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# Estimation of the severity of safety critical events☆

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ABSTRACT

Today, various measures are used to estimate the severity of a traffic conflict. However, these measures are all limited to estimating the crash risk and do not include any estimates of the possible consequences of a potential crash. In accident analysis the estimated severity of the event is related to the outcome of the crash, such as injury levels. This article proposes a new method for estimating the severity of safety critical events based on both an estimate of crash risk and an estimate of possible consequence that, in addition to a measure of safety margins, takes vehicle mass as well as the relative speed of the involved road users into consideration. The article compares the estimated severity of 61 conflicts and 9 accidents of the proposed method with the traffic conflict technique.

The results from the severity estimates of our proposed method show a significant difference in the severity levels of events involving vehicles with similar mass compared to critical events involving vehicles with dissimilar mass and events involving pedestrians. The proposed method gives the possibility to compare different conflicts, with regard to severity, with each other regardless of what type of conflict it is, e.g. intersection or rural road, or what kind of road users that are involved.

In addition, an event classification, i.e. serious or very serious event, based on the severity estimate of the proposed method, shows promising results indicating that the severities are estimated in a homogenous way. The article concludes that our proposed method of estimating the severity of critical event seems to be able to reflect the dangerousness in a more realistic way than the traffic conflict technique and should facilitate the development of traffic safety analysis methods.



## 1. Introduction

Drivers who perform risky driving manoeuvres reduce the safety margins for themselves and/or other road users. A smaller safety margin to compensate for their own errors or those of others increases the risk of safety critical events such as crashes or traffic conflicts (Risser, 1985). Today, various measures are used to estimate the severity of a traffic conflict. Examples are post-encroachment time, time headway, minimum time-to-collision, time-to-accident or time advantage (Hydén, 1987; Van Der Horst, 1990; Gettman and Head, 2003; Laureshyn et al., 2010). In addition, there are also time-to-collision related measures to estimate the closeness of a collision, or crash risk, e.g. collision proximity, where the distance to a collision or departure point is measured (Tarko, 2012). Another measure of crash risk is the range/range rate measure presented by Najm and Smith (2004) where the rate of the current distance between the road users is calculated and the distance divided by range rate, calculates the time until the distance reaches zero. The range/range rate measure is a continuous measure in a similar fashion as TTC. Sayed and Saunier presented a vehicle trajectory based method to calculate the probability of a crash using video recordings (Saunier and Sayed, 2007; Saunier et al., 2010).

However, these measures are all limited to estimating the crash risk (Svensson and Hydén, 2006) and do not include any estimates of the possible consequences of a potential crash. The traffic conflict technique, TCT (Hydén, 1987) is an exception to the methods mentioned above, since it uses the conflicting speed as a measure of the severity of the consequences and, in conjunction with the time-to-accident value, estimates the severity of the traffic conflicts (Svensson and Hydén, 2006). Still, using conflicting speed combined with the time-to-accident value as the only measures of consequences is not sufficient, as the estimated severity of the consequence in a conflict situation will be the same regardless of what kinds of road users are involved (Laureshyn et al., 2010).

As Laureshyn et al. point out, "a method for combining the accident risk and the severity of consequences into one severity measure is still lacking" (Laureshyn et al., 2010). Second, TCT uses the speed of the road user who performs the evasive manoeuvre, which could at times be the road user with the lowest speed. If so, the severity estimate will be lower than an estimate using the conflict speed of the fastest road user instead. Also, previous research

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has shown that the consequences of a crash are dependent on the relative speed of both vehicles involved, combined with the mass ratio of the vehicles (Hutchinson, 1977; Evans and Wasielewski, 1987; Evans and Frick, 1993; Evans, 1994, 2001). Thus, it is assumed that a method for estimating the severities of conflicts based on both an estimate of crash risk and an estimate of possible consequence should, in addition to a measure of safety margins, takes vehicle mass into consideration. It is reasonable to argue that the estimated severity should also reflect the increased risk of injury that a higher relative speed would inflict upon the involved road users.

As traffic conflicts occur much more frequently than accidents, from approximately 3000 up to 40,000 times depending on the severity of the conflict (Ekman, 1996), and analyses of traffic conflict situations are known to give valuable knowledge about the course of events leading up to a crash situation (Hydén, 1987), a method for estimating the severity of the situation that considers not only the risk of a crash, but also the potential consequences for different types of involved road users, would facilitate traffic safety analyses.

Naturalistic driving studies have recently become more common in traffic safety research. One of the great benefits of naturalistic driving studies is the possibility of studying driver behaviour in rare situations, such as conflicts or even crashes.

However, existing conflict measures are limited to measuring how close in time a crash will occur, i.e. they measure safety margins, and do not distinguish between involved road users, e.g. between pedestrians and heavy vehicles when estimating the severity outcome. Hence, according to TCT and minimum time to collision, a conflict between two light vehicles is estimated to be as serious as a similar conflict between a vehicle and a pedestrian, despite the fact that it is common knowledge that pedestrians or other vulnerable road users have a higher risk of getting seriously injured in a crash. Thus, assessments of conflicts, with regard to the severity grade, are limited to comparisons of conflicts with the same kind of road users involved and do not enable comparisons between different kinds of conflicts, e.g. vehicle–vehicle or vehicle–pedestrian conflicts.

### 1.1. Aim

The aim of this study is to develop a method, based on both the risk of crashing, in terms of a safety margin available for the driver to undertake an evasive manoeuvre, and the potential consequences, to estimate conflict severities in naturalistic driving studies. The proposed method combines a time based safety margin measure with a potential consequence measure in a way that gives an overall estimate of the dangerousness of the situation in question.

The study includes an assessment of the proposed method's capability to evaluate traffic conflict severities in a homogenous way, regardless of the kind of conflict, e.g. vehicle–vehicle or vehicle–pedestrian.

In normal circumstances, a crash should always be classified as more serious than the corresponding conflict, i.e. conflicts that are very similar to the crash except for the actual outcome. However, it is still possible that conflicts that substantially differ from the crash, such as high speed conflicts versus low speed crashes, could very well be estimated as more serious due to the possible consequences. Therefore, this paper conducts an analysis of the severity estimates of crashes and corresponding conflicts.

### 1.2. Safety margins

Svensson and Hydén (2006) describe the severity of a conflict situation as being a measure of the closeness of a crash. The outcome of the conflict situation, according to them, is dependent on how successful the evasive action is, which in turn is dependent on factors such as road and tyre conditions as well as the driver's ability to handle the vehicle during the evasive action.

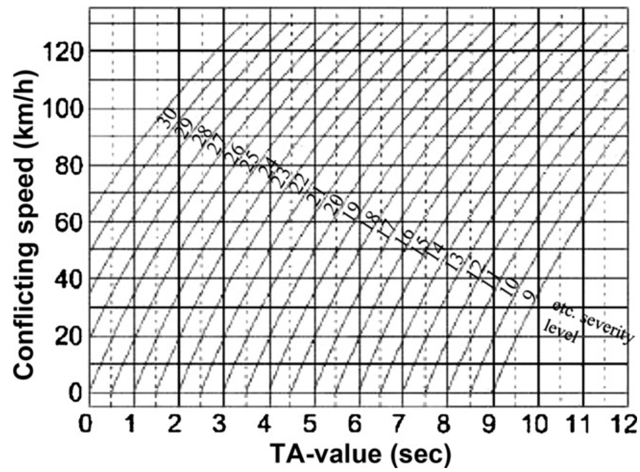


**Fig. 1.** Time-to-accident/conflicting speed graph defining the conflict severity levels of TCT (Svensson, 1998).

One of the most widely used techniques for measuring conflict severity is the traffic conflict technique, TCT, developed for the evaluation of severities of traffic conflicts in urban environments (Hydén, 1987; Svensson, 1998). TCT estimates the severity of a conflict by its conflict speed and time-to-accident value, see Fig. 1. Conflict speed equals the speed of the vehicle that performs the evasive action at the moment just before the evasive action takes place. The severity, time-to-accident/conflicting speed value, obtained by the TCT method, refers to the severity of the event at the initiation of the evasive action. Thus, the actual outcome depends on the success of the evasive action as well as on the behaviour of the other involved vehicle's driver. The time-to-accident value is the estimated time remaining before a crash will occur if the direction and speed of the involved road users remain the same as at the moment before the onset of braking, i.e. if no evasive action takes place and indicates the risk of a crash (Svensson and Hydén, 2006). By incorporating conflicting speed the risk of injury is also taken into consideration. Thus the severity scale in TCT indicates the risk of injury crash (Svensson, 1998).

By plotting the estimated time-to-accident value and conflict speed in the time-to-accident/conflicting speed the severity level of the conflict situation is determined by severity zones rating from 1 to 30. The severity zones are a relative severity measure which indicates that severity zone 30 is more severe than zone 29 and thus the probability of an accident with injury outcome is increasing with increased number of the zones.

Besides time-to-accident, there are other measures of safety margins, of which time headway and minimum time to collision, TTCmin, are two that are often used. Both are based on the continuous measure of time-to-collision, except that time-to-accident is measured at the onset of braking, i.e. before the evasive manoeuvre, while TTCmin is the smallest time-to-collision value during an intervention, which means that the value can be obtained during or after an evasive manoeuvre. Vogel (2003) compared time headway and TTCmin and concluded that while TTCmin values cannot be smaller than time headway values, time headway does not say anything about if or when the headway is reduced further. Therefore, it is considered a measure of potential danger, whilst TTCmin may be regarded as a measure of the residuals in the safety margin available for drivers, i.e. if TTCmin is zero, a crash will occur.