Car model safety rating based on real life accidents.

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Introduction

Every year more than 30 million cars are produced and sold around the world. A large proportion of these cars (at least 1 per 10) are involved in an accident where people are injured. For this reason, the car is one of the consumer products causing most harm in terms of injuries.
It has however been found, both theoretically and in practice, that the risk of being injured can be reduced effectively by constructing cars with high interior safety, that is, the number and severity of accidents is constant, but the outcome is affected, both regarding the risk of injury and injury severity. It has also been showed that cars are different in this sense, that is there are cars with higher interior safety than others. The objective of this study is to present methods and results that can be used for rating the interior safety of different car models.

Background

There are several ways of rating the interior safety of cars. Today, at least four different systems are in use and published. Two of the systems are based on real life accidents, while one is barrier tests and the last is based on a thoroughful inspection. There are some important differences between the ways of rating cars. In methods based on systematic tests or investigations of undeformed cars, the most complicated area is how to generalize the results to real life. In methods based on real life accidents, however, the problem is to normalize the accident data with respect to exposure and other relevant factors influencing the outcome.
The risk of injury can be considered as a dose-response problem where the exposure in terms of number exposed to an accident, the type of accident and the accident severity are factors related to the dose while the injuries to the occupants is the response. The possibilities to measure the dose as well as the response is however limited in that most of the factors related are unknown. Methods must therefore be developed to handle the exposure problem where traditional data is not available. In most statistical models, the dose must be measured with almost no error, while the random error is addressed to biological or similar variation in the response or dependent variable.
It is also of importance to assess the injuries related to the exposure in adequate terms. A traditional threat-to-life or just risk-of-injury concept is not sufficient to describe injuries. Instead, the large variety of injury severity must be taken into account, where some basic definitions of injury outcome is used. In the rating method presented, much attention has been paid to both the exposure and the injury severity problem. While some limitations in the possibility to generalize the results have been introduced, the exposure is measured with fairly high precision.
The objective of this paper was to present a technique to rate individual car models, and to present some results, especially in relation to vehicle size.

Methods

The methods used for rating cars can be divided into two parts: the risk to be injured and the severity of injuries.

The risk to be injured

The fundamental problem can be described with probability distribution functions. In Fig. 1 two hypotetical curves showing the risk of injury linked to accident severity for two different car models is showed. One car is better than the other in that the distribution is shifted to the right, that is for a given accident severity, the probability of injury is lower.

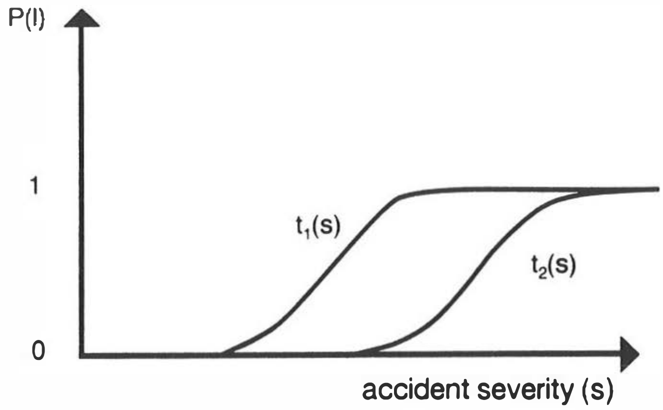


Fig. 1. Schematic probability functions for injury risk for different accident severity. $t_1(s)$ refers to car 1 and $t_2(s)$ to car 2.

In Fig. 2. Two accident severity distributions for two car models is showed. The distributions are hypothetical. Car (2) is involved relatively more frequently in severe collisions compared to car (1).

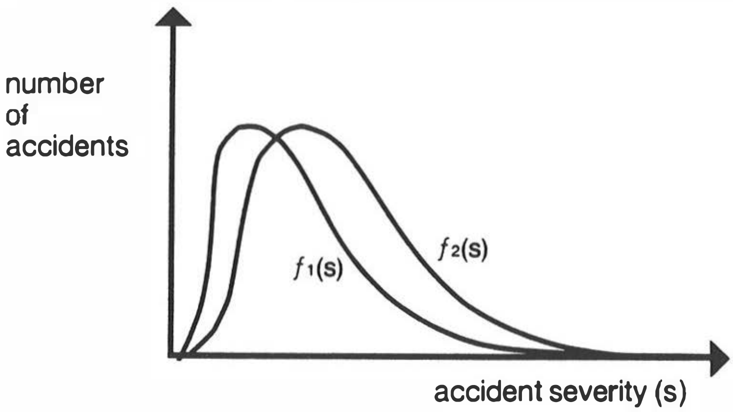


Fig. 2. Schematic distribution of accident severity. $f_1(s)$ refers to car 1 and $f_2(s)$ to car 2.

The accident severity distribution is, however, unknown for different car models. This would not create any problem if all accident severity distributions for different cars were identical. This seems however to be a too optimistic assumption. There is though one situation where this is true and that is when the two different car models collide with each other (given a mass relation of 1:1).
According to Evans, the relation of injuries for car 1 and 2 given the same accident severity distribution is: d/e
where:
d = the number of injured in car 1 = $N\int t_1(s)f(s)ds$
e = the number of injured in car 2 = $N\int t_2(s)f(s)ds$
N = total number of accidents
For a given segment m where the accident severity can be considered to be constant (Fig. 3) d and e can be considered to be products of two probabilities; p_1 and p_2, where p_1 is the risk to be injured in car 1 for a given severity and p_2 the corresponding probability for car 2.

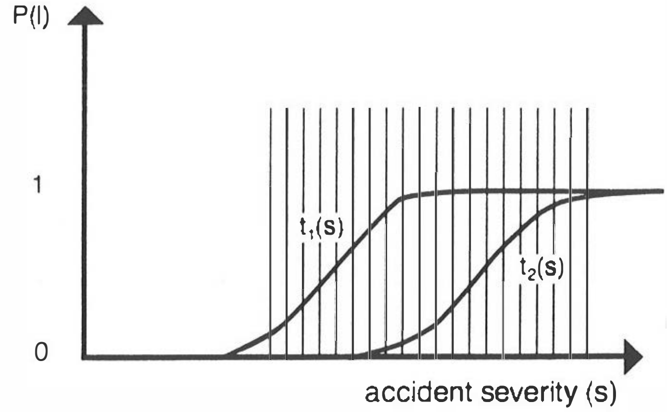


Fig. 3. Segmented probability functions for injury risk for different accident severity for car 1 $t_1(s)$ and car 2 $t_2(s)$.

		Car 2 injured in	not injured in	
Car 1	injured in	$N \cdot p_1 \cdot p_2 = x_1$	$N \cdot p_1 \cdot (1 - p_2) = x_2$	total $Np_1p_2 + Np_1(1 - p_2) = Np_1$
	not injured in	$N \cdot (1 - p_1) \cdot p_2 = x_3$	$N \cdot (1 - p_1) \cdot (1 - p_2) = x_4$	

total $Np_1p_2 + N(1 - p_1)p_2 = Np_2$

Table. 1a. Probabilities of injury in car 1 and 2 in a given segment of accident severity.
In table 1 a the probabilities are separated. The probabilities are assumed to be independent for all given segments where the accident severity and probabilities of injury respectively can be considered as constant. It can be seen that the ratio d/e in this segment is equal to the ratio.

$R = x_1+x_2/x_1+x_3$ (where $d=x_1+x_2$ and $e = x_1+x_3$)

which is the same as;

$$R = p_1/p_2 \quad \left[\frac{Np_1 \cdot p_2 + Np_1 \cdot (1 - p_2)}{Np_1 \cdot p_2 + Np_2 \cdot (1 - p_1)} \right]$$

X_y is not used due to the fact that accidents with uninjured are not known in most data materials.

It is easy to show that if p_1/p_2 is the estimator for a given segment, it is also true for the whole range of accident severity. Identical formulas are therefore used for all accidents together.

The complete accident material used is shown in table 1b.
Table 1b. Probability of injury and number of injured for all segments of severity of accidents. Drivers and passengers.

		Car 2 injured	Car 2 not injured	
Car 1	injured	$\sum_{i=1}^{m} (N_i\, p_{1i}\, p_{2i}) = X_1$	$\sum_{i=1}^{m} (N_i\, p_{1i}\, (1 - p_{2i})) = X_2$	Np_1
	not injured	$\sum_{i=1}^{m} (N_i\, (1 - p_{1i})\, p_{2i}) = X_3$		
		Np_2		

It is also possible to include passengers under som simple assumptions. By assuming that all cars have a similar proportion of front sent passenger, all accidents where there are injured passengers can be used, although it is not known from the accident material if there was an uninjured passenger in the vehicle, too.

The individual N_i is the number of accidents in a given segment. It is easily understood, that a higher proportion of severe accidents will lead to a relatively larger X_1 vs X_2 and X_3.

The same assumptions and theory is used for estimating the variance of the estimates p_1/p_2. By using Cochran's theorem for subdivison of variances, it can be seen that the variance could be calculated from the estimates of p_1 and p_2. By using Gauss approximation for the variance of ratios, the variance is calculated by;

$$\hat{V}(R) = \frac{p_1^*}{p_2^*} \left[\frac{(1 - p_1^*)}{(x_1 + x_2)} + \frac{(1 - p_2^*)}{(x_1 + x_3)} \right]$$

p_1^*/p_2^* is estimated by R, while p_1^* and p_2^* must be chosen arbitrarily.

It can be understood from the formulas that the method as described above cannot be used directly on a true accident material, as the number of combined accidents for different cars will be to few. Instead, the opposite car (ie car 2) will be all cars that were involved in accidents (with car 1). Thereby, it must be assumed that the distribution of all opposite cars is similar for all investigated car models, or can be normalized.
If so, the opposite cars must be known concerning make, model and weight.
It is also obvious that there must be a possibility to compensate for other mass relation than 1:1 as the opposite car can gain from a low weight car and vice versa.

Table 2. The number of drivers injured in SAAB 900, and cars colliding with SAAB 900, x_1 refers to drivers injured in both cars. x_2 is the number of cars where the driver injured in SAAB 900 but not in the opposite care while x_3 refers to the opposite case.

$x_1 = 122$
$x_2 = 166$
$x_3 = 220$
$R = 0.84$
$s_R = 0.04$

In table 2, an example of one car is showed. The weight of this car is approx. 1200 kg, but no attention has been paid to the mass ratio to the opposite cars. The correct interpretation of R is that in 84% of the accidents, where at least one driver was injured, there was an injury in the SAAB 900.

Injury classification and assessment

Basically, all injuries were classified according to the 1980 revision of the Abbreviated Injury Scale (AIS). AIS is a scale with values of 1-6, where

AIS 1 = minor injury
AIS 2 = moderate injury
AIS 3 = serious injury
AIS 4 = severe injury
AIS 5 = critical injury and
AIS 6 = maximum injury virtually unsurvivable.

AIS was originally meant to include several parameters such as threat to life, energy dissipation, permanent impairnent and treatment period, but today it is mainly used as a threat to life scale. The scale was developed on a consensus basis in collaboration with experts in different fields of traffic injury specialities such as physicians and engineers. The different values of AIS cannot be treated as risk figures. Furthermore, the steps are not equidistant and the scale is therefore an ordinal scale, that is, a ranking scale.

The severity of multiple injuries was expressed according to the ISS where highest or maximum AIS values (HAIS or MAIS) for up to three out of six body regions are squared and summed. ISS thus has a range from 1 to 108, for those over 75, however, a fatal injury is always included (AIS 6). ISS was derived empirically and the formula used has no theoretical background. Like AIS, ISS is an ordinal scale whose levels are not equidistant in predicting mortality risk or any other risk. The body regions used in ISS are:

Skull and brain, including the neck
Face
Extremities and pelvic girdle
Chest
Abdominal and pelvic contents
External.

External injuries include soft-tissue injuries which may involve more than one region, such as lacerations or burns.

ISS is also mainly a threat to life scale.

In order to have a scale that fulfills some of the criteria for statistical analysis and also includes one other serious outcome of traumatic injuries, namely permanent disability, the RSC (Rating System for Serious Consequenes) was used. RSC is a scale from 0 to 1 which reflects the risk of either dying or sustaining a permanent disability of at least 10% according to the procedures used by the Swedish insurance companies.

ISS and AIS for up to 10 body regions are used as prior information for calculation of RSC. RSC is calculated from the formula:

$$RSC = r_f + ((1 - r_f) * (1 - \pi (1 - r_{id})))$$

where

r_f is the risk of dying associated with an ISS value, and r_{id} is the risk of being medically disabled as a result of an injury of a certain AIS level to body region i.

The r_f values were derived from different studies of the relationship between ISS and mortality risk. Table 3 shows the values used in the RSC.

Table 3. ISS values and mortality risks (r_f) used in the RSC scale.

ISS	Mortality risk
1-3	0.000
4-8	0.001
9-14	0.005
15-19	0.040
20-24	0.080
25-29	0.160
30-34	0.260
35-39	0.370
40-44	0.500
45-49	0.650
50-54	0.850
55-	1.000

If at least one AIS 5 is present, the mortality risk (r_f) is set at at least 0.5. An AIS 6 is set at 1.0.
The r_{id} values were derived from empirical materials on the relationship between AIS for different body regions and the proportion of permanently disabled. The r_{id} values are treated as independent.
In Sweden, the cases of all injured persons who sustain medical disability that is considered as permanent and of a level of at least 10% are evaluated regarding this disability by a partly governmental committee with representatives of all insurance companies. The evaluations are based on a publication with fixed latitudes in the area 1-100% for the majority of persisting problems due to trauma. The evaluation of medical disability includes only loss of function and pain and should not include occupational or social handicap. Cases with medical disability of 1-9% are judged by the individual insurance company, but these were not included in the present study. 12,000 injured were followed during at least five years to produce the probabilities in table 4.

Table 4 shows the values for permanent medical disability for different body regions and AIS levels, used in the RSC scale.

Table 4. Disability risks (r_{id}) used in the RSC scale.

Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Skull/brain	0.01	0.02	0.15	0.30	0.55
Neck	0.05	0.10	0.40	0.50	1.00
Face	0.0002	0.01	0.10	0.10	-
Arm	0.005	0.05	0.20	0.60	-
Leg	0.005	0.15	0.30	0.60	-
Chest	0.001	0.003	0.01	0.03	0.05
Abdomen	0.0001	0.0001	0.02	0.04	0.04
Pelvis	0.001	0.05	0.10	0.10	-
Back	0.01	0.10	0.30	0.75	1.00
External	0.0001	0.05	0.05	0.05	n.a.

Table 5 gives one example of how the data on injured were coded in terms of AIS, HAIS, ISS and RSC.

Table 5. Assessment of the injury severity of an injured in terms of AIS, HAIS, ISS, and RSC.

Injury description	AIS	HAIS	$HAIS^2$	r_{id}	$1 - r_{id}$
Cerebral concussion Unconsciousness 1-15 min	2	2	4	0.02	0.98
Neck pain	1			0.05	0.95
Fractured patella, complicated	3	3	9	0.30	0.70
Fractured tibia	2				
ISS			13		
r_f			0.005		
$1 - \pi (1 - r_{id})$				0.348	
RSC = 0.005 + (1 - 0.005) * 0.348 = 0.351					

In this example ISS had to be based on the highest AIS for only two body regions, as the skull, brain and neck are treated as one body region in ISS and out of the two lower extremity injuries the one with the highest AIS was chosen. For the disability risk calculations three values were used, as in this case the skull/brain injury and neck injury are separated, while only one lower extremity injury is included. In the example, the injured occupant recieved injuries that were not likely to lead to death, while the disability risk was high (34.8%). The most probable disabling injury was the fractured patellae (30% risk) followed by the neck injury (5,0% risk).
If RSC is treated as a random variable, the density function is probably very skew. The minimum number of observations that have to be available to consider the mean RSC (mrsc) as approximately normally distributed is therefore 20–25. The mean RSC, mrsc, is calculated as an arithmetic mean. The variance of RSC is calculated from:

$$V(RSC) = \frac{\Sigma(RSC_i - MRSC)^2}{N - 1}$$

The sample variance of mrsc is calculated from:

$$V(mrsc) = \frac{\Sigma(rsc_i - mrsc)^2}{n(n-1)}$$

where n is the number of injuried.

Injury risk and injury severity matched together.

In order to get the risk of receiving a disabling or fatal injury in an accident, the injury risk and injury severity is matched together. The estimation is given by the formula:

$$Z = R * mrsc$$

where R is the relative risk of being injured based on the paired comparison, and mrsc is the risk of serious consequenses in terms of death or disability.

The variance of the estimate is:

$$V(Z) = R^2 \cdot V(mrsc) + V(R) \cdot mrsc^2$$

Z is considered to be normally distributed. The variance of RSC was considered to be known, while the number of injured was varying.

Material

The material can also be divided in two parts, one relates to the injury risk, and the other to the injury severity.

The injury risk is calculated from matched accidents. The accidents were reported to the National Bureau of Statistics (SCB) by the police. Only accidents where two private cars were involved and where at least one occupant over 18 years was injured were included in the material. From this criteria it will follow that lorries, busses etc that were not registered as private cars were excluded, while small vans and pick ups could be included.
The accidents occured in Sweden during 1985 to 1989 and were in all 13 228. Although the police also assess the injury severity, this was not used.
The material used to assess the injury severity is based on insurance claims reported to Folksam Insurance Company during 1976 to 1989. Only adult front seat occupants were included, in all 26 764.
All injuries were coded according to AIS - 80 based on doctor's certificates, hospital records or, for minor injuries, on the basis of occupants' reports.

The quality of the data has been studied in other investigations. It has been shown, that the police material is not covering all cases. Depending on accident type, 20-80% is not reported to or by the police and thereby not found in the official statistics used in this study. It has, however, been found that the accident type with the highest probability to be reported is combined accidents, while single accidents, especially with minor or moderate injuries, are far less often reported.
The number of injured reported to an insurance company seems to be higher.
The quality of the injury severity assessment conducted by the police can also be questionned. In this study, no such data was used. It has, however, been shown, that in 10% of the cases, the police claimed that there was an injury, while in fact the occupant was uninjured according to adequate definitions.

Rating procedure

The calculations were based on the following procedure:

1. The injury risk was calculated from the paired comparison where an individual car model was rated in relation to all opposite cars. The weight of the individual car was taken into account in a way, where for every 100 Kg service weight, the ratio is reduced or added with 0.05. This constant was based on the empirical data (see table 6).

2. The injury severity calculations (RSC) were based on ISS and AIS calculations.

3. The injury risk and injury severity were matched together. The variance was also calculated, giving confidence limits and the basis for hypothesis testing.

4. The results from individual car models were compared to the average among all cars as well as within the weigth class of every car model. All statistical tests were 5% tests, one-tailed where the result of the car was compared to a certain limit.

Results

In table 6, the risk of injury calculated from paired comparisons, is showed. Both the original as well as the normalized figures are shown. In the calculation for the normalized results, all deviations from 1 200 kg is taken into account. For every 100 Kg deviation, 0,05 is added or subtracted from the ratio R(C). It can be seen, that the injury risk is highly correlated to the weight of the car.

Table 6. The number of drivers in a specific car where, x_1 the driver was injured in both the specific and the opposite car, x_2 the driver was injured in the specific car but not in the opposite car, and, x_3, vice versa. Both original and normalized ratios R. Correcting factor C according to service weight of specific car.

weight	X_1	X_2	X_3	R original	R normalized	C
751- 850	119	368	84	2.40	1.92	0.80
851- 950	346	710	259	1.75	1.48	0.85
·951-1050	492	913	453	1.49	1.34	0.90
1051-1150	354	534	373	1.22	1.16	0.95
1151-1250	373	471	468	1.00	1.00	1.0
1251-1350	664	896	1088	0.89	0.93	1.05
1351-1450	375	411	613	0.80	0.88	1.10
1451-1550	167	201	359	0.70	0.80	1.15

[1)] Total R, normalized, is set to 1.10

In table 7. The specific cars have been divided into four weight classes; -950 kg, 951-1050 kg, 1051-1250 kg and 1251- kg. These weight classes are used in the tables onwards.

Table 7. See table 6, except the specific car is divided into four classes and s_R = standard deviation for R. Correcting factor C.

weight class	X_1	X_2	X_3	R original	R normalized	C	s_R normalized
751- 950	465	1078	343	1.91	1.62	0.85	0.03
951-1050	492	913	453	1.49	1.34	0.90	0.02
1051-1250	727	1005	841	1.10	1.05	0.95	0.02
1251-1550	1206	1509	2060	0.83	0.87	1.05	0.01

From both table 6 and 7, it can be seen that within the weight range 800 kg to 1 500 kg, there is a factor 2 in injury risk, when corrected for the weight factor in the calculation of the paired comparison. The random error is very small, and the confidence limits are in the region of only 3-4% (95% C. limits).

The injury severity, as measured by mrsc, is not correlated to service weight. In the material, the mean value (mrsc, total) was 0.085, that is, out of the injured, based on ISS and AIS to body regions, 8.5% of the injured would either die or become medically disabled. The variance of RSC in the sample was 0.015.

In table 8, some basic figures concerning the injury severity is given.

Table 8. Number of injured front seat occupants ≧ 15 years. mrsc, standard deviation of mrsc and 95% c.i. for mrsc. in %.

No of occupants	mrsc	Smrsc	95% c.i mrsc
26 764	0.085	$0.707 \cdot 10^{-3}$	8.5 ± 0.14%

In the sample we would expect 2 237-2 312 to be either killed or disabled.

ISS 1-3	ISS 4-10	ISS 11-	fatally injured	total
13 484	4 264	805	629	19 182
70.3%	22.2%	4.2%	3.3%	100%

From table 9 it can be seen, that approx 70% of the drivers were injured with an ISS of 1, 2 or 3, while 7.5% were either seriously or fatally injured.

Table 10. Limits for injury risk * Injury severity = Z for rating. (R * mrsc)

Weight class	**Average Z**
751-950 kg	0.138
951-1050 kg	0.114
1051-1250 kg	0.089
1251-1550 kg	0.074
Total	**0.094**

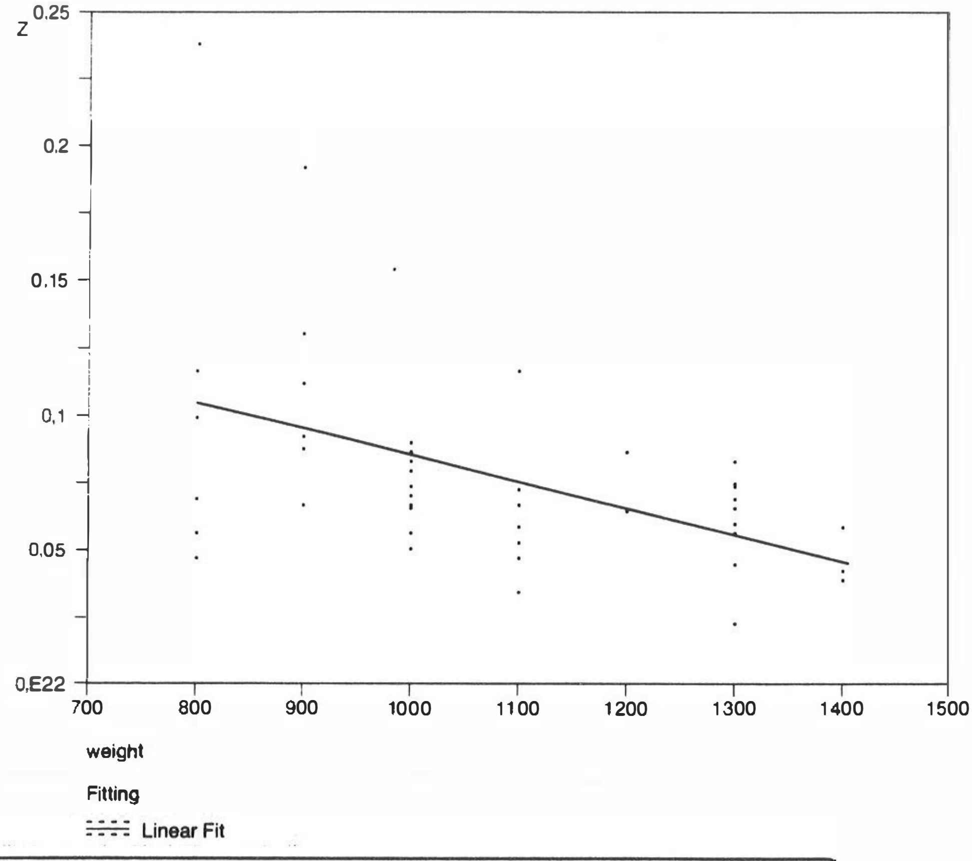
In the first place, the Z_i, which is the product of injury risk R_i and the injury severity $mrsc_i$ for every car model, is compared to the total Z (0.094).

Individual car model ratings

In figure 1, the results of the rating of 47 car models is showed. The Z-value, which is the risk of death or disability, varies to a large extent; between 0.019 (SAAB 9000) and 0,239 (NISSAN MICRA). Even when the random error is taken into account, there is a variation of more than five times between the best and the worst car model in the sample.

It can also be seen that there is a clear correlation between vehicle weight and the safety level as measured with Z. This risk is however not homogenious in the sense that even among the small cars, there are specific car models with a very low risk of death and disability (Opel Corsa), while among the larger cars, there are examples of models with the safety level of small cars. It seems, however, that the variation is smaller among the larger cars compared to the smaller ones. Nevertheless, weight of the vehicle is only one predictive factor among others, and to fully explain the variation between different cars would call for a more complex mathematical model.

Figure 1. Relation between Z and vehicle weight.



Linear Fit

Summary of Fit

Rsquare	,2525977
Root Mean Square Error	,0327464
Mean of Response	,0786352
Observations (or Sum Wgts)	47

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0,01630856	0,016309	15,2085
Error	45	0,04825479	0,001072	Prob > F
C Total	46	0,06456334		0,0003

Discussion

The results in this study show, that there is a large and meaningful potential in guiding consumers to chose cars that have a low risk of injury in case of an accident, especially fatalaties and long-term disabling injuries.

The methods and materials used in the present study must, however, be discussed as well as future demands for development of better methods.

There is a fundamental drawback in the use of real-life accidents for rating car models. Even for a common car, with the limited size of a country like Sweden, it will take at least two years before the safety could be rated with a minimum of precision. This problem can be solved in some different ways, one being the development of better methods to estimate accident severity, preferably in every single case and linked to the injury outcome. With such a technique, also single accidents, and accidents with heavy vehicles can be used.

Another technique is to involve more countries in rating cars. This would be of great interest also in a way, that the results can be generalized on a broader basis. Differences in data collection and quality must be studied if more than one country is used.

The use of real-life accidents also have a positive side. Although there is a large problem of measuring the dose (exposure) with sufficient precision, the response (injuries), if measured adequately, is derived in a correct way, as the biological variation and the true output is noted. In contrast to dummy response, the possibility to interpretate and generalize the results is unlimited. The variety of accidents is also both a drawback and a positive factor in comparing real-life data to laboratory conditions.

In the present study, much effort has been put to control for accident severity. By using a method developed by Evans, it is possible to show that the accident severity and exposure can be normalized. There are, however, some assumptions that should be investigated further.

In the present study, there was no subdivision of the accidents into different types.

It would be of great interest to study, if i.e. side collisions follows the same pattern as other collision types. A slightly different accident configuration distribution for a single car model would though probably not affect the results. In the present material based on police records it was not possible to classify accident configuration, but only accident types. The type and the configuration are, however, probably not very high correlated.

In order to have a broader accident base, it would be of importance to develop methods, like Evans', that can enable also single accidents and heavy-vehicle accidents to be included. In the long run, however, the development of methods to assess accident severity in individual, and not induced, cases is more important. Such methods are available for e.g. in-depth studies, but must be available also on a large-scale basis.

In the present study, there was no information about how the injuries occured relative to the vehicle. It is there fore not possible to link certain constructions and designs to the presence or absence of specific injuries. For car manufacturers this is a major drawback, as this fact limits the possibility to let the rating guide new constructions and designs.

In the future, it must therefore be of major concern to include such factors. Predictive systems, such as crash tests or in-depth studies of design, can only partly be of help in this matter, if not guided by real-life accident studies of the present type, where a variety of constructions and accidens types can be analyzed.

There are several ways of measuring injury severity. In the method used in the present study, two different out-come from an injury are calculated. Both fatal and medical disability are serious outcome. Many injuries will never reach the severity, where the patient could either die or become disabled and are therefore ranked very low. Using only a threat-to-life approach would affect the results dramatically, as there are a number of injuries assessed as AIS 1 and 2, that are ranked as serious when taking the risk of disability into account, while there are also injuries classified as AIS 3 and 4 that, if survived, seldomly leads to disability.

Typical injuries with a high risk of disability are injuries to the brain, neck and extremities, while injuries to chest and abdomen seldomly lead to disability.

In the judgement of disability, functional loss, pain, neurological and mental disturbances are included, while i.e. cosmetical injuries are not included, if not affecting any body function.

Facial injuries causing scars will therefore not be ranked high, while this may not be accepted by i.e. consumers of safety products.

In the future development, this factor should be included. Another factor that should be taken into account is, that the injuries to a body region on a certain AIS level may not be homogenious, that is, there may be injuries classified equally that can lead to long term consequenses to a different degree. This is probably true for joint vs long-bone fractures of the extremities and skull vs brain injuries. The material used for the disability scaling must therefore be extended to enable for such a subdivision where it is necessary.

The diagnoses used in AIS must also be changed in a way that makes it necessary to distinguish between i.e. joint injuries and others.

The confidence limits varies between different cars, mostly due to different numbers of accidents. The possibility to draw conclusions for cars that are rare is therefore limited. There could therefore be cars that are better or worse, but where the number of observations were too few.

The relation to other rating systems is complicated to follow. It seems, however, that the results for some car models is similar. In all four rating systems mentioned earlier, SAAB 9000 is ranked as one of the best cars. Also, Volvo 740, has very high safety according to all systems.

The results of the study show that there are large differences between different car models, also within the same weight class. There is still a potential in increasing the interior safety that could be used by trying to change the behavior in bying cars and to encourage car manufacteurs to build the best possible car. In average, the cars sold today in Sweden are approx. 30% safer than the cars that are already sold and used.

It is however not a good idea to try to encourage consumers to bye larger cars. In average these are safer, but there are small cars with a better safety level than larger cars. In addition, such a small car may give opposite vehicles a better chance. Therefore, individual car rating is of better value than general advices. More generally, it would also be of interest to take aggressiveness into account, that is if some cars due the structure causes more injuries than expected due to the vehicle weight. A safety measure based on both the crashworthiness and the aggressiveness could thereby be developed.

The potential is though even higher, probably in the magnitude of a 50% reduction if the consumers would chose the best car in every weight class. In Sweden, this would reduce the number of fatalies and disabilities by approx. 500 per year.

There seems, however, to be a possibility to build even safer cars. The type of injuries that could reduce the number of fatalities and disabilities are severe injuries to the brain (AIS 3+), all injuries to the neck (AIS 1+), and injuries to the lower extremities, probably knee and foot joints (AIS 2+). These injuries count for 27% of all injuries in a SAAB 99 (as example), while 67.3% of the fatal and disabling injuries are concentrated to these regions and severities.

A rating system based on real life accidents and with an adequate injury severity assessment could guide the car manufacteurs in their future work of improving the safety in ways that are effective in reducing injuries that are a threat to the health.

Today, there is a tendency to optimize the safety only towards regulations, while such standards never can cover all situations and severities where injuries occur.

The results of this study are based on the use of seat belts. The belt use is not known in most cases, but in Sweden, the use of seat belts is high (approx. 85%), especially in newer cars. An increase of the seat belt use, would though still affect the number of injured to a great extent. Automatic restraint systems may increase the safety in the future.

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