AGGRESSIVITY VARIABLES AND THEIR SENSITIVITY IN CAR AGGRESSIVITY RATINGS

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Paper Number 2001-S4-O-190

ABSTRACT

This paper presents a review of possible parameters that effect on vehicle aggressivity ratings and also gives a definition of aggressivity of vehicle models. The selection of the most important aggressivity variables in vehicle aggressivity measures is based on expert evaluations and detailed variable analyses. Further, the sensitivity of the most important aggressivity variables in vehicle aggressivity measures is examined using logistic regression analysis.

INTRODUCTION

This paper sums up the analyses of sub-tasks 3.1 and 3.2 of the project *Quality Criteria for the Safety Assessment of Cars based on Real-World Crashes* carried out by the Safety Rating Advisory Committee (SARAC) for the European Commission. The definition of aggressivity of vehicles and the aggressivity parameters selected for further analyses are described in this report. The sensitivity of aggressivity variables was studied based on two crash databases: Police crash reports from three US states and accident compensation claims from Finland.

AGGRESSIVITY AND EXPOSURE

The perspective in crashworthiness and aggressivity analysis is different. In crashworthiness analysis we usually use the samples of certain type of crashes occurred to the focus car model. In addition, we have also the characteristics of the opponent vehicle available.

On the other hand, in aggressivity analysis the accident involvement risk of the focus vehicle and injury risk in the other (i.e. opponent) vehicle should be taken into consideration at the same time. The roles of accident type and the structure of the front-end of the striking vehicle are more essential parameters in aggressivity analysis than in crashworthiness analysis. Therefore frontal, side and rear-end collisions are most natural accident types in aggressivity and compatibility ratings; though, most injury outcomes in rear-end crashes especially in striking vehicle are relatively slight.

Based on the discussions at the second and the third SARAC-workshop, 19 exposure items regarding to crashworthiness ratings were identified and presented by the committee members and other experts. The exposure items were categorised according to their priority into three classes (table 1).

Table 1.
Summary of Exposure Item Priority (Langwieder et al, 1997)

Priority	Exposure item
High priority	Vehicle mass or size
	Crash severity
	Injury severity
	Type of crash
	Age of the driver
	Sex of the driver
	Guilt of the driver
	Engine power
Medium priority	Vehicle model year
	Vehicle identification number
	Use of safety systems
	Two or four doors
	Transmission
	Crash location
	Driver size and weight
Low priority	Mileage (total+annual)
	Number of registered vehicles
	Years of insurance
	Marital status of the driver
	Number of occupants

The first (high priority) category consists of items which are typically available in accident data or which later can be measured and/or connected to the accident file.

Furthermore, different exposures and parameters can be classified into four categories: crash involvement, vehicle characteristics, injury risk of occupants and traffic environment parameters. We must, however, remember that there is normally a very restricted number of information available in the accident databases.

In addition to the recorded accident data we can also measure or pick from other databases some other important details (vehicle register, technical data, etc.) like some vehicle characteristics (bumper height, age of the vehicle, engine power, etc.) and try to use also them as variables, parameters, exposures or explanatory variables to each other.

AGGRESSIVITY VARIABLES

General

There are numerous parameters which more or less effect on the aggressivity of the vehicle. Nevertheless, the evaluation of the parameters is problematic because many of the parameters have only a very low effect on the aggressivity itself. Instead, they effect primarily on some other parameter or variable, which has a closer connection to the aggressivity.

When the parameters consist of occupant (O), vehicle (V), environment (E) and accidents characteristics (C), which are also connected to one another, the backgroud of the aggressivity and compatibility ratings is especially tangled.

Based on the expert evaluations of SARAC members, table 2 shows a list of those parameters and variables that can be used in the aggressivity ratings.

In the categories of primary and secondary parameters, the information is typically recorded or it can easily be completed with other databases crash by crash. Most of the parameters in the category "supplementary parameters" include such details that are impossible, difficult or too inaccurate to measure or estimate. Obviously, the more relevant and detailed the iformation available in the databases, the more the weight of aggressivity will become emphasized.

It will be possible to include also some new parameters into the list, if we are able to harminize the recording systems of vehicle crashes in the future.

Table 2.
Classification of possible variables, parameters and exposures in aggressivity (and compatibility) ratings.

Categories	Variables/Parameters
Primary variables or parameters	C Accident type V Mass V Identification code O age of occupant O Injury severity E Speed limit
Secondary variables or parameters	C Crash severity V Height arrangement V Engine arrangement V Age of Vehicle V Body type V Transmission O Guilt O Sex of occupant O Sitting position E Crash location E Weather conditions
Supplementary parameters	C Impact angle C Impact speed V Stiffness V Longitudinal arrangement V Engine power/mass V safety systems of vehicle V Mass ratio O Use of safety restraints O Injury type E Investigation period E Annual mileage
Exposures	Number of accidents Number of vehicle in fleet Number of insurance years No of inhabitants Total mileage Time

Crash variables

Accident type In most databases the accident type of each recorded crash has been coded in numeral form according to the accident type catalogue. Typically, the number of alternatives describing the manoeuvres and the movements of the colliding vehicles varies between 30 and 80 from one database to another. Accordingly, accident type can be sub-divided into three accident types: head-on, junction and rear-end accidents. This sub-division into three categories is sufficient enough to describe the accident type variable, because most of the injuries and especially severe injuries occur in them.

From the vehicle aggressivity point of view, mostly the damages caused by the front-end of the vehicle to the opponent vehicle are essential. In a rear-end accident the crash descriptions are quite clear. The front-end of the second vehicle hits the rear-end of the first vehicle with an overlap of 0-100 per cent or with an angle of 0-90 degrees. Head-on accidents occur when the front-ends of the vehicles closing each other from the opposite directions hit together. Head-on accidents normally occur on road or street sections outside junctions but sometimes also during left turning manoeuvres in junctions. Junction accidents are more or less side collisions with an impact angle of 30-150 degrees, depending on the turning manoeuvres.

Crash severity A potential variable when estimating the damages of a crash is crash severity. The damages of a vehicle in an accident are very difficult to measure, because the damages correlate strongly with the collision speeds and the masses of the collided vehicles. Naturally, it is possible to measure or estimate the intrusions and the deformations of the vehicle after the crash. For the aggressivity ratings, deformations and other parameters that describe the crash severity would be very useful.

Some very simple trials regarding to crash severity have been done in previous ratings. MUARC and IIHS have used a tow-away criteria in choosing the cases into the sample (Cameron & al.). The sum of FIM 3000 (about USD 500) has been used as the minimum compensation at the university of Oulu to qualify the crashes into the rating (Tapio & al. 1995).

Vehicle variables

Mass and size According to Newton's law, the kinetic energy of a vehicle in a collision is directly related to its mass and to the square of its velocity. In a two-vehicle collision, the changes of velocity for the vehicles and hence the decelerations of are directly related to the mass ratio. The vehicle mass is therefore a dominant variable and has fundamental influence in determining the outcome of a two-vehicle collision. The increase of average vehicle mass, mostly 150-200 kg, has been significant during the last 10-15 years. For example, in Great Britain the median mass has increased from 946 kg to 1120 kg between 1988 and 1997 (Rogers & al 1998). The increase of 100 kg seems to decrease the risk of driver's MAIS 3+ injury in the focus vehicle by 9 per cent on an average, but simultaneously it increases the injury risk in the opposite vehicle by that same 9 per cent (Huttula & al 1998a).

The mass correlation is obvious in aggressivity ratings, but there can also be seen big differences in the aggressivity rating between the models in the same weight class. In the Finnish database, the driver's injury risk in the opposite vehicle increases with the mass of the focus vehicle (N=110 models) depicted in figure 1.

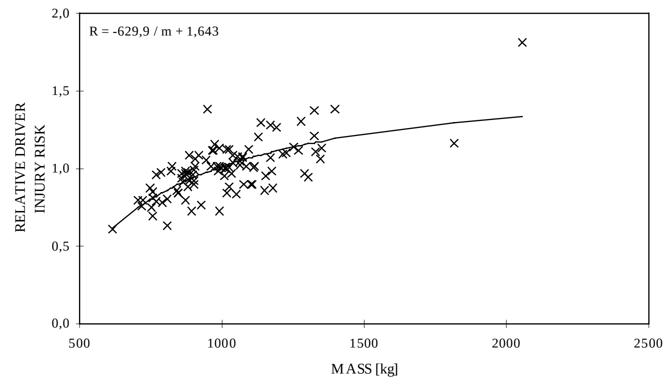

Figure 1. The relationship between mass and relative aggressivity of the car model in two-car crashes. (Huttula & al 1998b)

The size of the vehicle correlates with the mass of the vehicle. From the point of view of aggressivity, a larger vehicle as an opponent usually offers more space to its occupants, greater tolerances for intrusions and deformations, and perhaps other structural solutions to survive. As a focus vehicle, a larger and heavier vehicle is typically more aggressive, but also great differences within the same size class have been shown both in crashworthiness and aggressivity ratings.

Identification code The vehicle Identification systems vary in different countries and therefore it is often difficult to use and connect different databases. Several systems are used within the EU to identify different characteristics of different vehicles. Since 1996, all vehicles have been defined with a 17-digit VIN-code round the world. However, some problems exist in the use of the VIN-codes regarding to older models, and, on the other hand, the VIN-codes are not commonly used in all countries. Unfortunately, the vehicle identification systems on national levels have developed over a long period of time and the willingness to replace well working systems is low.

The key link is usually the registration number of the vehicle, which in many countries offers the connection element from a database to another, but only on national level. In addition to the 17-digit

VIN-code, we will need some 10-15 digits to define the vehicle and its characteristics with sufficient detail for the ratings.

Occupant variables

Age and sex Accident risk, Injury risk and severe injury risk correlate with the age of the occupant. Depending on databases either the driver's, all involved drivers', injured occupants' or even all involved occupants' age information is available. The most detailed data files have generally been recorded in on-scene investigations.

Generally in severe and fatal two-car crashes, the injury risk of female drivers is 25-30 per cent higher than that of male drivers (figure 2). The increase of the severe or fatal injury risk is relatively slow up to the age of 55-60 years, but after that age the risk begins to increase more quickly.

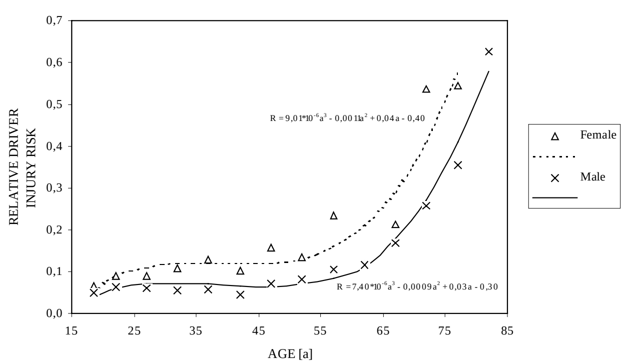

Figure 2. Relative severe or fatal injury risk according to age and gender of the driver (Huttula & al 1998b).

In slight injuries the risk of female drivers compared to male drivers' injury risk seems to be more than two times higher. Also the increase of age tends to effect more on the severe or fatal injury risk than on slight injury risk. The injury risks of female and male drivers increase by about two per cent per a year (figure 3).

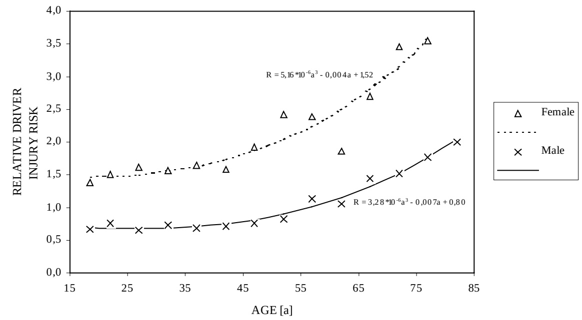

Figure 3. Relative injury risk according to age and gender of the driver (Huttula & al 1998b).

Injury severity Injury severity has generally been recorded with a 3-step scale: slight (or minor), severe and fatal. In some databases also more detailed systems have been used. The AIS-classification (Abbreviated Injury scale) consists of six categories, in which most of the typical injuries are classified in detail according to their outcome, severity and the body area the injury concerns. The injury severity of all injuries of each car occupant should be recorded. The six categories on the scale are: low (1), moderate (2), severe (3), significant (4), critical (5) and maximum (fatal) (6). (Langwieder &al 1999)

The lack of detailed injury data (hospital data) reduces the representativeness of most accident databases. However, the injury severity is extremely important variable both in crashworthiness and aggressivity ratings. How to take it into consideration is more complicated, and the three-step classification could be the first alternative. Because of the low number of severe and fatal crashes by a car model, we will also need to include the slight injuries into the analysis. For the ratings we should find out a method how to weight the accident of different severity.

Traffic environment variables

Speed limit Many international comparisons show that speeding is a very common type of traffic violence everywhere. In many European countries the speed limits are 40, 50 or even 60 kph in urban areas. Correspondingly, the respective mean speeds in the traffic are 44-46 kph, 52-54 kph and 59-63 kph, and more than a half of the drivers exceed the actual speed limit (Ernvall 1999).

The actual speed limit, of course, does not tell the real speed before or at the moment of the crash, but in a large sample, the speed limit can be regarded as a relatively good estimate of the speeds typically used on a corresponding road or street type.

The injury risk correlates with the speed limit area in all severity classes and accident types. It is estimated that each addition of 10 kph to the speed limit raises the injury risk of an occupant by 4 per cent in severe two-car collisions (Ranta & al 1996).

Speed limit area is obviously the best estimate of used speeds available in all large accident databases. It is one of the key variables in aggressivity analyses.

SENSITIVITY ANALYSIS

Data and parameters

In the sensitivity analysis are analysed two-car crashes which occurred in Finland and three states of USA: Florida, Ohio and Pennsylvania. Finnish data consists of two-car crashes where at least one driver is injured. VALT/Oulu data encompasses one crash and parameter values related to the crash in one record. The IIHS data consists of all two-car crashes encompassing one crash and parameter values related to the crash in two records. There are 22 757 accidents in VALT/Oulu data that can be analysed. IIHS data encompasses 1 117 037 crashes that are used in the sensitivity analysis.

The parameters included in the sensitivity analysis are shown in table 3. The same parameters are investigated in both databases except injury severity and vehicle damage of the other car. In addition to the main effects, the first order interaction effects of the main parameters were investigated in IIHS database. There are 8 main effects in both databases that will be investigated.

Table 3.
The aggressivity parameters studied in the sensitivity analyses.

	Databases	
Key Parameters of Aggressivity	**VALT/Oulu**	**IIHS**
Other car driver age	X	X
Other car driver sex	X	X
Weight of the subject car	X	X
Weight of the other car	X	X
Speed limit at the crash site	X	X
Crash location	X	X
Year of crash	X	X
Injury severity of the other car	X	
Vehicle damage of the other car		X
First order interaction effects		X

Research methods

<u>Obtaining the covariate models and risk measures</u> The sensitivity of the parameters were analysed with logistic regression analyses, scatter diagrams and non-parametric test. The logistic regression analysis was used to calculate the injury risk and the injury severity risk for different makes and models of vehicles. The effect of parameters of aggressivity on the rating of vehicle models was analysed using scatter diagrams. In addition, the changes in the rank order of vehicle models were studied using non-parametric test; the Wilcoxon Signed-Rank test.

In the calculation of injury risk and severe injury risk the MUARC method was used /Newstead et al. 1999/. The first step in the sensitivity analysis was to find out which parameters have a significant effect on injury risk or severe injury risk. Each parameter selected to the entire model by forward stepwise procedure is a significant predictor of crash outcomes (eg. injury risk or severe injury risk). It means that each one of these parameters is important variable defining the outcomes of crashes.

In addition, the logistic procedure in statistical programs gives estimates of odds ratios defining the magnitude of an effect of a categorical or continuous variable on predicted probabilities. Interpretation of the values of odds ratios is one way to find out the sensitivity of a variable.

All aggressivity parameters were included into the entire model in the initial phase. In order to find out the effect of aggressivity parameters on the ratings each parameter was excluded from the entire model one at a time and after each exclusion risk measures were calculated for vehicle models. All the interaction effects were excluded at the same time with their corresponding main effects from the entire model.

The final entire model was obtained by selecting all main effects and only statistically significant interaction effects obtained by forward stepwise procedure in the model. Furthermore, the vehicle model code was added to the model to obtain estimates of the coefficients of the logit function (equation 1) and their associated standard errors for car models.

The logistic regression model of a probability is expressed as follows:

$$\text{Logit(P)}=\ln\left(\frac{P}{1-P}\right)=\beta_0+\beta_1 x_1+...+\beta_k x_k=f(x) \quad (1).$$

The injury risk (R) and injury severity risk (S) was calculated on the estimated coefficients of each vehicle model using the inverse logistic transformation (equation 2).

$$R_j=\frac{e^{\alpha_j}}{1+e^{\alpha_j}} \quad S_j=\frac{e^{\beta_j}}{1+e^{\beta_j}} \qquad (2).$$

The sensitivity analysis was performed comparing separately injury risk and severe injury risk obtained with entire model and all sub-models. The sub-models were obtained by excluding one main effect and all corresponding interaction effects simultaneously one at a time from the entire model. The Finnish data was analysed without interaction effects.

In the logistic regression analysis effect method was used as parameterization method for the classification variables. This method gives a value of –1 for all dummy variables in the reference level of the classification variable in the design matrix (table 4). According to this parameterization method odds ratio values are interpreted by comparing nonreference levels to the first level.

Table 4.
The aggressivity parameters studied in the sensitivity analyses.

Age	Design matrix	
under 25	-1	-1
25-64	1	0
65-	0	1

Using the effect method for parametrization of a variable the odds ratio is calculated as follows:

Let β_1 = 0.0272 and β_2 = 0.0658. β_1 and β_2 are respective regression coefficients of age groups 25-64 and 65-.

Hence,

$$\text{odds ratio (25-64)} = \text{EXP}(2\beta_1+\beta_2) = \text{EXP}(2*0.0272+0.0658) = 1.1277$$

$$\text{odds ratio (65-)} = \text{EXP}(2\beta_2+\beta_1) = \text{EXP}(2*0.0658+0.0272) = 1.1721$$

In the logistic regression analysis the odds ratio is interpreted as the change in the odds for 1 kg increase in vehicle weight. The odds ratio corresponding to 100 kg increase in the vehicle weight- variable is computed as follows

$$\text{odds ratio (weight other)} = [\text{EXP}(-0.0016)]^{100-1} = [\text{EXP}(-0.0016)]^{99} = 0.8535$$

Comparison of rating/rank order of vehicle models with statistical test The rating of the vehicle models was compared with scatter diagrams and rank correlation coefficient (Spearman's). The rating produced with each sub-model was compared to the rating produced with the entire model. The Scatter plots were used to show the relationship between two series. The form of the relationship is expected to be linear or, on the other hand, there can be no correlation between series. Though, the correlation seems to be very high the results can differ from each other. Hence, the results must be compared with non-parametric statistical test. (Lehmann E.L.)

The rank order of the vehicle models was compared with non-parametric statistical test: the Wilcoxon Signed-Rank test. The non-parametric or distribution-free methods can be easily applied to testing differences in rank order of vehicle models. A good side in non-parametric tests is that they don't assume knowledge of the distribution of the underlying population except that it is continuous. (Lehmann E.L.)

The Wilcoxon Signed-Rank test utilises both magnitude and direction of the difference. The differences are now being ranked without regard to the sign and proceed as with the single sample case. If the null hypothesis is true, the total of the ranks corresponding to the positive differences should nearly equal the total of the ranks corresponding to the negative differences. (Lehmann E.L.)

Analysis results

Injury risk measure comparison on IIHS data The entire model was obtained with forward stepwise selection procedure. The entire model includes all main effects showed in table 3 as significant variables except crash year, which was entered in the entire model, nevertheless. In addition, all statistically significant first order interaction effects that corresponded with statistically significant main effects were included in the model. Table 5 gives the variables selected into the entire injury risk model in the order of selection.

Table 5.
Parameters selected into the entire injury risk model.

Order	Parameter	ChiSq	Signif.
1	Vehicle damage of the other car	164279.8	<.0001
2	Speed limit	2971.9	<.0001
3	Sex of the other car driver	2494.2	<.0001
4	Weight of the other car	1707.0	<.0001
5	Age of the other car driver	1233.0	<.0001
6	Weight of the focus car	810.5	<.0001
7	Location	327.0	<.0001
8	spd_lim*veh_dam2	244.1	<.0001
9	hlwght2*veh_dam2	199.0	<.0001
10	sex2*location	96.7	<.0001
11	sex2*veh_dam2	89.8	<.0001
12	age2*sex2	55.5	<.0001
13	age2*location	43.4	<.0001
14	hlweight*veh_dam2	34.7	<.0001
15	hlwght2*spd_lim	24.5	<.0001
16	hlweight*location	25.3	<.0001
17	hlweight*sex2	22.0	<.0001
18	age2*spd_lim	21.5	<.0001
19	age2*veh_dam2	24.0	<.0001
20	location*spd_lim	15.0	0.0005
21	location*veh_dam2	20.7	0.0004
22	hlwght2*age2	14.7	0.0007
23	hlweight*age2	12.4	0.0020
24	hlweight*hlwght2	4.1	0.0433
25	year		>0.05

According to odds ratios, the odds of driver being injured are decreased by 94%, when a vehicle was not damaged in a crash (table 6). Further, the odds of female driver is injured are multiplied by 1.61 compared to male driver.

Table 6.
The odds ratios of the main variables of the injury risk model.

Variable	Odds ratio
Sex other (female)	1.6138
Age other (26-59)	1.2401
Age other (60-)	1.5052
Weight other (100 kg increase)	0.9640
Weight subject (100 kg increase)	1.0138
Speed limit (50- mph)	1.0803
Crash location (non-intersection)	1.0771
Crash location (other)	1.0326
Vehicle damage (functional)	0.1299
Vehicle damage (no damage)	0.0604

The vehicle damage of the other vehicle had affected the most to the injury risk rating (figure 4). Nevertheless, the two ratings have very high value of the Spearman's correlation coefficient between them (R = 0.903). The equation of the best fitting quadratic spline is also shown on figure to functionally illustrate the level of curvature in the relationship.

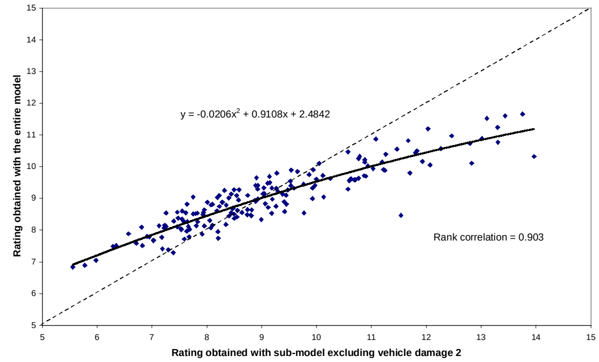

Figure 4. Relationship between the entire model and the sub-model obtained excluding vehicle damage of the other vehicle and all corresponding interaction effects.

The speed limit and all its interaction effects had a minor effect on the rating when they were excluded from the model, but still the value of the Spearman's correlation coefficient was very high of 0.995 (figure 5). The equation of the best fitting quadratic spline is also shown on figure 4 to functionally illustrate the level of curvature in the relationship.

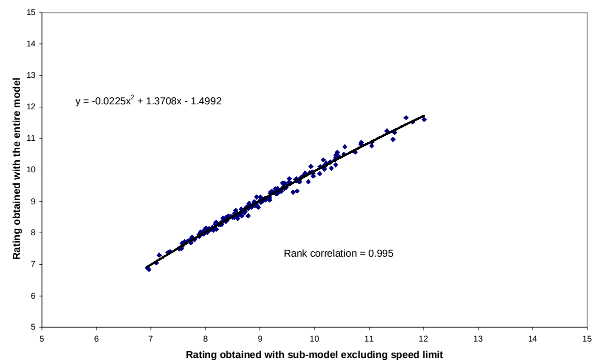

Figure 5. Relationship between the entire model and the sub-model obtained excluding speed limit and all corresponding interaction effects.

The non-parametric test showed that none of the parameters affect to the rankings at any statistical significance level. Asymptotic significance (α) values varied between 0.589 and 1.000 for Wilcoxon Signed-Rank test.

<u>Severe injury risk measure comparison on IIHS data</u> The entire model was obtained with forward selection procedure. The entire model includes all main effects listed in table 3 as significant variables. In addition, all statistically significant first order interaction effects that corresponded with statistically significant main effects were included in the model.

Table 7.
Parameters selected into the entire severe injury risk model.

Order	Parameter	ChiSq	Signif.
1	Vehicle damage of the other car	3150.8	<.0001
2	Location	312.3	<.0001
3	Age of the other car driver	326.6	<.0001
4	Speed limit	149.0	<.0001
5	spd_lim*veh_dam2	72.3	<.0001
6	Weight of the other car	67.9	<.0001
7	Weight of the focus car	53.5	<.0001
8	location*veh_dam2	53.9	<.0001
9	age2*veh_dam2	50.1	<.0001
10	Sex of the other car driver	34.3	<.0001
11	location*spd_lim	29.6	<.0001
12	hlwght2*veh_dam2	27.0	<.0001
13	year	16.4	<.0001
14	hlwght2*age2	16.9	0.0002
15	age2*spd_lim	11.5	0.0031
16	hlweight*veh_dam2	10.1	0.0063
17	sex2*location	7.8	0.0203
18	sex2*veh_dam2	8.4	0.0153
19	Sex2*year	4.6	0.032

Table 8 shows the odds ratios of main variables. Drivers over 60 years of age have 2.52 times higher severe or fatal injury risk compared to the drivers under 26 years old. The odds of driver being injured severely or killed are increased by 27% in the speed limit area of over 50 mph compared to the speed limit area of 0-50 mph.

Table 8.
The odds ratios of the main variables of the injury risk model.

Variable	Odds ratio
Sex other (female)	<0.0000
Age other (26-59)	1.4263
Age other (60-)	2.5166
Weight other (100 kg increase)	0.9911
Weight subject (100 kg increase)	1.0059
Crash year	1.0388
Speed limit (50- mph)	1.2695
Crash location (non-intersection)	1.1197
Crash location (other)	1.0413
Vehicle damage (functional)	0.2259
Vehicle damage (no damage)	0.9329

The vehicle damage of the other vehicle had affected the most to the severe injury risk rating (figure 6). Nevertheless, the two ratings have very high value of the Spearman's correlation coefficient between them (R = 0.984). The equation of the best fitting quadratic spline is also shown on figure to functionally illustrate the level of curvature in the relationship.

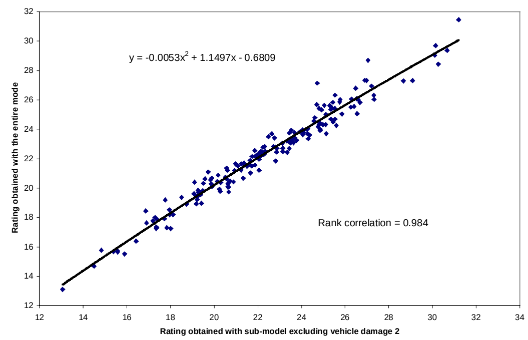

Figure 6. Relationship between the entire model and the sub-model obtained excluding vehicle damage of the other vehicle and all corresponding interaction effects.

The non-parametric test showed that none of the parameters affect to the rank order at any statistical significance level. Asymptotic significance (α) values varied between 0.664 and 0.967 for Wilcoxon Signed-Rank test.

<u>Injury risk measure comparison on VALT/Oulu data</u> The entire model was obtained with forward stepwise selection procedure. The entire model includes all main effects showed in table 3 as significant variables except crash location, which was entered in the entire model, nevertheless. Table 9 gives the variables selected into the entire injury risk model in the order of selection.

Table 9.
Parameters selected into the entire injury risk model.

Order	Parameter	ChiSq	Signif.
1	Injury severity of the other car driver	1141.5	<.0001
2	Sex of the other car driver	860.9	<.0001
3	Weight of the other car	586.7	<.0001
4	Weight of the focus car	461.9	<.0001
5	Speed limit	308.8	<.0001
6	Year	74.8	<.0001
7	Age of the other car driver	14.8	0.0006
8	Crash location		

Table 10 shows the odds ratios of main parameters of injury risk. According to odds ratios, female drivers have 2.286 times higher risk of injury in an accident than male drivers. The odds of driver being injured are increased by 17 % for old drivers (over 64) compared to the young drivers (under 25). The odds of driver being injured are multiplied by 1.85 in the speed limit area of 80-120 km/h compared to the speed limit are of under 80 km/h. A 100 kg increase in the weight of the subject vehicle increases the odds of driver being injured in the other vehicle by 20 %.

Table 10.
The odds ratios of the main variables of the injury risk model.

Variable	Odds ratio
Sex other (female)	2.2855
Age other (25-64)	1.1277
Age other (65-)	1.1721
Weight other (100 kg increase)	0.8535
Weight subject (100 kg increase)	1.1951
Crash year	0.9616
Speed limit (50- mph)	1.8471

The injury severity of the other vehicle driver had affected the most to the injury risk rating (figure 7). The value of the Spearman's correlation coefficient between the two ratings was very low (R = 0.125) indicating significant differences between ratings. The equation of the best fitting quadratic spline is also shown on figure to functionally illustrate the level of curvature in the relationship.

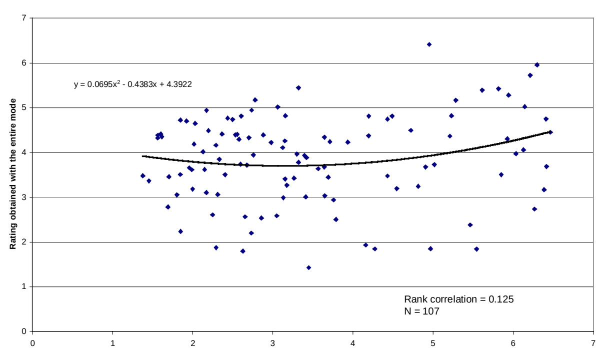

Figure 7. Relationship between the entire model and the sub-model obtained excluding injury severity of the other vehicle driver.

The weight of the focus vehicle, contrary to the weight of the other vehicle, has moderate effect on the rating of vehicle models (figure 8). A good indication of the effect is the value of the Spearman's correlation coefficient of 0.703. The equation of the best fitting quadratic spline is also shown on figure to functionally illustrate the level of curvature in the relationship.

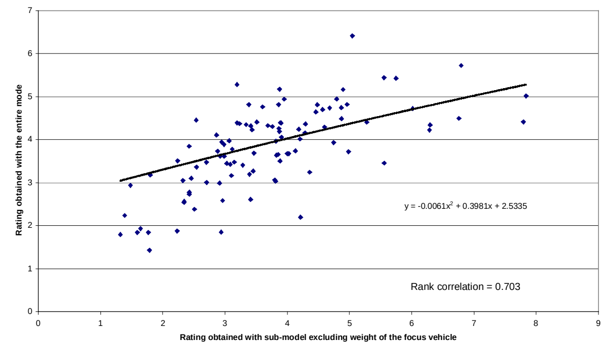

Figure 8. Relationship between the entire model and the sub-model obtained excluding weight of the focus vehicle.

The Exclusion of the age of the other vehicle driver from the entire model contributes significant changes to the aggressivity rating of vehicle models (figure 9). The non-parametric Spearman's correlation coefficient is only 0.114 being one indication of the difference between these two ratings. The equation of the best fitting quadratic spline is also shown on figure to functionally illustrate the level of curvature in the relationship.

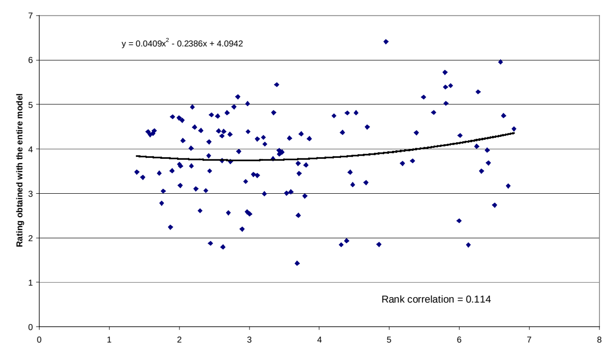

Figure 9. Relationship between the entire model and the sub-model obtained excluding age of the other vehicle driver.

The non-parametric test showed that the exclusion of age of the other vehicle driver, weight of the focus vehicle, crash year and injury severity caused statistically significant effects on the rank order of vehicle models. The asymptotic significance (α) value was 0.051 for the sex of the other vehicle driver.

CONCLUSIONS

The key parameters of aggressivity were speed limit, mass of vehicles, vehicle damage of the other vehicle, drivers' age and sex, accident type and injury severity, according to sensitivity analysis. In addition, experts rated vehicle identification code and accident type as primary variables. The sensitivity analysis results agreed with expert evaluations.

The results of preliminary expert evaluations of parameters regarding to aggressivity (and compatibility) ratings and the sensitivity analysis show that the classification of aggressivity variables and parameters was quite successful. All parameters in the primary category that were studied in the sensitivity analyses were statistically significant predictors of injury risk and severe injury risk.

On the other hand, there were two parameters in the secondary variables category that were also significant predictors of injury risk. The other parameter was sex of the other vehicle driver which was one of the most important predictors of injury risk, but which is not as important predictor of injury severity risk. The damage severity of the other vehicle was the most important predictor of both injury risk and injury severity risk, but it gives us only a hint of the importance of crash severity, because vehicle damage of the other vehicle describes only a part of the damage outcomes in an accident.

The redundancy of information in explanatory variables may have kept the magnitude of differences in ratings/ranking so minor in IIHS data set analyses. The difference between the IIHS and VALT/Oulu injury risk measure comparison was probably caused by the injury severity variable that was used only in VALT/Oulu injury risk calculation as an adjustment effect and whose coefficient estimate does not differ significantly from 0 according the Chi-Square test.

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