions	Duration of interaction observation (h)	Number of interactions per hour	Vehicle flow per hour	Pedestrian flow per hour
KSp91	170	1.0	170	565	993
KSp94	145	1.0	145	494	1116
KSv91	0	1.0	0	565	993
KSv94	0	1.0	0	494	1116
KTp	142	7.15	19.9	48	1115
KTv[2]	123	7.15	17.2	48	1115

Värnhemstorget, Malmö, Sweden

The interaction observations are from recordings in May, June and July, 1997.

Table 4:2 Interactions and flow at Värnhemstorget, Malmö, Sweden with regard to category cell.

Category cell	Number of inter-actions	Duration of interaction observation (h)	Number of interactions per hour	Vehicle flow per hour	Pedestrian flow per hour
VSp	163	3.4	47.9	378	377
VSv	0	3.4	0	378	377
VTp	9	7.7	1.2	39	369
VTv[2]	111	7.7	14.4	39	369

[2] This is an estimate of what the numbers might be as interactions have been excluded due to limitations in camera coverage.

Djäknegatan-Baltzarsgatan, Malmö, Sweden
The interaction observations are from recordings in May 1995 and late March 1998.

Table 4:3 Interactions and flow at Djäknegatan-Baltzarsgatan, Malmö, Sweden with regard to category cell.

Category cell	Number of inter-actions	Duration of interaction observation (h)	Number of interactions per hour	Vehicle flow per hour	Pedestrian flow per hour
DSp	134	3.2	41.9	377	206
DSv	83	8.9	9.3	383	201
DTp	104	13.8	7.5	93	222
DTv[3]	94	12.8	7.3	89	175

Conflict data

The severity levels mentioned in Tables 4:4-4:6 are defined in Figures 4:1 and 4:2. More detailed information of the conflict studies is found in Appendix 2.

Kaivokatu-Keskuskatu
Conflicts were observed during 39.4 hours, 6/6/95 and 7/6/95, covering both daytime, evening, and part of the night.

***Table 4:4 Observation of conflicts at Kaivokatu-Keskuskatu, Helsinki, Finland. The distribution of conflicts with regard to type of conflict and severity level. The duration of the conflict observation is 39.4 hours*.**

		KSp	KSv	KTp	KTv
Number of conflicts at each severity level[4] for each type of conflict	Severity level 27	0	1	0	0
	Severity level 26	0	1	0	3
	Severity level 25	0	2	1	4
	Total number of conflicts	0	4	1	7

[3] This is an estimate of what the numbers might be as interactions have been excluded due to limitations in camera coverage.
[4] The severity levels are defined in Figures 4:1 and 4:2.

Värnhemstorget

Conflicts were observed during 24 hours split into 4 days in April 1998. Each day the 6 hours of observation were evenly distributed over the day from 9.30 a.m. to 5.30 p.m.

Table 4:5 ***Observation of conflicts at Värnhemstorget, Malmö, Sweden. The distribution of conflicts with regard to type of conflict and severity level. The duration of the conflict observation is 24 hours.***

		VSp	VSv	VTp	VTv
Number of conflicts at each severity level[5] for each type of conflict	Severity level 27	0	0	0	0
	Severity level 26	1	0	0	0
	Severity level 25	0	0	0	6
	Total number of conflicts	1	0	0	6

Djäknegatan-Baltzarsgatan

Conflicts were observed during 34 hours split into 6 days, late March and early April in 1998. Each day the periods of observation were evenly distributed over the day from 8.30 a.m. to 5 p.m.

Table 4:6 ***Observation of conflicts at Djäknegatan-Baltzarsgatan, Malmö, Sweden. The distribution of conflicts with regard to type of conflict and severity level. The duration of the conflict observation is 34 hours.***

		DSp	DSv	DTp	DTv
Number of conflicts at each severity level[5] for each type of conflict	Severity level 27	0	0	0	0
	Severity level 26	1	2	0	1
	Severity level 25	3	14	4	4
	Total number of conflicts	4	16	4	5

[5] The severity levels are defined in Figures 4:1 and 4:2.

Accident data

Kaivokatu-Keskuskatu
At the Kaivokatu-Keskuskatu intersection accidents have been registered and video recorded from January 1991 to June 1995. The number of accidents at the actual pedestrian crossing, involving the relevant road users and relevant manoeuvres, is four during these 4.4 years, two with vehicles driving straight ahead and two with turning vehicles. As the accidents are recorded on video it has been possible to make an estimate of the TA/Speed values, i.e. to make an estimate of the severity. In Finland the accidents are classified as injury accidents and non-injury accidents. It is not possible to differentiate between slight and serious injuries. The two KSv accidents, in Table 4:7, with severity 28 and 29 are injury accidents. One of the KTv accidents with severity 27 is an injury accident and the other is a non-injury accident.

Table 4:7 Police reported accidents at Kaivokatu-Keskuskatu, Helsinki, Finland. The distribution of accidents with regard to type of accident and severity level. The duration of the accident observation is 4.4 years.

		KSp	KSv	KTp	KTv
Number of accidents at each severity level[6] for each type of accident	Severity level 30	0	0	0	0
	Severity level 29	0	1	0	0
	Severity level 28	0	1	0	0
	Severity level 27	0	0	0	2
	Total number of accidents	0	2	0	2

Värnhemstorget
For Värnhemstorget, injury accidents from 1/1/91 to 31/12/95, i.e. during five years, have been collected from the police files. The number of accidents at the actual pedestrian crossing, involving the relevant road users and relevant manoeuvres, is three during these 5 years, two with vehicles driving straight ahead and one with a turning vehicle. These accidents have been collected from the police files. The road user categories are definite. The type of manoeuvre is almost quite certain, but not whether one or both of the road users did not comply with a red signal. It is also impossible to find out whether evasive action was taken and, if so, by whom. Thus there is no possibility to estimate the severity in terms of TA/Speed value, but there is information in the police files about the consequences in terms of seriousness of the injuries.

[6] The severity levels are defined in Figures 4:1 and 4:2.

***Table 4:8 Police reported accidents at Värnhemstorget, Malmö, Sweden. The distribution of accidents with regard to type of accident. The duration of the accident observation is 5 years*.

Vehicle manoeuvre	Straight forward	Turning
Party taking evasive action	Not known	Not known
Number of accidents	2	1

Djäknegatan-Baltzarsgatan

For Djäknegatan-Baltzarsgatan, accidents from 1/1/91 to 31/12/95, i.e. during five years, have been collected from the police files. In the police statistics there are no registered accidents at the actual pedestrian crossing involving the relevant road users and the relevant types of manoeuvres during these 5 years.

Time of day for the data collection

There are differences between the data sets accidents, conflicts and interactions with regard to during which period of the day and night the data are collected.

Table 4:9 Time of day when the accidents, conflicts and interactions are collected at the three different sites.

	Accidents	Conflicts	Interactions
Kaivokatu-Keskuskatu, Helsinki	Day and night	Day and night	Day
Värnhemstorget, Malmö	Day and night	Day	Day
Djäknegatan-Baltzarsgatan, Malmö	Day and night	Day	Day

4.4.1 Possible error sources

Noticeable evasive action
Motor vehicles are driven at rather constant speeds. When there is a change in speed it is rather easy to determine when it takes place. Pedestrian speed, however, can fluctuate much more. Here it is more difficult to determine whether there is an evasive action or not. On the other hand is it probably easier to trace the evasive behaviour when watching the pedestrian behaviour in relation to approaching vehicles than if the evasive action was to be traced by an automatic method. With an automatic and very precise method, we would probably find many different moments when the speed either increased or decreased. Then we would have the problem of deciding which evasive action is to be considered as **the** evasive action or whether there is an evasive action at all.

We have worked with the goal of detecting a noticeable evasive action. As far as it has been possible to check the accuracy of what is to be considered as a noticeable evasive action, there do bot seem to be any major problems. This was tested before the start of the actual study. Three observers were trained to observe and estimate the interactions. In a reliability test, the observers were instructed to register and estimate all interactions during a certain selected video sequence. Altogether 29 different interactions were selected by the three observers. Out of these 29 interactions, 26 were selected by all three observers. The scores (which road users were involved, position of evasive action, speeds and TA value) were very similar for 20 of the 26 interactions. When the TA value estimates were compared for the three observers, systematic differences among the observers were found. In order to keep these systematic differences under control, all observations and estimates in the study were conducted by the same observer.

The previously mentioned “semiautomatic image processing system” could of course have been an alternate method for the observations and estimates. It was decided not to use this method as it is a very time consuming procedure to position the road users in every possible interaction. To at least get a notion about the magnitude of the difference between “objective” and “subjective” estimates, approximately 10 different sequences were estimated by both the manual observer and by using the semiautomatic system. As compared to the “objective” method, the manual observer systematically made an

- overestimation of the pedestrian speed by 0.2 km/h.
- underestimation of the distance to the collision point by 0.3 m
- underestimation of the TA value by 0.4 seconds.

That is, compared to the “objective” method, the manual observer has a tendency to position the evasive action somewhat later than when it “really” took place. To try to compensate for this, at least to some extent, in the study, the observer has been running the same sequence many times in order to better determine if there was an evasive action and when it took place.

As the registration of interactions has proceeded, different kinds of irrelevant evasive actions have been detected. It has not been regarded as an evasive action if

- the pedestrian as he/she approaches the pedestrian crossing suddenly decides to walk in another direction
- the pedestrian stops some distance from the pedestrian crossing and then decides to proceed in another direction
- the pedestrian stops some distance from the pedestrian crossing to talk to somebody

These conditions have mainly been placed on interactions at the signalised intersections when the pedestrian approaches a red light. Generally for these situations it is regarded as an evasive action if the pedestrian approaches the pedestrian crossing, stops and waits some distance from the kerb or at the kerb. Then as the signal turns green the pedestrian crosses. So even when the pedestrian stops just for the red signal and not for the approaching vehicle, it has been classified as an evasive action, if there was also a collision course.

Area covered

At all three sites the video camera is mounted high up in a building nearby. Even if the intention is to cover all interactions that take place, this is impossible in reality. There is always a limitation in the coverage and it might very well be so that there are interactions that are not detected due to the evasive action occurring outside the range of the camera. Both the Kaivokatu-Keskuskatu site and the Värnhemstorget site are very open in the sense that there are no high buildings blocking the view from the camera. There are of course situations here as well as at Djäknegatan-Baltzarsgatan where road users are “hidden” behind cars, but more often perhaps behind buses. At Djäknegatan-Baltzarsgatan, situated in the CBD area of Malmö, high buildings block the view. Here the camera was mounted at two different positions in order to better detect road users taking evasive action some distance from the intersection. Even if there is a possibility to get greater coverage by mounting the camera higher up this would create greater difficulties when determining evasive actions, speeds and TA values. Of the three sites, the camera at the Kaivokatu-Keskuskatu intersection is mounted at the highest position. Here we also had more problems determining evasive actions as compared to the other two sites.

Restraints due to the camera coverage

The area covered by the camera is different at the three different locations. It was not possible at any of the locations to meet all requirements concerning the coverage of all approaches from one camera position. At Djäknegatan-Baltzarsgatan the limitations were so evident that the recording of the turning vehicles taking evasive action had to be redone from a more advantageous camera position. Despite this there are still limitations for this type of manoeuvre. In order to have an idea about the restraints due to the camera coverage the maximum observable distances from the collision point have been calculated for the three sites and for the different types of manoeuvres. Also, the maximum TA value for different involved speeds was calculated. This is then put in relation to the severity levels 1 to 30 that have been used for the analyses, see Figures 4:1, 4:2 and section 4.5. With a speed of 5 km/h severity level 1 is equal to a TA value of 13 seconds.

The limitation due to the camera coverage has been estimated on one hand with regard to the highest severities and on the other hand with regard to the convexity of the distribution. The convexity is here understood as the range over the severity levels within which most observations are located. The distributions for some category cells show a very distinct and narrow convexity while others' convexities are more widely spread over the severities.

<u>Kaivokatu-Keskuskatu</u>

The pedestrian enters the picture at a maximum distance of 29 meters from the collision point. At an approaching speed of 5 km/h the maximum TA value that can be observed is 21 seconds. This TA/Speed value indicates that it is possible to detect interactions at all severity levels 1-30. For both situations with the pedestrian taking evasive action, vehicle driving straight on and turning vehicle, the camera coverage is no limitation

The vehicle driving straight ahead enters the picture at a maximum distance of 53 meters from the collision point. With an approaching speed of 50 km/h the maximum TA value is 3.8 seconds. Interactions on severity levels 23-30 would be included. There are, however, no interactions of this type registered at all. One reason for this could be that the interaction frequency is so low that no interaction is registered during the time of observation. Another reason could of course be that the camera coverage is a limitation. This is, however, less likely as this type of interaction would arise when either a pedestrian is walking against red or a vehicle is driving against red, and for these situations the severity would most certainly be higher than severity level 23.

The turning vehicle enters the picture at a distance of 43 meters from the collision point. With an approaching speed of 30 km/h interactions on severity levels 18-30 would be included. For this type of interaction the interaction frequency has, according to the analyses in Chapter 5, by that severity level already passed the maximum value and has started to level away. The camera coverage is thus a minor limitation.

<u>Värnhemstorget</u>

The pedestrian enters the picture at a maximum distance of 16 meters from the collision point. With an approaching speed of 5 km/h the maximum TA value is 11.6 seconds. For the straight forward vehicle situation all interactions on severity levels 4-30 are included. Already at severity level 8 the analyses show the start of a clear decrease of the interaction frequency. The camera coverage is not a limitation in this type of manoeuvre. For the turning vehicle situation there are hardly any interactions registered and the camera coverage cannot be a limitation, since it would be possible to detect interactions on severity levels 4-30.

The vehicle driving straight ahead enters the picture at a maximum distance of 78 meters from the collision point. With an approaching speed of 50 km/h the maximum TA value is 4.7seconds. There are no interactions where this vehicle takes evasive action, and it is not likely that the camera coverage is a limitation as interactions on severity levels 19-30 will most likely be detected.

The turning vehicle enters the picture at a maximum distance of 31 meters from the collision point. With an approaching speed of 30 km/h the TA value is 3.7 seconds. For the situation with the turning vehicle taking evasive action it can only be certain that situations on severity levels 21-30 are included. The most severe interactions are, therefore, most certainly included. Analyses regarding the convexity of the interaction frequency must, however, be regarded as uncertain.

Djäknegatan-Baltzarsgatan

The pedestrian enters the picture at a distance of maximum 26 meters. With an approaching speed of 5 km/h the TA value is 18.6 seconds. With the results at hand, the camera coverage is no limitation in the situations involving vehicles driving straight ahead and turning vehicles with the pedestrian taking evasive action. Thus, it would be possible to detect interactions on all severity levels, i.e. 1-30.

The vehicle driving straight ahead enters the picture at a maximum distance of 122 meters. With an approach speed of 50 km/h the maximum TA value is 8.8 seconds. The camera coverage is no limitation on the data collected since it would be possible to detect interactions on severity levels 11-30 and there are no observations at all in this interval.

The turning vehicle enters the picture at a maximum distance of 22 meters. With an approaching speed of 30 km/h the maximum TA value is 2.7 seconds. The most severe interactions where a turning vehicle has taken evasive action are most certainly all included in the registration on severity levels 22-30. The curve has started to move into lower frequencies when the coverage can be questioned. The maximum of the interaction frequency is therefore quite certainly also included.

Observations on location and from video recordings

Conflict studies are most often conducted on location. Conflict observers work out in the field. The observations of interactions are, however, made from video recordings only. There are several reasons for this. First of all we have the prospect of working with conflicts in a more automatic manner with the help of image processing in the near future. To study interactions from video might bring valuable information to the development of such an automatic analysis tool. As the interactions are so much more numerous than the conflicts it would be impossible for an observer in the field to keep track of all these situations. It would furthermore be very difficult to detect evasive actions taken far away from the conflicting point.

As far as possible the accidents, conflicts and interactions have been observed in the same way at the three different sites. Due to practical reasons it has not always been possible to accomplish this intention. All estimates of the TA/Speed values for accidents, conflicts and interactions at the three sites have been conducted in the same way; the severities are estimated from video recordings. The registration of accidents and conflicts do, however, differ. At Kaivokatu-Keskuskatu the occurrence of an accident is registered by the police and stored on video tapes. Both conflicts and interactions are registered from video. At Värnhemstorget the accidents are only in police files, not on video at all. The conflicts have been registered on location, while the interactions have been registered from video recordings. At Djäknegatan-Baltzarsgatan there are no accidents in the police files. The conflicts have been registered on location, while the interactions have been registered from video recordings.

4.5 Structure of the analyses

The analyses in the next chapter are based on the hypotheses briefed in Chapter 4.3 about which factors might influence the distribution of interactions with regard to severity. The hypotheses are:

A) There might be similarities between the severity shapes even though the data are collected during different time periods.
B) There might be similarities between the hierarchy shapes at similar types of intersections.
C) Type of control at the intersection might influence the hierarchy shape.
D) Type of manoeuvre at the intersection might influence the hierarchy shape.
E) Type of road user taking evasive action might influence the hierarchy shape.

The general structure of the presentations of the analyses is to handle the hypotheses one by one. Each hypothesis will be analysed from three different perspectives, sections 4.5.1-4.5.3 below. Due to the restraints mentioned above regarding the inability to register all interactions with less severity, all steps in the analyses are not possible to carry out for all hypotheses.

4.5.1 The whole frequency distribution of interactions

This analysis is to show the whole distribution, with regard to the location in the severity hierarchy, for all severity levels i.e. 1-30. The severity interval 1-30 is a reconstruction after the data collection, as it was obvious from the data collection that there were hardly any observations for any of the category cells located at lower severity than severity 1. The interaction frequency is of very different magnitude for different category cells. The aim of the data collection was to collect at least 100 interactions for each category cell or to make the observation during at least one hour. Due to different changes of the data set as the analyses of the interactions proceeded, the final number of interactions in each category cell ranges from n=58 to n=170. This analysis describes the distribution of interactions from the individual road user's point of view. It can be interpreted as the likelihood for the individual road user to be involved in an interaction with a certain severity if exposed to this type of situation n times. When interpreting comparisons between distributions of different category cells, the fact that the distributions are based on different numbers of interactions has to be kept in mind. The distributions are shown in a graph, like Figure 4:6, where the severity interval is between 1 and 30 and where the number of interactions is the total number of interactions observed for each severity level.

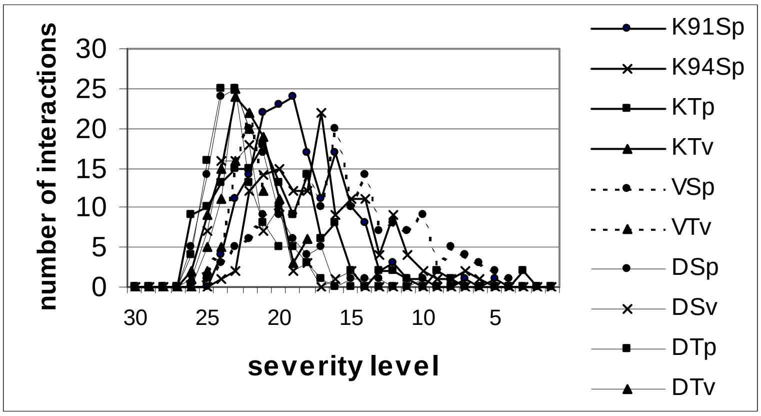

Figure 4:6 The whole frequency distribution of interactions for all the different category cells.

4.5.2 Percentage distribution

This analysis shows the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions in severity levels 11-30.
All observed interactions for each category cell are registered no matter how far away the road users are from each other in time and space when the evasive action starts. In that way interactions with very low severity are also registered. These interactions

are, however, very few for most category cells. The following numerical example of an interaction with severity of 10 or less also shows that interactions with severity of 1-10 must be considered to have very small safety relevance. Pedestrians approaching at 5 km/h with a TA value above 8 seconds have to take evasive action at least 11 meters before the conflicting point. The interacting vehicle with a speed of 30 km/h is at that moment at least 65 meters away from the conflicting point. If the vehicle speed is 50 km/h the vehicle is at least 110 meters away from the conflicting point when the pedestrian takes evasive action. The limit could of course be set between severity levels 9 and 10 or between severity levels 11 and 12, but it should at least be put far enough down in the hierarchy to make sure not to miss the most relevant aspects of the distribution.

A second reason for doing this type of analysis is the fact that it is not the same number of observations that are the basis for the different comparisons. There are, for instance, approximately 150 Kaivokatu-Keskuskatu straight forward observations registered during one hour while most other registrations, about 100 observations for each category cell, are registered during 3-14 hours. By calculating the percentage of the number of interactions for each severity in relation to all interactions between severity 11 and severity 30, the observations for the most interesting severity intervals are made more comparable. This analysis is also aimed at describing the interactive situation from the road user's perspective. The distributions will be shown in graphs like Figure 4:7.

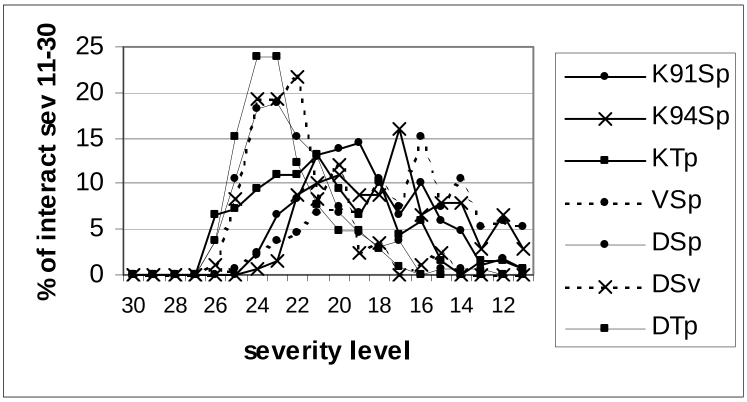

Figure 4:7 The percentage distribution of interactions while only regarding the more severe parts of the hierarchies. Only those category cells where it has been possible to detect interactions for all severity levels 11-30, are included.

4.5.3 Distribution based on interaction occurrence frequency

The third analysis consists of the interactions per hour for each severity level, for each category cell. This analysis describes a perhaps more interesting relationship from e.g. a traffic safety policy point of view, namely, the frequency of the interactions with regard to severity in a unit of time. The distributions will be shown in graphs like Figure 4:8.

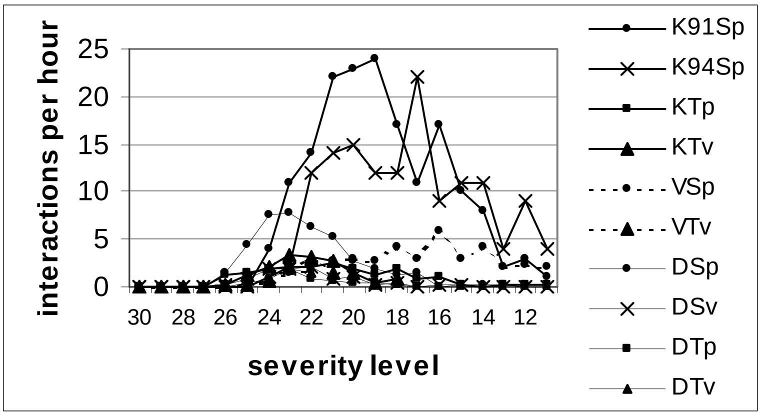

Figure 4:8 Distributions based on the occurrence rate of interactions for all the different category cells per unit of time.

4.5.4 Statistical analyses of the distributions

Besides analysing the shapes of the distributions by comparing the shapes in the graphs, it is also of great help to apply a statistical method to determine whether or not there is a statistically significant difference between the distributions. In the analyses of whether two distributions belong to the same distribution, the Kolmogorov-Smirnov test in Marascuilo & McSweeney (1977), has consistently been used. The Kolmogorov-Smirnov test (K-S test) has been based on the total number of interactions for each severity level. In the K-S test, the null hypothesis states that the distributions belong to the same distribution, i.e. that the distributions are identical. The procedure is to first rank-order the data. Next the cumulative relative frequencies for each sample are determined. Then the terms for the two samples are subtracted. The largest difference between the samples is called the KS value. The critical value is calculated with help of desired significance level and the sample numbers. If KS is greater than the critical value, the null hypotheses is rejected and we can conclude that the two distributions are not identical. All tests are two-sided and on a 95% significance level.

For all interactions registered it has been important to note whether it is the vehicle or the pedestrian that takes evasive action. When results from earlier conflict and accident studies are presented in terms of ratios, it might be worthwhile to note that those analyses were not based on which party it is that takes evasive action. Due to these differences it is perhaps not always appropriate to make a comparison, or at least these differences should be taken into consideration.

5 Results of the analyses

The procedure here, as explained in Chapter 4, is to present the hypotheses one by one. For each hypothesis, the three different types of analyses are then presented.

1) An analysis of the whole distribution, with regard to the location in the severity hierarchy for all severity levels i.e. 1-30.
2) An analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions in severity levels 11-30.
3) An analysis of the number of interactions per hour for each severity level, for each category cell.

For each analysis the distributions are compared both visually and by applying the Kolmogorov-Smirnov test. In the K-S test, the null hypothesis states that the distributions belong to the same distribution i.e. that the distributions are identical. If the null hypothesis is rejected we can conclude that the two distributions most likely are not identical.

The parameters in the tests and the category cells are explained in Chapter 4. The different types of interactions as viewed from the camera, are found in Appendix 3.

5.1 Results of hypothesis A

Hypothesis A) There might be similarities between the severity shapes even though the data are collected during different time periods.

The true hierarchy shape should reflect the sum of all road user behaviour at the location. If the intersection has remained unchanged, then observations collected during different years should produce similar hierarchy shapes. When interaction data from different years are compared it is not only a comparison with regard to possible general changes in traffic and behaviour, it is also a comparison with regard to actual changes at the intersection.

<u>A1) Comparison between 1991 and 1994 data at Kaivokatu-Keskuskatu</u>
Vehicle drivers driving straight ahead and pedestrians taking evasive action
Category cells: K91Sp versus K94Sp

A1.1) Analysis of the whole distribution, with regard to the location in the severity hierarchy, for all severity levels i.e. 1-30.

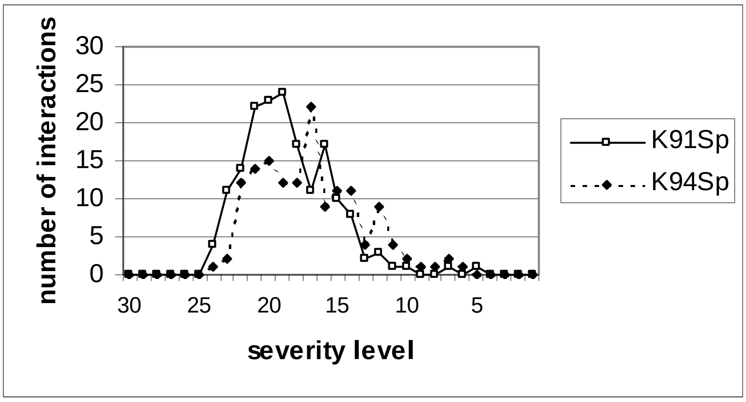

Figure 5:1 Total number of interactions on severity levels 1-30. Comparison between K91Sp (interactions at Kaivokatu-Keskuskatu 1991 data, vehicles driving straight ahead, pedestrian taking evasive action) and K94Sp (interactions at Kaivokatu-Keskuskatu 1994 data, vehicles driving straight ahead, pedestrian taking evasive action).

For both distributions, K91Sp and K94Sp in Figure 5:1, the observations with the highest severity are located on severity level 24. The two distributions resemble each other to some extent when the part of the curves with the majority of the interactions are compared. The convexity of the distributions ranges between severity level 11 and severity level 23. At the lowest severity levels both distributions level off and there are no interactions at all observed at severity level 4 and lower. Incidentally this pattern is not unique for these two category cells. It is on the contrary a general trend for all category cells where it has been possible to observe interactions with very low severity. There is a difference between the distributions with regard to the number of interactions observed; 170 in 1991 and 145 in 1994. Both studies are conducted during 1 hour. Besides this, it also seems, from Figure 5:1, as if the distributions are somewhat displaced in relation to each other. There is a tendency for the K91Sp data to be located more towards the higher severity levels than the K94Sp data. There is, by the way, no evident explanation for why the K94Sp interactions on severity level 17 are so numerous as compared to the adjacent severity levels. According to the K-S test the two distributions do not differ significantly between severity levels 14 and 30. When severity levels 13 and less severe are added, the differences between the distributions are too great to consider them as belonging to the same distribution. The null hypothesis about similar distribution therefore has to be rejected.

The Kaivokatu-Keskuskatu intersection has, however, not remained totally unchanged during the time of data collection. In spring 1992 the speed limit was reduced from 50 km/h to 40 km/h. The partly different distribution of category cells K91Sp and K94Sp might be due to this speed limit reduction. The change is in the expected direction, towards lower severities.

A1.2) Analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions in severity levels 11-30.

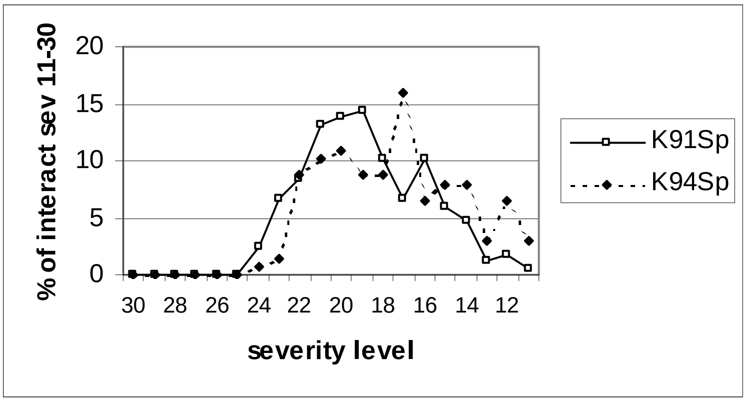

Figure 5:2 Percentage of interactions on each severity level in relation to all interactions in severity levels 11-30. Comparison between K91Sp (interactions at Kaivokatu-Keskuskatu 1991 data, vehicles driving straight ahead, pedestrian taking evasive action) and K94Sp (interactions at Kaivokatu-Keskuskatu 1994 data, vehicles driving straight ahead, pedestrian taking evasive action).

The shape of the distributions does not change between this analysis, Figure 5:2, and the previous analysis, Figure 5:1. Thus, when comparing category cells K91Sp and K94Sp there is no additional information achieved when analysing the percentage of the interactions in relation to all interactions within the severity interval 11-30. That is because most interactions observed for these category cells are located on severity levels 11-30.

If the frequency of the interactions observed on severity levels 11-30 were to be presented, analysis number 3 according to the structure set up, they would also have the same shape as the graph above since both K91Sp and K94Sp are observed during one hour.

From the road user's perspective, a distribution with the shape in Figure 5:2 indicates that once involved in an interaction, the likelihood that it is an interaction with fairly low severity is high. The flows of the vehicles driving straight ahead and the pedestrians to cross are rather high, which means that for each road user involved in this type of manoeuvre it is very likely that the road user at some point during the approach is on a collision course with another road user.

A1.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

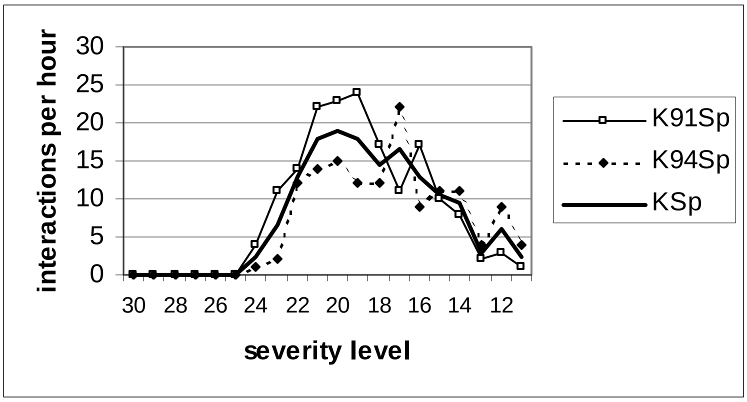

Figure 5:3 Number of interactions per hour on each severity level, for severity levels 11-30. Vehicles driving straight ahead, pedestrian taking evasive action. Comparison between 1991,1994 and 1991+1994 data at Kaivokatu-Keskuskatu i.e. comparison between K91Sp, K94Sp and KSp.

The interaction frequency is high, according to Figure 5:3, compared to the interaction frequencies for most other category cells, Figure 4:5. If the true hierarchy shape resembles this shape, this is a location with a high occurrence rate of interactions but where most interactions are of fairly low severity. From the traffic system's point of view this would be a ”safe” situation.

Both by looking at the distributions K91Sp and K94Sp and by testing the distributions statistically, it was previously stated that it is very likely that the two distributions differ. If the aim, however, is to consider what the distribution most likely will look like for interactions occurring between 1991 and 1994, when for instance the accident data have been collected, it could be appropriate to combine K91Sp and K94Sp into KSp, Figure 5:3.

Conclusions

The analyses show that data collected in 1991 most likely produce a different severity shape than the data collected in 1994 even though the data are collected at the same intersection with the same type of road users and manoeuvres. There might be several explanations for this difference. One of the more obvious explanations is associated with the difference in speed limits. The speed limit was changed from 50 km/h in 1991 to 40 km/h in 1994. In combination with this change there is also a difference in exposure. The straight ahead vehicle flow when the 1994 data was collected is somewhat lower than the corresponding flow when the 1991 data was collected. It is very probable that a lowering of the speed limit would influence the severity shape in the sense that it would be displaced towards lower severities. The difference in flow would also influence the size of the hierarchy. With higher interacting flows the probability of getting into a collision course increases, which is also evident from the data collected.

5.2 Results of hypothesis B

Hypothesis B) There might be similarities between the hierarchy shapes at similar types of intersections.

There is every reason to assume that similar intersections with regard to type of control (signal / priority / right-hand-rule etc.) will produce similar hierarchy shapes when the same type of road users and the same type of manoeuvres are studied.

B1) Comparison between Kaivokatu-Keskuskatu, Helsinki and Värnhemstorget, Malmö.
Vehicle driving straight ahead, pedestrian taking evasive action
Category cells: KSp and VSp

KSp = all interactions observed at Kaivokatu-Keskuskatu for data collected in 1991 and 1994, where the vehicle driver drives straight ahead and the pedestrian takes evasive action.
K91Sp = as KSp but only based on data collected in 1991.
K94Sp = as KSp but only based on data collected in 1994.
(I.e.
KSp = K91Sp+K94Sp.)
mKSp = an average of the interactions in 1991 and 1994 at Kaivokatu-Keskuskatu, where the vehicle driver drives straight ahead and the pedestrian takes evasive action = KSp/2.
VSp = all interactions observed at Värnhemstorget, where the vehicle driver drives straight ahead and the pedestrian takes evasive action.

This is not only a comparison between two signalised intersections. It is also an analysis of the difference between a signalised intersection in Helsinki and a signalised intersection in Malmö. It can furthermore be considered as an analysis of a signalised intersection in Finland and a signalised intersection in Sweden. In a previous analysis it turned out that there might be a difference for the interaction distribution with regard to when the data was collected at Kaivokatu-Keskuskatu. I have therefore chosen to compare both when the Kaivokatu-Keskuskatu data is based on interactions in 1994, KS94Sp and when the data either is based on an average of the interactions in 1991 and 1994, mKSp, or when the data is based on the total number of interactions observed in 1991 and 1994, KSp.

When observing the pedestrians taking evasive action at Värnhemstorget, the limitations in the camera coverage made it only possible to be certain to have registered interactions on severity levels 4-30. The analyses below therefore are always based on interactions on severity level 4 and higher.

B1.1) Analysis of the distribution of the total number of interactions for each severity level.

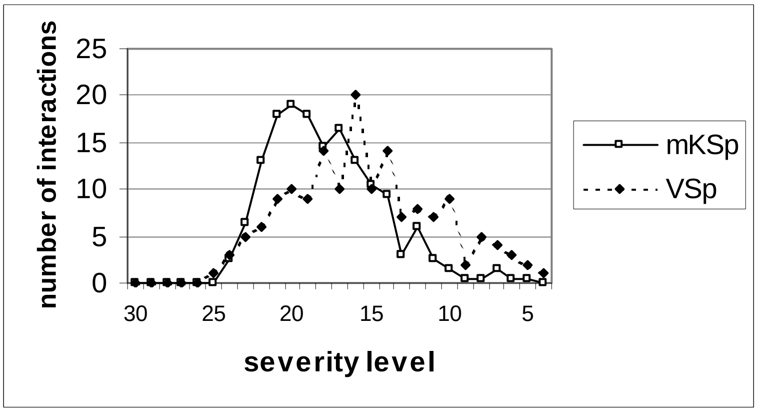

Figure 5:4 The total number of interactions on severity levels 4-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between an average of the 1991 and 1994 data at Kaivokatu-Keskuskatu, mKSp, and Värnhemstorget, VSp.

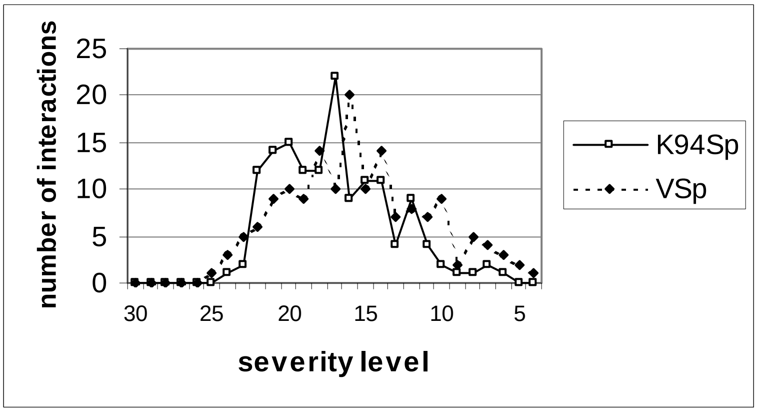

Figure 5:5 The total number of interactions on severity levels 4-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between Kaivokatu-Keskuskatu 1994 data, K94Sp, and Värnhemstorget, VSp.

If the comparison in Figure 5:4 was to be based on the whole interaction sample at Kaivokatu-Keskuskatu, KSp, the difference between the distributions could be misleading as the KSp is based on more than 300 observations while the VSp distribution is only based on approximately half that amount. The comparison in Figure 5:4 is therefore based on the mean number of interactions observed in 1991 and 1994 at Kaivokatu-Keskuskatu, mKSp, i.e. (K91Sp+K94Sp)/2 and VSp. In Figure 5:4 there seems to be a difference between the distributions. The convexity of the Kaivokatu-Keskuskatu curve is located more towards the higher severities as compared to the Värnhemstorget curve. According to the Kolmogorov-Smirnov test the null-hypothesis about similar distributions has to be rejected, i.e. it is not very likely that they belong to the same distribution.

The comparison between K94Sp and VSp in Figure 5:5 also shows a difference between the distributions. Even if the difference here is not as evident as for the mKSp versus VSp comparison, it is nevertheless big enough to make it difficult to claim that they would belong to the same distribution. If the distributions were to be cut off beneath severity level 11, then no significant differences between the distributions could be shown according to the K-S test. If, however, the K-S test was to be based on the whole distribution, severity levels 4-30, then it is more likely that the K94Sp and VSp do not belong to the same distribution.

B1.2) Analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all interactions on severity levels 11-30.

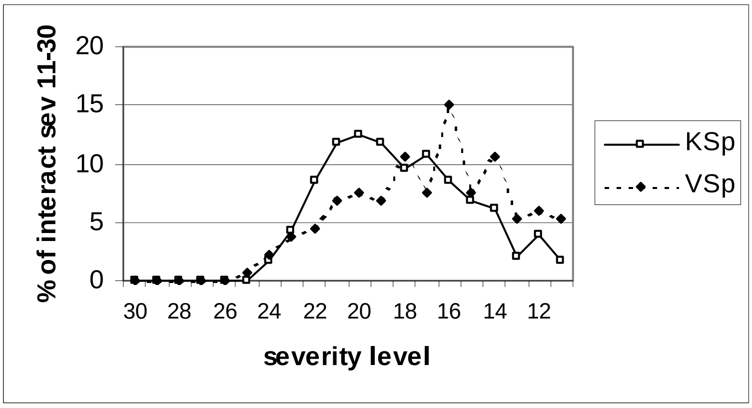

Figure 5:6 Percentage of interactions on each severity level in relation to all interactions on severity levels 11-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between 1991 and 1994 Kaivokatu-Keskuskatu data, KSp, and Värnhemstorget, VSp.

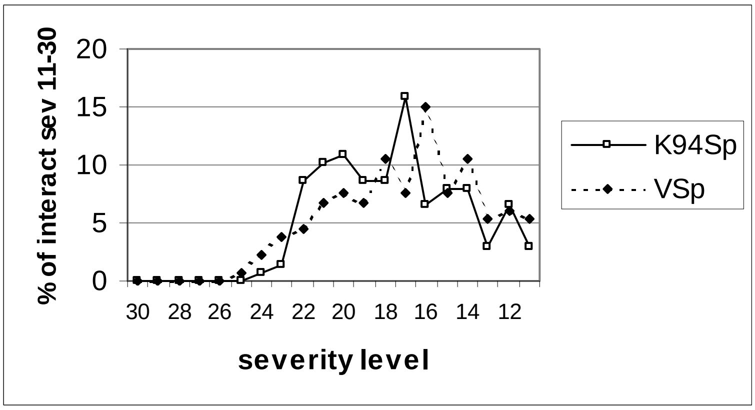

Figure 5:7 Percentage of interactions on each severity level in relation to all interactions on severity levels 11-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between 1994 Kaivokatu-Keskuskatu data, K94Sp, and Värnhemstorget, VSp.

There is not so much information added in Figure 5:6 when the KSp and VSp distributions are based on the percentage of interactions within severity levels 11-30 as compared to Figure 5:4 when the distributions are based on the total number of interactions. The foremost difference is that the distributions seem to be brought closer together for the highest severity levels in Figure 5:6. The reason is that VSp has comparably more observations than KSp at the lowest severity levels (which are not included in this analysis) and thereby VSp gets comparably higher values in the severity interval 11-30 when these are calculated as a percentage of the interval. The shapes of the distributions, therefore, in both Figure 5:6 and in Figure 5:4 look very similar for severity levels 23-30, and then they start to differ for the severity levels with less severity.

For the K94Sp and VSp comparison the distributions do not look identical, but do have some similarities in their form. For the interactions in severity interval 11-30, no significant differences could be shown between the distributions according to the K-S test. For the whole interval 4-30, however, the distributions do most likely differ.

B1.3) Analysis of the interaction frequency per hour for each severity level.

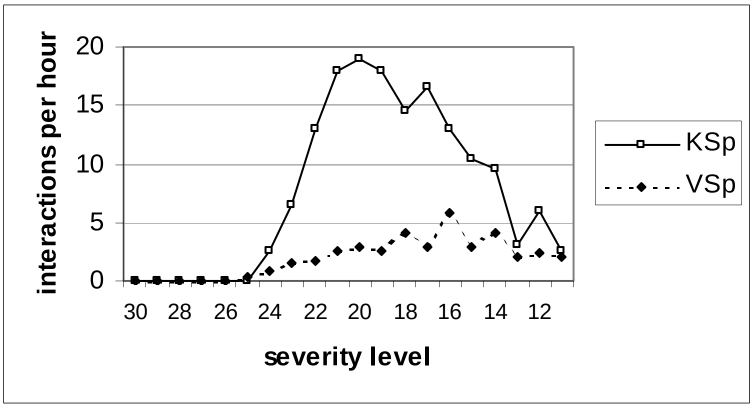

***Figure 5:8 Number of interactions per hour on each severity level, for severity levels 11-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between 1991 and 1994 Kaivokatu-Keskuskatu data, KSp, and Värnhemstorget, VSp*.**

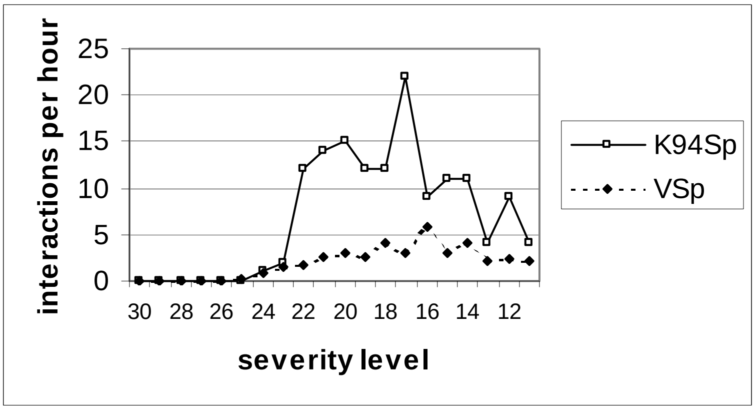

***Figure 5:9 Number of interactions per hour on each severity level, for severity levels 11-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between 1994 Kaivokatu-Keskuskatu data, K94Sp, and Värnhemstorget, VSp*.**

The interaction frequency differs very much between the straight forward interactions at Kaivokatu-Keskuskatu and those at Värnhemstorget. The greatly differing number of interactions in a unit of time might cause some difference in the severity distributions due to e.g. varying expectations of the road users. The road users should much more expect to be involved in an interaction at the Kaivokatu-Keskuskatu intersection.

Conclusions

The conclusion of the analyses in this section is that there might of course be similarities between the hierarchy shapes at similar types of intersections but there might as well be differences. The main similarity between the distributions at Kaivokatu-Keskuskatu and Värnhemstorget is the general pattern of a drawn-out convexity covering several severity levels. This, as we will discover in analyses further on, will be a different pattern than the distribution at the non-signalised intersection Djäknegatan-Baltzarsgatan. The differences between the distributions KSP, mKSp or K94Sp and VSp are, however, the most significant common characteristic of these analyses. Even if both Kaivokatu-Keskuskatu and Värnhemstorget are signalised intersections there are other factors that most likely cause the interaction patterns at these intersections to be different. The number of interactions per unit in time is different. This is likely due to the difference in exposure. The pedestrian flow at Värnhemstorget is approximately only 35% of the pedestrian flow at Kaivokatu-Keskuskatu. The vehicle flow is also somewhat lower at Värnhemstorget, approximately 70% of the vehicle flow at Kaivokatu-Keskuskatu. The difference in flow, everything else being equal, would primarily only influence the size of the severity hierarchies. The shapes of the hierarchies, the relation between the events with different severity, would remain the same. There must be something else besides, or due to, the difference in exposure that results in a difference in the interaction pattern. Expectations, the size of the city and cultural differences might affect the difference, but most probably the details in the intersection design and signal control schemes play a significant role.

Continuation B) There might be similarities between the hierarchy shapes at similar types of intersections.

<u>B2) Comparison between Kaivokatu-Keskuskatu, Helsinki and Värnhemstorget, Malmö</u>
Interactions where the vehicle driver turns and the vehicle driver takes evasive action.
Category cells: KTv and VTv

Because of the earlier results that there might be a difference in severity hierarchy shapes due to when the data was collected at Kaivokatu-Keskuskatu, not only KTv and VTv will be compared but also K94/95Tv and VTv. K94/95Tv consists of interactions collected in 1994 and 1995, i.e. after the speed reduction from 50 to 40 km/h at Kaivokatu-Keskuskatu.

There are rather great limitations in the camera coverage of interactions at Kaivokatu-Keskuskatu and Värnhemstorget where the vehicle driver turns and takes evasive action. The analyses are therefore only valid for interactions on severity levels 18-30 for KTv and 21-30 for VTv. The second analysis about the percentage of the interactions in the interval between severity levels 11 and 30 is therefore excluded.

B2.1) Analysis of the distribution of the total number of interactions for each severity level.

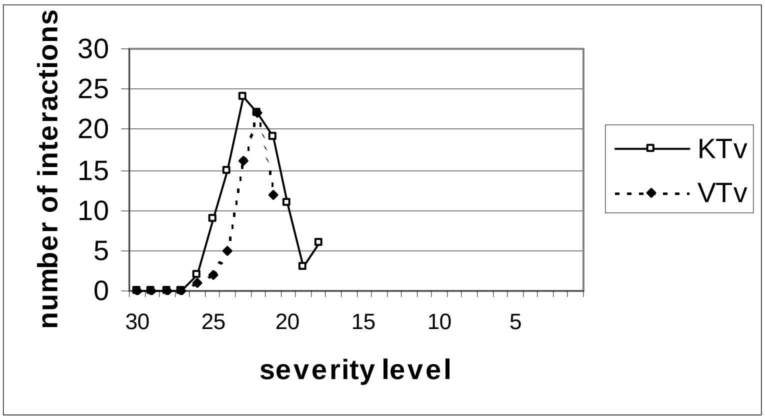

Figure 5:10 The total number of interactions on severity levels 18-30 for KTv and 21-30 for VTv. Vehicle drivers driving straight ahead and pedestrians taking evasive action. Comparison between all interactions at Kaivokatu-Keskuskatu, KTv, and Värnhemstorget, VTv.

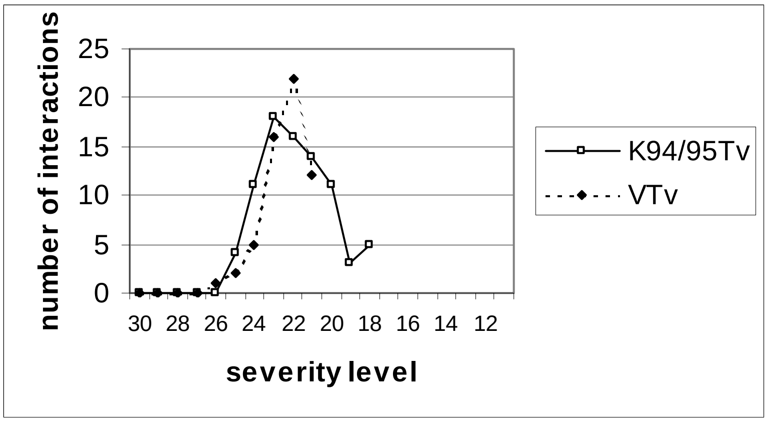

Figure 5:11 The total number of interactions on severity levels 18-30 for K94/95Tv and 21-30 for VTv. Vehicle drivers driving straight ahead and pedestrians taking evasive action. Comparison between interactions collected in 1994 and 1995 at Kaivokatu-Keskuskatu, K94/95Tv, and Värnhemstorget, VTv.

For the small part of the severity hierarchy where it is possible to compare KTv and VTv in Figure 5:10, the distributions look very similar, perhaps with a tendency for the KTv to be located more towards the higher severities. This tendency must certainly not be exaggerated, but it could be noted that it complies with the impression from the observations. At interactions with turning vehicles at Värnhemstorget it was very rarely the pedestrian that took evasive action. This can be interpreted as there seldom being any need for the pedestrian to take evasive action as most vehicle drivers obeyed the rule to give priority to the crossing pedestrian. It might be possible to follow this reasoning by suggesting that the evasive action most often was taken in such ample time that the pedestrian rarely felt the need to take an evasive action him/herself. At Kaivokatu-Keskuskatu it was just as often the vehicle driver as the pedestrian that took evasive action at interactions with a turning vehicle driver. For some reason, perhaps due to higher pedestrian flows, it seems to be more common at Kaivokatu-Keskuskatu than at Värnhemstorget for the turning vehicle driver to force his/her way through the crossing pedestrians and to drive with lower safety margins. This tendency is much smaller when comparing K94/95Tv and VTv in Figure 5:11, if there is any tendency at all. The main conclusion is nevertheless that KTv and VTv, K94/95Tv and VTv, most probably are similar, i.e. that the interaction pattern is probably about the same for turning vehicle drivers taking evasive action at Kaivokatu-Keskuskatu as at Värnhemstorget. Nor do there seem to be any major differences between this type of interaction in the 1994 and 1995 data set as compared to the whole data set at Kaivokatu-Keskuskatu.

B2.3) Analysis of the interaction frequency per hour for each severity level

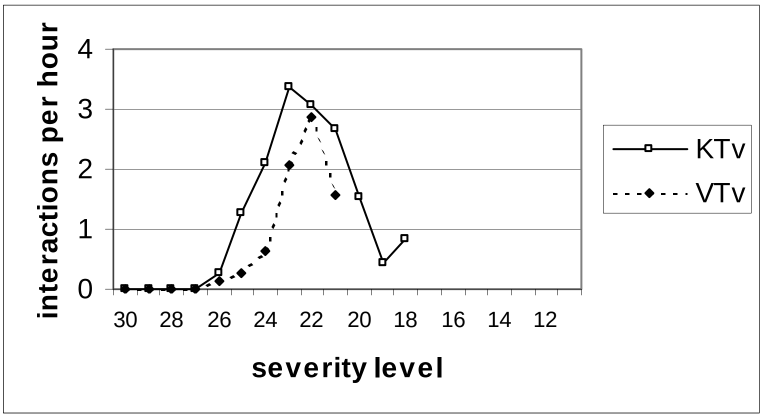

***Figure 5:12 Number of interactions per hour on each severity level, for severity levels 18-30 for KTv and 21-30 for VTv. Turning vehicle drivers and vehicle drivers taking evasive action. Comparison between Kaivokatu-Keskuskatu, KTv, and Värnhemstorget, VTv*.**

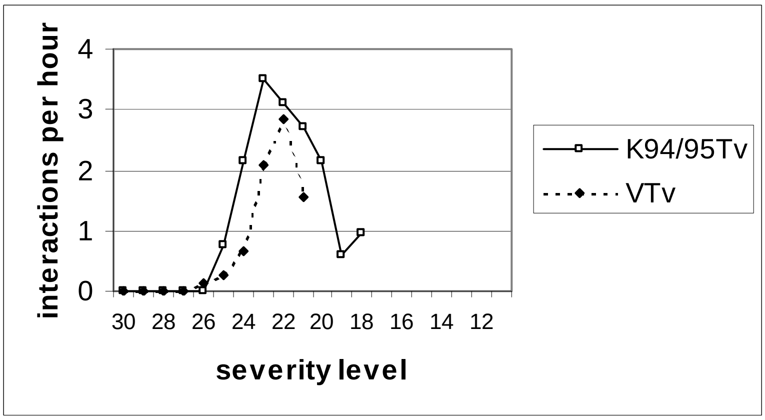

***Figure 5:13 Number of interactions per hour on each severity level, for severity levels 18-30 for K94/95Tv and 21-30 for VTv. Turning vehicle drivers and vehicle drivers taking evasive action. Comparison between 1994 and 1995 Kaivokatu-Keskuskatu data, K94/95Tv, and Värnhemstorget, VTv*.**

According to Figure 5:12 and 5:13 the interaction frequency per unit of time is very similar for the Kaivokatu-Keskuskatu and the Värnhemstorget category cells. Nor does there seem to be any difference depending on which data period the Kaivokatu-Keskuskatu distribution is based. The turning vehicle flows are very much of the same magnitude at Kaivokatu-Keskuskatu as at Värnhemstorget. The pedestrian flows, however, differ considerably. The pedestrian flow at Värnhemstorget is about 35% of the pedestrian flow at Kaivokatu-Keskuskatu. As this analysis deals with the turning vehicle taking evasive action and the flows are of the same magnitude, naturally the interaction frequency must also be of the same magnitude. The distributions with regard to number of interactions per unit of time are indeed very similar, and this is also supported by the K-S test; the null hypothesis about similar distribution cannot be rejected. There is however a tendency in Figures 5:12 and 5:13 that the Kaivokatu-Keskuskatu interactions are more widely spread over the severity levels as compared to the more concentrated Värnhemstorget interactions. The difference in pedestrian flow can perhaps give a clue to this small tendency of difference. At Kaivokatu-Keskuskatu it is perhaps more understandable that a vehicle driver tries to force his/her way through, as the driver otherwise would have to stop and wait for a long period of time until all pedestrians have passed. At the same time the distribution points at the possibility that vehicle drivers usually take evasive action in ample time. Taking evasive action in ample time when the flow of pedestrians is high is perhaps not equal to taking evasive action for a specific pedestrian but rather to taking evasive action for the crowd of pedestrians. If the vehicle driver takes evasive action due to a subjective collision course with the crowd, then there is most certainly a real collision course with at least one pedestrian in the crowd. That pedestrian can, however, very well cross fairly far way from the vehicle driver.

Conclusions

For the relatively small part of the severity hierarchy where it has been possible to compare KTv and VTv and K94/95Tv and VTv, severity levels 21-30, it must be concluded that it is likely that the distributions are similar.

5.3 Results of hypothesis C

Hypothesis C) Type of control at the intersection might influence the severity hierarchy shape.

The accident-to-serious conflict ratios are different, according to previous studies, at signalised intersections from those at non-signalised intersections. It is therefore reasonable to believe that the whole shape of the severity hierarchy could look different at signalised intersections as compared to non-signalised intersections when the same type of road users and the same type of manoeuvres are studied. In the analyses, the hierarchy shape at the signalised intersection Värnhemstorget will be compared with the hierarchy shape at the non-signalised intersection Djäknegatan-Baltzarsgatan. Both intersections are located in Malmö, Sweden.

C1) Comparison between Djäknegatan-Baltzarsgatan and Värnhemstorget
The vehicle driver drives straight ahead and the pedestrian takes evasive action
Category cells: DSp and VSp
For VSp there is a limitation in camera coverage. Thus, for both distributions only interactions within the severity interval 4-30 are included.

C1.1) Analysis of the distribution of the total number of interactions for each severity level.

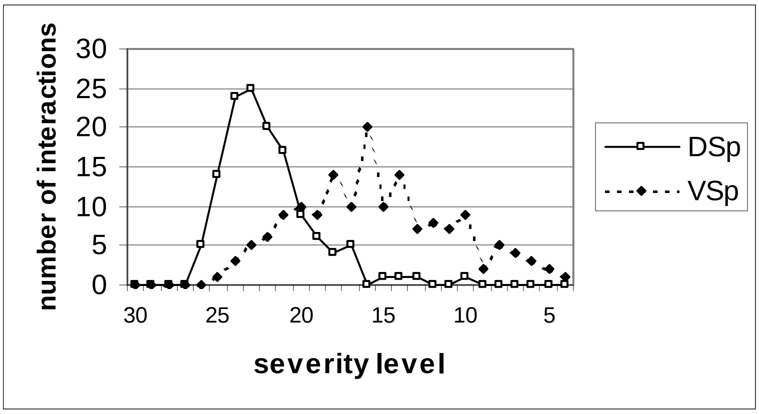

Figure 5:14 The total number of interactions at severity levels 4-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between interactions at the non-signalised intersection Djäknegatan-Baltzarsgatan, DSp, and interactions at the signalised intersection Värnhemstorget, VSp.

The two distributions differ considerably. For interactions involving a vehicle driving straight ahead the evasive behaviour of the pedestrian is very different depending on if the interaction takes place at a signalised intersection or at a non-signalised intersection. At the non-signalised intersection (Djäknegatan-Baltzarsgatan) these interactions, DSp, are concentrated towards higher severities. The safety margin for an interaction located on severity level 26, the most severe level with DSp interactions, is not extremely small. If the pedestrian approaches with a speed of 5 km/h, then he/she starts to take evasive action approximately 0.4 seconds or 0.5 meters before the kerb. For the signalised intersection (Värnhemstorget) the interactions, VSp, are more spread out, with a tendency to be located towards the lower severities. The distributions are located in contradictory directions to what we anticipated. According to accident data the signalised intersection of Värnhemstorget is a less safe location than the non-signalised intersection of Djäknegatan-Baltzarsgatan. It was anticipated that a location towards higher severities among events less severe than serious conflicts could also be considered as a sign of a higher probability of getting seriously injured in traffic. This way of reasoning presupposes a continuous relation between increase of severity and increase of the probability of the event to result in a collision with serious injury. The relation must indeed most certainly be continuous, but not necessarily linear.

The interactions at Djäknegatan-Baltzarsgatan, DSp, are characterised by closeness in time and space. The awareness of the continuous presence of other crossing road users is high. The speeds of the vehicles are mostly quite moderate. This type of traffic climate makes it possible to interact with quite small safety margins and thus perhaps create the basis for safe interactions. These types of interactions with mutual adaptation of speed and direction at fairly high severity levels cannot be found at Värnhemstorget category cell VSp. This is a logical effect due to Värnhemstorget being a signal controlled intersection. At signalised intersections there is a high degree of delegation of responsibility. Few interactions at these severity levels with higher severity might create false expectations about the signal always working as it should and about other road users always behaving in compliance with the signal. If, as at VSp, most interactions are handled with an evasive action at a very early stage, perhaps so early that the other road user is never aware of the existence of an interaction, it might create an expectation about a traffic situation without any possible interaction. Once a pedestrian or a vehicle driver does not comply with the red signal and at the same time moves on a collision course with another road user, the preparedness to handle the situation safely must be low. Especially if the interaction is very close in time and space.

As the total number of interactions for severity levels 11-30 is very similar for the two category cells, there is no additional information to obtain by analysing the percentage of interactions in severity levels 11 to 30, i.e. the pattern resembles of the one in Figure 5:14. Thus, the ”second” analysis is excluded.

C1.3) Analysis of the interaction frequency per hour for each severity level.

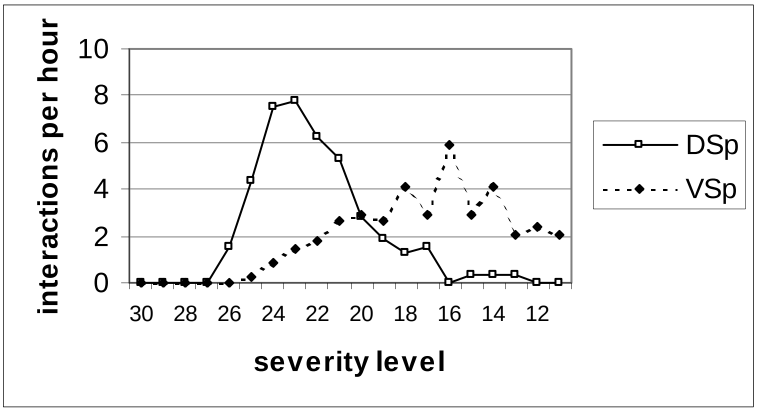

Figure 5:15 Number of interactions per hour on each severity level, for severity levels 11-30. Vehicles driving straight ahead and pedestrians taking evasive action. Comparison between interactions at the non-signalised intersection Djäknegatan-Baltzarsgatan, DSp, and interactions at the signalised intersection Värnhemstorget, VSp.

The interaction frequency is of the same magnitude at Djäknegatan-Baltzarsgatan (non-signalised) as at Värnhemstorget (signalised). The probability of an interaction with higher severity to occur is higher at the non-signalised intersection than at the signalised intersection. The duration of the time of observation has been approximately the same for the two category cells. During this period about the same number of interactions within severity levels 11 to 30 have been registered (for VSp there are also interactions registered in severity levels 1-10)

Conclusions

There is a difference with regard to the shape of the severity hierarchy depending on whether the interactions take place at the non-signalised intersection, DSp, or at the signalised intersection, VSp. The distribution of the interactions for DSp are located more towards higher severities as compared to the interactions for VSp. Up to a certain point in the severity hierarchy, it might be that increased severity does not necessarily imply a considerable increase of the probability for an event to result in a collision with injuries. The analyses here might, therefore, not be contradictory to the accident data which implies the signalised intersection of Värnhemstorget to be a less safe location.

Continuation C)   Type of control at the intersection

C2) Comparison between Djäknegatan-Baltzarsgatan and Värnhemstorget.
The vehicle driver turns and the driver takes evasive action
Category cells: DTv and VTv

For both DTv and VTv there is a limitation in the camera coverage. For VTv only interactions within severity levels 21-30 are included. The total number of interactions observed at these severity levels is 58. DTv is even more limited. For DTv only interactions within severity levels 22-30 are included. The total number of interactions observed at severity levels 22-30 is, however, of the same magnitude as VTv, 61. Due to the fairly small data sets it will probably not be possible to draw any firm conclusions from the distributions in the analyses.

C2.1) Analysis of the distribution of the total number of interactions on each severity level.

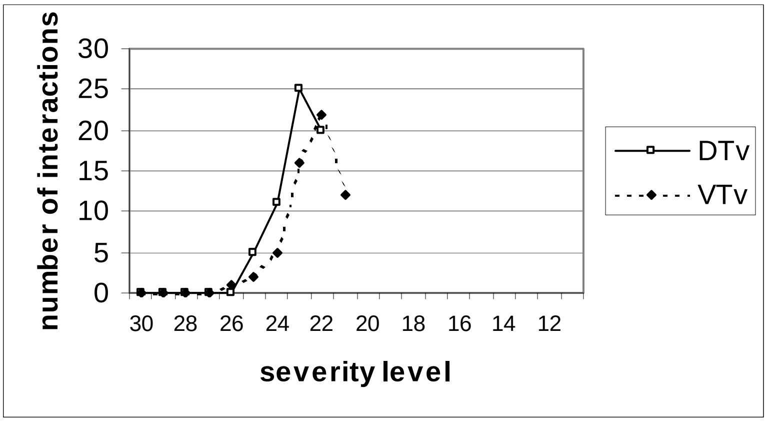

Figure 5:16 The total number of interactions within severity levels 22-30 for DTv and severity levels 21-30 for VTv. Interactions involve turning vehicles; the vehicle driver takes evasive action. Comparison between the non-signalised intersection Djäknegatan-Baltzarsgatan (DTv) and the signalised intersection Värnhemstorget (VTv).

The two distributions DTv and VTv look very similar for the limited parts of the severity hierarchies where it has been possible to observe interactions. No significant differences could be shown by the Kolmogorov-Smirnov test. It is very likely that the severity distributions are similar. It might be interesting to note that the DTv is somewhat displaced towards higher severities as compared to VTv.

As it has not been possible to observe interactions on all severity levels between 11 and 30, the second analysis of percentages is excluded.

C2.3) Analysis of the interaction frequency per hour for each severity level.

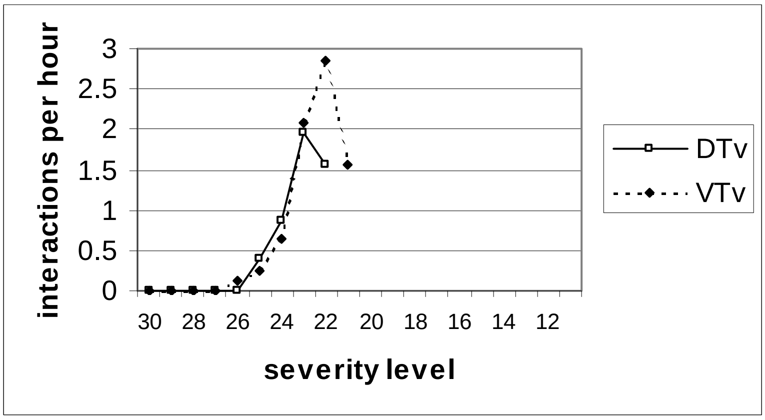

Figure 5:17 Number of interactions per hour on each severity level, i.e. for DTv severity levels 22-30 and for VTv severity levels 21-30. Interactions involve turning vehicles; the vehicle driver takes evasive action. Comparison between the non-signalised intersection Djäknegatan-Baltzarsgatan (DTv) and the signalised intersection Värnhemstorget (VTv).

There is no great difference between the distributions with regard to occurrence rate of interactions, either. The distributions look very similar.

Conclusions
For the turning vehicle interactions, the comparison between the signalised intersection Värnhemstorget, VTv, and the non-signalised intersection Djäknegatan-Baltzarsgatan, DTv, shows contradictory results from the previous comparison for vehicles driving straight ahead, i.e. the comparison between VSp and DSp.

Traffic behaviour at a signalised intersection is different from the behaviour at a non-signalised intersection. The greatest difference must nevertheless be found for the interactive behaviour between road users in conflicting traffic flows (flows that at a signalised intersection are separated in time) i.e. in my case between the vehicle driving straight ahead and the pedestrian on a perpendicular course. At a signalised intersection most pedestrians approach the pedestrian crossing with the intention of stopping for the red light. A corresponding behaviour cannot be found at a non-signalised intersection.

The situation with the turning vehicles can, however, involve similar behaviour at a signalised and at a non-signalised intersection. Due to the turning manoeuvre, the turning vehicles generally have to slow down irrespective of whether the intersection is signalised or not. This might induce similar interactive behaviour with turning vehicles at a signalised and at a non-signalised intersection.

5.4 Results of hypothesis D

Hypothesis D) Type of manoeuvre at the intersection might influence the shape of the severity hierarchy.

The accident-to-serious conflict ratios differ, also here according to previous studies, due to type of manoeuvre. It is therefore also here reasonable to assume that the whole shape of the severity hierarchy could look different for different types of manoeuvres at the same intersection. The analyses are based on a comparison between interactions where the vehicle drives straight ahead and interactions where the vehicle turns.

D1) Comparison between interactions with vehicles driving straight ahead and turning vehicles.

Situations with pedestrian taking evasive action at Kaivokatu-Keskuskatu.
Category cells: mKSp and KTp, KSp and KTp.

mKSp = an average of the interactions in 1991 and 1994 at Kaivokatu-Keskuskatu, where the vehicle driver drives straight ahead and the pedestrian takes evasive action = KSp/2.

D1.1) Analysis of the whole distribution, with regard to the location in the severity hierarchy for all severity levels, i.e. 1-30.

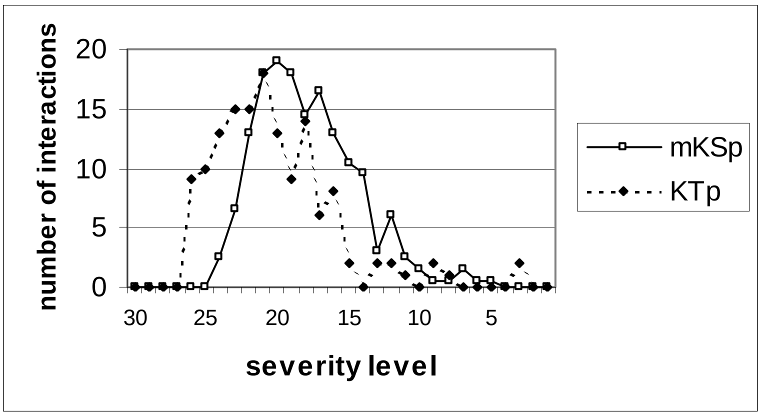

Figure 5:18 Total number of interactions on severity levels 1-30. Interactions at Kaivokatu-Keskuskatu where the pedestrian takes evasive action. Comparison between interactions with vehicles driving straight ahead, mKSp, and interactions with turning vehicles, KTp.

If the comparison in Figure 5:18 was to be based on the whole interaction sample at Kaivokatu-Keskuskatu, KSp, the difference between the distributions could be misleading as the KSp is based on more than 300 observations while the KTp distribution is only based on approximately half that amount. The comparison in Figure 5:18 is therefore based on the mean number of interactions observed in 1991 and 1994 at Kaivokatu-Keskuskatu, mKSp, i.e. (K91Sp+K94Sp)/2 and KTp.

In Figure 5:18 there seems to be a difference between the distributions with regard to location in the severity scale even if there might be some similarities regarding the convexity. This interpretation is supported by the result of the Kolmogorov-Smirnov test, where the null hypothesis about similar distribution has to be rejected. The turning vehicle situations seem to be located towards higher severities. There is of course the possibility that the interactions between the turning vehicles and crossing pedestrians, with the closeness in time and space that is characteristic for these interactions, would form a distribution pattern that is located more towards the higher severities than the interactions between vehicles driving straight ahead and approaching pedestrians. It is nevertheless quite remarkable for KTp that the number of interactions with very high severity, level 26, is so large and then drops to zero at level 27. This discontinuity suggests that the registration procedure perhaps includes interactions where the contribution of near misses is too great.

As described in Chapter 4, the registration procedure would assure that all relevant interactions were to be included. Near-misses with a time gap of 0.2 seconds were to be regarded as interactions. Such small time gaps are almost impossible for the human eye to distinguish from a real collision course. In addition, the interactions have been analysed as if the vehicle fills up the whole driving lane. The reasons for this were, as mentioned, first of all to make sure that all interactions with a collision course were registered. It can be seen as an attempt to make up for deficiencies due to apparatus and human observation errors. A second reason was the assumption that subjective collision courses, events where the road user behaves as if there was a collision course, could be safety related. The margins for relevant interactions have perhaps been set too wide and the discontinuity seen at the top of the severity hierarchy for KTp could be a result of this.

D1.2) Analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions on severity levels 11-30.

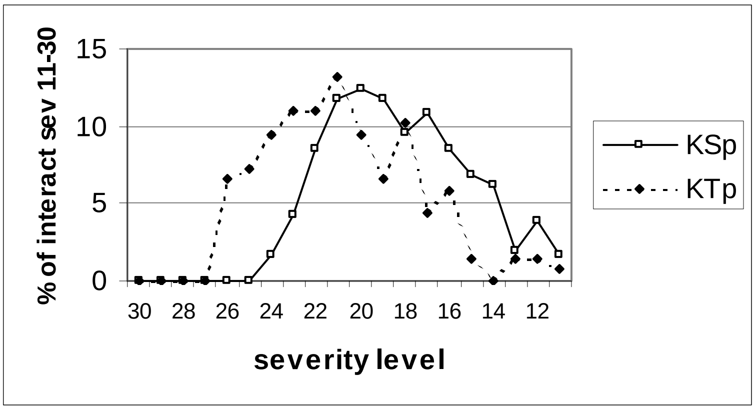

Figure 5:19 Percentage of interactions on each severity level in relation to all interactions on severity levels 11-30. Interactions at Kaivokatu-Keskuskatu where the pedestrian takes evasive action. Comparison between interactions with vehicles driving straight ahead, KSp, and interactions with turning vehicles, KTp.

The distributions in Figure 5:19, the percentage of interactions within severity levels 11-30, resemble the patterns in Figure 5:18 as most interactions for both KTp and KSp are located at severity level 11 and higher.

D1.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

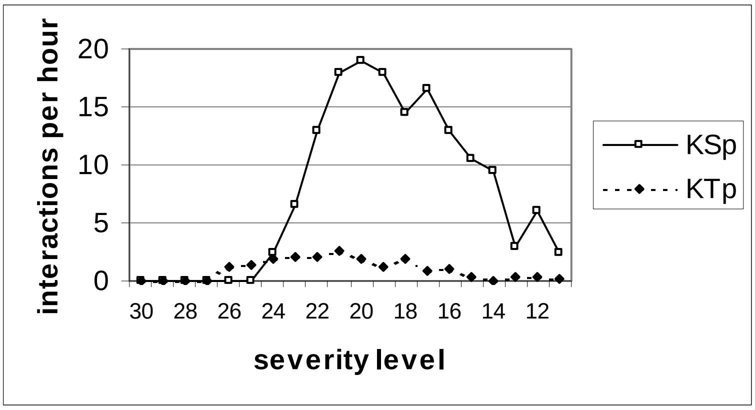

Figure 5:20 Number of interactions per hour on each severity level, for severity levels 11-30. Interactions at Kaivokatu-Keskuskatu where the pedestrian takes evasive action. Comparison between interactions with vehicles driving straight ahead, KSp, and interactions with turning vehicles, KTp.

There is a big difference between the straight ahead situations, KSp, and the turning situations, KTp, with regard to occurrence rate of interactions of different severities, Figure 5:20. The KSp interactions are much more frequent than the KTp interactions. This is not very surprising as the pedestrians taking evasive action in the KSp interactions are also stopping at a red signal at the same time. The interaction is also likely to be of not too high severity.

Conclusions

There is a difference between KSp and KTp with regard both to location in the severity hierarchy and occurrence frequency of interactions at different severity levels. These differences between the distributions are also valid for all category cells where the data sets have been disaggregated with regard to time for data collection, even though the results of these comparisons are not presented here. The turning vehicle interactions are located towards higher severities than the straight ahead interactions. There is, however, a discontinuity at the highest severities for KTp that might give reason to investigate whether the registration procedure perhaps includes disproportionately many interactions at the highest severity levels. The occurrence rate of interactions is significantly higher for KSp than KTp.

Continuation D) Type of manoeuvre at the intersection might influence the shape of the severity hierarchy.

D2) Comparison between interactions with vehicles driving straight ahead and turning vehicles

Interactions where the pedestrian takes evasive action at Djäknegatan-Baltzarsgatan
Category cells: DSp and DTp

D2.1) Analysis of the whole distribution, with regard to the location in the severity hierarchy for all severity levels, i.e. 1-30.

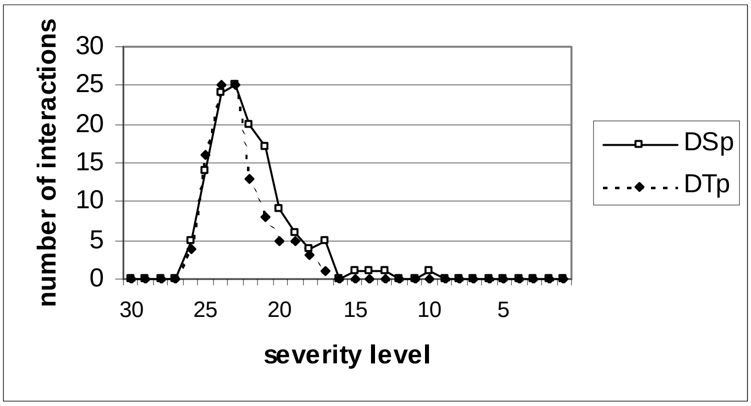

Figure 5:21 The total number of interactions on severity levels 1-30. Situations with pedestrians taking evasive action at Djäknegatan-Baltzarsgatan. Comparison between vehicles driving straight ahead, DSp, and turning vehicles, DTp.

For interactions where the pedestrians take evasive action, the distributions for vehicles driving straight ahead and turning vehicles look very similar, if not almost identical. The similarity is supported by the Kolmogorov-Smirnov test, where the null hypothesis about similar distribution for DSp and DTp cannot be rejected. Both distributions have the observed interactions with the highest severity on severity level 26. The convexities of the distributions look very similar, and the peaks of the distributions are located on the same severity level for both distributions. Both distributions also level off in the same way towards the lowest severity levels. For DTp there are no interactions registered at all on severity level 16 and lower. At these severity levels there are only a few scattered observations for DSp.

From the pedestrians' perspective the severity distribution looks very similar, irrespective of whether the vehicle drives straight ahead or turns, for situations where the pedestrian takes evasive action. The pedestrian's adaptive behaviour is very similar for the two situations. There seem to be fairly small time margins in both situations.

D2.2) Analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions on severity levels 11-30.

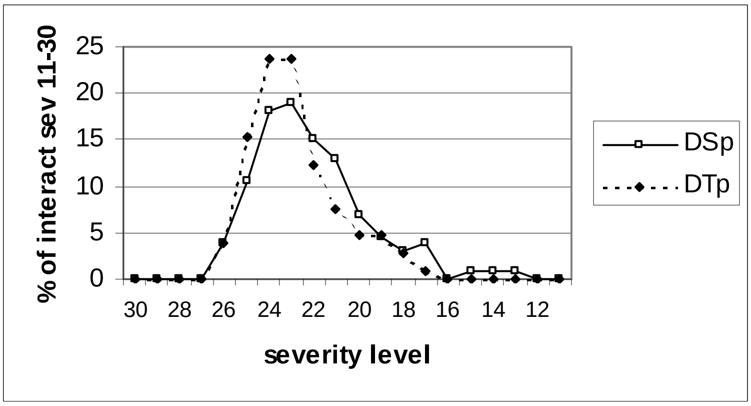

Figure 5:22 Percentage of interactions on each severity level in relation to all interactions on severity levels 11-30. Situations with pedestrians taking evasive action at Djäknegatan-Baltzarsgatan. Comparison between vehicles driving straight ahead, DSp, and turning vehicles, DTp.

The two distributions, DSp ans DTp, have similar patterns when the percentages of all interactions within severity levels 11-30 are analysed. There is perhaps a small tendency for the turning vehicle interactions, DTp, to have proportionally more interactions with higher severity than the straight ahead vehicle interactions, DSp. When watching the interactions on video it is quite evident that the vehicles driving straight ahead on Djäknegatan drive as if they have the right of way even if they should give way to the vehicles coming from the right, the turning vehicles. The turning vehicles also generally behave as if they have to give way to the traffic on Djäknegatan. This might put the approaching pedestrian in the position of expecting the turning vehicles to approach with lower speeds. At low enough speeds the pedestrian might interpret the low speeds as an indication that the driver will give way to the pedestrian. In this perspective it is perhaps not so strange that the interactions with the turning vehicles and the pedestrian taking evasive action have a somewhat higher severity than the interactions with the vehicles driving straight ahead and the pedestrian taking evasive action. It is perhaps even so that it is more likely that pedestrians have more interactions with higher severities with turning vehicles as the pedestrian possibly is more convinced that the turning vehicles with the lower speeds would more easily stop for them than the vehicles driving straight ahead with higher speeds. The mean speed for the vehicles in the DSp situation is 27.6 km/h and the mean speed for the vehicles in the DTp situation is 16.0 km/h.

If we do not want to go as far as saying that the turning situations have more interactions with higher severity than the straight ahead situations, due to the actually fairly small differences, we must conclude that the distributions look very similar. How can this similarity be explained? One possible explanation could be a consistency in the subjective safety margins of the crossing pedestrians. Let’s say that a pedestrian approaches Djäknegatan with a speed of 5 km/h. The pedestrian moves on a collision course with a vehicle, takes evasive action and the TA value is estimated to be 1.0 seconds. To obtain the same TA value and the same severity whether the approaching vehicle drives at a higher or lower speed, the pedestrian has to take evasive action when the vehicle is at different distances from the collision point.

If the interacting vehicle is a vehicle driving straight ahead with a speed of 27.6 km/h, the pedestrian has to take evasive action when the vehicle is approximately 7.5 meters from the collision point in order to obtain a TA value of 1.0 seconds. If the interacting vehicle instead is a turning vehicle with a speed of 16 km/h, the pedestrian has to take evasive action when the vehicle is approximately 4.5 meters from the collision point to obtain the same TA value. This is how the similarities, despite the differences in speed, between the DSp and DTp distributions can be described. This relation might indicate the existence of a constant subjective safety margin in time for the conditions at Djäknegatan-Baltzarsgatan.

D2.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

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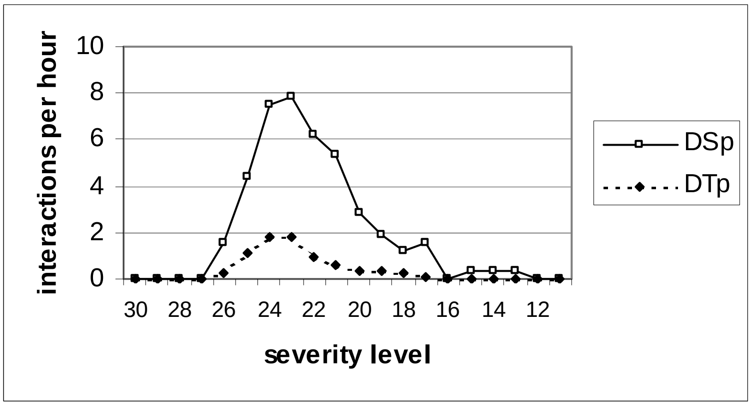


Figure 5:23 Number of interactions per hour on each severity level, for severity levels 11-30. Situations with pedestrians taking evasive action at Djäknegatan-Baltzarsgatan. Comparison between vehicles driving straight ahead, DSp, and turning vehicles, DTp.

The interaction frequency differs considerably between the turning and the straight ahead situations. For interactions with pedestrians taking evasive action it is more likely that this interaction involves a vehicle driving straight ahead than a turning vehicle, as the flow of vehicles driving straight ahead is much higher than the flow of turning vehicles. It is also very likely that the severity of this interaction is located towards the higher severity levels.

Conclusions

The null hypothesis about similar distribution cannot be rejected. The hypothesis about a difference with regard to severity distribution depending on whether the vehicle turns or drives straight ahead cannot be supported for the Djäknegatan-Baltzarsgatan conditions.

Continuation D) Type of manoeuvre at the intersection might influence the shape of the severity hierarchy

D3) Comparison between interactions with vehicles driving straight ahead and turning vehicles

Interactions at Djäknegatan- Baltzarsgatan where the vehicle takes evasive action. Category cells: DSv and DTv.

There are limitations in the camera coverage for DTv. It has only been possible to include interactions observed within the severity interval 22-30. All analyses are, therefore, based on interactions observed on severity levels 22-30, even if the figures show the whole distribution for DSv. For both data sets, the total number of interactions within severity levels 22-30 are also quite limited. DSv is based on 58 interactions and DTv on 61 interactions. Due to the fairly small data sets it will probably not be possible to draw any firm conclusions from the distributions in the analyses.

D3.1) Analysis of the whole distribution, with regard to the location in the severity hierarchy for severity levels 1-30.

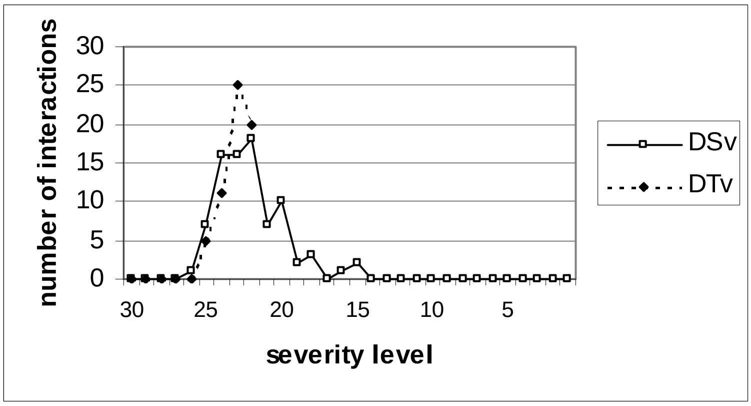


Figure 5:24 Total number of interactions on severity levels 1-30 for DSv and 22-30 for DTv . Interactions at Djäknegatan where the vehicle takes evasive action. Comparison between vehicles driving straight ahead, DSv, and turning vehicles, DTv.

For the parts of the distributions where it is possible to make a comparison, severity levels 22-30, the distributions look very similar in Figure 5:24. In the Kolmogorov-Smirnov test the null hypothesis about similar distribution cannot be rejected. The vehicle driver's adaptive behaviour is very similar whether the driver turns or drives straight ahead at the Djäknegatan-Baltzarsgatan intersection despite a difference in speed. The mean speed of the vehicles driving straight ahead; vehicle taking evasive action, is 19.3 km/h. For the interactions on severity levels 22-30 the mean speed is the same, 19.5 km/h. The mean speed for the turning vehicles; vehicle taking evasive action, severity levels 22-30, is 14.2 km/h. For the whole distribution the mean speed is presumably a little bit lower.

For the vehicles driving straight ahead it might be interesting to notice the difference in speed between DSp, pedestrian takes evasive action, 27.6 km/h (analysed in D2) and DSv, vehicle takes evasive action, 19.3 km/h. The corresponding difference for the turning situations is smaller, DTp 16.0 km/h and DTv 14.2 km/h. There might be some reason to believe that when the speed of the interacting vehicle is higher the pedestrian prefers to take evasive action for otherwise the safety margin might become too small for the pedestrian. At lower approaching speeds of the interacting vehicle the pedestrian more often puts the vehicle driver in the position of having to take evasive action.

As the observed interactions are limited to severity levels 22-30, the percentage analysis is excluded.

D3.3) Analysis of the number of interactions per hour on each severity level, for each category cell.

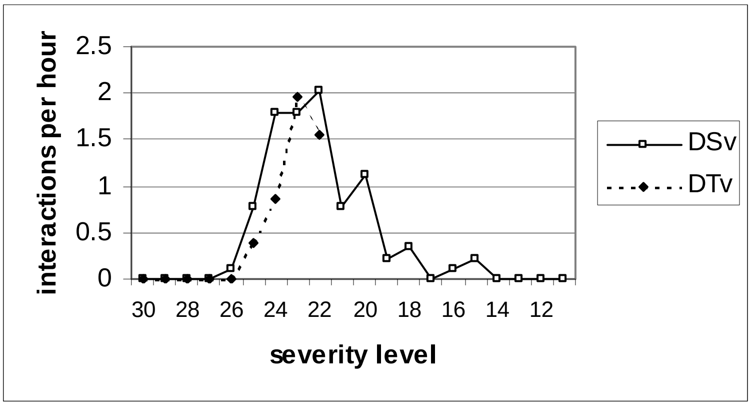


Figure 5:25 Number of interactions per hour on each severity level at severity levels 1-30 for DSv and 22-30 for DTv. Interactions at Djäknegatan where the vehicle takes evasive action. Comparison between vehicles driving straight ahead, DSv, and turning vehicles, DTv.

There are no significant differences between DSv and DTv when it comes to occurrence rate of interactions on different severity levels, Figure 5:25. There is perhaps a small tendency for an interaction with higher severity to rather involve a vehicle driving straight ahead than a turning vehicle.

Conclusions

With regard to the severity distribution, the two category cells with vehicles taking evasive action at Djäknegatan-Baltzarsgatan, DSv and DTv, show very similar patterns irrespective of whether the vehicle turns or drives straight ahead. The speeds of the involved vehicles are not very high, and are of the same magnitude; hence it is not so surprising that the adaptive behaviour is similar.

5.5 Results of hypothesis E

Hypothesis E) Type of road user taking evasive action might influence the shape of the severity hierarchy.

Among the few accidents analysed from the Kaivokatu-Keskuskatu intersection, it seemed as if it was more often the vehicle than the pedestrian that took evasive action. It would be very interesting to further analyse the influence of the party taking evasive action on the shape of the hierarchy. Could it be that the interactions where the vehicle takes evasive action are more severe than the interactions where the pedestrian takes evasive action, for the same type of manoeuvre at the same intersection?

E1) Comparison of when the vehicle and the pedestrian takes evasive action
Vehicles driving straight ahead at Djäknegatan-Baltzarsgatan.
Category cells: DSv versus DSp.

E1.1) Analysis on the whole distribution, with regard to the location in the severity hierarchy for all severity levels, i.e. 1-30.

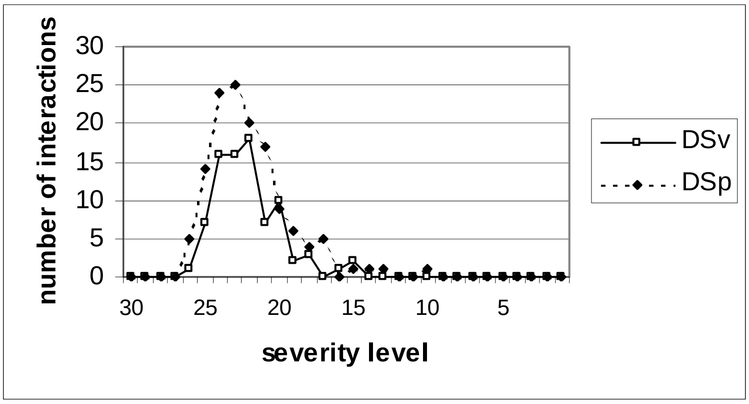


***Figure 5:26 The total number of interactions on severity levels 1-30. Vehicles driving straight ahead at Djäknegatan-Baltzarsgatan. Comparison between when the vehicle takes evasive action, DSv, and when the pedestrian takes evasive action, DSp*.**

The two test units seem to follow the same distribution, Figure 5:26. The convexity has the same shape and the peak is located around the same severity level. The two distributions also level off towards the levels with less severity in very much the same way. The two distributions may also belong to the same distribution for the observed severity levels 1-30, as the Kolmogorov-Smirnov test did not show any significant differences. The interactions with the highest severity are located on severity level 26. There are no interactions observed on severity level 9 and less.

Once on a collision course with a vehicle driving straight ahead involved, the likelihood for the individual road user to be involved in an interaction with a certain severity is the same and independent of whether it is the vehicle or the pedestrian that takes evasive action. The assumed difference due to type of road user taking evasive action cannot be supported for the straight ahead interactions at the non-signalised intersection Djäknegatan-Baltzarsgatan.

E1.2) Analysis of the percentage of the number of interactions for each severity level, 11-30, in relation to all observed interactions on severity levels 11-30.

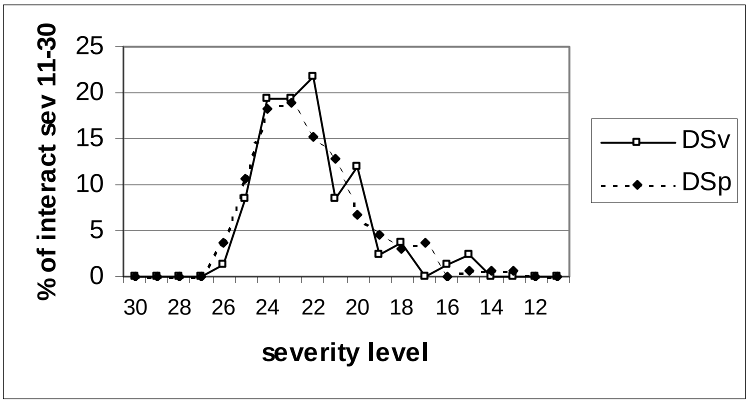


***Figure 5:27 Percentage of interactions on each severity level in relation to all interactions on severity levels 11-30. Vehicles driving straight ahead at Djäknegatan-Baltzarsgatan. Comparison between when the vehicle takes evasive action, DSv, and when the pedestrian takes evasive action, DSp*.**

The number of interactions differs at the two test units, 134 interactions for DSp and 83 for DSv. The duration of the observation periods also differs, 3.2 hours for DSp and 8.9 hours for DSv. When the percentage of the interactions on each severity level is analysed with regard to all interactions within severity levels 11-30, Figure 5:27, the similarity between the two distributions becomes very evident.

For the road users involved in interactions like these, it is very likely that the interaction has a fairly high severity. Compared to the interactions at Kaivokatu-Keskuskatu with vehicles driving straight ahead it is more likely for the involved road users at Djäknegatan-Baltzarsgatan to be involved in an interaction with higher severity.

E1.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

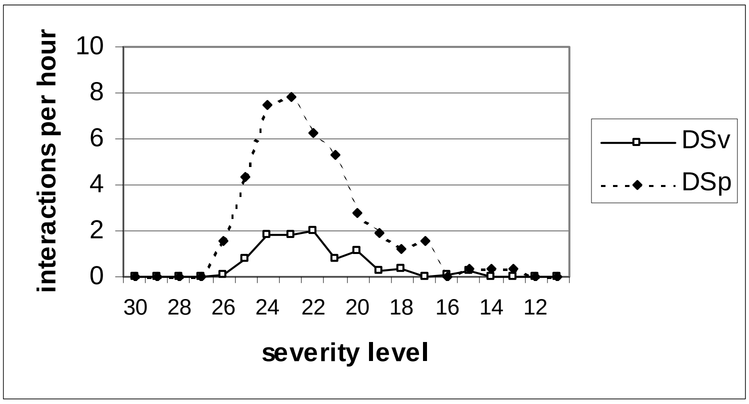


Figure 5:28 Number of interactions per hour on each severity level, for severity levels 11-30. Vehicles driving straight ahead at Djäknegatan-Baltzarsgatan. Comparison between when the vehicle takes evasive action, DSv, and when the pedestrian takes evasive action, DSp.

The occurrence rates of the interactions on different severity levels differ considerably according to Figure 5:28. The DSp interactions are about three times as frequent as the DSv interactions. For interactions with higher severity with vehicles driving straight ahead at Djäknegatan-Baltzarsgatan, it is more likely to find the pedestrian than the vehicle to be the party taking evasive action.

For all interactions at Djäknegatan-Baltzarsgatan involving a vehicle driving straight ahead it is more likely that it is the pedestrian than the vehicle that takes evasive action. Compared with this type of interaction at the signalised intersections Värnhemstorget and Kaivokatu-Keskuskatu, where it is almost always the pedestrian that takes evasive action, the pattern at Djäknegatan-Baltzarsgatan could indicate that the road users do not travel through the intersection on completely equal terms. The road is the territory of the vehicles, and the pedestrian must be prepared to take evasive action if interacting with a vehicle driving straight ahead.

Conclusions
The assumed difference due to type of road user taking evasive action cannot be supported for the straight ahead interactions at the non-signalised intersection Djäknegatan-Baltzarsgatan.

The severity with regard to TA/Speed value seems to be independent of whether it is the pedestrian or the vehicle that takes evasive action. This could indicate that the safety margins at this site, with its sight and speed conditions, are consistent and independent of whether the road user walks or drives a car. As the distribution with regard to severity is the same this means that the road users adapt the evasive action in relation to the travelling speed. In order to get two interactions with different conflicting speeds to be located on the same severity level, the road user with the higher speed has to take evasive action earlier than the road user with a lower speed. This could also be regarded as an indication of the validity of the TA/Speed severity hierarchy, at least with regard to road users' own perception and behaviour.

For all interactions at Djäknegatan-Baltzarsgatan involving a vehicle driving straight ahead it is more likely the pedestrian than the vehicle that takes evasive action. It is also more likely that the interaction is of fairly high severity.

Continuation E) Type of road user taking evasive action might influence the shape of the severity hierarchy.

E2) Comparison of when the vehicle and the pedestrian takes evasive action
Turning vehicles at Djäknegatan-Baltzarsgatan
Category cells: DTv versus DTp

For DTv there is a limitation in the camera coverage, i.e. only interactions within severity levels 22-30 are included. For this part of the severity hierarchy where a comparison is possible, the total number of interactions for DTv is 61 and for DTp 83. Due to the fairly small data sets it will probably not be possible to draw any firm conclusions from the distributions in the analyses.

E2.1) Analysis of the distribution of the total number of interactions on each severity level.

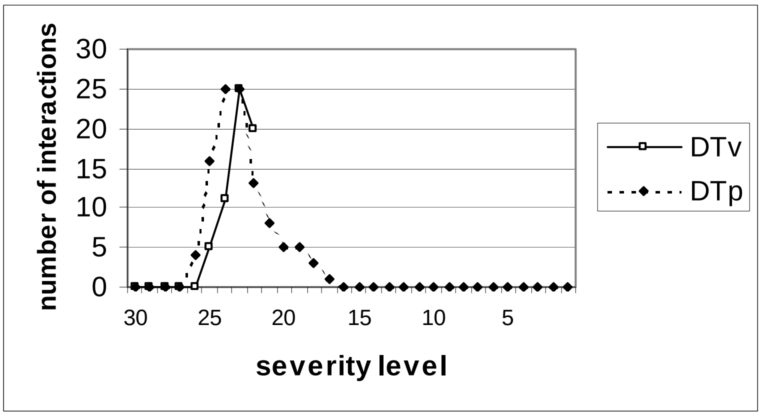


Figure 5:29 The total number of interactions within severity levels 22-30 for DTv and severity levels 1-30 for DTp. Interactions involving turning vehicles at Djäknegatan-Baltzarsgatan. Comparison between interactions where the vehicle takes evasive action, DTv, and interactions where the pedestrian takes evasive action, DTp.

The distributions in Figure 5:29 show some differences for the limited parts of the severity hierarchies, severity levels 22-30, where it has been possible to compare the distributions. For this part, according to the Kolmogorov-Smirnov test, the distributions may not belong to the same distribution. DTp is located more towards the higher severities as compared to DTv. The mean speed of the involved vehicles in

DTp is somewhat higher than the speeds at DTv, but it is not very likely that this difference of approximately 2-3 km/h would influence the distributions significantly. Furthermore, the influence on the hierarchy shape is in contradiction to the assumed direction, that the events with vehicle taking evasive action would be located more towards the higher severities than the interactions where the pedestrian takes evasive action.

As it has not been possible to observe interactions on all severity levels between 11 and 30, the second analysis of percentages is excluded.

E2.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

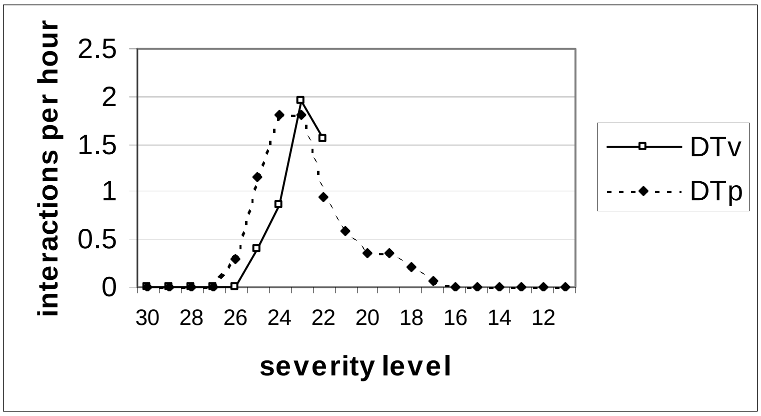


Figure 5:30 Number of interactions per hour on each severity level, i.e. for DTv severity levels 22-30 and for DTp severity levels 11-30. Interactions involving turning vehicles at Djäknegatan-Baltzarsgatan. Comparison between interactions where the vehicle takes evasive action, DTv, and interactions where the pedestrian takes evasive action, DTp.

The occurrence rates of interactions on each severity level, Figure 5:30, show resembling patterns to the distribution of DTv and DTp in Figure 5:29. The interaction observation duration is about the same for both category cells, and the number of observed interactions on severity levels 22-30 is also of the same magnitude.

Conclusions

At Djäknegatan-Baltzarsgatan the turning vehicles with the vehicle taking evasive action, DTv, show a different distribution with regard to severity than corresponding interactions where the pedestrian takes evasive action, DTp. DTp seems to be located more towards the higher severities than DTv. The fact that there are no police reported accidents at all registered at Djäknegatan-Baltzarsgatan during a period of 5 years suggests that the likely displacement of DTp probably remains within the area in the severity hierarchy where the probability of an event to result in a collision with injuries is comparably small.

Continuation E) Type of road user taking evasive action might influence the shape of the severity hierarchy.

E3) Comparison of when the vehicle and the pedestrian takes evasive action
Turning vehicles at Kaivokatu-Keskuskatu.
Category cells: KTv versus KTp.

For KTv there is a limitation in the camera coverage, i.e. only interactions within severity levels 18-30 are included. For this part of the severity hierarchy where a comparison is possible, the total number of interactions for KTv is 111 and for DTp 116.

E3.1) Analysis of the distribution of the total number of interactions on each severity level.

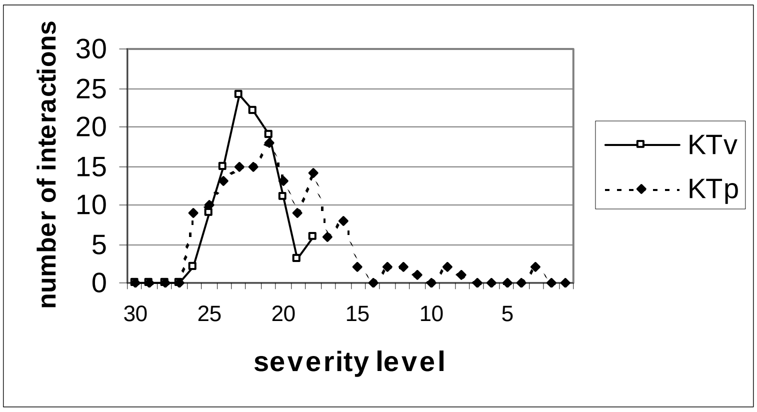


Figure 5:31 The total number of interactions on severity levels 18-30 for KTv and severity levels1-30 for KTp. Interactions involving turning vehicles at Kaivokatu-Keskuskatu. Comparison between interactions where the vehicle takes evasive action, KTv, and interactions where the pedestrian takes evasive action, KTp.

For the interval between severity levels 18 and 30, Figure 5:31, there seems to be a difference between the two distributions KTv and KTp. According to the Kolmogorov-Smirnov test, however, the null hypothesis about similar distribution cannot be rejected. Irrespective of whether there is a difference or not, the distributions are somewhat difficult to interpret. As mentioned earlier in connection with the analysis of type of manoeuvre and differences between KTp and KSp, the discontinuity for KTp at the highest severities might be a result of a perhaps too broad definition of an interaction. Even if the difference between the distributions is not significant it might be of interest.

As it has not been possible to observe interactions on all severity levels between 11 and 30, the second analysis of percentages is excluded.

E3.3) Analysis of the number of interactions per hour for each severity level, for each category cell.

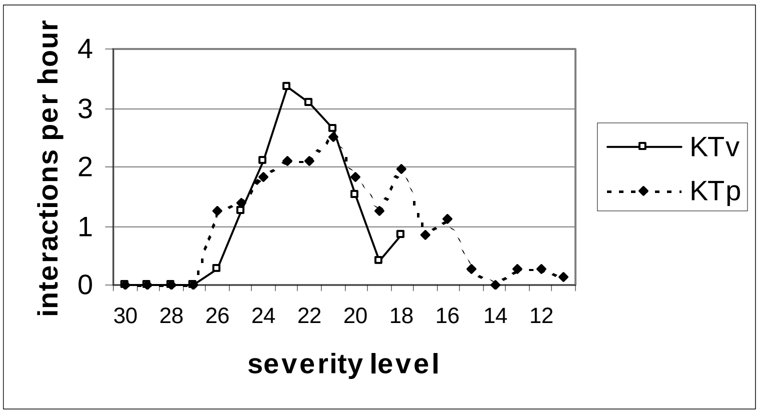


Figure 5:32 Number of interactions per hour on each severity level, for severity levels 11-30. Turning vehicles at Kaivokatu-Keskuskatu. Comparison between when the vehicle and the pedestrian takes evasive action.

The frequency of the interactions for the two test units is of the same magnitude. For turning vehicle situations at Kaivokatu-Keskuskatu, it is just as likely to find the pedestrian as the vehicle taking evasive action for interactions down to severity level 18.

Conclusions

The null hypothesis about similar distribution cannot be rejected. The appearance of the distributions in Figure 5:31 nevertheless indicates that there might be some difference with regard to severity depending on whether the road user taking evasive action is a pedestrian or a vehicle. The final comment must be that it is quite likely that once there is a collision course with a turning vehicle involved, the likelihood for the individual road user to be involved in an interaction with a certain severity is the same and independent of whether it is the vehicle or the pedestrian taking evasive action.

The traffic rule at a signalised intersection is that the turning vehicle has to give way to the crossing pedestrian. The interaction study indicates, however, that it is just as often the pedestrian as the vehicle that takes evasive action when they are moving on a collision course. This type of result suggests that both vehicles and pedestrians try to push their way through the interaction point. The distributions of the interactions are also ‘displaced’ towards higher severities. This indicates that the safety margins in these types of situations are comparably small.

5.6 Conclusions of the analyses

1) All distributions decline towards the higher severities. There is however a difference with regard to where the declination is located, and degree of declination.
2) All distributions decline towards the less severe severities. There is however a difference with regard to where the declination is located, and degree of declination
3) The shape of the distributions and the convexity of the distributions differ to varying extent between the distributions.

Interactions at Kaivokatu-Keskuskatu.
KSp, K91Sp, K94Sp, mKSp = vehicles driving straight ahead and the pedestrian takes evasive action.
KTv = turning vehicles and the vehicle takes evasive action. The observations are limited to severity levels 18-30.
KTp= turning vehicles and the pedestrian takes evasive action.

All variants of KSp have widely spread distributions over the severity levels. The interaction frequency per unit of time is also of the same magnitude for all KSp's and at a considerable higher level as compared to all other category cells. K91Sp is located more towards the higher severities than K94Sp. This might be due to the higher speed limit in 1991, 50 km/h, compared to 40km/h in 1994. There are no observations of vehicles driving straight ahead and vehicles taking evasive action. This is of course due to the fact that the vehicles have a green light and the pedestrians a red light at the signal. The turning vehicle situations are located more towards the higher severities than the straight ahead situations.

The appearance of interactions starts at higher severities and declines earlier for KT as compared to KS. The interaction frequency per unit of time is significantly lower for KT than KS. This is not very surprising as the pedestrians taking evasive action in the KS interactions are stopping for a red signal at the same time. There seems to be a difference between the turning interactions depending on whether the vehicle or the pedestrian takes evasive action. This discrepancy must however be considered to be fairly vague, as KTp shows a remarkable discontinuity among the highest severities. The interaction frequencies per unit of time are, however, of the same magnitude for KTp and KTv.

Interactions at Värnhemstorget

VSp= vehicles driving straight ahead and the pedestrian takes evasive action. The observations are limited to severity levels 4-30.

VTv= turning vehicles and the vehicle takes evasive action. The observations are limited to severity levels 21-30.

VSp is the category cell with most interactions located towards the lower severities. Thus, compared to KSp, the VSp distribution of interactions is located more towards the lower severities. Also the interaction frequency per unit of time differs between VSp and KSp. KSp has a much higher occurrence rate than VSp due to the higher flows at KSp. Like the Kaivokatu-Keskuskatu intersection, there are no observed interactions with vehicles driving straight ahead and the vehicle taking evasive action at Värnhemstorget.

For the turning vehicle interactions at Värnhemstorget there are, unlike the Kaivokatu-Keskuskatu interaction, hardly any observations of the pedestrian taking evasive action. At the turning vehicle interactions it is almost exclusively the vehicle that takes evasive action, VTv. The distributions of the interactions of these category cells, VTv at Värnhemstorget and KTv at Kaivokatu-Keskuskatu, show similar patterns, perhaps with a tendency for KTv to be located towards the higher severities. The occurrence rates of interactions at different severities are also of the same magnitude for VTv and KTv.

Interactions at Djäknegatan-Baltzarsgatan

DSp= the vehicles drive straight ahead and the pedestrian takes evasive action

DSv= the vehicles drive straight ahead and the vehicle takes evasive action

DTp= turning vehicles and the pedestrian takes evasive action

DTv= turning vehicles and the vehicle takes evasive action. The observations are limited to severity levels 22-30.

The common characteristics for all distributions at Djäknegatan-Baltzarsgatan are that all distributions are located towards the higher distributions and that the interactions have a limited spread with regard to severity levels, i.e. the declination take place at higher severities than most other distributions at the other intersections. This is very much in line with the difference in interactive behaviour at the non-signalised intersection as compared to the signalised interactions. The interactions at Djäknegatan-Baltzarsgatan are very close in time and space without necessarily implying increased probability for an event to result in a collision with injuries. For the straight ahead interactions the difference between the interactive behaviour at a signalised intersection, VSp, and at a non-signalised intersection, DSp, is most obvious. VSp is more located towards the levels with less severity than DSp. For the turning interactions, however, there is an indication of the interactive behaviour being quite similar at Värnhemstorget, VTv, and at Djäknegatan-Baltzarsgatan, DTv.

The major difference between the distributions at Djäknegatan-Baltzarsgatan is with regard to type of road user taking evasive action. Interactions with the pedestrian taking evasive action seem to be located towards higher severities than interactions with the vehicle taking evasive action. The discrepancy is most obvious for the turning situations. This is similar to the corresponding interactions at Kaivokatu-Keskuskatu, KTv and KTp. There the discontinuity among the highest severities for KTp calls for precautions when interpreting the results. Perhaps this could be valid for the DTp as well.

Category cells DSv, DTp and Dtv, all have about the same occurrence rates of interactions. DSp differs by having a much higher interaction frequency per unit of time.

6 Comparison of accidents, conflicts and interactions

6.1 The most severe parts of the severity hierarchy

This is an attempt to bring together information from the three data sources, accident data, conflict data and interactional data. From the analyses in the previous chapter there seem to be similarities between the distributions of interactions involving turning vehicles irrespective of whether the intersection is signalised or not (i.e. similarities between Djäknegatan-Baltzarsgatan and Värnhemstorget) and irrespective of whether the turning interactions take place at different signalised sites (i.e. similarities between Kaivokatu-Keskuskatu and Värnhemstorget). For vehicle driving straight ahead interactions, however, there seems to be a difference between the distributions with regard to whether the intersection is signalised or not. At the signal controlled intersections, the severity distributions differ between the two sites. From the analyses it has, however, not been possible to unambiguously describe the importance of the type of road user taking evasive action. When the most severe parts of the severity distributions are discussed here, the data will be analysed with regard to the specific site and with regard to type of manoeuvre at the site.

In Figures 6:1-6:6 the markings on the x-axis mean that there are observations but the frequencies are almost equal to zero, but still ≠ 0. The figures are based on data from tables in Appendix 4.

Intersection Kaivokatu-Keskuskatu

KT- turning vehicle interactions at Kaivokatu-Keskuskatu

The characteristics for the different types of data (interaction data, conflict data and police reported injury accident data) are presented in Figure 6:1 below.

***Figure 6:1 Interaction frequency per hour for accident, conflict and interactional data for turning interactions at Kaivokatu-Keskuskatu. intKT= data from interactional studies. confKT= data from conflict studies. accKT= data from police reported accidents*.**

Figure 6:1 shows that data from both the interaction study and the conflicts study cover severity levels 25 and 26. The relationship between the interaction frequency and conflict frequency is of the same magnitude for both severity levels, but the interaction frequency is about 20 times higher than the conflict frequency. At the most severe level with observations there is no overlap; the interactions at severity 27 are police reported accidents, one with injuries and one with no injuries.

KS – vehicle driving straight ahead interactions at Kaivokatu-Keskuskatu
For the vehicle driving straight ahead situation it is not possible to make the same comparison between overlapping severity levels for interactional and conflict data as for the turning vehicle situation. Here the different sources of data information are located at different levels of severity according to Figure 6:2 below.

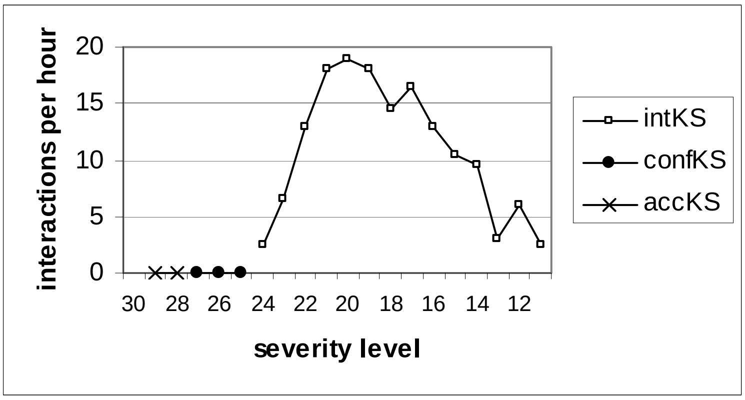


***Figure 6:2 Interaction frequency per hour for accident, conflict and interactional data for straight ahead interactions at Kaivokatu-Keskuskatu. intKS= data from interactional studies. confKS= data from conflict studies. accKS= data from police reported accidents*.**

The two accidents are located on severity levels 28 and 29, both with injuries. The conflicts are located on severity levels 25, 26 and 27. The interactions registered all have a severity less or equal to severity level 24.

According to Figures 6:1 and 6:2 the interactions with turning vehicles look more severe than the interactions with vehicles driving straight ahead. For the most severe parts of the distributions, however, the severity is higher for the KS distribution as compared to the KT distribution. Both KS accidents are injury accidents. One of the KT accidents is an injury accident while the other is a non-injury accident. From the police files it is unfortunately not possible to classify the injury accidents with regard to seriousness of the injury.

Intersection Värnhemstorget

There is unfortunately no possibility to analyse the accidents at Värnhemstorget in terms of "exact" TA/Speed location in the severity hierarchy due to the fact that they are collected from police files. The knowledge of the existence of accidents is nevertheless so vital that the information must be included. The definition of severity presupposes a higher probability of finding serious injury accidents at a more severe level than at a less severe level. This presupposes that the accidents with different injury outcome are also judged with different severity an infinitesimal time unit before the evasive action. The injury outcome of a pedestrian accident is of course influenced by age, height, fragility etc. of the individual pedestrian. In this analysis we are, however, interested in the average pedestrian and the likely connection between severity and injury outcome. The probability for a pedestrian to be killed in a car collision decreases rapidly at decreasing collision speed in the interval between 60 and 30 km/h. In an accident causing slight injuries to the pedestrian, the collision speed must most probably be lower than 30 km/h. By putting this in relation to the average speeds at Värnhemstorget, an accident with slight injuries is estimated to be located in severity level 27 and an accident with severe injuries to be located in severity level 28 (possibly 29).

VT- turning vehicle interactions at Värnhemstorget

There is only one slight injury accident from the 5 years of accident data. The characteristics of the accident, conflict and interactional data are presented in Figure 6:3 below.

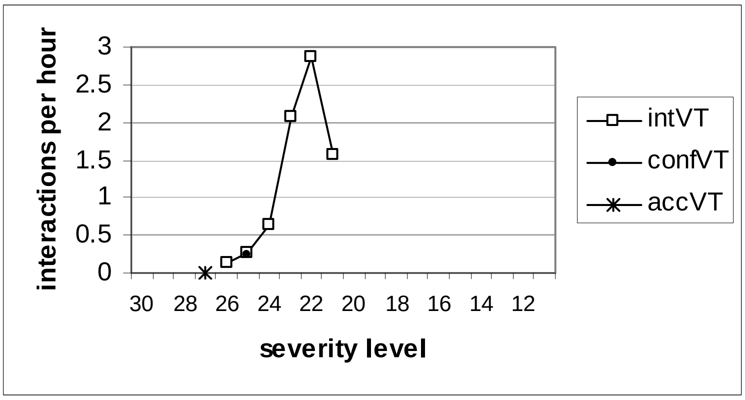


Figure 6:3 Interaction frequency per hour for accident, conflict and interactional data for turning vehicle interactions at Värnhemstorget. intVT= data from interactional studies. confVT= data from conflict studies. accVT= data from police reported accidents (estimate of severity level). Severity levels with lower severity than 18 cannot be presented due to limitations in the camera coverage.

The observed interactions are located on high severity levels. On severity level 25 there is data both from interactional studies and from conflict studies, the frequencies seem to be of approximately the same magnitude.

VS- vehicle driving straight ahead interactions at Värnhemstorget
The accident data consists of two injury accidents with a car driving straight ahead. One of the accidents resulted in slight injuries and the other resulted in severe injuries. The characteristics for the accident, conflicts and interactional data are presented in Figure 6:4 below.

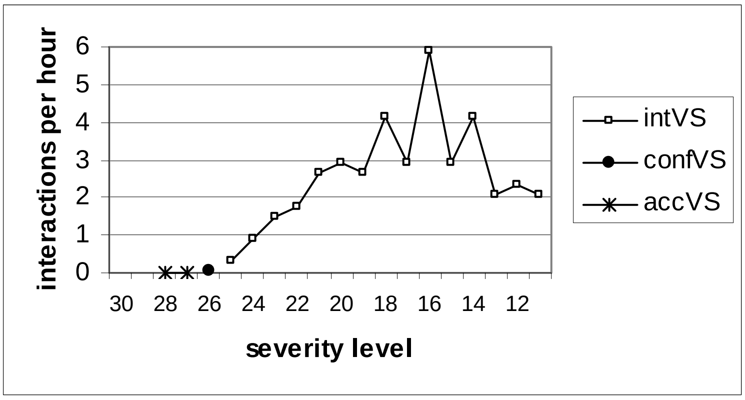


Figure 6:4 Interaction frequency per hour for accident, conflict and interactional data for vehicle driving straight ahead interactions at Värnhemstorget. intVS= data from interactional studies. confVS= data from conflict studies. accVS= data from police reported accidents (estimate of severity level).

There are characteristics of the interaction data at Kaivokatu-Keskuskatu, KS, and Värnhemstorget, VS, that are very similar. The distributions of the interactions are spread over several severity levels. The most frequent interactions are located at the lower severities. But serious conflicts and injury accidents do occur, which results in a thin strip towards the highest severity levels in the severity hierarchies.

Other characteristics diverge between KS and VS, see Appendix 4. The conflict frequency is lower at Värnhemstorget (1 serious conflict per 24 hours) compared to that at Kaivokatu-Keskuskatu (4 serious conflicts per 39.4 hours). According to the conflict studies the probability of injury accidents is higher for the KS interactions as compared to the VS interactions. The conflict registrations are, however, conducted in different ways at Värnhemstorget and at Kaivokatu-Keskuskatu. As mentioned before, the conflict registrations and the estimates of the TA/Speed values were done directly from video at Kaivokatu-Keskuskatu, while at Värnhemstorget the conflict observer made conflict registrations on location and then estimated the TA/Speed values from video.

Intersection Djäknegatan-Baltzarsgatan

For Djäknegatan-Baltzarsgatan there are no police reported injury accidents at the selected part of the intersection, with the relevant type of road users and manoeuvres involved, during the 5 year data collection.

DT- turning vehicle interactions at Djäknegatan-Baltzarsgatan
The interactions on severity level 21 and less cannot be analysed since the camera does not cover the interactions with the vehicle taking evasive action for this part completely. The characteristics for the different types of data are presented in Figure 6:5 below.

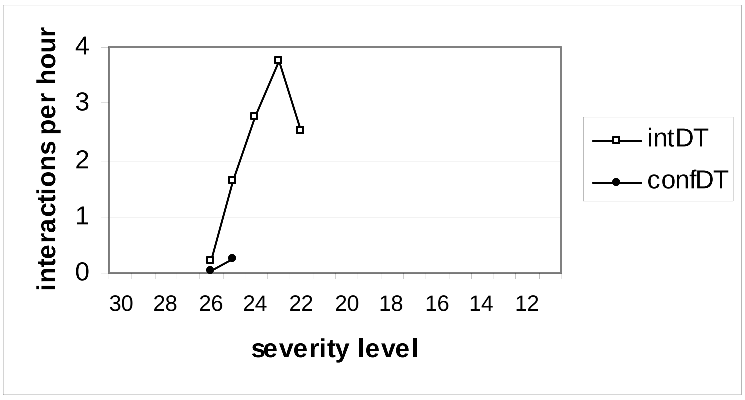


Figure 6:5 Interaction frequency per hour for conflict and interactional data for turning vehicle interactions at Djäknegatan-Baltzarsgatan. intDT= data from interactional studies. confDT= data from conflict studies.

For the turning interactions there is a difference in interaction frequency for the most severe levels depending on whether the frequency is based on interactional or conflict data.

DS – vehicle driving straight ahead interactions at Djäknegatan-Baltzarsgatan
The characteristics for the different types of data are presented in Figure 6:6 below.

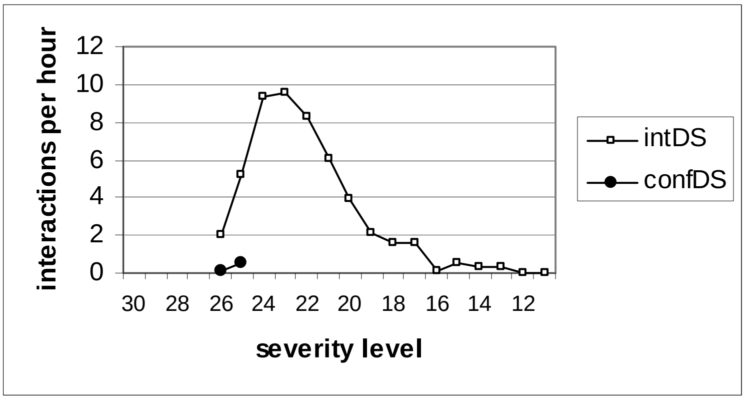


Figure 6:6 Interaction frequency per hour for conflict and interactional data for vehicle driving straight ahead interactions at Djäknegatan-Baltzarsgatan. intDS= data from interactional studies. confDS= data from conflict studies.

For the straight ahead interactions there is a similar difference, as was shown for DT, in interaction frequency for the most severe levels depending on whether the frequency is based on interactional or conflict data.

Conclusions

The similarities between the distributions of interactions with vehicles driving straight ahead at Kaivokatu-Keskuskatu and at Värnhemstorget are quite striking. The convexity of distributions, the part of the distributions where most interactions are located, range over several severity levels for both distributions. Most often the interactions are also of less severity, around levels 16-20. From the interactional data there are hardly any interactions with higher severity. The interaction frequency at severity 24-26 is very low. Both accident data and conflicts data do, however, show for both distributions that the top parts of the hierarchies presumably reach up to very high severities and that KS perhaps reaches up to even higher severities than VS.

The distribution of interactions at Djäknegatan-Baltzarsgatan, with vehicles driving straight ahead, has a totally different shape compared to those at KS and VS. The interactions from the interactional data are located at high severities. According to the accident data, however, there doesn't seem to be any tendency for this hierarchy to reach the most severe levels

The interpretation of the shapes of the turning vehicle interactions is not so clear. The interaction distributions for KT, VT and DT seem to recall the DS distribution, i.e. location of the interactions at high severities. On the other hand, it could be so, at least for VT and KT, that the top parts of the hierarchies reach up to higher severity levels than DS but not as high as the VS and KS hierarchies. The top part of the DT hierarchy rather resembles the DS hierarchy, i.e. it reaches perhaps not up to the most severe levels.

As the issue was to compare the different data sources (accident data, conflict data and interaction data) it must be concluded that there are striking differences between interaction frequencies and conflict frequencies for those severity levels that contain data from both sources. These differences, together with possible similarities, will be further discussed and analysed in the next section.

6.2 Difference in interaction and conflict frequencies

6.2.1 Interaction and conflict frequencies at common severities

According to the comparisons in Chapter 6.1, there are no overlapping severity levels with both conflict and interactional data for the vehicle driving straight ahead interactions at Värnhemstorget, VS. For VT the interaction and serious conflict frequencies seem to be of about the same magnitude for the common severity levels. It is, however, evident that the interaction and serious conflict frequencies differ when common severities are studied at Kaivokatu-Keskuskatu and at Djäknegatan-Baltzarsgatan. The differences become even more acute when the data at common severities for interaction data and conflict data are disaggregated with regard to type of road user taking evasive action. See Table 6:1 for the Djäknegatan-Baltzarsgatan situation and Table 6:2 for the Kaivokatu-Keskuskatu situation.

Table 6:1 The interaction frequency per hour and the conflict frequency per hour for the different test units at Djäknegatan-Baltzarsgatan. Ratio between interaction frequency and conflict frequency for the severity levels where there are data from both sources.

Test unit	Severity level	Interaction frequency	Conflict frequency	Ratio (interact /conflict)
DTp	25	1.16	0.12	10
DTv	25	0.47	0.12	4
DSp	26	1.56	0.03	53
	25	4.38	0.09	50
DSv	26	0.11	0.06	2
	25	0.79	0.41	2

Table 6:2 The interaction frequency per hour and the conflict frequency per hour for the different test units at Kaivokatu-Keskuskatu. Ratio between interaction frequency and conflict frequency for the severity levels where there are data from both sources.

Test unit	Severity level	Interaction frequency	Conflict frequency	Ratio (interact /conflict)
KTp	26	1.26	0	High
	25	1.40	0.03	55
KTv	26	0.28	0.08	4
	25	1.26	0.10	12

According to Tables 6:1 and 6:2, the differences between interaction and conflict frequencies are in all cases studied greater for the interactions where the pedestrian takes evasive action than for the interactions where the vehicle takes evasive action. At Djäknegatan-Baltzarsgatan the greatest difference occurs when interaction and conflict frequencies are compared for the vehicle driving straight ahead interactions. This latter type of comparison is not possible at the Kaivokatu-Keskuskatu intersection as there is no overlap regarding severity between interaction studies and conflict observations for the straight ahead interactions.

6.2.2 What is the similarity between interactions and serious conflicts?

So far the focus has been on the differences between the conflict and interaction frequencies. Are there then no similarities between interactions and conflicts as such? The next issue was therefore to try to analyse the seriousness of an event as defined by the conflict observer and apply this to the interaction data. This is not to be confused with the conflict studies that were the bases for the comparisons conducted so far. Now the task for conflict observer was to judge the severity of a selected set of interactions from video. The issue was to estimate whether an event, earlier registered as being in accordance with the definition of an interaction, was to be regarded as a serious conflict or not. The location in the conflict severity hierarchy was, however, not determined for the interactions classified as serious conflicts.

The highest severity levels with observations from the interactional data are severity levels 25 and 26. If there is a continuum with regard to the severity of the events in the severity hierarchy based on interactional data, the events on severity level 26 ought to have a higher streak of seriousness than events on severity level 25. Interactions with severity 25 and 26, therefore, were again estimated but now with regard to whether the interaction was a serious conflict or not.

The reason for stating the interactions and the serious conflicts resulting from them as frequencies instead of total numbers in Table 6:3 is the difference in observation duration for interactions of different category cells.

Table 6:3 Interaction frequency per hour and, from these interactions, the serious conflict frequency per hour at each severity level. Percentage of interactions scored as serious conflicts among interactions with severity 25 and 26.

Severity, the estimate from the interactional studies	Interaction frequency from the interactional studies	Frequency of serious conflicts out of the interaction frequency	Percentage of the interactions being serious conflicts (%)
KT - interactions with turning vehicles at Kaivokatu-Keskuskatu			
26	1.54	0.84	54
25	2.66	0.14	5
DS - interactions with vehicles driving straight ahead at Djäknegatan-Baltzarsgatan			
26	1.67	0.11	7
25	5.16	0	0
DT – interactions with turning vehicles at Djäknegatan-Baltzarsgatan			
26	0.29	0.07	25
25	1.63	0.07	4

Similar comparisons were not possible at VS or VT as these category cells contain either only one or no interactions.

For all category cells where it was possible to make the estimate, the interactions with a severity of 26 had a higher proportion of events that were considered to be serious conflicts as compared to the interactions with the lower severity 25, Table 6:3. Without going into any more detailed analyses, the main conclusion is that the interactions at a higher severity level are to a large extent also more severe according to the conflict observer’s perception of a serious conflict. However, this does not necessarily imply that an interaction regarded as a serious conflict would get the same TA/Speed value in the hierarchy based on interactions as in the hierarchy based on the TCT concept. This is due to the differences in the application of the TA/Speed scale to interactions and to conflicts.

6.3 Different severity hierarchies

As noted earlier; a severity hierarchy is a continuum of events with different severity. The severity is based on certain presumptions. Depending on the presumptions it is possible to consider correspondingly different hierarchies.

The discrepancy between the interaction frequencies (the original interaction studies) and the serious conflict frequencies (the conflict studies), shown previously in this chapter (6.1 and 6.2.1), is most likely due to the existence of two different severity hierarchies; two different hierarchies based on different presumptions. One and the same interaction would therefore most likely get different positions in the two different hierarchies, if it were indeed included in both. The hierarchies are probably not altogether different. Both the conflicts and the interactions are based on a hierarchy where the severity is decided by the TA/Speed value at the time of evasive action. In the text further on it is, however, concluded that the application of the TA/Speed concept varies to such an extent that the shapes of the hierarchies are quite different. Nevertheless, it was shown in the previous section (6.2.2) that the more severe events, severity level 26 in the interactional hierarchy, were more similar to the serious conflicts than the somewhat less severe events on severity level 25.

Presumptions influencing the interactional hierarchy
In the interactional studies all events with evasive action and a collision course or near collision course are registered and analysed as if the vehicle fills up the whole lane. The TA/Speed value is estimated at the time of evasive action. This hierarchy is based on an assumption about a relation between injury accident frequency and, closeness in time and space to a possible conflicting area. The increased possibility that both road users might end up in the same conflicting area, the vehicle lane, if the evasive action is taken at a very late stage is assigned a higher severity than if the evasive action was taken at an earlier stage.

Presumptions influencing the TCT hierarchy
The serious conflicts are registered according to the Swedish TCT. The severity is accomplished by the TA/Speed value at the moment of evasive action. The threshold between serious conflicts and non-serious conflicts intersects the X-axis of the TA/Speed graph at TA = 0.5. Converted to the graphs with the severity levels here, this would mean that the threshold should be located between severity level 25 and 26. According to the original theoretical definition of a serious conflict, all interactions with more severe TA/Speed values than this threshold should be regarded as serious conflicts. There is, however, a continuous ongoing discussion about the "correct" location of the border between serious conflicts and non-serious ones. The results of the analyses here also point to the possibility that the border could be located at different severity levels depending on type of road users involved in the interaction. This was partly resolved at a period in the history of the Swedish TCT

when subjective scores of the conflict observers were included in the estimate of the severity of the conflict. This subjective score, the observer's estimate of the likelihood of the interaction ending up in an accident with injuries, could be different between two interactions with otherwise identical location in the severity hierarchy. To some extent this subjective streak still exists in today's TCT. This is expressed in the interpretation of the serious conflict which says that a serious conflict is a situation that nobody puts him or herself into voluntarily. The evasive action must be more distinct than just a noticeable adaptation of speed or direction. The situation must be perceived as hazardous. When conflict observers carry out the conflict studies on location they have to consider both the TA/Speed threshold and the question of the situation being sudden or hazardous enough. As a result of these considerations, an interaction is therefore not regarded as a serious conflict if the situation is not regarded as being out of control, even if the TA/Speed value would indicate so. It is on the basis of these types of serious conflicts that a correlation with police reported injury accidents has been established.

What does this mean for the estimate of a certain interaction's severity?

An illustrative example might be the adaptive interaction between a pedestrian approaching the kerb and a vehicle approaching from straight ahead with the pedestrian taking evasive action.

The normal behaviour for a pedestrian with the intention of stopping and letting the vehicle pass is to walk all the way to the kerb and stop there. The conflict observer notices that the pedestrian is aware of the approaching vehicle and the stopping, the evasive action, is fully under control. The interaction is not considered to be a serious conflict. It can also be explained as the adaptive interaction includes a planned evasive action that takes place "inside the head" of the pedestrian before it is noted by the observer. The collision course actually diminishes at the time when the pedestrian makes the decision to stop. This would mean that the collision course has already diminished when the pedestrian takes a noticeable evasive action. Therefore several of the adaptive interactions are not serious conflicts, as the situation as such was already handled before it turned into severities indicating a serious conflict.

In the interaction study the observer verifies that the pedestrian and the vehicle move on a collision course under the presumption that the conflicting area starts immediately after the kerb. When the pedestrian starts to slow down close to the kerb, the evasive action starts and from this point the TA value is estimated. If the vehicle passes almost immediately after the pedestrian has stopped at the kerb, the TA value becomes very small. If the TA value is 0.5 seconds and the pedestrian speed at the moment of the evasive action is 5 km/h, a quite common situation, then the interaction gets a severity as high as 26.

6.3.1 Interactions based on new presumptions

The utility of the Swedish TCT in the future very much depends on the possibilities of working with the detection and registration of conflicts more automatically. At my Department at Lund University, work with a more automatic conflicts technique using image processing is in progress. An automatic detection and registration of course brings along limitations to what aspects of the conflict can be estimated. The subjective influence on the estimate of the interaction can perhaps not be fully transferred to an automatic conflict detection system. On the other hand, simplifications like using the whole vehicle lane as the interacting area with the aim of reducing time spent on analysis are no longer needed. An event to be regarded as an interaction in a future image processing system would of course have collision courses as the foremost criteria. But it would also be likely to include interactions with near collision courses, i.e. evasive action as if there was a collision course, with small time differences to a real collision course. If the interaction definition were to be changed, then the severity hierarchy would have another shape. What would it look like?

Presumptions relevant for a future automatic TCT

The severity hierarchy would be based on the TA/Speed value at the moment of evasive action. Interactions with evasive action and near collision course with time gaps of approximately 0.5 seconds or less would be accepted. If a pedestrian proceeds with a speed of 4 km/h and takes evasive action 2 meters before the collision point, the TA value is 1.8 seconds. If the same pedestrian instead walks with a speed of 6 km/h and takes evasive action 2 meters before the collision point, the TA value is 1.2 seconds.

Comparison between the original definition of an interaction and a future definition of an interaction

To get a data set based on the new “image processing” definition of an interaction, the original data set of interactions is used again. The “new” definition’s foremost divergence from the original definition of an interaction is that the whole vehicle lane is no longer defined as the conflict area. The collision course is only analysed with regard to the actual amount of space occupied by the road users. As the “new” definition is more restricted in its acceptance of events to be interactions, it is most likely that interactions in accordance with the “new” definition can be found among the “original” interactions. The procedure for getting a data set based on the “new” presumptions was to analyse the original interactions once more but now with regard to the “new” definition of an interaction. In accordance with the discussion in the preceding paragraph, an interaction is an event where two road users

* either move onto a collision course
* or take evasive action as if there was a collision course; time gaps of up to 0.5 seconds from a real collision course are accepted.

The analyses in Chapter 5 indicated a difference between the interaction distributions depending on whether the vehicle driving straight ahead interactions took place at a signalised intersection or at a non-signalised intersection, i.e. there was a difference between DSp and VSp. These two category cells will now be analysed and compared with regard to the "original" definition and the "new" definition of an interaction.

The most interesting question to ask in such comparisons are:

1) Will there still be a difference between DSp and VSp when the distributions are based on the "new", more restrictive, definition of an interaction?
2) How will the individual shapes of DSp and VSp differ with regard to the "original" and the "new" definitions?

<u>Explanation of the graphs in the analyses</u>

The figure after the name of the category cell differentiates the presumptions.

1= "original" presumption. The presumption about evasive action and collision course and near collision course. The TA/Speed value is calculated as if the whole vehicle lane is a conflict area.

2= "new" presumption. The presumption most likely to be used with a future automatic TCT. The existence of evasive action together with collision course and near collision course. The TA/Speed value is calculated with regard to the actual amount of space occupied by the road users.

E.g. DSp1 = DSp according to the "original" presumption
thus DSp2= DSp according to the "new" presumption

The analyses are restricted to the severity interval 4-30 as there are limitations when observing events with less severity for VSp.

1) Will there still be a difference between DSp and VSp when the distributions are based on the "new", more restrictive, definition of an interaction?

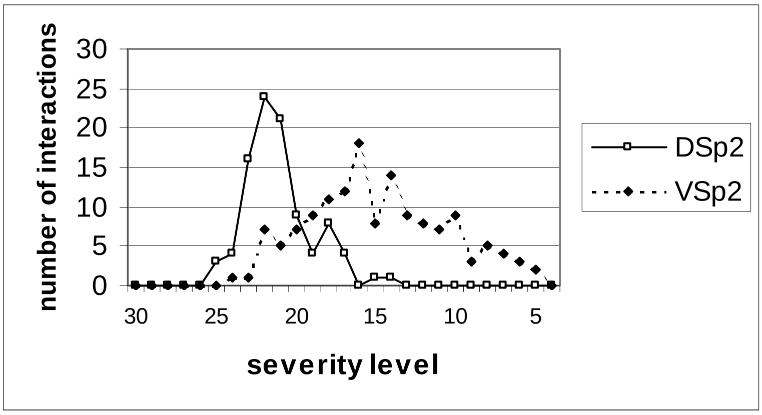


Figure 6:7 Interactions based on the "new" presumption. Comparison between vehicle driving straight ahead and pedestrian taking evasive action at Djäknegatan-Baltzarsgatan, DSp2, and at Värnhemstorget, VSp2.

To remember what the distributions looked like with the "original" assumption, the comparison here defined as between DSp1 and VSp1, please look at Figure 5:14 in Chapter 5. By comparing Figure 6:7 to Figure 5:14 it is evident that the original difference between the distributions can still be found when the definition of an interaction has been changed according to the "new" presumption.

2) How will the individual shapes of DSp and VSp differ with regard to the "original" and the "new" definition?

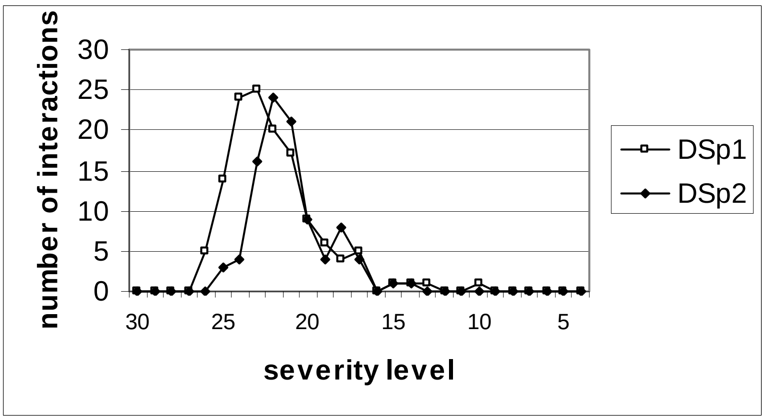


Figure 6:8 Vehicle driving straight ahead and pedestrian taking evasive action at Djäknegatan-Baltzarsgatan. Comparison between the original definition, DSp1, and the new definition, DSp2.

The distribution of the new DSp2 interactions seems to be different for the top part of the hierarchy as compared to the original DSp1 distribution of interactions, Figure 6:8. The original data set DSp1 consists of 133 interactions. The "new" data set DSp2 consists only of 95 interactions. Some interactions in the original definition do not comply with the "new" definition of an interaction. These are primarily interactions that in the original data set were regarded as events with high severity. The interpretation is that a rather high proportion of the encounters where the pedestrian takes evasive action close to the kerb are not regarded as interactions according to the "new" definition. For some of the interactions also approved as interactions according to the "new" definition there is a shift in severity towards lower severities as compared to the "original" severity of the interaction.

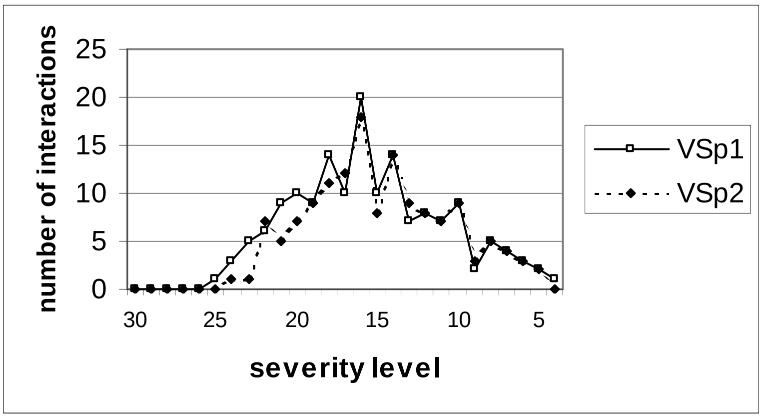


Figure 6:9 Vehicle driving straight ahead and pedestrian taking evasive action at Djäknegatan-Baltzarsgatan. Comparison between the original definition, DSp1, and the new definition, DSp2.

The distributions at Värnhemstorget also seem to be somewhat different when the interactions are defined according to the "original" definition, VSp1, as compared to the "new" definition, VSp2, Figure 6:9. Similarly to the changes at Djäknegatan-Baltzarsgatan, it seems to be the interactions with high severity in the "original" definition that are located towards lower severities at Värnhemstorget. At Värnhemstorget the data sets do, however, have approximately the same number of interactions in the "original" data set, VSp1, as in the "new" data set, VSp2. The number of interactions approved by the "original" definition is 159. This is reduced to 143 for the "new" definition. The effect on the distributions with regard to the definition of an interaction, "original" or "new", is less for the Värnhemstorget condition than for the Djäknegatan-Baltzarsgatan condition. The difference in the behaviour of the approaching pedestrians is presumably the major explanation for this. The habit of taking evasive action very close to the kerb, as if the pedestrian had almost decided to cross, is more prevalent at Djäknegatan-Baltzarsgatan than at

Värnhemstorget. At Värnhemstorget the pedestrian has usually already taken the decision to stop for a red signal some distance before reaching the kerb.

6.3.2 Different hierarchies depending on different presumptions

From the analyses in section 6.3.1 it is obvious that the shape of the severity hierarchy is dependent on the presumptions it is based upon. When the "original" definition of an interaction was changed to the "new" definition of an interaction, the interactions with high severity were displaced. It was earlier concluded that the differences in the conflict frequencies and the "original" interaction frequencies for common severities are most likely also an effect of the different data sets actually belonging to different hierarchies. So instead of trying to incorporate the events from obviously different hierarchies into one common hierarchy, a more feasible task must be to look at the different shapes of the hierarchies based on different presumptions and try to interpret the results. These types of comparisons have already been analysed to some extent; now a more comprehensive approach will be applied. Please note that the comparisons are restricted to the highest severities, severity level 25 and higher.

The three different hierarchies of interest in the coming analyses are based on partly different presumptions:

"Original presumption"

This is the presumption according to which the original interaction studies, analysed in Chapter 5, are carried out. Interactions with collision courses are included, as well as those with evasive actions and near collision courses. The severity is accomplished by the TA/Speed scale and the conflicting area is the whole vehicle lane.

"TCT presumption"

The Swedish TCT definition of a serious conflict, evasive action and collision course. As it is human observers carrying out the registration, interactions with evasive action and near collision course are most certainly also included. The severity is accomplished by the TA/Speed scale.

"New presumption"

This presumption is something in between the "original" and the "TCT" presumption. Interactions with collision courses are included, as well as those with evasive actions and near collision courses. A time gap of 0.5 seconds has been accepted. The severity, as in "TCT", is accomplished by the TA/Speed scale and the conflicting area is only the actual amount of space occupied by the road users, also as in "TCT". That is, "new" is like "original" but the analyses are not conducted as if the whole vehicle lane is a conflict area.

Explanation of Tables 6:4 to 6:6 and Figures 6:10 to 6:12

For those accidents where the information is available, thus only at Kaivokatu-Keskuskatu, the pedestrian is in the road when the vehicle takes evasive action. This means that an accident gets the same location in the TA/Speed graphs irrespective of which definition of an interaction the hierarchy is based on. The accidents at Värnhemstorget therefore, mainly due to simplification, also get the same location in the TA/Speed graphs irrespective of type of hierarchy.

Types of interactions:
KS – Kaivokatu-Keskuskatu, vehicle driving straight ahead interactions, severity levels 28 and 29 are injury accidents.
KT – Kaivokatu-Keskuskatu, turning vehicle interactions, severity level 27 is based on one injury and one non-injury accident.
VS – Värnhemstorget, vehicle driving straight ahead, severity estimate of one serious injury accident, severity level 28, and one slight injury accident, severity level 27.
VT- Värnhemstorget, turning vehicle interactions, severity estimate of one slight injury accident, severity level 27.
DS – Djäknegatan-Baltzarsgatan, vehicle driving straight ahead interactions, no accidents.
DT – Djäknegatan-Baltzarsgatan, turning vehicle interactions, no accidents

In Figures 6:10-6:12 the height of the line or figure represents the highest severity level with observations for each type of interaction. The width of the figure represents the interaction frequency at each severity level.

Original presumption

Table 6:4 Interaction frequency per hour per severity level for the different types of interaction. Interactions on severity levels 25 and 26 are from the "original" interaction study. The interactions on severity levels 27, 28 and 29 are police reported accidents according to the explanations above.

Severity level	Interaction frequency per severity level for different category cells					
	KS	KT	VS	VT	DS	DT
30						
29	2.59E-05					
28	2.59E-05		2.28E-05			
27	-	5.19E-05	2.28E-05	2.28E-05	-	-
26	0	1.54	0	0.13	1.67	0.29
25	0	2.66	0.29	0.26	5.16	1.63

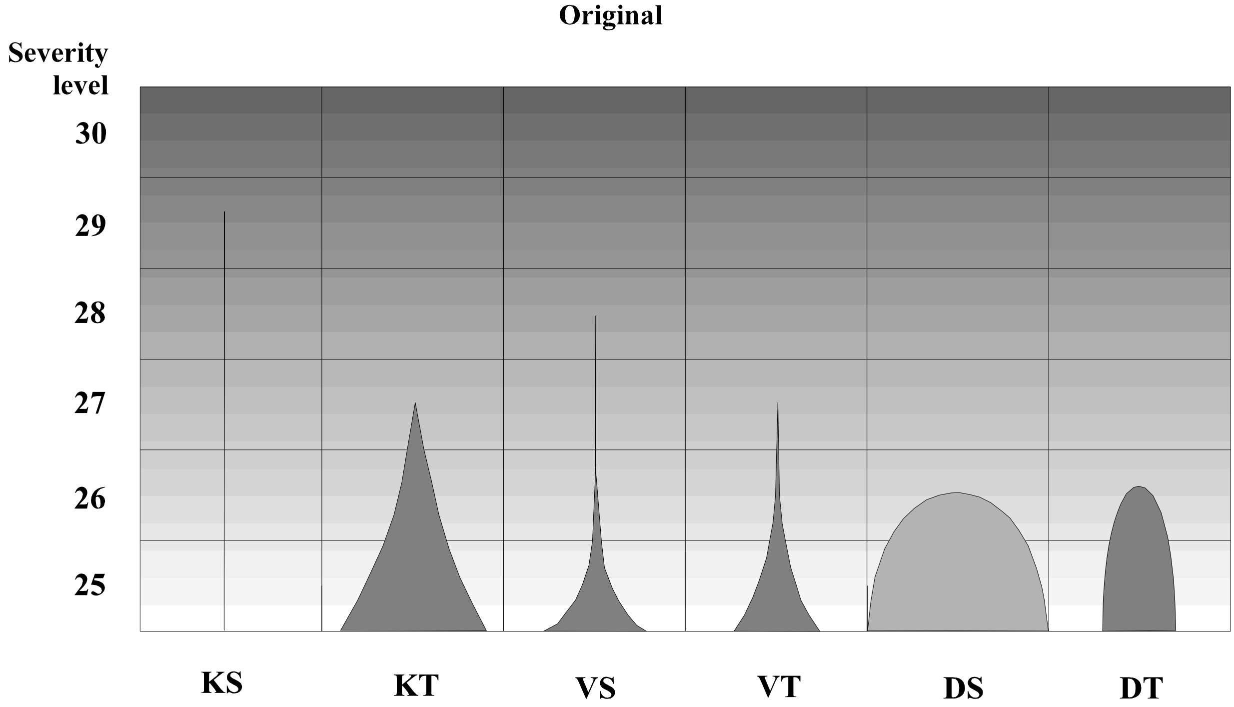


Figure 6:10 The shape of the top of the hierarchies for the different types of interaction, based on interaction frequencies in Table 6:4.

TCT presumption

Table 6:5 ***Interaction frequency per hour per severity level for the different types of interaction. Interactions on severity levels 25 and 26, and KS severity 27 are from the conflicts study. The interactions on the other severity levels are police reported accidents according to the explanations above.***

Severity level	Interaction frequency per severity level for different category cells					
	KS	KT	VS	VT	DS	DT
30						
29	2.59E-05					
28	2.59E-05		2.28E-05			
27	0.025	5.19E-05	2.28E-05	2.28E-05	-	-
26	0.025	0.076	0.042	-	0.088	0.029
25	0.051	0.127	-	0.250	0.500	0.235

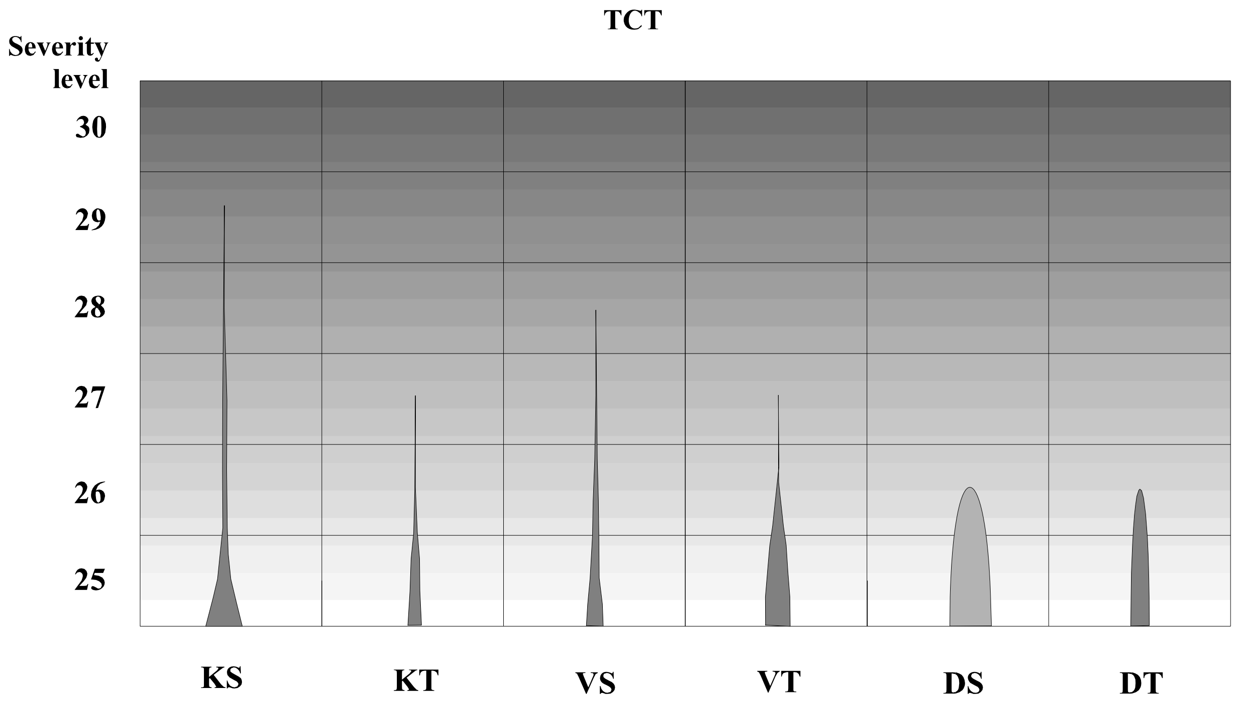


Figure 6:11 The shape of the top of the hierarchies for the different types of interaction based on interaction frequencies in Table 6:5.

New presumption

Table 6:6 ***Interaction frequency per hour per severity level for the different types of interaction. Interactions on severity levels 25 and 26 are from the "new" interaction study. The interactions on severity levels 27, 28 and 29 are police reported accidents according to the explanations above.***

Severity level	Interaction frequency per severity level for different category cells					
	KS	KT	VS	VT	DS	DT
30						
29	2.59E-05					
28	2.59E-05		2.28E-05			
27	-	5.19E-05	2.28E-05	2.28E-05	-	-
26	0	0.44	0	0	0	0.07
25	0	2.2	0	0.13	1.4	0.7

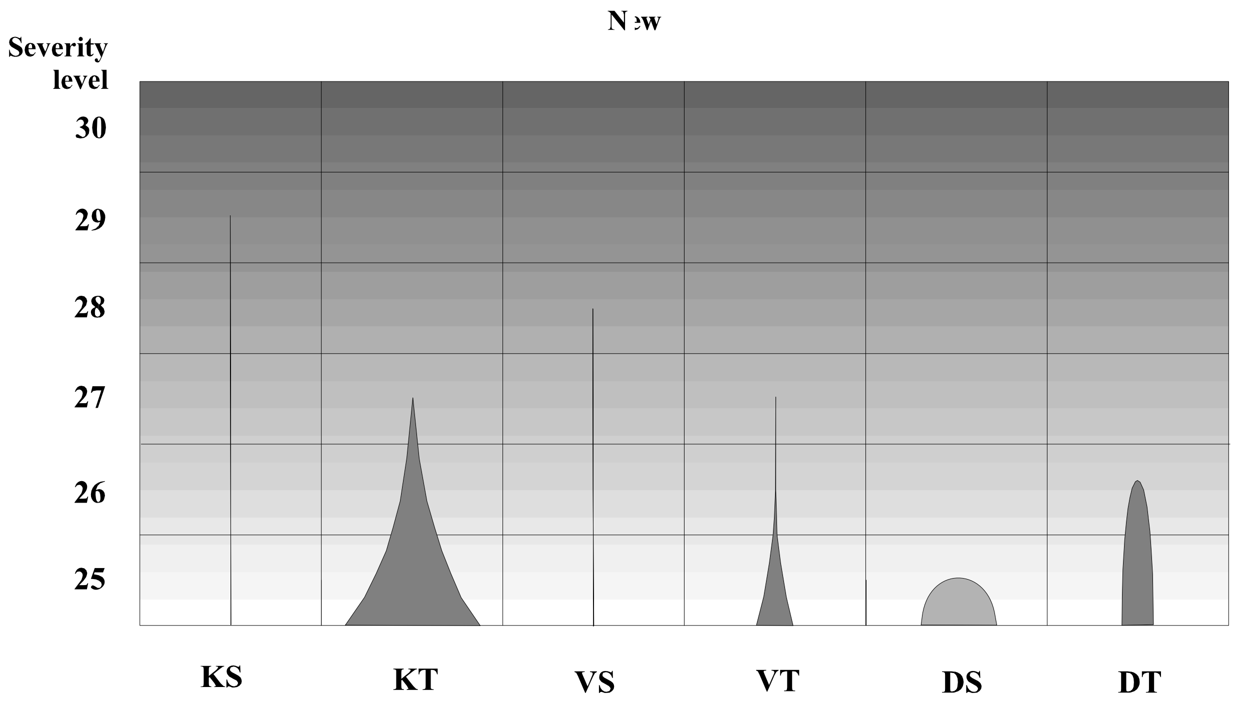


Figure 6:12 The shape of the top of the hierarchies for the different types of interaction based on interaction frequencies in Table 6:6.

Are the traffic safety implications from the hierarchies in line with each other despite the different presumptions on which they are based?

Border in the severity hierarchy?
First of all I would like to present the following reflection based on the general impression provided by the analyses and the road user behaviour studied in the interactional studies based on the "original" presumption.

When the shapes were discussed in Chapter 3, the continuum of events in the severity hierarchy was thought of as a continuity with regard to severity. A location higher up in the severity hierarchy must be regarded as more severe than a location further down in the hierarchy. This somehow also seemed to generally indicate that a location towards higher severities among events less severe than serious conflicts could also be considered as a sign of a higher probability of injury accidents. This reasoning, however, presupposes a continuous relation between increase of severity and increase of the probability of the event resulting in a collision with serious injury. The relation must indeed most certainly be continuous, but not necessarily with linear increase.

There could be two adjacent severity levels with a constant probability of a serious injury but with considerable differences in the probability of a serious injury between the levels. Then there could of course be two other adjacent severity levels located somewhere else in the hierarchy where the difference in the probability of a serious injury could be considerably less. My interpretation of the results of the analyses here is that there might be at least one border, somewhere in the severity hierarchies, above which the probability of an event resulting in a collision with injuries is much higher than the corresponding probability just beneath that border. The knowledge of such a border and where in the severity hierarchy it would be located can only be obtained through the estimation of the "true" severity hierarchy and the injury accident probability at each level.

If there is such a border, it could on the contrary be an indication of a safe location if there are many interactions on the severity level just beneath the border, even if this severity level is located fairly high up in the severity hierarchy. This is, as discussed in connection with the DSp/VSp comparison in Chapter 5, most probably due to the increased awareness of the road users regarding the severe interactions due to the learning process brought about by these interactions just below the border level. The obverse, the lack of interactions with mutual adaptation of speed and direction at the severity level just beneath the border, means that this learning process is missing. Once there is an interaction, the preparedness to handle the situation safely must be low, especially if the road users are close in time and space.

Furthermore, this shape of the hierarchy could indicate an efficient way to proceed at the location as also indicated by Summala's (1996) zero-risk theory mentioned earlier. Besides risk, the zero-risk theory includes other motives like hurry, maintaining speed and conservation of effort as important for the explanation of setting safety margins. According to the zero-risk theory, risks are normally avoided by staying within certain safety-margin thresholds and the behaviour is corrected when the safety-margin threshold is violated. The border between serious and non-serious conflicts in the TCT concept contains a similar message. A serious conflict, an interaction "above" the border, is an event road users try to avoid as its severity is perceived as being too threatening to the road users. Furthermore, validation studies show a clear relation between serious conflicts and injury accidents.

Thus, a high interaction frequency below "the border" in the severity hierarchy could be an indication of an approved severity that is in accordance with the road users preferences regarding risk, time efficiency, degree of control etc. If in addition the probability of a serious injury accident is fairly low at this location in the severity hierarchy, this shape of a severity hierarchy seems to satisfy both the traffic engineer's and the road users' notions of a safe type of interaction.

With these thoughts in mind the final analyses are conducted.
The approach is that all three hierarchies do convey the same safety information through their shapes. The border between the location that would promote safety through many interactions with not too high severity and the location where interactions indicate a considerably higher probability for injury accidents, is assumed to be between severity levels 25 and 26. Explanation to the abbreviations KS, KT, VS, VT, DS and DT are found on page 129.

KS and VS - unsafe
For all three presumptions there are similarities regarding the straight ahead interactions at the signal controlled sites. It is expressed in different ways but the gist is that due to the absence of communicative interactions at a level where the road users are aware of each other (level 25), an interaction that still takes place can become very serious. The conflict data for KS support this by having observations as high as severity level 27. The conflict data for VS, however, are more ambiguous. There are generally low conflict frequencies, but those serious conflicts registered are located on severity level 26.

DS – probably safe but…
"Original" – analyses based on the original presumption point at DS perhaps not being so safe as we imagined. The learning process is there with a high interaction frequency at the lower severity level. But the great number of interactions at the

higher severity level suggests that there is a potential danger from these very close interactions. The vehicle driver passing by cannot be 100 % certain that the pedestrian will really stop and not just continue.
"TCT" – analyses based on the TCT presumption produce similar interpretations as discussed for the "original" above. The frequency of the non-serious conflicts is high, but at the same time the magnitude of the conflict frequency on severity level 26 points to some kind of seriousness for this type of interaction.
"New" – analyses based on the "new" presumption point more than the other two to this type of interaction being safe, with a high interaction frequency on severity level 25 and an absence of interactions on severity level 26 and higher.

KT - unsafe
"Original" – analyses based on the "original" presumption show a comparably high interaction frequency on severity level 25, but at the same time the interaction frequency on severity level 26 is too high. A high interaction frequency on severity level 26 suggests a potential danger from these very close interactions. This type of interaction must, therefore, be considered rather unsafe.
"TCT" – analyses based on the TCT presumption show a somewhat different pattern for the hierarchy shape as compared to the "original", but the safety message is the same. Too few interactions on severity level 25 and comparably many serious conflicts on severity level 26 do not promote safety.
"New" – analyses based on the "new" presumption show that the interaction frequency is high at level 25. The interaction frequency at level 26, however, is at the same time too high to be able to talk about a safe situation.

VT – difficult, and the presumptions point in partly different directions
"Original" – analyses based on the "original" presumption show a comparably low interaction frequency on the learning level 25 that would suggest an unsafe type of interaction. The interaction frequency on severity level 26 is, however, also low. This pattern of the VT interactions suggests that the shape of the VT hierarchy perhaps could be comparable to the shapes of the VS and KS hierarchies.
"TCT" – analyses based on the TCT presumption suggest a high interaction frequency of non-serious conflicts and a very low frequency of serious conflicts. According to the "TCT" presumption the shape of the VT hierarchy seems to be more comparable with the shape of the DT hierarchy than with the VS and KS hierarchies.
"New" – analyses based on the "new" presumption point to the occurrence rate of interactions on severity level 25 perhaps being too low for VT to be considered "safe" from a learning perspective. If we didn't know of the existence of injury accidents at VT, and there were none at DT, we would probably not be able to distinguish any difference between them, based on the "new" presumption.

DT – also difficult
"Original" – analyses based on the "original" presumption show that the interaction frequency on severity level 25 is something in between high and low. The frequency is not high enough to promote safety, but at the same time not as low as for KS, VS and VT. The interaction frequency on severity level 26 indicates the occurrence of interactions that are perhaps too close in time and space to promote safety. There are circumstances promoting a learning effect, but at the same time there is also a small tendency for unsafe interactions.
"TCT" – as mentioned above the shape of the DT hierarchy, based on the "TCT" presumption, rather resembles the shape of VT than of VS and KS, i.e. a high frequency of non-serious conflicts and a low frequency of serious conflicts. So, based on the TCT presumption, the DT conditions would be regarded as safe.
"New" – as mentioned before, both VT and DT, based on the "new" presumption, are more difficult to interpret than the rest of the severity hierarchies. The occurrence rate of interactions on severity level 25 is not as high as for DS and KT, i.e. there is not an obvious sign of safe interactions. On the other hand, the occurrence rate of DT interactions on severity level 25 is not as low as for KS, VS and VT, i.e. neither are there any obvious signs of unsafety. DT has hardly any occurrence of interactions on severity level 26. If we didn't have the knowledge of no occurrence of injury accidents, it would probably be difficult to unambiguously point to DT as a safe type of interaction.

Conclusions

It seems highly possible to interpret the different shapes of the hierarchies based on different presumptions very similarly with regard to safety implications. As said before, depending on the aim of setting up a hierarchy, the shapes can of course be interpreted in different ways. The main difference between the hierarchies is the interpretation of closeness as such. It could be a parameter of interest with regard to safety, but it would probably be even more useful if it was analysed in relation to the relative speeds of the involved road users. The TA/Speed concept only takes the speed of the road users taking evasive action into consideration. If the speed of the other party was put in relation to small TA values, then it would be more probable that "safe" interactions with small time margins could be distinguished from "unsafe" interactions with small time margins. Traffic safety research on this specific topic is currently being pursued at Lund University by Lina Shbeeb.

Now the top parts of the different hierarchies based on different presumptions have been compared and analysed. A perhaps even more interesting analysis would be to look at the linkage between the top part and the rest of the hierarchy with regard to safety implications. However, this cannot be done for all three hierarchies based on the three different presumptions. The instructions for the conflict studies were to only register serious and almost serious conflicts. We can, therefore, only be certain to have included all relevant interactions on severity level 25 and higher. By definition there are no serious conflicts on the lower severity levels in the TCT hierarchy. For the hierarchies based on the “new” presumption the whole severity hierarchy is only obtained for category cells DSp and VSp, analysed earlier in this chapter. For the other category cells only the top parts of the hierarchies have been analysed according to the “new” presumption. An analysis of the linkage between the more severe and the less severe interactions in the severity hierarchy can only be conducted for the hierarchies based on the “original” presumption. This has, furthermore, already been done for the different individual category cells, in Chapter 5. More comprehensive safety implications derived from different shapes of the hierarchies will be discussed in the next chapter, on the basis of the “original” presumption.

7 Discussion

7.1 Synthesis of results

The aim of this work is to extend the scope of traffic safety analysis to also cover analysis of events with less severity than accidents and serious conflicts. By introducing events with less severity in the severity hierarchy, I hope to achieve a number of objectives: 1) to increase our understanding of the traffic safety process, 2) to achieve safety assessment of a location or other entity in a much shorter time span and in more detail than with accident or even conflict studies, 3) to make possible the formulation of new, innovative safety strategies.

The convexity of the hierarchy
What do then these events with less severity describe? 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. Different convexities at different types of locations are due to the individual road user's perception of the prevailing circumstances regarding safety, comfort etc. which might vary with regard to type of intersection, type of manoeuvre etc., if we have no reason to consider the sample of road users at the different locations as differing.

The form of the convexity ranges from being narrow with regard to the extension over severity levels to being more widely spread over several severity levels. The latter could be an indication of road users' difficulty to interpret and decide upon signs of possible threat. The analyses indicate that the "exact" location of the convexity in the hierarchy contains more useful information than just knowing whether the convexity is "towards" the lower or the higher severity levels.

What kind of safety information does the convexity of the hierarchy contain? According to the analyses there seems to be a relation between the convexity, including its location in the severity hierarchy, and safety implications. At the locations with strict priority rules, rules that most road users comply with (i.e. the intersections with signal control), the convexity of the hierarchy seems to be widely spread over several severity levels with the focus being on the low severity levels. This is the case for interactions with vehicles driving straight ahead. This type of distribution seems to be negatively correlated to safety. At the location with less strict rules (i.e. the non-signalised Djäknegatan-Baltzarsgatan intersection), the distribution of the less severe events is narrower and restricted to extend over only a few severity levels. This narrower convexity is located at reasonably high severity levels. According to the analyses, this type of convexity seems to be positively related to safety.

The shape at the top of the hierarchy

The shape at the top of the hierarchy has been thoroughly discussed in the previous chapter. A location with observations at the highest severity levels in the hierarchy indicates a high injury accident potential. The number of observations on the highest severity levels in such a hierarchy is, however, often very low and, subsequently, it is also very difficult to statistically verify the occurrence rate of events, i.e. the shape at the highest severity levels. Validation work with the Swedish TCT has confirmed a relation between occurrence rate of serious conflicts and injury accidents. We concluded at the very beginning of this report that injury accidents must be located high up in the safety hierarchy[Δ)]. The conflict registrations of this study show, as also noticed in earlier conflict studies, that the serious conflict frequencies are generally very low. This can of course be an indication of low probabilities for injury accidents. We can, however, not disregard the random variation inherent in small numbers, and the conclusion must be that it is very difficult to describe the top part of the hierarchy from the conflict data. In the attempt to get information about the most severe levels of the hierarchy, information must therefore be sought on the lower levels.

The relation between the top and the convexity of the hierarchy

The hypotheses first outlined in this work assumed a continuous and almost linear relation between movement upwards in severity levels and increase in injury accident potential. According to my results, these hypotheses must be modified. A location with a high interaction frequency at low severity levels seems, on the contrary, to produce the conditions for occasional events with high injury accident potential. The convexity of these interactions with less severity is in addition widely spread over several severity levels. The opposite pattern, a narrow convexity at reasonably high severities, seems to be a guarantee for preventing the most severe types of events from occurring. It is, therefore, from a safety perspective interesting, not only to analyse the part of the hierarchy with the most severe events, but also to take the convexity of the distribution into consideration. The shape of the hierarchy as such includes valuable safety information.

The synthesis regarding the narrow convexity at reasonably high severity as an indicator of safe interactions naturally raises the question of how far up in the

[Δ)] A severity hierarchy whose defined severity is in agreement with the safety hierarchy should be so constructed that serious injury accidents with a high probability are located on high severity levels in the severity hierarchy.

severity hierarchy the occurrence of interactions is a sign of good traffic safety. There must logically be a border above which a high occurrence rate of interactions is a sign of unsafety. At this border there is a substantial difference between the probability of serious injury accident in the severity level just below the border and the level just above it. On the level below this border, the events have high enough severity for the road users to serve the purpose of teaching them about the presence and behaviour of other road users. On the level above this border, the interactions are out of control and it is very much due to the ability and luck of the involved road users whether the outcome will be an injury accident or not. If there is such a border, then we would be able to differentiate between locations with mainly safe road user behaviour and locations characterised by unsafe road user behaviour. This would significantly increase the possibility of analysing the influence of different parameters on safe and unsafe behaviour, and the possibility of discussing proper measures to promote safe behaviour. If we were to change the concept of traffic safety work from only focusing on events with high injury accident potential, events with unsafe behaviour, to also including the element of inducing safe behaviour, then we would be able to engage in more offensive work to promote traffic safety. We would also work with traffic safety in the literal meaning of the word.

7.2 Validation

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. As mentioned earlier, 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. Why are we interested in the “true” severity hierarchy?
Two reasons might be offered.

- Understanding of the border in the severity hierarchy distinguishing events with high injury accident potential from the events that are believed to promote safe behaviour through the learning effect. The location of the critical border in the severity hierarchy can only be found through the estimation of the “true” severity hierarchy and the injury accident probability at each level.
- Being able to suggest traffic safety strategies, e.g. to reduce the interactions on the severity levels of greatest importance, also requires the information in the “true” hierarchy.

The validation work can presumably only be done with regard to one of the presumptions earlier described. The interaction studies in my investigation are conducted by an observer. The time spent on observing and registration cannot be justified in future work. Therefore, work with these types of hierarchies based on interactions requires automatic processing of data. The “original” and the “new” presumptions are based on parameters more easily transferred into an automatic processing system than are some of the “subjective” parameters in the “TCT” presumption. There might, nevertheless, very likely be information in the “TCT” presumption from which future hierarchy presumptions would benefit. One option could be to work with an expansion of the condition in the “new” presumption, e.g. by an enlarged imaginary extension of the road users in relation to the actual amount of space occupied by the road users. An enlarged extension could also be used to cover situations that are very close in time and space without actually being on a collision course. That is, if the wish is to cover the potential risk described by the closeness in the interactions. An enlarged imaginary extension was discussed in connection with the method used in Chapter 4. The amount of data required to validate and make the concept applicable depends on the level of aggregation. The “true” hierarchies are of course never totally revealed, as it will not be possible to make observations during an infinite time. The aim must, however, be to reach good estimates with acceptable variances.

7.3 Potential use of the method

My hope is that the concept in its current status, even before any validation work has been done, will be of use in ordinary traffic safety work. 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.

In future traffic safety work, after the validation, this concept will be even more useful, 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 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 has already been mentioned as a very interesting one to apply to the severity hierarchy and its potential border differentiating events with a substantial difference in injury accident potential. The theory of describing road users' behaviour and decisions with regard to level of mental control could also be interesting to apply to the severity hierarchy concept, as mentioned in Chapter 3. Where in the severity hierarchy will the interactions characterised by knowledge-based and skill-based decisions be located? If the top of the severity hierarchy represents interactions where the decision is knowledge-based, and the levels of low severity represent interactions where the decision has been skill-based, what does this mean for the work of promoting safety? And so on. 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.

7.4 Direction for further research

Speed is a high priority topic for researchers all over the world. Today a lot of research is being devoted to developing and analysing promising speed reduction measures. The most promising, from a safety perspective, seem to be the speed-adaptation measures. In the context of severity hierarchies and use of the concept, it would be very interesting to make a link to work on speed adaptation and its application on ISA (Intelligent Speed Adaptation). For instance identifying what characterises and creates good or bad speed adaptation, with regard to traffic safety, would be very interesting. This could be analysed with regard to the shape of the severity hierarchies based on the actual road user behaviour induced by different speed adaptation and speed reduction measures.

Another very interesting task for the hierarchy concept could be to analyse objective and subjective safety. An ideal severity hierarchy should also put those events that road users perceive as being most unsafe, injury accidents, at the top. For the less severe events it might very well be that the severity according to the severity hierarchy is not in total agreement with subjective opinions of the severity of the situation. To what extent do they differ and on which severity levels? It could very well turn out that a location felt to be unsafe in objective terms is quite safe and vice versa. Thus, differences between objective and subjective safety could provide insight into reasons behind events with high injury accident potential. On the other hand, any convergence should be taken into consideration in traffic planning to facilitate measures that might satisfy both subjective and objective safety.

Studies show (e.g. Ekman, 1988) that the pedestrian crossing is not a very safe location for the pedestrian to cross at. This probably has a lot to do with pedestrians' false expectations. Pedestrians regard the pedestrian crossing as their territory and we all are taught from childhood that the pedestrian crossing is a safe location to cross at. In Sweden the rules for pedestrians and vehicles approaching a pedestrian crossing will be changed in the near future. The vehicle will be obliged to stop if a pedestrian is about to cross. Today the rules simply say that the vehicle driver has to take precautions for the pedestrian to be able to cross safely. How will the road users' behaviour change with a change of the rules? Presumably, more vehicle drivers than today will actually stop when a pedestrian is about to cross. But the pedestrian can never be able to totally disregard the fact that there might be vehicles not complying with the rules. To apply the concept of regarding the whole severity hierarchy instead of just the most severe events, the accidents and the serious conflicts, it would hopefully be possible to estimate the safety effect during a relatively short time span.

The actual changes in road user behaviour could also be analysed. It could be possible to quickly determine if the change of rules might create the same consequences as a signal control, a delegation of responsibility resulting in interactions with high accident potential if a road user, here a vehicle, does not comply with the rules. It could perhaps also be possible to describe at what distances ahead of the pedestrian crossing the vehicle has to give a clear sign of its intention to stop for the pedestrian to cross safely. The new rules could also imply a change in expectations among the vehicle drivers, as they would soon learn that pedestrians might step out into the street without looking very carefully. How would this change the shape of the severity hierarchy, and thereby the safety outcome?

Other applications of the use of the severity hierarchy could be to suggest intersectional designs that induce interactions with reasonably high severity but where the severity does not exceed the "border". How, for instance, could signalised intersections be changed in this sense? The use of the severity hierarchy could make it possible to disaggregate the traffic safety analyses to a greater extent than is possible today. It could, for instance, be interesting to describe the severity hierarchies for different road users both with regard to road user type and also with regard to age, e.g. elderly people or children.

Another scenario would be to think of how the concept could be used in driver education. Statistics show that young drivers with fresh driving licences are overrepresented in accident involvement (Evans, 1991). The age as such and the inexperience in driving are concurrent factors. If pupils already in driver education could acquire clues about safe and unsafe behaviour, a lot would be gained both for the individual road users and for society. The notion of the whole severity concept could be used to point out unsafe ingredients in what otherwise will be perceived as normal safe interactions, for instance the fact that pedestrians usually comply with a red signal, but sometimes they do not and if you as a vehicle driver are not prepared for this there might be a collision. It could also be interesting to explore likely severity hierarchy shapes for younger drivers and relate these to the drivers' notions about safe and unsafe behaviour in traffic. If these types of information were fed back to the driver education perhaps measures could be taken in order to make the driver education even more successful.

This research has resulted in what seems to be a promising method for analysing the traffic process in a safety perspective and I hope that you who read this thesis will be able to benefit from applying this method.

References

Anderson R.W.G., McLean A.J., Farmer M.J.B., Lee B.H., Brooks C.G.; Vehicle travel speeds and incidence of fatal predestrian crashes. AA&P, Vol 29, No 5, pp 667-674. 1997.

Baruya A, Finch D J; Investigation of traffic speeds and accidents on urban roads. Proceedings of the 22nd European Transport Forum, PTRC. Warwick University. 1994.

Baruya A; MASTER. EU 4th framework programme. A review of speed-accident relationship for European roads. Working paper R1.1.1. TRL. UK. 1997.

Berntman M; ”Metoder för insamling av uppgifter om svårt trafikskadade – några källor och tekniker.” Bulletin 6. Department of Traffic Planning and Engineering. Road Construction, Lund University, Lund, Sweden. 1994.

Chaloupka Ch, Risser R.; Don't wait for accidents - possibilities to assess risk in traffic by applying the 'Wiener Fahrprobe'. Safety Science 19. 137-147. 1995.

Draskóczy M; Traffic Conflict and Behavioural Studies. WP 2.3 in DRIVE V1062 ”Multilayered safety objectives”. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1990.

Ekman L; “Fotgängares risker på markerat övergångsställe jämfört med andra korsnings punkter.” Bulletin 76. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1988.

Ekman L; On the treatment of flow in traffic safety analysis – a non-parametric approach applied on vulnerable road users. Bulletin 136. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1996.

Elvik R, Borger Mysen A, Vaa T; Trafikksikkerhetshåndbok Oversikt over virkninger, kostnader og offentlige ansvarsforhold for 124 trafikksikkerhetstiltak. Tredje utgave. ISBN 82-480-0027-3. TθI. Oslo. Norway. 1997.

Englund A, Gregersen N.P., Hydén C, Lövsund P, Åberg L; ”Trafiksäkerhet – En kunskapsöversikt.” KFB. Art.nr 6319. Printed by Studentlitteratur, Lund, Sweden. 1998.

Evans L; Traffic safety and the driver. New York: Van Nost-rand Reinhold. 1991.

Grayson G.B. ed; The Malmö Study. A calibration of traffic conflict techniques. Institute for Road Safety Research SWOV, Leidschendam, the Netherlands, 1984.

Grayson G.B., Hakkert A.S.; Accident analysis and conflict behaviour. In Road Users and traffic safety; J.A. Rothengatter and R.A. de Bruinj, Eds. Van Gorkum Publishers, the Netherlands. 1987.

Gηttinger V.A.; Conflict observation in theory and practice. International Calibration Study of Traffic Conflict Techniques. Asmussen E. Ed. Springer-Verlag. pp17-24. Printed in co-operation with NATO Scientific Affairs Division. Series F: Computer and Systems Science Vol.5. 1984.

Hauer E, Gårder P; Research into the Validity of the Traffic Conflicts Technique. Accident Analysis and Prevention. Vol 18, No. 6, pp471-481, 1986.

Holmberg B, Hydén C et al; ”Trafiken i samhället.” Printed by Studentlitteratur, Lund, Sweden. Art nr 6231, ISBN 91-44-00077-4. 1996.

van der Horst R; A time-based analysis of road user behaviour in normal and critical encounters. TNO Institute for Perception, Soesterberg, the Netherlands. 1990.

van der Horst R, Kraay J; The Trautenfels Study: A diagnosis of road safety using the Dutch conflict observation technique DOCTOR. Leidschendam, the Netherlands. 1985.

van der Horst R, Kraay J: The Dutch conflict observation technique 'DOCTOR'; Proceedings of the workshop 'Traffic conflicts and other intermediate measures in safety evaluation', Budapest. Hungary. 1986.

Hydén C; “En konfliktteknik för riskbestämning i trafiken.” Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1976.

Hydén C; The development of a method for traffic safety evaluation: The Swedish Traffic Conflicts Technique. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1987.

Hydén C, Ståhl A; "Åtgärder i trafikmiljön för att öka oskyddade trafikanters säkerhet på stomgator". Measures to increase safety for vulnerable road users on arterial streets. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1979.

Häkkinen S, Luoma J; Liikennepsykologia (Traffic Psychology). Karisto Oy. Hämeenlinna. p.38 (total 171p). ISBN 951-672-110-9. 1991.

Linderholm L; “Vidareutveckling av konflikttekniken för riskbestämning i trafiken.” Rapport 7025. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1981.

Linderholm L; ”Signalreglerade korsningars funktion och olycksrisk för oskyddade trafikanter. Delrapport II: Gående.” Bulletin 71. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1987.

Linderholm L; Traffic Safety Evaluation of Engineering Measures – Development of a method and it’s application to how physical lay-outs influence bicyclists at signalised intersection. Bulletin 105. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1992.

Lugnér Norinder A, Persson U, Svensson M; ”Värdet av att minska risken för icke-dödliga trafikskador.” Bulletin 122. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1995.

Marascuilo L, McSweeney M; Nonparametric and Distribution-Free Methods for the Social Science. California, USA. Brooks/Cole Publishing Company, Monterey, California 93940, USA, a division of Wadsworth Publishing Company, Inc. 1977.

Migletz D.J., Glauz W.D., Bauer K.M.; Relationships Between Traffic Conflicts and Accidents. Volume 2 – Final Technical report. FHWA/RD-84/042. Federal Highway Administration, Virginia, USA. 1985.

Nilsson G et al; ”Samhällsekonomisk prioritering av trafiksäkerhetsåtgärder. Trafiksäkerhetsprognos och beräknade trafiksäkerhetseffekter för ett urval av åtgärder.” TFB&VTI Forskning Research. 7:6. 1991.

Näätänen R, Summala H; Road user behaviour and traffic accidents. North-Holland / American Elsevier, Amsterdam and New York. 1976.

Odelid K, Rajesh T, Svensson Å; ”Automatisk bildbehandling vid trafikanalyser – en utveckling av den svenska konflikttekniken.” Report no 7117. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1991.

Odelid K, Svensson Å; ”Bildbehandling och konflikttekniken.” Report no 7126. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1993.

Pasanen E; The problem of right-turning drivers with cyclists coming from the right. Report L4. Traffic Planning Division, City of Helsinki, Finland. 1992a.

Pasanen E; Driving speeds and pedestrian safety; a mathematical model. Publication 77. Helsinki University of Technology, Helsinki, Finland. 1992b.

Pasanen E; The Video Recording of Traffic Accidents, 1993:4. Helsinki City Planning Department, Finland. 1993.

Perkins S R, Harris J I; Traffic conflict characteristics: Accident potential at intersections. Highway Research Record. 225, pp.35-43, Highway Research Board, Washington D.C. 1968.

Rajesh, T; Towards theory for describing accepted time gap in interactions between pedestrians and vehicles. Bulletin 133. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1995.

Ranney T.A.; Models of driving behaviour: A review of their evolution. Accident Analysis & Prevention, Volume 26, No. 6, December 1994, pp. 733-750. 1994.

Risser R, Tamme W; The Trautenfels Study. Kuratorium für Verkehrssicherheit, Wien, Austria. 1987.

RWA (Roads and Waterways Administration) 1982. Traffic Accident statistics representativity study. Part IV: Main report. Summary of individual studies. Helsinki: Roads and Waterways Administration. Federation of Traffic Insurance Companies Kehittämistoimisto Oy ERG Ab. 65 p. + app. 4p. 1982.

SNRA (Swedish National Road Administration); THE ZERO VISION – A road transport system free from serious health loss. 1996.

Summala H; Accident risk and driver behaviour. Safety Science, Vol. 22, No 1-3, pp. 103-117. 1996.

Summala H, Pasanen E, Räsänen M, Sievänen J; Bicycle accidents and drivers' visual search at left and right turns. Accident Analysis and Prevention. 1996/03. 28(2) pp.147-153. Elsevier Science Ltd. 1996.

Svensson Å; "Vidareutveckling och validering av den svenska konflikttekniken." Department of Traffic Planning and Engineering, Lund University, Lund Sweden. 1992.

Szanto G; Automated tracking of vehicles using video tape. Progress report on phase 1A. IZF 1989 C-9. TNO Institute for Perception, Soesterberg, the Netherlands. 1989.

Towliat M, Ekman L; ”Föregångsmarkering – En utvärdering av trafiksäkerhetseffekten av föregångsmarkering vid markerat övergångsställe på breda gator. Bulletin 130. Department of Traffic Planning and Engineering, Lund University, Lund, Sweden. 1997.

Trafikkontoret i Göteborg; ”Lämnar bilister gående företräde vid oreglerade övergångsställen? Studie av säkerhet och beteende.” ISRNGBG-TK-R10.1994-SE. Rapport nr 10:1994.

Appendix 1 Duration of interaction observation and number of interactions and flow

Duration of the interaction observation and the number of interactions registered, at Kaivokatu-Keskuskatu, Helsinki, Finland

1/6/91	Saturday	10.30-12.31.20	*Accident tape
3/9/94	Saturday	10.30-12.13.50	*Accident tape
6/6/95	Tuesday	11.02-13.00	
7/6/95	Wednesday	11.13-12.36	

Total recording of 7.1 hours
Straight forward driving vehicle interactions were observed for 2 hours.
Turning vehicle interactions were observed for 7.1 hours.

Type of interaction	Date, Day of week	Number of interactions	Duration of interaction observation (h)	Number of interactions per hour	Vehicle flow per hour	Pedestrian flow per hour
KSp	1/6 1991,sat	170	1.0	170.0	565	993
	3/9 1994,sat	145	1.0	145.0	494	1116
KTp	1/6 1991,sat	30	2.0	15.0	39	993
	3/9 1994,sat	15	1.75	8.6	37	1116
	6/6 1995,tue	60	2.0	30.0	58	1219
	7/6 1995,wed	37	1.4	26.4	62	1137
KTv[7]	1/6 1991,sat	29	2.0	14.5	39	993
	3/9 1994,sat	28	1.75	16.0	37	1116
	6/6 1995,tue	41	2.0	20.5	58	1219
	7/6 1995,wed	25	1.4	17.9	62	1137

[7] This is an estimate of what the numbers might be as interactions have been excluded due to limitations in camera coverage. Only interactions with severity 18 and more severe should be included.

Duration of the interaction observation and the number of interactions registered, at Värnhemstorget, Malmö, Sweden

30/5/97	Friday	10.00-12.02.30
2/6/97	Monday	09.00-11.03.10
3/6/97	Tuesday	09.33-11.30
3/7/97	Thursday	10.00-11.40

Total recording of 7.7 hours
Straight forward driving vehicle interactions were observed for 3.4 hours.
Turning vehicle interactions were observed for 7.7 hours.

Type of intera-ction	Date Day of week	Number of interac-tions	Duration of interac-tion observa-tion (h)	Number of inter-actions per hour	Vehicle flow per hour	Pedest-rian flow per hour
VSp	30/5 1997, fri	105	2.0	52.5	394	405
	2/6 1997,mon	58	1.4	41.4	355	337
VTp	30/5 1997,fri	2	2.0	1.0	48	405
	2/6 1997,mon	4	2.0	2.0	31	337
	3/6 1997,tue	0	2.0	0	42	362
	3/7 1997,thu	3	1.7	1.8	35	371
VTv[8]	30/5 1997,fri	36	2.0	18	48	405
	2/6 1997,mon	23	2.0	11.5	31	337
	3/6 1997,tue	30	2.0	15	42	362
	3/7 1997,thu	22	1.7	12.9	35	371

[8] This is an estimate of what the numbers might be as interactions have been excluded due to limitations in camera coverage. Only interactions with severity 21 and more severe should be included.

Duration of the interaction observation and the number of interactions registered, at Djäknegatan-Baltzarsgatan, Malmö, Sweden

14/5/96	Tuesday	9.38.26 - 13.35.59 and 13.38.55 - 17.12.06
15/5/96	Wednesday	9.33.47 - 11.47.34 and 11.48.42 - 15.53.47
23/3/98	Monday	9.18.00 – 16.45.00
24/3/98	Tuesday	8.54.00 – 14.15.00

Total recording of 26.6 hours
Straight forward driving vehicle interactions were observed for 8.9 hours
Turning vehicle interactions where the pedestrian takes evasive action, were observed for13.8 hours. Turning vehicle interactions where the vehicle takes evasive action, were observed for 12.8 hours.

Type of interac-tion	Date Day of week	Number of interac-tions	Duration of interac-tion observati on (h)	Number of inter-actions per hour	Vehicle flow per hour	Pedest-rian flow per hour
DSp	14/5 1996,tue	134	3.2	41.9	377	206
DSv	14/5 1996,tue	77	7.5	10.3	386	210
	15/51996, wed	6	1.4	4.3	369	155
DTp	14/5 1996,tue	58	7.5	7.7	93	210
	15/5 1996, wed	46	6.3	7.3	93	236
DTv[9]	23/3 1998, mon	56	7.45	7.5	93	194
	24/3 1998,tue	38	5.35	7.1	84	148

[9] This is an estimate of what the numbers might be as interactions have been excluded due to limitations in camera coverage. Only interactions with severity 22 and more severe should be included.

Flow

For those periods of the recordings when observations have been carried out, the flow has also been measured. If nothing else is stated the flow is based on measurements every 10th minute for the whole observation period.

Kaivokatu-Keskuskatu

	Straight forward vehicle flow per hour	Turning vehicle flow per hour	Pedestrian flow per hour
1/6/91	568	39	993
3/9/94	529	37	1116
6/6/95*	712	58	1219
7/6/95*	676	62	1137

*) conflicts are registered during 19-20 hours each day, but the flow has only been measured during 2 hours (in the middle of the day) each day.

Värnhemstorget

	Straight forward vehicle flow per hour	Turning vehicle flow per hour	Pedestrian flow per hour
30/5/97	394	48	405
2/6/97	355	31	337
3/6/97	359	42	362
3/7/97	319	35	371
6/4/98*	410	58	501
7/4/98*	382	56	487
14/4/98*	385	41	407
17/4/98*	398	40	510

*) conflicts are registered during the whole day but the flow has only been measured during one hour between 11 a.m. and noon each day.

Djäknegatan-Baltzarsgatan

	Straight forward vehicle flow per hour	Turning vehicle flow per hour	Pedestrian flow per hour
14/5/96	386	93	208
15/5/96	396	88	223
23/3/98	427	93	194
24/3/98	382	84	148
27/3/98*	494	132	153
30/3/98*	440	94	236
31/3/98*	429	75	178
1/4/98*	466	113	146

*) conflicts are registered during the whole day but the flow has only been measured during one hour between 11 a.m. and noon each day.

Appendix 2 Duration of the conflict studies

Kaivokatu-Keskuskatu intersection
Conflicts were observed during 39.4 hours, covering both daytime, evening, and part of the night.

6/6/95	Tuesday	07.00-02.00 i.e. 19.0 hours
7/6/95	Wednesday	07.00-03.26 i.e. 20.4 hours

Värnhemstorget intersection
A special recording in April 1998 during 4 days.
6/4/98 Monday 09.35-13.39, 13.49-17.54 i.e. 8.15 hours
Observation: 9.45-10.45, 11.15-13.15, 14.00-15.00, 15.15-16.15, 16.32-17.32 i.e. 6 hours
7/4/98 Tuesday 09.40-13.31, 13.55-17.35 i.e. 7.52 hours
Observation: 9.45-10.45, 11.15-13.15, 14.00-15.00, 15.15-16.15, 16.30-17.30 i.e. 6 hours
14/4/98 Tuesday 09.39-13.43, 13.46-17.50 i.e. 8.13 hours
Observation: 9.45-10.45, 11.15-13.15, 14.00-15.00, 15.15-16.15, 16.30-17.30 i.e. 6 hours
17/4/98 Friday 09.40-13.44, 13.53-17.35 i.e. 7.77 hours
Observation: 9.45-10.45, 11.15-13.15, 14.00-15.00, 15.15-16.15, 16.30-17.30 i.e. 6 hours

Total duration of recording: 31.6 hours
Total duration of observation: 24 hours.

Djäknegatan-Baltzarsgatan intersection
A special recording in March/April 1998 during 6 days.
23/3/98 Monday 09.18-16.45 i.e. 7.45 hours
Observation: 9.23-10.23, 10.42-11.57, 12.02-13.02, 13.45-14.45, 15.00-16.45 i.e. 6 hours
24/3/98 Tuesday 08.54-16.42 i.e. 7.80 hours
Observation: 9.00-10.00, 10.30-11.45, 12.00-13.00, 13.45-14.45, 15.00-16.45 i.e. 6 hours
27/3/98 Friday 08.55-16.43 i.e. 7.80 hours
Observation: 9.00-10.00, 10.30-11.45, 12.00-13.00, 13.45-14.45, 15.00-16.45 i.e. 6 hours
30/3/98 Monday 08.56-16.46 i.e. 7.83 hours
Observation: 9.00-10.00, 10.30-11.45, 12.00-13.00, 13.45-14.45, 15.00-16.45 i.e. 6 hours
31/3/98 Tuesday 08.57-16.46 i.e. 7.82 hours
Observation: 9.00-10.00, 10.30-11.45, 12.00-13.00, 13.45-14.45, 15.00-16.45 i.e. 6 hours
1/4/98 Wednesday 08.25-13.31 i.e. 5.10 hours
Observation: 8.30-10.01, 10.30-11.45, 12.00-13.15 i.e. 4.02 hours

Total duration of recording: 43.8 hours
Total duration of observation: 34 hours.

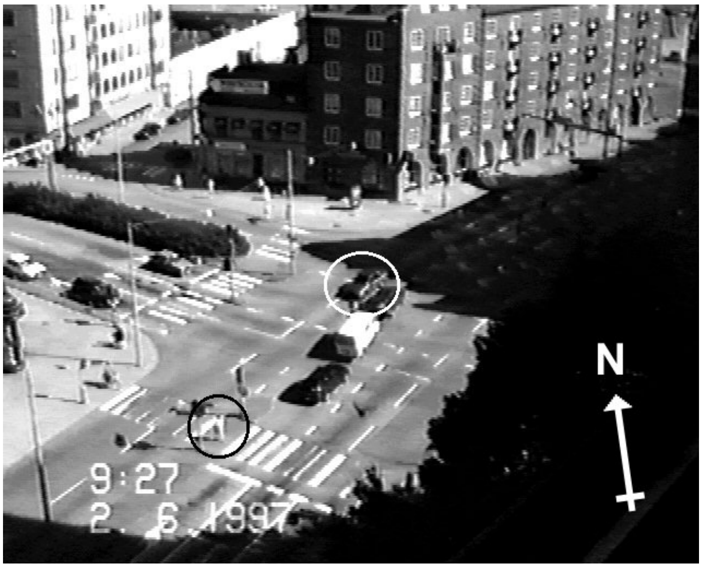
Appendix 3   Pictures of different types of interactions

Kaivokatu-Keskuskatu

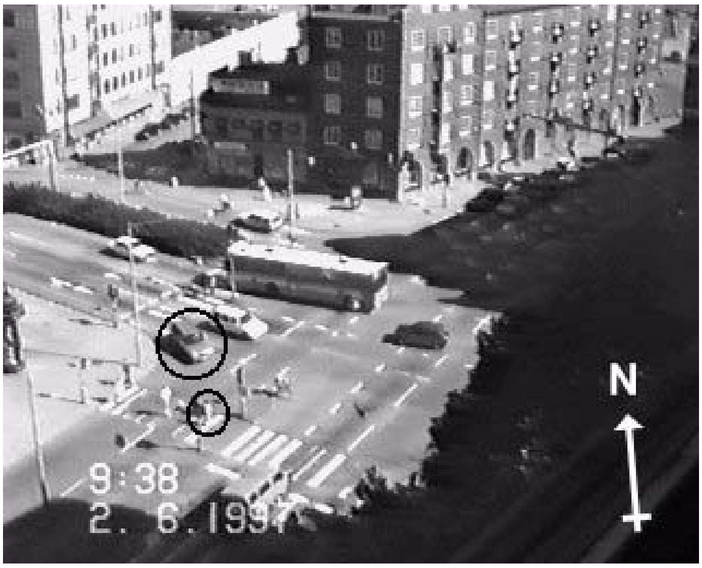
Vehicle driving straight ahead and an approaching pedestrian, KSp

Turning vehicle and an approaching pedestrian, KT

Värnhemstorget



Vehicle driving straight ahead and an approaching pedestrian, VS



Turning vehicle and an approaching pedestrian, VT

Djäknegatan-Baltzarsgatan

Vehicle driving straight ahead and an approaching pedestrian, DS

Turning vehicle and an approaching pedestrian, DT

Appendix 4 Characteristics

In the tables below the characteristics for the different types of data are presented. The column "highest severity level" is the severity level where the observation with the highest severity is located. The "interval" column is the interval based on the interactions between severity level 11 and 30, where 95% of the interactions are located.

Test unit	Type of data	Total number of observations	Duration of registration (hours)	Highest severity level with observation	Interval (11-30) with 95% of the observations

Kaivokatu-Keskuskatu

KTv	Interaction	nr[10]	7.15	26	limit[11]
	Conflict	7	39.4	26	25-26
	Accident	2	38 544	27	27

KTp	Interaction	142	7.15	26	15-26
	Conflict	1	39.4	25	25
	Accident	0	38 544	-	-

KT	Interaction	Nr[12]	7.15	26	Limit[13]
	Conflict	8	39.4	26	25-26
	Accident	2	38 544	27	27

[10] It is only possible to calculate interaction frequency per hour and severity level as interactions due to limitations in the camera coverage have been excluded.
[11] Do only include observations from severity levels 18-30, due to limitations in the camera coverage
[12] See footnote above
[13] See footnote

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K91Sp	Interac-tion	170	1.0	24	14-23
	Conflict	0	39.4	-	-
	Accident	0	38 544	-	-

K94Sp	Interac-tion	145	1.0	24	12-22
	Conflict	0	39.4	-	-
	Accident	0	38 544	-	-

KSp = K91Sp + K94Sp	Interac-tion	315	2.0	24	12-23
	Conflict	0	39.4	-	-
	Accident	0	38 544	-	-

KSv	Interac-tion	0	2.0	-	-
	Conflict	4	39.4	27	25-27
	Accident	2	38 544	29	28-29

KS (KSp + KSv)	Interac-tion	315	2.0	24	12-23
	Conflict	4	39.4	27	25-27
	Accident	2	38 544	29	28-29

VTv	Interac-tion	nr[14]	7.7	26	limit[15]
	Conflict	6	24	25	25
	Accident	1	43 800	27[16]	27[17]

VSp	Interac-tion	163	3.4	25	12-23
	Conflict	1	24	26	26
	Accident	2	43 800	28[18]	27-28[19]

[14] It is only possible to calculate interaction frequency per hour and severity level as interactions due to the limitations in camera coverage are excluded
[15] Do only include observations in severity levels 21-30 in the analyses, due to limitations in the camera coverage
[16] Estimate of severity level as there is no information about severity level for the injury accident from the police files
[17] Same comment as to the footnote above
[18] Estimate of severity level. No information about severity levels for the two injury accidents from the police files
[19] Same comment as to the footnote above

Djäknegatan-Baltzarsgatan

DTp	Interac-tion	104	13.8	26	19-25
	Conflict	4	34	25	25
	Accident	0	43 800	-	-

DTv	Interac-tion	nr[20]	12.8	25	limit[21]
	Conflict	5	34	26	25-26
	Accident	0	43 800	-	-

DT	Interac-tion	nr[22]	dura-tion[23]	26	limit[24]
	Conflict	9	34	26	25-26
	Accident	0	43 800	-	-

DSv	Interac-tion	83	8.9	26	18-25
	Conflict	16	34	26	25-26
	Accident	0	43 800	-	-

DSp	Interac-tion	134	3.2	26	17-25
	Conflict	4	34	26	25-26
	Accident	0	43 800	-	-

DS	Interac-tion	nr[25]	dur[26]	26	17-25
	Conflict	20	34	26	25-26
	Accident	0	43 800	-	-

[20] It is only possible to calculate interaction frequency per hour and severity level as interactions due to limitations in camera coverage are excluded
[21] Do only include observations in severity levels 22-30 in the analyses, due to limitations in the camera coverage
[22] It is only possible to calculate interaction frequency per hour and severity level as interactions are excluded due to limitations in the camera coverage.
[23] DTp during 13.8 hours and DTv during 12.8 hours. Interactions have been omitted (limitations in camera coverage). It is therefore not possible to state a duration of observation as this includes all interactions.
[24] Same comment as to footnote above
[25] DT is a combination of DSv: 83 interactions in 8.9 hours and DSp; 134 interactions in 3.2 hours
[26] See the footnote above