EMPIRICAL COMPARISON OF VEHICLE AGGRESSIVITY RATING SYSTEMS

Max Cameron
Magda Les
Stuart Newstead
Sanjeev Narayan
Monash University Accident Research Centre
Australia
Timo Ernvall
Vesa Laine
University of Oulu, Road and Transport Laboratory
Finland
Paper Number 2001-S7-O-133

ABSTRACT

This paper describes an empirical comparison of seven vehicle aggressivity rating methods in order to identify the most satisfactory vehicle aggressivity 'rating' system. Vehicles were distinguished by make and model, and the aggressivity of each model was estimated from data on real two-vehicle crashes. For comparison purposes, two common crash databases were used for estimation of ratings by each method: Police-reported tow-away crash data from three US states, and accident compensation claims from Finland. New methods of vehicle aggressivity rating were also proposed and tested.

INTRODUCTION

This paper describes the analysis in sub-task 3.4 of the project *Quality Criteria for the Safety Assessment of Cars based on Real-World Crashes* being carried out by the Safety Rating Advisory Committee (SARAC) for the European Commission. An agreed set of aggressivity rating systems was applied to a common crash database, for the purpose of making a comparison of the ratings results produced by each system and to develop an understanding of the differences which emerge.

Most research into vehicle safety has focused on vehicle crashworthiness, measured by the risk of injury to a *subject* vehicle driver that was involved in a crash with the *other* vehicle in a two-car collision. This focus has lead to the development of several vehicle crashworthiness rating systems promoting vehicle designs that potentially overlook the protection of occupants in the *other* car in a car-to-car collision. The SARAC project aimed to develop criteria for a high quality method of vehicle aggressivity rating. An earlier paper (Les and Fildes 2000) focused on mathematical considerations and theoretical evaluation of vehicle aggressivity rating systems. This paper presents a comparison of empirical results produced by all of the aggressivity rating methods considered.

EXISTING AGGRESSIVITY RATING SYSTEMS

Existing aggressivity rating systems have been developed by the following international organisations:

- Transport Research Laboratory (TRL), U.K. (Broughton 1994, 1996)
- Road and Transport Laboratory, University of Oulu, Finland (Tapio et al 1995; Huttula et al 1997)
- Monash University Accident Research Centre (MUARC), Australia (Cameron et al 1998; Newstead et al 2000)

All three systems have been applied to databases of real crashes from the host countries, but ratings results by make and model from only the last two countries have been published. The nature of the databases to which the rating systems are applied varies. There is a fundamental difference depending on whether the database is limited to crashes involving personal injury, or whether it also includes crashes resulting only in material damage.

The aggressivity rating systems also vary by whether the rating criterion is a measure of either injury risk or severe injury risk to the driver of the other car in two-car crashes, and whether the risk is estimated in an absolute sense or relative to the average in all other makes and models. The rating criteria of the existing systems all include an estimate of driver injury risk, but one system (MUARC) involves a second step where this is multiplied by injury severity to produce an estimate of severe injury risk. The injury risk criteria of the existing systems are illustrated by the following conceptual framework developed by Folksam for the derivation of their injury risk measure based on the two-car crash matched-pair concept.

Consider N observed two-car crashes involving vehicle model k. Let p_{1k} be the average injury probability to the driver of the focus vehicle model, k, and p_{2k} be the average injury probability to the drivers of vehicles colliding with vehicle model k. The crashworthiness of model k is measured by p_{1k} and aggressivity is measured by p_{2k}. Categorising the N observed crashes into a 2x2 table defined by injury or no injury to the focus and other vehicle drivers, Table 1 represents the expected crash frequencies, assuming p_{1k} and p_{2k} to be independent, and Table 2 represents the observed frequencies.

Table 1.
Expected Number of Two-car Crashes Between Vehicle Model (k) and Other Vehicles

Drivers of vehicle model *k*	**Drivers of other vehicles**		
	INJURED	NOT INJURED	
INJURED	$N\ p_{1k}\ p_{2k}$	$N\ p_{1k}\ (1-p_{2k})$	$N\ p_{1k}$
NOT INJURED	$N(1-\ p_{1k})p_{2k}$	$N(1-\ p_{1k})(1-p_{2k})$	$N\ (1-p_{1k})$
	$N\ p_{2k}$	$N\ (1-p_{2k})$	N

Table 2.
Observed Number of Two-car Crashes Between Vehicle Model (k) and Other Vehicles

Drivers of vehicle model *k*	**Drivers of other vehicles**		
	INJURED	NOT INJURED	
INJURED	n_{iik}	n_{ink}	$n_{iik} + n_{ink}$
NOT INJURED	n_{nik}	n_{nnk}	$n_{nik} + n_{nnk}$
	$n_{iik} + n_{nik}$	$n_{ink} + n_{nnk}$	N

TRL Injury Risk Criterion

For data systems not reporting non-injury crashes, n_{nnk} will be unknown in Table 2. Broughton (1994, 1996) proposed an aggressivity rating criterion to be based on Police-reported road accidents in Great Britain, which cover only those in which one or more people are injured. Broughton's aggressivity index, and its expected value in terms of p_{1k} and p_{2k} , are:

$$R_{Tk} = \frac{n_{iik} + n_{nik}}{n_{iik} + n_{ink} + n_{nik}} \quad \text{and} \quad E(R_{Tk}) = \frac{p_{2k}}{p_{1k} + p_{2k} - p_{1k}\,p_{2k}}$$

Boughton's index measures the risk of driver injury in the other vehicle. This index has been calculated for makes and models of cars rated by their crashworthiness (Transport Statistics Report 1995), but the makes/models were not identified. Crashworthiness ratings based both on driver injury risk and driver severe injury risk have been published in the U.K. Following this approach, an additional aggressivity rating criterion based on Boughton's index, but including only crashes involving severely injured drivers in the numerator, has been examined in this study.

Oulu Injury Risk (Absolute) Criterion

The University of Oulu have developed aggressivity rating criteria measuring either the absolute or relative risk of the injury to the other driver, but the principal criterion used in the published ratings in Finland is the former. The Oulu criterion reflects the inclusion of non-injury crashes and is defined as:

$$R_{Ok} = \frac{n_{iik} + n_{nik}}{N_k}$$

MUARC Injury Risk and Aggressivity Rating Criteria

The MUARC injury risk criterion, R_{Mk} , is the same as the Oulu injury risk (absolute), though in their application to real crash data they are each adjusted for crash exposure differences between makes/models of cars in different ways. From Tables 1 and 2, it can be seen that the expected value of each injury risk criterion is:

$$E(R_{Mk}) = E(R_{Ok}) = p_{2k}$$

The MUARC aggressivity rating is calculated in two steps: (1) other driver injury risk criterion, multiplied by (2) injury severity of the other driver. Injury severity is measured by the proportion of injured other drivers who were killed or severely injured. This rating criterion is considered to measure the risk of severe injury to the other driver in a crash.

NEW AGGRESSIVITY RATING SYSTEMS

The study also considered three new criteria for rating the aggressivity of car makes/models:

- A modification of the Folksam safety rating method (developed by Les and Fildes 2000)

- MUARC2 method (developed by Les, Newstead and Fildes)
- MUARC3 method (developed by Newstead)

Modified Folksam Method

The Folksam method is a two-step vehicle safety rating, involving an initial estimate of the relative risk of the driver being injured in focus make/model cars in two-car crashes. This relative risk is then multiplied by a measure of injury severity of front seat occupants to produce the Folksam rating (Hägg et al 1992).

The modified Folksam method is based on the reciprocal of the Folksam relative injury risk, providing an estimate of the relative risk of injury to the other driver, R_{Fk}. The relative injury risk estimate is:

$$R_{Fk} = \frac{n_{iik} + n_{nik}}{n_{iik} + n_{ink}} \quad \text{and} \quad E(R_{Fk}) = \frac{p_{2k}}{p_{1k}}$$

This is multiplied by the injury severity of injured other drivers to provide the modified Folksam aggressivity rating, which is considered to measure the risk of severe injury to other drivers in two-car crashes. In this study, the injury severity measure was the same as the MUARC method. This second step is also part of the aggressivity ratings produced by the following two new methods after an estimate of (relative) other driver injury risk has been calculated for each make/model of the focus cars.

MUARC2 Method

MUARC2 is a two-step aggressivity rating method which combines the MUARC and modified Folksam approaches to estimate the relative risk of injury to other drivers. Following MUARC, the other driver injury risks in two-car crashes with the focus make/model, *k*, and with all other makes/models, *t*, respectively, are estimated by:

$$R_{M2_k} = \frac{n_{iik} + n_{nik}}{N} \quad \text{and} \quad R_{M2_t} = \frac{n_{iit} + n_{nit}}{N}.$$

The relative risk of other driver injury, R_{M2}, is:

$$R_{M2} = \frac{R_{M2_k}}{R_{M2_t}} = \frac{\frac{n_{iik} + n_{nik}}{N}}{\frac{n_{iit} + n_{nit}}{N}} = \frac{n_{iik} + n_{nik}}{n_{iit} + n_{nit}} \quad \text{and} \quad E(R_{M2}) = \frac{p_{2k}}{p_{1k}}$$

In practice, the adjustments for crash exposure variations in two-car crashes involving the focus make/model and all other makes/models, respectively, are made to the separate proportions forming the penultimate quotient in the equation for R_{M2} above, and not to the last quotient (see later).

Newstead Method (MUARC3)

It can be seen above that the expected value of the aggressivity measure of other driver injury risk in the TRL and modified Folksam systems includes p_{1k} as well as p_{2k} . To overcome the problem of crashworthiness and aggressivity being confounded in these aggressivity rating systems based on two-car injury crashes, Newstead proposed an estimator of the other driver injury risk in crashes with vehicle make/model *k*, given by:

$$R_{Nk} = \frac{n_{iik}}{n_{iik} + n_{ink}} \quad \text{with} \quad E(R_{Nk}) = p_{2k}$$

R_{Nk} is an unbiased estimator of p_{2k} and as such is not confounded with the crashworthiness parameter for vehicle model *k*, p_{1k}. As an unbiased estimator of absolute injury probabilities, it can be estimated using logistic regression techniques. This allows simultaneous adjustment of crash exposure factors affecting injury risk, in a way identical to that used in the MUARC aggressivity rating system.

SELECTION OF A COMMON CRASH DATABASE

The ideal common database of crashes would be one on which each of the aggressivity rating systems could be applied in full. Such a database would need to possess the following characteristics:

- Entry criterion: all types of (two-car) crashes resulting in injury or material damage
- Injury outcome: record of driver death, hospital admission, injury requiring medical treatment, or non-injury
- Adjustment factors: each of those used by existing methods
- Linkage data: information to link driver/vehicle data of specific model cars involved in two-car crashes with the driver/vehicle data of the opposite car
- File size: information on sufficient numbers of crashes to provide reliable aggressivity ratings on an adequate number of makes/models of car

Within Europe, the VALT/Oulu database of accident compensation claims in Finland has all of these characteristics. Outside Europe, the database of Police crash reports from three US states, provided by the Insurance Institute for Highway Safety, covers injury and tow-away crashes and includes a large number of potential adjustment factors, namely:

- driver age (both cars)
- driver sex (both cars)
- driver restraint use (both cars; however questionable accuracy)
- speed limit at the crash location
- collision type
- geographic location (urban; rural)
- road location (intersection; non-intersection)
- point of impact on each vehicle (absent in one state)
- vehicle damage (no damage; functional; disabling)
- vehicle type

It was agreed that these two databases were each suitable to act as the common data for the comparison of the aggressivity rating methods. The absence of point of impact in one US state meant that state's data could not be considered in the common crash database provided by IIHS.

The US crash database covered 690,826 two-car crashes during 1995-1997 for which the relevant adjustment factors were available in each case. These two-car crashes included 145,960 in which at least one driver was injured, the type of database used in the TRL, modified Folksam and Newstead systems. The US crash database was sufficient in magnitude to provide reliable rating results for each of the rating systems applied to it. The calculation was made only if there were at least 700 two-car crashes involving the specific make/model.

The VALT/Oulu database covered 186,125 two-car crashes in Finland during 1987-1998 for which the adjustment factors were known. Of these crashes, 12,904 resulted in at least one driver injury. Ratings were calculated only for makes/models which had been involved in at least 400 two-car crashes.

METHODS OF COMPARISON OF RATING RESULTS

The level of comparison of the results of the aggressivity rating systems, when applied to a common real crash database, varies according to the expectations of the consumers of these systems. These expectations may include:

1. The ratings will produce the correct rank order of the aggressivity of the car models
2. The ratings will provide a reliable estimate of a measure of aggressivity for each car model
3. The ratings will provide scientifically-defensible evidence (ie. not explainable by chance) that nominated car models are inferior in regard to aggressivity and that other nominated car models are superior

For the first criterion, the ranks produced by each rating system, and the rank correlation between pairs of methods, were assessed. For the second criterion, the comparison was the graphical relationship between actual values of each pair of results. For the third set of comparisons, the ratings results (together with their confidence limits or statistical testing procedure) were used to classify each model car as "inferior", "not defined" or "superior" in regard to its aggressivity. The classes produced by each pair of rating systems were then compared via criteria such as the percentage of car models for which the two systems agree.

As well as making comparisons of the aggressivity ratings representing the final results from each system, comparisons were made of those components/ratings which measure only the risk of injury (not severe injury) to other drivers in crashes. The rating criterion for the Oulu system apparently measures no more than this risk, whereas other systems include injury risk as a component.

RESULTS

Before the comparisons were made, each of the aggressivity rating criteria were adjusted to take into account the differences between makes/models of cars related to crash exposure factors affecting the risk of injury or injury severity. From those available in the common crash database, the adjustment factors were those used to adjust existing ratings or those factors used in the crashworthiness rating system from which the aggressivity ratings were derived. The method of adjustment was also chosen on the same basis.

Effect of Adjustment of the Ratings

TRL Aggressivity Ratings These ratings were adjusted using logistic regression in the same way as the secondary safety ratings published by the Department of the Environment, Transport and Regions, U.K. (Transport Statistics Report 1995). The adjustment factors were speed limit, type of impact, and the other driver age and sex.

The relationship between the adjusted and unadjusted ratings, together with their rank correlation, is shown in Figure 1. This and subsequent figures display the principal rating criterion in each rating system; the effects of the adjustment process on the rating components and supplementary criteria were similar in each case. For presentation purposes, a quadratic regression line was fitted to the data to demonstrate the degree of linearity of the relationship. The equation of the fitted regression line is also shown on each figure.

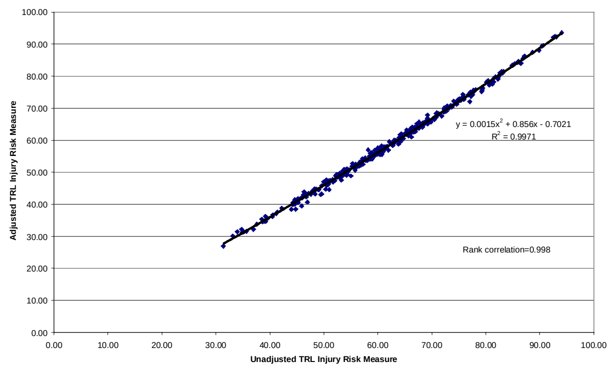

Figure 1. Relationship Between Adjusted and Unadjusted TRL Injury Risk (US Data).

__Oulu Injury Risk (Absolute)__ The Oulu (absolute) injury risk criterion was adjusted in an indirect way described by Huttula et al (1997). Correction factors are applied to the expected number of other driver injuries, for comparison with the actual number, based on the speed limit, accident type, and other driver age, sex and injury severity. Figure 2 shows the relationship between the adjusted and unadjusted results.

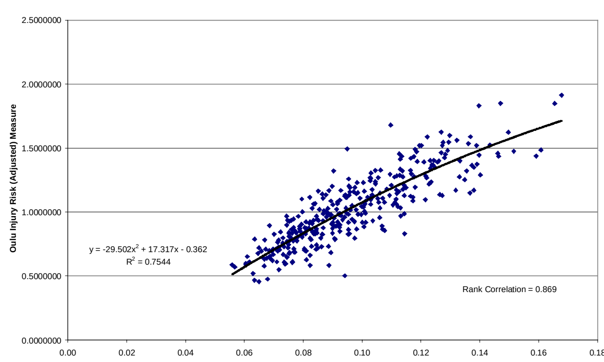

Figure 2. Relationship Between Adjusted and Unadjusted Oulu Injury Risk (Absolute) (US Data).

__MUARC Aggressivity Ratings__ The two components of these ratings were adjusted separately using logistic regression based on the following factors and their significant interactions: speed limit and other driver age and sex. The adjusted injury risk and adjusted injury severity criteria were then multiplied to form the aggressivity ratings. Figure 3 shows the adjusted and unadjusted ratings.

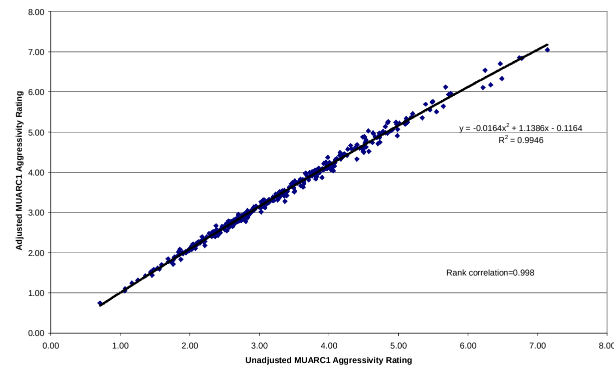

Figure 3. Relationship Between Adjusted and Unadjusted MUARC Aggressivity Ratings (US Data).

__Modified Folksam Aggressivity Ratings__ The criterion measuring the relative risk of injury to the other driver was adjusted in the same way as the driver relative injury risk in the Folksam safety ratings (Hägg et al 1992). This adjustment is intended to take into account differences in the crash energy distribution to which each make/model of car is exposed. Heavy vehicles are in general exposed to crashes with lighter vehicles, and vice versa. A heavy vehicle could be expected to be more aggressive than expected if all vehicles crashed with other vehicles of fixed mass.

It is understood that the adjustment to the Folksam safety ratings is not intended to remove the influence of mass on crashworthiness, ie. the safety rating is expected to be superior for heavier cars. In a similar way, the adjustment to the modified Folksam aggressivity ratings was not intended to remove the influence of the mass of the focus make/model cars on their aggressivity characteristics.

The injury severity component of the modified Folksam ratings is the same as that in the MUARC aggressivity ratings and was adjusted in the same way. The adjusted injury risk and adjusted injury severity criteria were then multiplied to form the aggressivity ratings. Figure 4 shows the adjusted and unadjusted ratings.

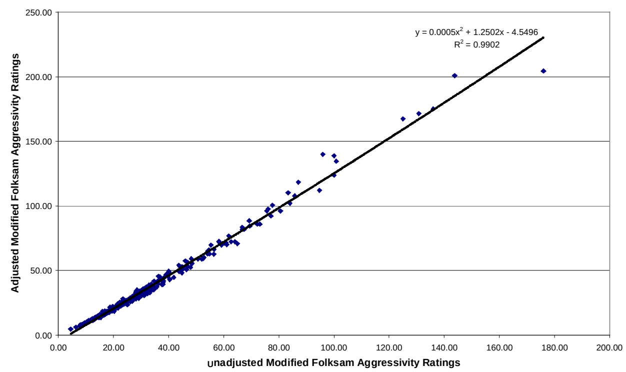

Figure 4. Relationship Between Adjusted and Unadjusted Modifed Folksam Aggressivity Ratings (US Data).

<u>MUARC2 Aggressivity Ratings</u> The MUARC2 relative risk of other driver injury was adjusted by separately adjusting each of the absolute risks of other driver injury in two-car collisions with the focus make/model and collisions with all other makes/models, respectively. The adjustment factors used for each injury risk were the same as those used to adjust the MUARC injury risk.

The injury severity component of the MUARC2 ratings is the same as that in the MUARC aggressivity ratings and was adjusted in the same way. The adjusted injury risk and adjusted injury severity criteria were then multiplied to form the aggressivity ratings. Figure 5 shows the adjusted and unadjusted ratings. Note that the unadjusted MUARC2 ratings are the same as the unadjusted modified Folksam ratings, because the injury risks are equivalent.

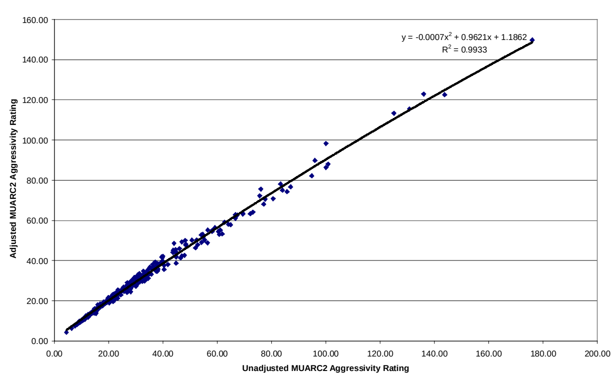

Figure 5. Relationship Between Unadjusted Modified Folksam Aggressivity Ratings (Unadjusted MUARC2 Rating) and Adjusted MUARC2 Aggressivity Ratings (US Data).

<u>Newstead Aggressivity Ratings</u> The adjustment method used to obtain the Newstead aggressivity ratings was the same as the MUARC ratings except that it used all of the relevant and unique factors available in the crash database to adjust the injury risk and injury severity probabilities. The adjustment factors for both components were:

- other driver sex
- other driver age (<=25 years, 26-59 years, >=60 years)
- speed limit (<50mph, >=50mph)
- road location of crash
- rural/urban geographic location
- focus vehicle damage severity.

Figure 6 shows the adjusted and unadjusted ratings.

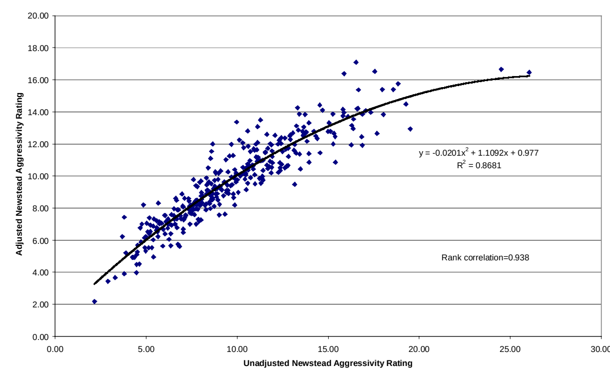

Figure 6. Relationship Between Adjusted and Unadjusted Newstead Aggressivity Ratings (US Data).

Comparison of the Adjusted Ratings Against a Benchmark Rating Method

To allow comparison of each of the adjusted ratings methods, a benchmark measure of aggressivity was developed. Ideally, this should have been the "real" aggressivity of each vehicle model when involved in crashes, however this was unknown.

<u>Aggressivity Ratings Based on a Maximum Data Model (MDM)</u> The most appropriate benchmark was ratings computed from the maximum amount of information available in the crash database. This considered both injury and non-injury crashes as well as adjusting the ratings for all relevant factors available. The resulting system was termed the "Maximum Data Model" (MDM). The base measures of injury risk and injury severity of other drivers were the same as used in the MUARC method. Logistic regression was used to adjust for the influence of other factors, apart from vehicle design, affecting injury risk and severity (which were adjusted independently). All such factors available in the common crash databases were used (the same as those used by the Newstead method). A key adjustment factor was the vehicle damage, but information on this factor was available only in the US crash data.

The rank correlation between the adjusted and unadjusted MDM aggressivity ratings was 0.948 (Figure 7). The effect of the adjustment process in MDM, when all available relevant factors were considered, was to reduce the rank correlation compared with when fewer factors were used for adjustment in the MUARC rating system (Figure 3).

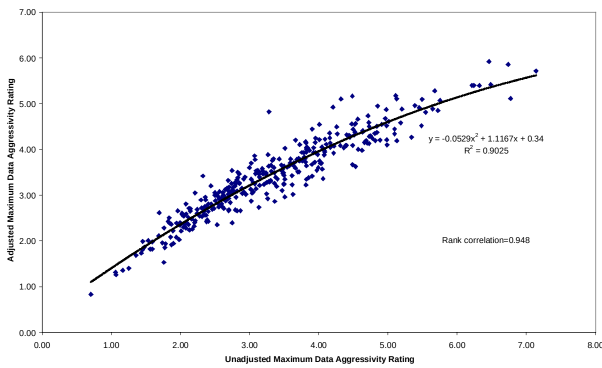

Figure 7: Relationship Between Adjusted and Unadjusted MDM Aggressivity Ratings (US Data)

Comparison Between MDM Rating System and Other Rating Systems Tables 3 and 4 give the rank correlations between each of the adjusted rating systems and the MDM ratings. The correlations shown in bold are those where the two ratings were considered to measure the same aspect of aggressivity, with the other correlations shown for information only.

The results show that the MUARC and Newstead ratings have high correlation with the MDM ratings. In the Finnish data comparison (Table 4), the former result was expected because vehicle damage was not available for inclusion in the MDM.

Of the methods based on injury crashes only, the Newstead methods were most consistent in having the highest correlations with the MDM ratings. The exception was the Newstead Injury Risk compared with the MDM Injury Risk, based on the Finnish data (Table 4).

Table 3.
Rank Correlations of Aggressivity Rating Systems using the MDM Ratings as the Benchmark (US Data)

Rating Criteria	MDM Aggress-ivity Ratings	MDM Other Driver Injury Risk
Severe Injury Risk Ratings		
Modified Folksam Rating	**0.819**	0.699
TRL Severe Injury Risk	**0.903**	0.608
MUARC Aggressivity Rating	**0.951**	0.703
MUARC2 Aggressivity Rating	**0.832**	0.688
Newstead Aggressivity Rating	**0.978**	0.652
Injury Risk Ratings		
Modified Folksam Injury Risk	0.675	**0.746**
Oulu Injury Risk	0.912	**0.758**
TRL Injury Risk	0.694	**0.768**
MUARC Injury Risk	0.754	**0.912**
MUARC2 Injury Risk	0.664	**0.747**
Newstead Injury Risk	0.754	**0.912**

Table 4.
Rank Correlations of Aggressivity Rating Systems using the MDM Ratings as the Benchmark (Finnish Data)

Rating Criteria	MDM Aggress-ivity Ratings	MDM Other Driver Injury Risk
Severe Injury Risk Ratings		
Modified Folksam Rating	**0.828**	0.565
TRL Severe Injury Risk	**0.763**	0.377
MUARC Aggressivity Rating	**0.994**	0.753
MUARC2 Aggressivity Rating	**0.909**	0.752
Newstead Aggressivity Rating	**0.921**	0.579
Injury Risk Ratings		
Modified Folksam Injury Risk	0.449	**0.510**
Oulu Injury Risk	0.767	**0.708**
TRL Injury Risk	0.715	**0.510**
MUARC Injury Risk	0.740	**0.998**
MUARC2 Injury Risk	0.645	**0.775**
Newstead Injury Risk	0.612	**0.528**

The relationship between each of the adjusted rating systems and the MDM ratings, based on the US crash data, is shown in Figures 8-12 and 14-19. The high correlation between the Newstead and MDM Aggressivity Ratings in the Finnish data is shown in Figure 13.

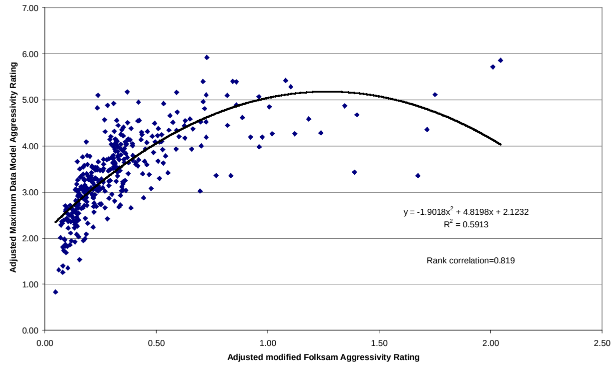

Figure 8. Relationship Between MDM and Modified Folksam Aggressivity Ratings (US Data).

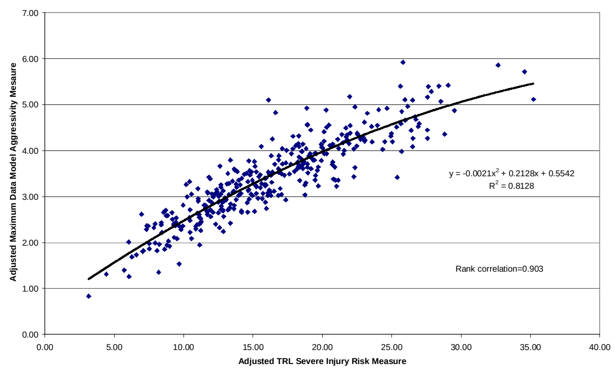

Figure 9. Relationship Between MDM Aggressivity Rating and TRL Severe Injury Risk (US Data).

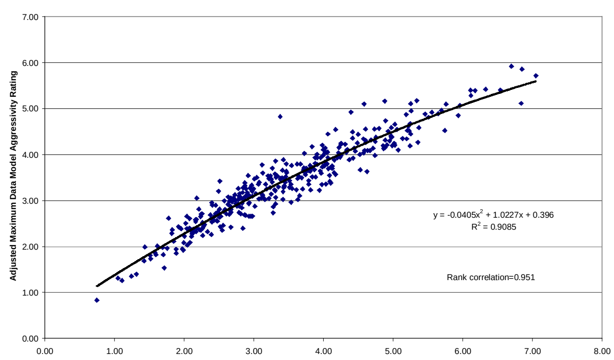

Figure 10. Relationship Between MDM and MUARC Aggressivity Ratings (US Data).

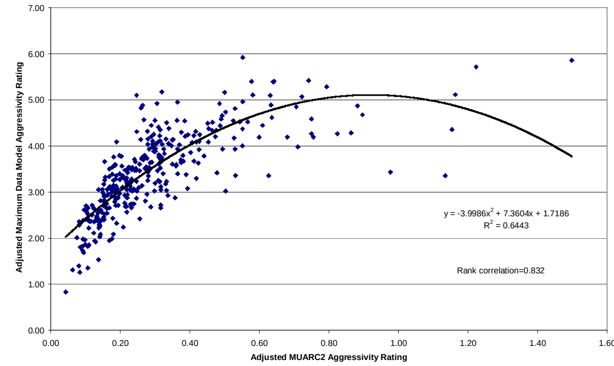

Figure 11. Relationship Between MDM and MUARC2 Aggressivity Ratings (US Data).

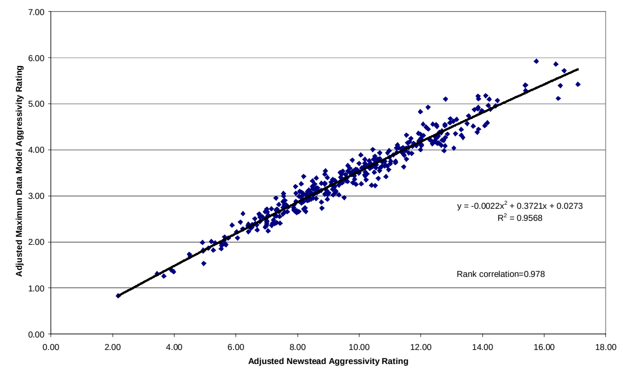

Figure 12. Relationship Between MDM and Newstead Aggressivity Ratings (US Data).

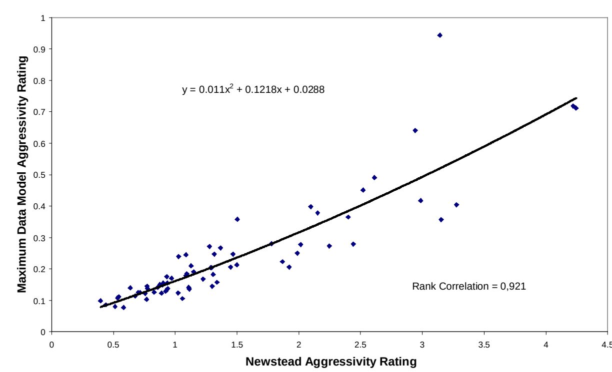

Figure 13. Relationship Between MDM and Newstead Aggressivity Ratings (Finnish Data).

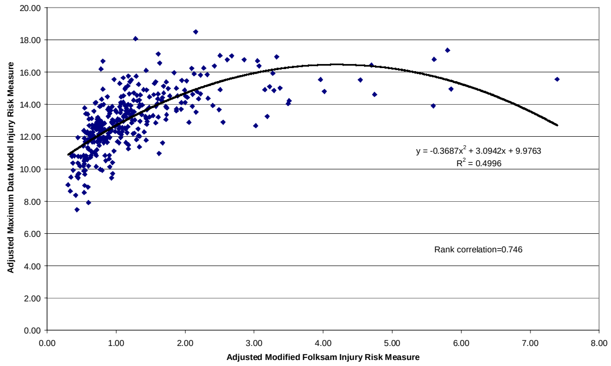

Figure 14. Relationship Between MDM Injury Risk and Modified Folksam Injury Risk (US Data)

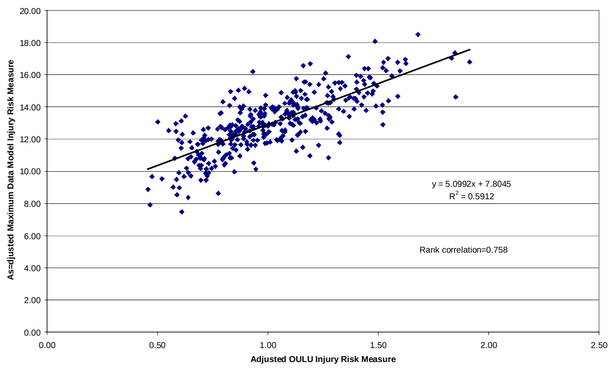

Figure 15. Relationship Between MDM Injury Risk and Oulu Injury Risk (US Data).

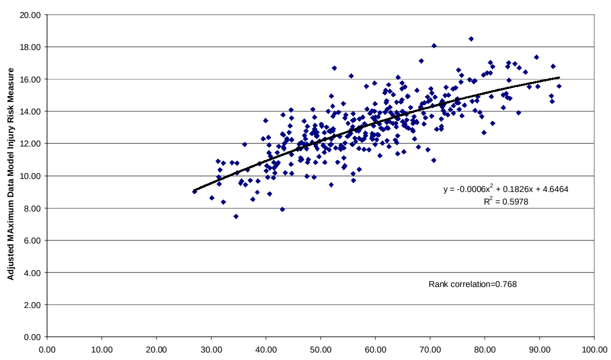

Figure 16. Relationship Between MDM Injury Risk and TRL Injury Risk Measure (US Data).

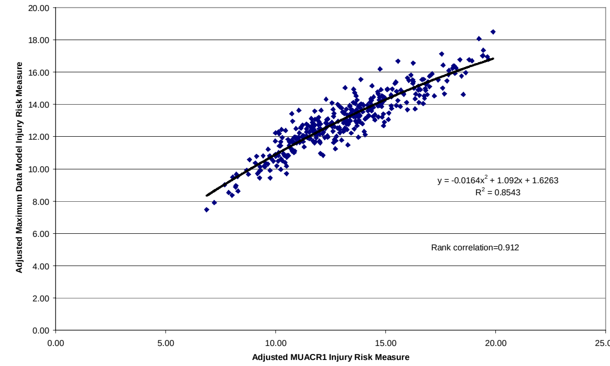

Figure 17. Relationship Between MDM Injury Risk and MUARC Injury Risk (US Data).

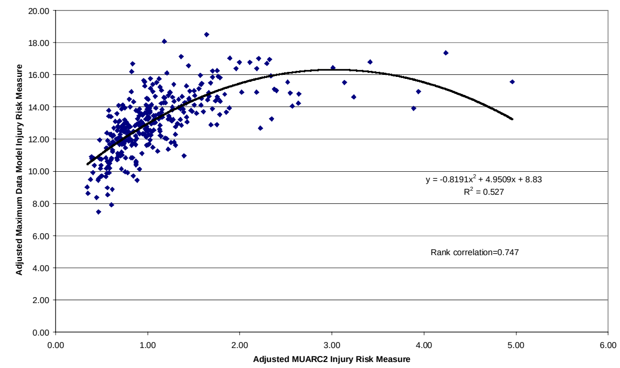

Figure 18. Relationship Between MDM Injury Risk and MUARC2 Injury Risk (US Data).

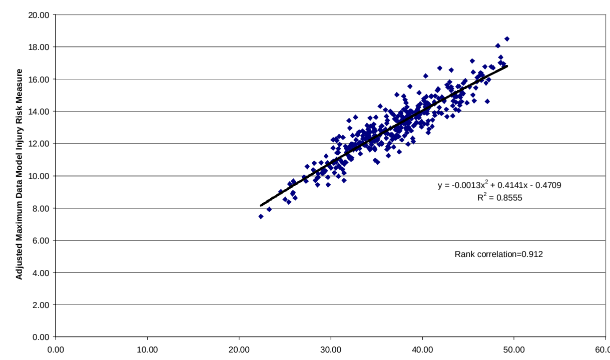

Figure 19. Relationship Between MDM Injury Risk and Newstead Injury Risk (US Data).

Adjusting for Mass Effects in Aggressivity Ratings

Mass is known to have a strong relationship with vehicle safety, with vehicles of higher mass generally exhibiting higher aggressivity in real crashes on each of the measures considered here. In the comparisons of each rating method, the correlations observed may be partly due to the strong relationship the ratings have with mass. It was considered relevant to remove the effects of vehicle mass from each rating set.

The method of adjustment for mass of the TRL, MUARC, MUARC2, Newstead and MDM aggresivity ratings was based on a logistic regression model of each rating against mass. The fitted logistic curve was subtracted from the original rating to provide the mass-adjusted rating. For the Oulu and the modified Folksam ratings, because the ratings are not estimated probabilities, another method of adjustment was required. A log-linear regression of each aggressivity rating against vehicle mass was used instead.

Mass Effects and MDM Aggressivity Ratings Figure 20 plots aggressivity measured by the MDM against mass. The fitted logistic regression curve is also shown. The other aggressivity rating measures considered were found to have similar general relationships with vehicle mass.

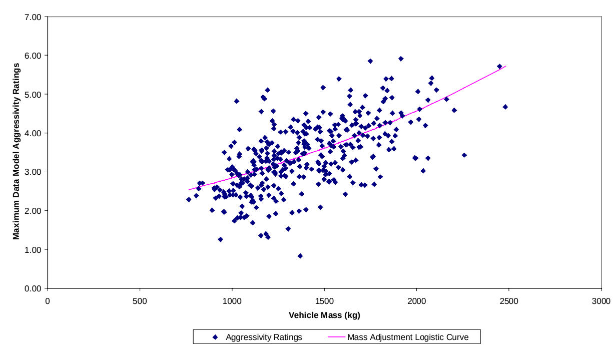

Figure 20. Relationship Between MDM Aggressivity Ratings and Vehicle Mass (US Data).

Comparison Between Mass-adjusted MDM Rating System and Other Rating Systems Tables 5 and 6 give rank correlations between each mass-adjusted rating system and the mass-adjusted MDM ratings. The rank correlations are lower compared to the correlations observed in Tables 3 and 4. This is due to the removal of mass effects from the respective ratings.

The MUARC and Newstead ratings continue to have high correlation with the MDM ratings after the influence of mass has been removed. Of the methods based on injury crashes only, the modified Folksam ratings and TRL Severe Injury Risk have higher correlations with MDM than the Newstead ratings, based on the Finnish data, but the opposite is true when the comparisons are made on the US data.

Table 5.
Rank Correlations of Different Mass-Adjusted Aggressivity Rating Systems using Mass-Adjusted MDM Rating Criteria as Benchmark (US Data)

Rating Criteria	MDM Aggress-ivity Ratings	MDM Other Driver Injury Risk
Severe Injury Risk Ratings		
Modified Folksam Rating	**0.677**	0.309
TRL Severe Injury Risk	**0.742**	0.216
MUARC Aggressivity Rating	**0.826**	0.443
MUARC2 Aggressivity Rating	**0.667**	0.309
Newstead Aggressivity Rating	**0.867**	0.372
Injury Risk Ratings		
Modified Folksam Injury Risk	0.288	**0.428**
Oulu Injury Risk	0.789	**0.525**
TRL Injury Risk	0.321	**0.478**
MUARC Injury Risk	0.533	**0.857**
MUARC2 Injury Risk	0.254	**0.437**
Newstead Injury Risk	0.552	**0.860**

Table 6.
Rank Correlations of Different Mass-Adjusted Aggressivity Rating Systems using Mass-Adjusted MDM Rating Criteria as Benchmark (Finnish Data)

Rating Criteria	MDM Aggress-ivity Ratings	MDM Other Driver Injury Risk
Severe Injury Risk Ratings		
Modified Folksam Rating	**0.893**	0.275
TRL Severe Injury Risk	**0.879**	0.186
MUARC Aggressivity Rating	**0.987**	0.527
MUARC2 Aggressivity Rating	**0.691**	0.480
Newstead Aggressivity Rating	**0.838**	0.272
Injury Risk Ratings		
Modified Folksam Injury Risk	0.211	**0.491**
Oulu Injury Risk	0.490	**0.512**
TRL Injury Risk	0.436	**0.695**
MUARC Injury Risk	0.484	**0.997**
MUARC2 Injury Risk	0.180	**0.685**
Newstead Injury Risk	0.345	**0.377**

Comparison of Presentation of Rating Results for Vehicle Models

The adjusted aggressivity rating were also compared by their ability to rank the most common vehicle models, and by the classification of each vehicle model as "inferior" or "superior" in regard to its aggressivity.

The first comparison was made by ranking the rating results of 20 vehicle models most frequently involved in two-car crashes. The 20 models most involved in crashes were chosen in order to minimise, as far as possible, the effects of random variation on the rating estimates. Figure 21 shows the rank order of the ratings from each of the methods based on a measure of severe injury risk as the criterion.

The mass of each vehicle model (in kg) is also shown in brackets below each model ID. Generally, the rank order of aggressivity suggested by each of the rating methods was similar. Some vehicle models have been ranked essentially the same by all methods whilst some have been ranked very differently.

This could be due to the nature of crashes used by each method, ie. some methods are based on all crashes and some are based on injury crashes. There are other fundamental differences in the methods being compared.

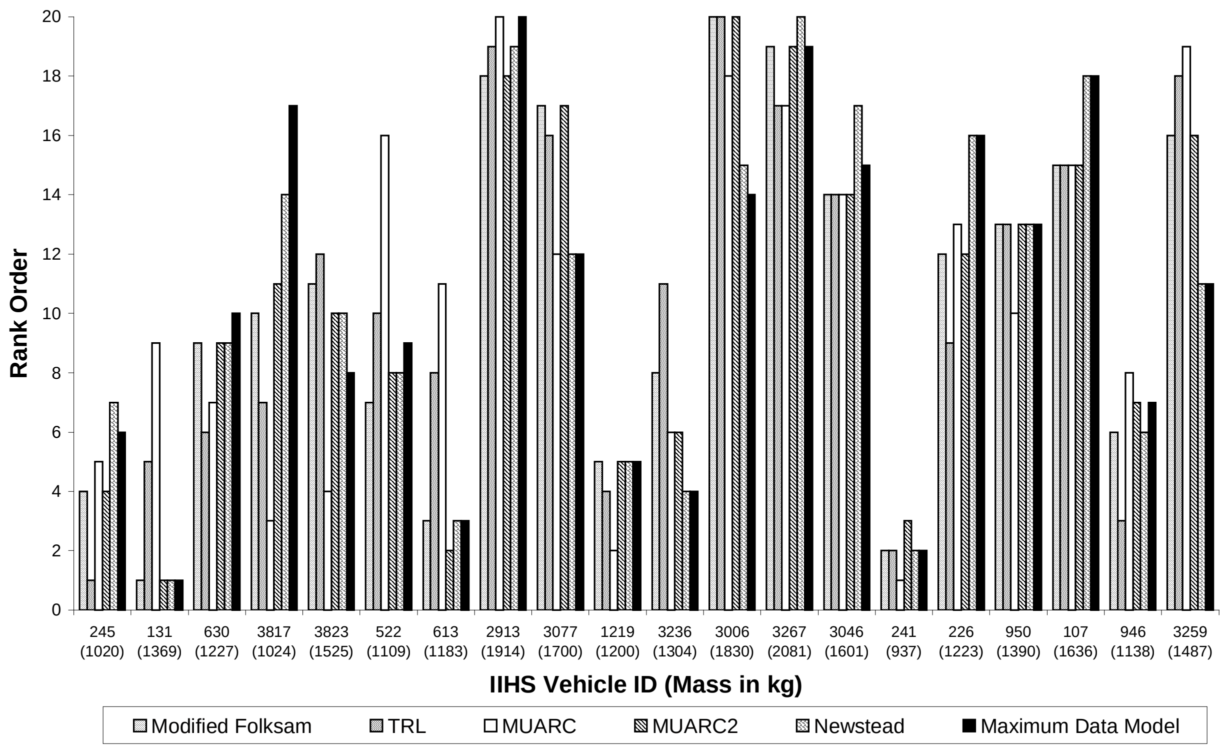

Figure 21. Rank Order of Aggressivity Ratings For Each Vehicle Model (US Data).

For the second comparison, classification of vehicle models into "inferior", "not defined" or "superior" was considered. The classification was based on the 95% confidence limits calculated for the aggressivity ratings, and the respective limits compared with the all model average point estimate (Tables 7 and 8).

In the tables, "agree" signifies the proportion of vehicle models that fall in agreement in classification between the rating methods being compared. There were no cases where a rating method was found to fundamentally "disagree" with the MDM ratings, ie. it classified a vehicle model as "superior" in regard to aggressivity whereas MDM classified the same vehicle model as "inferior", or vice versa.

CONCLUSIONS

All of the aggressivity rating systems correlate well with the ratings produced by a Maximum Data Model, which makes the maximum use of the crash data available to rate aggressivity. Of the methods based on all crashes, the MUARC method has the strongest correlation with the MDM ratings.

There are weaker correlations between the aggressivity rating systems and the MDM ratings when the effects of vehicle mass are removed. There is no clear pattern of strong correlation between the MDM ratings and each of the methods based on injury crashes.

Table 7.
Comparison of MDM Aggressivity Ratings and Other Aggressivity Ratings Based on Classification of Vehicle Models (US Data)

			Modified Folksam Aggressivity Ratings			TRL Severe Injury Risk			MUARC Aggressivity Ratings			MUARC2 Aggressivity Ratings			Newstead Aggressivity Ratings		
		Total	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**
MDM	**I**	**53**	49	4		45	8		47	6		46	7		48	5	
Aggress.	**ND**	**276**	80	92	104	30	192	54	31	218	27	70	102	104	20	249	7
Ratings	**S**	**24**			24		1	23		1	23		0	24		1	23
	Total	**333**	**129**	**96**	**128**	**75**	**201**	**77**	**78**	**225**	**50**	**116**	**109**	**128**	**68**	**255**	**30**
			Agree		47%	**Agree**		74%	**Agree**		82%	**Agree**		49%	**Agree**		91%

MDM – Maximum Data Model; I – Inferior, ND – Not Defined, S – Superior

Table 8.
Comparison of MDM Aggressivity Ratings and Other Aggressivity Ratings Based on Classification of Vehicle Models (Finnish Data)

			Modified Folksam Aggressivity Ratings			TRL Severe Injury Risk			MUARC Aggressivity Ratings			MUARC2 Aggressivity Ratings			Newstead Aggressivity Ratings		
		Total	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**	**I**	**ND**	**S**
MDM	**I**	**6**	4	2		1	5		6			6			3	3	
Aggress.	**ND**	**61**	2	41	15		40	21	1	60		4	50	7	2	56	3
Ratings	**S**	**2**		1	1			2			2			2		1	1
	Total	**69**	**6**	**44**	**16**	**1**	**45**	**23**	**7**	**60**	**2**	**10**	**50**	**9**	**5**	**60**	**4**
			Agree		70%	**Agree**		62%	**Agree**		99%	**Agree**		84%	**Agree**		87%

REFERENCES

BROUGHTON, J. (1994), "The theoretical basis for comparing the accident record of car models". Project Report 70, Safety and Environment Resource Centre, Transport Research Laboratory, Crowthorne, Berkshire, U.K.

BROUGHTON, J. (1996), "The theoretical basis for comparing the accident record of car models". *Accident Analysis and Prevention*, Vol. 28, No. 1, pp. 89-99.

CAMERON, M.H., NEWSTEAD, S.V. and LE, C.M. (1998) Rating the aggressivity of Australian passenger vehicles towards other vehicle occupants and unprotected road users. Proceedings of IRCOBI Conference, Goteborg, Sweden, September 16-18. Also in: *Journal of Crash Prevention and Injury Control*, Vol. 1, No.2, pp. 129-141.

HÄGG, A., KAMREN, B., van KOCH, M., KULLGREN, A., LIE, A., MALMSTEDT, B., NYGREN, A, and TINGVALL, C. (1992), *Folksam car model safety rating 1991-92.* Folksam Insurance, Stockholm.

HUTTULA, J., PIRTALA, P., and ERNVALL, T. (1997), *Car safety, aggressivity and accident involvement rates by car model 1997.* Report 40, Road and Transport Laboratory, University of Oulu, Finland.

LES, M., and FILDES, B. (2000), *Comparison of vehicle aggressivity rating methods.* Proceedings, ISATA 2000 Conference, Dublin, Ireland, 25-27 September. ISATA-Düsseldorf Trade Fair, Epsom, U.K.

NEWSTEAD, S., CAMERON, M., and LE, C.M. (2000), *Vehicle crashworthiness and aggressivity ratings and crashworthiness by year of manufacture: Victoria and NSW crashes during 1987-98, Queensland crashes during 1991-98.* Report no. 171, Monash University Accident Research Centre, Melbourne, Australia.

TAPIO, J., PIRTALA, P., and ERNVALL, T. (1995), *The accident involvement and injury risk rates of car models.* Report 30, Road and Transport Laboratory, University of Oulu, Finland.

TRANSPORT STATISTICS REPORT (1995), Cars: Make and Model: The Risk of Driver Injury and Car Accident Rates in Great Britain: 1993. Department of Transport, London.