Vehicle Aggressivity Rating Methods – Theoretical Comparison

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Abstract

Vehicle aggressivity is a measure of the degree to which a vehicle injury is inflicted upon the occupants of the other vehicles with which it crashes. During the last decade several methods of vehicle aggressivity rating were developed and applied in different countries. The question arises about the theoretical differences between the models and which is the most satisfactory vehicle aggressivity rating method. The aim of this paper is the theoretical analysis of the mathematical foundations of the existing aggressivity models and their comparison with regards to their ability to 'rate' vehicle models in terms of their aggressivity performance in two-vehicle crashes. Four vehicle aggressivity rating methods are described and compared, namely the TRL method, the MUARC method, the Oulu method and the modified Folksam method.

Introduction

Providing improved protection to vehicle occupants who are involved in accidents has rightly become a high priority for governments, industry and researchers in the past decade. Improvements in vehicle safety can focus on different issues such as *primary safety* and *secondary safety*, where primary safety is concerned with crash avoidance and secondary safety with avoiding injury sustained in a crash. The ideal solution to reducing road trauma is to improve both primary and secondary safety. In this review of the vehicle aggressivity rating methods the main focus is on secondary safety and methods developed to compare aggressivity of the car models with the future goal to increase self- and partner-protection when involved in a crash.

Classification of Aggressivity Methods

During the review of vehicle aggressivity methods, it was identified that the existing aggressivity rating methods could be classified into two groups:

- *relative risk* methods (which measures the relative aggressivity of one vehicle or market group to other vehicle or market group or the 'average' vehicle population), and
- *absolute risk* methods (which attempts to measure absolute vehicle aggressivity).

Both *relative* and *absolute* methods can be described using 2x2 table (see Table 1) that represents the injury outcome of drivers in two-vehicle crashes; for detailed discussion see Les et al. (2000b).

Table 1 Number of two-vehicle crashes between the 'subject' and the 'other' vehicle (frequency table)

	Drivers in the 'subject' vehicle		
Drivers in the 'other' vehicle	Injured	Not injured	Row Total
Injured	x_1	x_2	x_1+x_2
Not injured	x_3	x_4	x_3+x_4
Column total	x_1+x_3	x_2+x_4	$N=x_1+x_2+x_3+x_4$

For the purpose of the rating method comparison, one type of vehicle involved in a vehicle-vehicle crashes is called the 'subject' vehicle whereas the second vehicle is called the 'other' vehicle. The meaning of the symbols in Table 1 is as follows:

x_1 – the number of two-vehicle collisions where both drivers were injured,

x_2 - the number of collisions where only the driver of the 'other' vehicle was injured ,

x_3 - the number of collisions where only the driver of the 'subject' vehicle was injured

x_4 – the number of collisions where no driver was injured.

Vehicle aggressivity is measured by the risk of driver injury in the 'other' vehicle when struck by the 'subject' vehicle (see Table 1).

Comparison of the Car Aggressivity Rating Methods

A short theoretical comparison of the selected methods of rating vehicle aggressivity is proposed. These include

- the TRL method developed by Jeremy Broughton at the Transport Research Laboratory, in the U.K. (Broughton 1994, 1996),
- the Oulu University method (Ernvall et al. 1992; Tapio et. al. 1995a; Tapio et al. 1995b; Huttula et. al. 1997),
- the MUARC method (Cameron et al. 1998, 1999), and
- the modified Folksam method (Les et al. 2000a and 2000b).

The modified Folksam method was also included as one with the possibility to be applied to measure vehicle aggressivity as shown in the analysis of vehicle compatibility done in MUARC (Les et al., 2000a). This comparison is carried out assuming that the two events: driver injury in the 'other' vehicle and driver injury in the 'subject' vehicle are independent of each other, and as a result the probability that a driver chosen at random from a population belongs to cell eg. 'injured-not injured' can be computed as $p_1(1-p_2)$, where p_1 denotes the unknown theoretical probability of driver injury in the 'other' vehicle whereas p_2 denotes the unknown theoretical probability of driver injury in the 'subject' vehicle (see Table 2).

Table 2 Theoretical probabilities of injury in the 'other' and 'subject' vehicles (for one segment of impact severity; see Hägg 1999)

	Drivers in the 'subject' vehicle		
Drivers in the 'other' vehicle	Injured	Not injured	
Injured	$Np_1p_2=n_1$	$Np_1(1-p_2)=n_2$	Np_1
Not injured	$N(1-p_1)p_2=n_3$	$N(1-p_1)(1-p_2)=n_4$	
	Np_2		**N**

The issue is to find out which estimator of risk of injury $\hat{R}$ is a consistent estimator of true risk of injury R. The estimator $\hat{R}$ is said to be a consistent estimator of R if $E(\hat{R})=R$. Based on the notation in Table 2, unadjusted measures of vehicle aggressivity for each method can be presented as shown below using as an example the MUARC and modified Folksam methods only (for other methods see Les at al. 2000b).

The MUARC method analysed for one component of the aggressivity measure, namely R risk of injury (see Tables 1and 2):

$$E(\hat{R}_{MUARC}) = E\left(\frac{x_1 + x_2}{x_1 + x_2 + x_3 + x_4}\right) = \frac{n_1 + n_2}{n_1 + n_2 + n_3 + n_4} = p_1 = R_{MUARC} \,. \tag{1}$$

The MUARC method is the only one, in contrast to all other methods, which is an absolute measure of the average injury risk over the all observed crash severities.

The modified Folksam method (see Tables 1 and 2):

$$E(\hat{R}_{FOLKSAM}) = E\left(\frac{x_1 + x_2}{x_1 + x_3}\right) = \frac{n_1 + n_2}{n_1 + n_3} = \frac{p_1}{p_2} = R_{FOLKSAM} \tag{2}$$

Thus it was proved that the MUARC and modified Folksam measures are consistent estimators of driver risk of injury. For detailed analysis of other methods see Les et al. (2000b).

Influence of mass, structure and severity

There are several confounders distinguished that are more likely to influence vehicle aggressivity rating methods. These are: crash type, impact severity, vehicle mass, structural aggressivity, seat belt use, occupant age, sex etc. If these factors are not taken into account by the model, it is likely that the results produced will be biased.

This is a first attempt to analyse the influence of factors such as vehicle structural aggressivity, mass aggressivity and impact severity on the aggressivity rating of the particular car models. This approach is based on the research conducted by Hägg et al. (2000) and Kullgren & Tingvall (2000).

Assuming that m – mass aggressivity, r – structural aggressivity (size and geometry), and s – impact severity it is easy to show that by incorporating m, r, and s in the formulas (1) and (2) it is possible to study their influence on risk of injury R. For example, in the case of the MUARC method when taking into account risk of injury only (see formula (1)):

$$R_{MUARC} = \frac{Np_1 mrs}{N} = p_1 mrs \,.$$

Final risk of injury, using the MUARC method, is computed as:

$$R_{MUARC} = \frac{p_1 mrs}{N} / \frac{p_2 s/m}{N} = \frac{p_1 m^2 r}{p_2} \,.$$

That means, mass aggressivity and structural aggressivity is influencing the MUARC measure, whereas impact severity is not. For detailed analysis of influence of mass, structure and severity on other vehicle aggressivity rating methods see Les at al. (2000).

It was proved (Les at al., 2000b) that the modified Folksam and MUARC methods compensate for mass influence. However, it is not possible, except with some limiting assumptions, to differentiate between influence of aggressivity and design with the matched-paired technique. Hence, none of the methods compensate for structural aggressivity. Under some assumptions, there is a possibility to figure out the influence of structural aggressivity that is when impact severity could be held constant or controlled for.

Conclusions

From four reviewed vehicle aggressivity rating methods, only the modified Folksam and MUARC measures proved to be consistent estimators of driver injury risk. Those methods also compensate for impact severity and mass aggressivity and as such can offer greater potential for rating vehicle models by their aggressivity. However, more research is needed to prove which is the most satisfactory vehicle aggressivity rating method.

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