JNCAP: DEVELOPING OVERALL RATING PROTOCOL

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ABSTRACT

The Japan New Car Assessment Program (JNCAP) was launched in 1995 in order to improve car safety performance. According to this program, installation conditions of safety devices and the results for braking performance and full-frontal crash test are published every year. The side impact test was introduced in 1999. In 2000, the offset frontal crash test was also introduced. From the viewpoint of such a diversification of the crash tests, an overall assessment method for the safety of cars which reflects road accidents has been demanded. In this study, we have examined a new overall assessment method capable of reflecting the traffic accident situation in Japan using methods employed or planned by USA-NCAP, Euro-NCAP, TUB-NCAP and others as references.

As the basic concept, JNCAP conducts three types of crash tests including the full-frontal crash test, offset frontal crash test, and side impact test to assess the dummy injury parameters. For the portions of the body which cannot be represented by the dummy injury parameters, the amount of car deformation is added to the assessment.

The dummy injury parameters are set by referencing the standards used in test methods and NCAPs conducted in overseas countries. In a conventional assessment method, dummy injury parameters are converted into a composite probability of the occurrence of injuries. In the new assessment method, dummy injury parameters are converted into scores using conversion functions. The conversion functions used to convert dummy injury parameters into scores were determined with reference to the risk curves relating to dummy injury parameters and the assessment functions employed by USA-NCAP and Euro-NCAP.

Scores converted from the dummy injury parameters are weighted according to portions of the human body and modes of collision. The weighting functions are determined taking into consideration the traffic accident situation in Japan and anticipated economic losses.

We have compared collision data for the same vehicle according to both the JNCAP method and the Euro-NCAP method in order to determine the differences in the rating methods. As a result, high overall correlation between these methods was confirmed.

The rate of scores for individual cars was calculated according to the Euro-NCAP method and the new assessment method. Cars scored high in the Euro-NCAP method also got high points in the new assessment method, although some minor differences were observed in the ranking.

1.INTRODUCTION

In Japan, the number of persons killed in traffic accidents is still over 9,000 each year, although the number has been decreasing for these several years. The total number of casualties in traffic accidents has reached as many as millions of persons and those who were in the cars make up approximately 60% of this total. This rate is increasing year after year. In order to reduce the number of sufferers from traffic accidents, the Ministry of Land, Infrastructure and Transport (former Ministry of Transport) has considered employment of NCAP (New Car Assessment Program) implemented by government organizations in many overseas countries to be indispensable for Japan, and launched NCAP in 1991. After three years of research, “Car Safety Information” including the results for the crash tests was published in 1995. In March 2000, the fifth report was issued.

In the initial stage, only the full-frontal crash test was employed as the crash test as was done with US-NCAP. However, it is difficult to determine the safety of cars using only a single mode crash test. From the viewpoint of providing a wide range of safety information to users, the side impact test and the offset frontal crash test were added in 1999 and 2000, respectively.

Information obtained from such diversified tests confuses consumers. For example, it is difficult for consumers to objectively and accurately evaluate a given car if the evaluation of the car is different between each test mode. Therefore, it is necessary to comprehensively evaluate the results obtained from these tests in order to provide consumers with accurate evaluation.

As a method of conducting different types of tests and evaluating the results for these tests, assessment methods employed by Euro-NCAP conducted in Europe and TUB-NCAP proposed by Germany are given. We have referenced the techniques conducted or examined in overseas countries and developed a new overall assessment method which reflects the actual accident situation in Japan.

2.BASIC CONCEPTS

The overall assessment method has been developed from the following basic concepts.

(1) Testing mode

Three crash tests including the full-frontal crash test, offset frontal crash test, and side impact test are evaluated.

(2) Injury parameters

Internationally-agreed dummy injury parameters are mainly evaluated. Portions of which the evaluation using injury parameters is difficult or for which injury parameters are not established are complemented by the amount of car deformation.

(3) Score conversion

The dummy injury parameters are converted into scores showing safety performance for each portion of the human body using assessment functions (sliding scale). The amount of car deformation is also converted into scores using the sliding scale and deducted from the scores of the corresponding portion of the body.

(4) Weighting

Scores calculated for each portion of the body is weighted using coefficients set for each portion of the body and each collision mode. An overall score is determined from the sum of these scores.

Scores of each collision mode are expressed by the following equation.

$$S_i = \sum_j w_j s_j$$

Where, i = Collision mode, j = Injured portion, w_j = Weighting function for each portion of human body, and s_j = Score of each portion of human body.

An overall score is expressed as follows.

$$S_{Total} = \sum_i W_i S_i$$

Where, W_i = Weighting function for each collision mode.

(5) Rating

The overall score is rated using an appropriate threshold value.

3.MODE OF TESTS

The modes of the crash tests currently conducted by JNCAP are three modes shown in Figure 1. The solid black mark in the figure indicates the position of the dummy.

JNCAP employs one more frontal collision mode compared with USA-NCAP and Euro-NCAP (USA-NCAP employs full-frontal crash test and side impact test, and Euro-NCAP employs offset frontal crash test and side impact test). The full-frontal collision is considered to be the mode in which acceleration applied to the human body is the largest. The offset frontal collision produces the largest amount of car deformation. JNCAP has considered that it is desirable to employ these two modes for the frontal collisions.

In the case of frontal collision, two dummies (HYBRID-III) are installed in the driver's seat and front passenger seat. In the case of side collision, one dummy (Euro-SID) is provided.

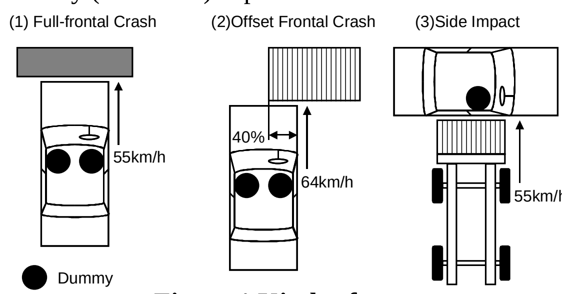


Figure 1 Kinds of tests

4. PORTIONS TO BE EVALUATED AND INJURY PARAMETERS

4.1 Portions to be Evaluated

We have selected the portions to be evaluated as described below based on the distribution of injured portions contained in the accident data while taking into consideration the measurable portions on the dummy.

4.1(1) Distribution of injured portions in frontal collisions

Figure 2 shows the percentage of injured portions of the driver in the case of death or serious injury accidents and the case of death accidents (by courtesy of the National Police Agency). In the death and serious injury accidents, the incidence of injury is most frequently observed in the legs, followed by the chest, neck, and abdomen.

In the death accidents, injury to the head is the most common, followed by the chest, neck, and abdomen. The share of injury to the legs, that occupies a substantial portion in the death or serious injury accidents, is extremely small in the death accidents.

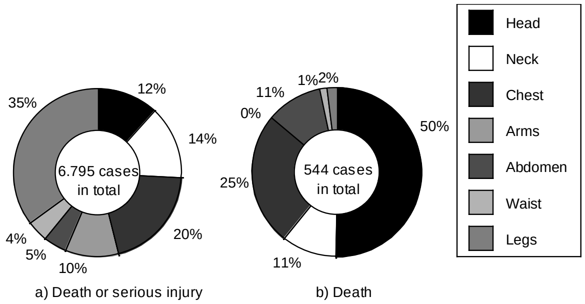


Figure 2 Percentage of injured portions of drivers using seatbelts in frontal collision (Statistics for 1996-1998 by the National Police Agency)

Figure 3 shows the percentage of the injured portions (AIS>=3) of drivers in frontal collisions. This data is supplied from the car accident survey initiated by the Ministry of Land, Infrastructure and Transport and the Traffic Accident Research and Data Analysis (ITARDA). The difference between Figures 2 and 3 is the source and that the injury level is indicated in AIS in Figure 3.

As shown in Figure 3, the incidence of injury in the femur and in the lower legs is almost the same. The incidence of injury in the neck in Figure 3 is lower than that shown in Figure 2. This is considered to be due to the differences in the definition of the injury level and the differences in classification of the border between the head and the neck (brainstem).

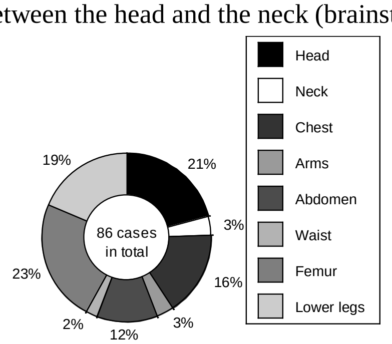


Figure 3 Percentage of injured portions (AIS3 or more) of drivers using seatbelts in frontal collision (Automobile Accident Investigation Data in 1988-1992 by the Ministry of Land, Infrastructure and Transport and ITARDA data in 1993-1999)

Judging from the distribution conditions of the injured portions shown in Figures 2 and 3, it seems reasonable to select the head, neck, chest, and lower legs as portions to be evaluated (abdomen and upper limb are excluded from assessment because applicable measurement or evaluating method is not available).

4.1(2) Distribution of injured portions in side collisions

Figure 4 shows the percentage of the injured portions of the passengers seated on the collision side in side collisions (based on statistics from the National Police Agency). In the accidents resulting in death or serious injury, injury to the chest is most often seen, followed by the neck, head, and waist. In accidents leading to death, injury to the head shows the highest percentage, followed by the chest and abdomen. Injury to the abdomen is greater than that observed in the death or serious injury accidents.

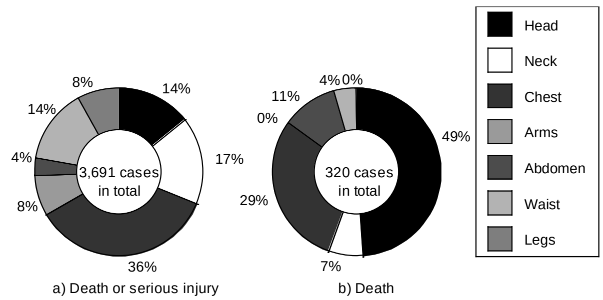


Figure 4 Percentage of injured portions of person using seatbelts in the collided car during side collision (Statistics for 1996-1998 by the National Police Agency)

Figure 5 shows the percentage of the injured portions of the passengers seated on the collision side in side collisions. It is created based on the data supplied from the car accident survey initiated by the Ministry of Land, Infrastructure and Transport as well from the Traffic Accident Research and Data Analysis (ITARDA). The distribution of injured portions shown in Figure 5 is similar to that observed in the death or serious injury accidents collected by the National Police Agency except for lower incidence in the neck and higher incidence in the abdomen. The reasons why injury in the neck is low are discussed in 4.1 (1) above. The difference is considered to result from differences in definition of the injury level as

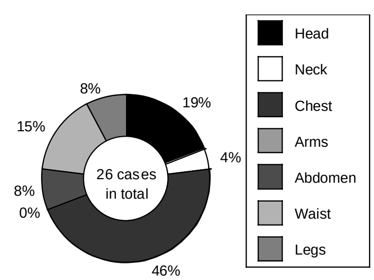


Figure 5 Percentage of injured portions (AIS3 or more) for persons using seatbelts on collided side at the time of side collision (Automobile Accident Investigation Data for 1988-1992 by the Ministry of Land, Infrastructure and Transport and ITARDA data in 1993-1999)

well as differences in classification of injured portions. The incidence of injury in the neck will be reduced in the statistics of the National Police Agency if AIS is used in the classification. Correlation between injury to the passengers' neck and that to the dummy in side collisions is not as yet determined. Taking the above into consideration, we have selected the head, chest, abdomen, and waist as portions to be evaluated in side collisions.

4.2 Dummy Injury Parameters

As for the dummy injury parameters, we have selected those for which there is international agreement as to correspondence to injuries on the human body as the main targets. It will help consumers to understand the results of the assessment. However, we have decided not to employ the dummy injury parameters for assessing injury to the corresponding portions of the human body when such values leave room for discussion in terms of bio-fidelity. This is one of the restrictions imposed on the assessment due to limitations in currently available measuring technology. In such a case, the amount of car deformation is used as the correction parameter.

4.2(1) Portions to be evaluated in frontal collisions
Portions of the human body to be evaluated and the dummy injury parameters are as follows.

Body portion		Injury parameter
Head		HIC_{36}
Neck		Shearing load, Tensile load, Extension moment (worst value)
Chest		3ms acceleration, Compression (worst value)
Legs	Thigh	Right femur load, Left femur load (worst value)
	Lower legs	Right, upper and lower tibia index Left, upper and lower tibia index (worst values at 4 places)

Injury to the neck has not been evaluated in JNCAP. However, the incidence of injury to the neck is high, as indicated in the accident data. Therefore, shearing load, tensile load, and extension moment being employed by the EC Regulation and Euro-NCAP are newly added. The worst value recorded in the above three is used.
For the chest injury parameter, JNCAP had employed only 3ms acceleration. However, many studies argue that a 3ms acceleration alone is not enough for correct assessment. Taking these situations into consideration, chest compression was added as another parameter to be used for the injury assessment. The worst value recorded in the above two is used for the judgment.
In the frontal collision, calculated scores are corrected by the amount of car deformation. The amount of deformation to be evaluated are as follows.

Body portion	Amount of deformation
Head	Steering upward displacement
Chest	Steering backward displacement
Legs	Brake pedal backward displacement Brake pedal upward displacement

The steering wheel displacement is employed in the safety standard by the EU Regulation. The steering wheel is relatively often an assailant injuring the human body and, at the same time, correlation is recognized between the steering wheel displacement and the injury rate. Thus, we have considered it necessary to assess displacement of the steering wheel in some way. In order to increase the reliability of the assessment using dummies, chest compression is newly employed in addition to the current 3ms acceleration to evaluate the dummy response of the chest. This may leave room for argument that injury to the chest is assessed twice, namely by the dummy and the amount of car deformation. In spite of the foregoing discussion, however, we believe it reasonable to employ steering wheel displacement as a correction parameter because correlation is not necessarily recognized (partly because of measuring problems) between the steering wheel displacement and the chest or head response obtained from the dummy. We must also take into consideration the fact that measurement of abdominal force is not available with the dummy.
In assessment of the legs, we are going to use steering wheel displacement as the correction parameter for the time being considering that there are different arguments concerning reliability of bio-fidelity of Hybrid-III as well as the fact that reproducibility of measurement data is low.

4.2(2) Portions to be Evaluated in Side collisions
Portions of assessment and the dummy injury parameters are selected as shown below.

Body portions	Injury parameters
Head	HIC
Chest	Compression
Abdomen	Total load
Pelvis	Load on pubis

These injured portions and dummy injury parameters are the same as those employed by Euro-NCAP. Correction by the amount of car deformation is not done in the side impact test since the relation between the amount of deformation and the degree of injury to the human body in this mode of collision is not yet determined.

4.3 Assessment Function

Table 1 shows the assessment functions (sliding scale) used in the frontal crash test. The maximum score for each portion is 4. The maximum score for the femur and lower legs are 2, respectively. The total of the femur and lower legs is the score for the legs. When two or more assessment items are used for a single portion, the worst score among them is employed.

Many of the assessment functions used in the frontal crash test are the same as those employed by Euro-NCAP. 3ms acceleration to the chest and the femur load for the legs are calculated based on the injury probability curve published by NHTSA and USA-NCAP.

Table 2 lists the assessment functions of the amount of deformation used to correct scores in frontal collision. The maximum score to be subtracted by the amount of deformation is 1 in respective deformation. However, if the score of the portion concerned becomes negative after deduction, it will be counted as a 0 score.

The upper and lower limit values used in the sliding scale of the amount of deformation are the same as those employed by Euro-NCAP.

Table 3 lists the assessment functions used in the side

Table 1 Assessment functions for frontal crash test

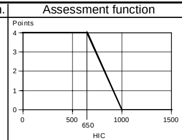
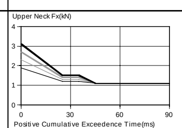
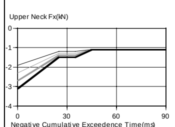
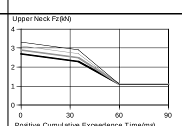
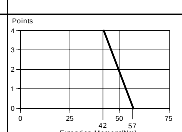
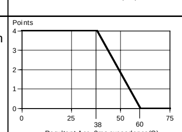
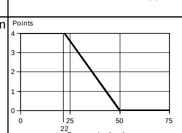
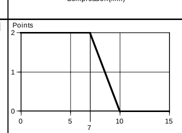
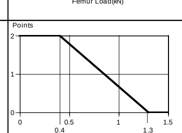
Test Method	Portion		Injury param.	Assessment function	Remarks
Full-frontal Crash Offset Frontal Crash	Head		HIC36		The same as Euro-NCAP. Nearly the same even if calculated from the USA-NCAP injury probability curve. The lower limit value is the 5% significance level of AIS4. The upper limit value is the 20% significance level of AIS4.
	Neck		Shearing load	 	The upper limit value was obtained from the significance level that causes serious injury and is the same as Euro-NCAP.
			Tensile load		The upper limit value was obtained from the significance level that causes serious injury and is the same as Euro-NCAP.
			Extension moment		The upper limit value was obtained from the significance level that causes serious injury and is the same as Euro-NCAP.
	Chest		3ms acceleration		Calculation from the USA-NCAP injury probability curve. The lower limit value is the 5% significance level of AIS4. The upper limit value is the 20% significance level of AIS4.
			Compression		Calculation from the NHTSA injury probability curve. The lower limit value is the 5% significance level of AIS3. The upper limit value is the 50% significance level of AIS3. The same as Euro-NCAP.
	Legs	Femur	Femur load		Calculation from the USA-NCAP injury probability curve for broken femur. The lower limit value is the 5% significance level of broken bone. The upper limit value is the 30% significance level of broken bone.
		Lower Leg	Tibia Index		The same as Euro-NCAP.

Table 2 Correction parameters for frontal crash

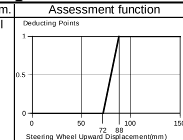
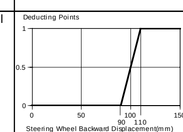
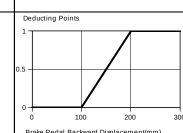
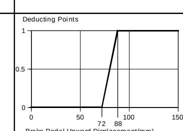
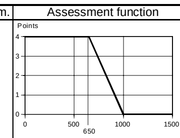
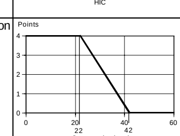
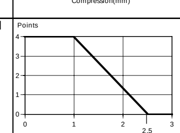
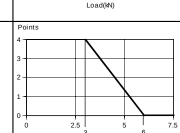
Test Method	Portion	Correction param.	Assessment function	Remarks
Full-frontal Crash Offset Frontal Crash	Head	Steering wheel upward displacement		The lower limit value is the 90% of the EEVC limits. The upper limit value is the 110% limit of the EEVC limits.
	Chest	Steering wheel backward displacement		The lower limit value is the 90% of the EEVC limits. The upper limit value is the 110% limit of the EEVC limits.
	Legs	Brake pedal backward displacement		The lower and the upper limits are the same as Euro-NCAP.
		Brake pedal upward displacement		The lower limit value is the 90% of the EEVC limits. The upper limit value is the 110% limit of the EEVC limits.

Table 3 Assessment functions for side impact test

Test method	Portion	Injury param.	Assessment function	Remarks
Side impact	Head	HIC		The same as Euro-NCAP. Nearly the same even if calculated from the USA-NCAP injury probability curve. The lower limit value is the 5% significance level of AIS4. The upper limit value is the 20% significance level of AIS4.
	Chest	Compression		The same as Euro-NCAP. The lower limit value is the 5% significance level of AIS3. The upper limit value is the 30% significance level of AIS3.
	Abdomen	Total load		The same as Euro-NCAP.
	Pelvis	Load on pubis		The same as Euro-NCAP. The upper limit value is the pelvis fracture limit of young male.

impact test. The maximum score for each portion is 4 as in the frontal crash test. The sliding scale used is the same as that used by Euro-NCAP.

5.WEIGHTING

5.1 Necessity of Weighting

5.1(1) Actuality of injuries in accident

The following discusses the necessity for weighting scores by injured portions of the human body, taking frontal collisions as the example.

There is a difference in the distribution of injured portions according to the seriousness of the resulting damages as shown in Figure 2 and 3. Figure 6 summarizes these distributions.

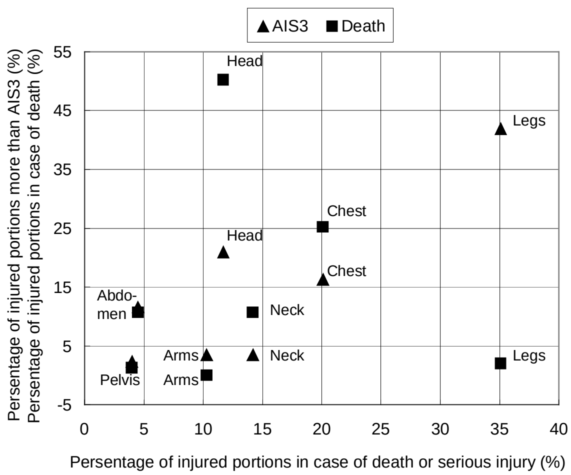


Figure 6 Distribution by human body portion

Almost the same distribution of injured portions is seen in the serious injury level and AIS3 level (incidence is distributed almost along line 45 except upper limb) though there are some differences between Figures 2 and 3 in the injury assessment method and the source data used.

Unlike the above, there are significant differences in injured portions in the case of fatal accidents. Namely, percentage of injury to the head increases radically and that of the legs falls substantially. In other words, probability of an injury to the head is the same as for injury to other portions of the body up to the serious injury level. Once the head is injured, however, the probability of this resulting in death is overwhelmingly higher than in injury to other portions. The opposite effect to the head is observed with the legs.

The above can be summarized as follows.

Case 1

Head:	Serious injury
Chest:	Minor injury
Legs:	Minor injury

Case 2

Head:	Minor injury
Chest:	Minor injury
Legs:	Serious injury

Although the two passengers in the above 1 and 2 are seemingly seriously injured in the same manner, Case 1 involves a significantly higher probability of resulting in death.

5.1(2) Problems in score assessment

When the above cases are reviewed from the car safety standpoint, following problems arise.

Assume that the test is conducted on two cars and the following scores are calculated for the femur and head.

	Car A	Car B
Score for head	4	2
Score for femur	2	4
Total	6	6

If scores of each injury portion are simply added, performance safety for Car A and Car B becomes the same. However, the head is more vulnerable than other portions in actual accidents as seen in above. Thus, when the above results are reviewed from the standpoint of the probability of resulting in death, we can say that Car B involves more menace to the passenger. Therefore, some correction must be made when adding scores for assessment.

It is needless to say that there are various arguments on how much impact to human life is involved in each of the injured portions. However, we believe that the different degrees of risks involved in respective injured portions should be reflected in the safety assessment in some form or other. Weighting by injured portion is proposed as a means of realizing the above concept.

5.1(3) Viewpoint of policy

Weighting is also needed from the car safety policy viewpoint. Automobile makers endeavor to receive good scores in NCAP and these efforts lead to the development of safer cars, which is one of the major objectives of NCAP. When it is aimed, from the safety policy standpoint at reducing incidence of a certain injury, we will be able to direct the makers' efforts to eliminate this injury by setting a greater score on this injury than on others.

5.2 Weighting by Injured Portion

When reflecting different degrees of seriousness arising from respective injured portions in the safety assessment, we must study how to evaluate differences in the injury levels. This actual accidents-based study is closely related to the selection of the types of injuries to be reduced from the safety policy standpoint.

Over 9,000 people are killed by traffic accidents in a year though this rate is decreasing (number of those who die within 24 hours from the accident). The current situation is very serious.

Given such situation, the car assessment program aims at reducing death or serious injury to passengers by helping in the development of safer cars and promoting their wider use.

In order to achieve the above objectives, we must first review statistics of passengers being killed or seriously injured in traffic accidents. It is difficult to appropriately assess differences in death and serious injury as well as differences in degrees of seriousness among those seriously injured because such an attempt is related to the sense of value of the assessors. Aside from the above, the following discusses personal damages from economic aspects.

In the following discussion, the concept of economic loss incorporating the distribution of accidents is employed as the weighting index.

Tables 4 and 5 show distribution of persons killed and seriously injured in frontal and side collisions, respectively, broken down by the injured portion.

Table 4 Distribution of injuries for person killed and seriously injured in frontal collision (Statistics for 1996-1998 by the National Police Agency)

Injured portions	Death	Serious injury
Head	273	524
Neck	58	907
Chest	137	1,232
Arms	0	701
Abdomen	58	249
Waist	7	267
Legs	11	2,371

Table 5 Distribution of injuries for persons killed and seriously injured in side collision (Statistics for 1996-1998 by the National Police Agency)

Injured portions	Death	Serious injury
Head	156	362
Neck	22	609
Chest	94	1,222
Arms	0	278
Abdomen	34	97
Waist	13	509
Legs	1	294

Serious injury in the statistics of the National Police Agency is generally considered to correspond to AIS2 to AIS4. In the following discussion, however, it is assumed that serious injury and death correspond to AIS3 and AIS6, respectively. Using this assumption, the personal injury amount by injured portion can be calculated from the distribution of killed and seriously injured persons shown in Tables 4 and 5. See Figure 7 below. If the average personal injury amount (\1 million) is put 1.0, injury at AIS6 level is 31.0 and that at AIS3 level becomes 4.1.

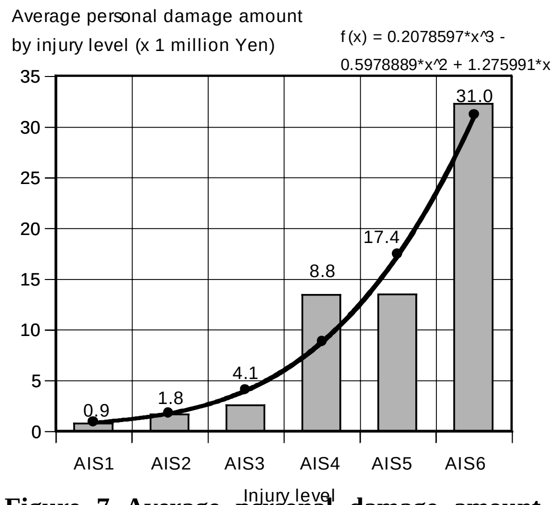


Figure 7 Average personal damage amount by injury level (Statistics of Compulsory Automobile Liability Insurance in 1991 and Statistics of Medical Treatment in 1991)

Frontal Collision

Head 273(cases)*31.0+524(cases)*4.1= 10,611
Neck 58(cases)*31.0+907(cases)*4.1= 5,517
Chest 137(cases)*31.0+1369(cases)*4.1= 9,860
Legs 11(cases)*31.0+2371(cases)*4.1= 10,062

Side Collision

Head 156(cases)*31.0+362(cases)*4.1= 6,320
Chest 94(cases)*31.0+1222(cases)*4.1= 7,924
Abdomen 34(cases)*31.0+97(cases)*4.1= 1,452
Waist 13(cases)*31.0+509(cases)*4.1= 2,490

Through comparison of Figure 2a) and Figure 3, you will find that the share of neck injuries is lower in Figure 3 that handles AIS3 or above. This is possibly because serious injury in Figure 2a) contains many AIS2 level neck sufferers. (Serious injury as defined in the statistics of the National Police Agency refer to those injuries that require 30 days minimum medical treatment. Treatment of injury in the neck generally requires longer periods than other injuries.) Thus, personal injury amount of the neck was recalculated as shown below assuming AIS2 for serious injury.

Neck 58(cases)*31.0+907(cases)*1.8= 3,431

Figure 8 shows the average personal injury amount by the injured portion. Damage to the abdomen is approximately twice that of the head and chest. The average doctor's fee for the abdomen is 600 (\ thousand). this is almost twice compared with 300 (\ thousand) for the head/face and 358 (\ thousand) for the chest (according to the Non-life Insurance Association).

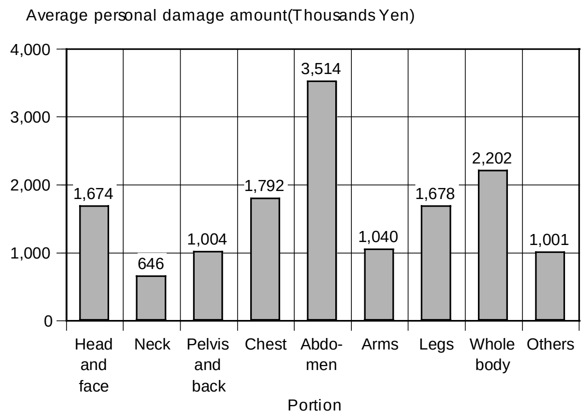


Figure 8 Average personal damage amount for each human body portion ("Practical Conditions of Traffic Accident Viewed from Automobile Insurance Data" of the Non-life Insurance Association, 2000)

From above calculations, ratio of personal injury amount between the target portions of the assessment can be determined. In the frontal collision, ratio between the head, neck, chest and legs is 3: 1: 3: 3. In the side collision, ratio between the head, chest, abdomen (amount is doubled from above statistics) and waist is approximately 4: 5: 2: 2. Similarly, when AIS2 and AIS4 are respectively assumed for serious injury, the ratio becomes as shown in Tables 6 and 7 below.

Table 6 Rates for personal damages for each human body portion in frontal collision

	When serious injury is regarded as AIS2	When serious injury is regarded as AIS3	When serious injury is regarded as AIS4
Head	3	3	4
Neck	1	1	1
Chest	2	3	5
Legs	1.5	3	6

Table 7 Rates for personal damages for each human body portion in side collision

	When serious injury is regarded as AIS2	When serious injury is regarded as AIS3	When serious injury is regarded as AIS4
Head	4	4	4
Neck	4	5	6
Abdomen	2	2	2
Waist	1	2	2

Results of the above calculations give more importance to injury of the head and chest that can result more frequently in death. Taking these findings into consideration, we have assigned the following weightings to respective portions.

Frontal crash test

Ratio between the head, neck, chest and legs 4:1:4:4

(0.923, 0.231, 0.923 and 0.923 are applied to results of Table 1 as coefficient w_j. The score is 12).

Side impact test

Ratio between the head, chest, abdomen and pelvis 4:4:2:2

(1.0, 1.0, 0.5 and 0.5 are applied to results of Table 3 as coefficient w_j. The score is 12).

5.3 Weighting by Modes of Collision

Weighting of respective modes of collision was determined from the incidence of accidents.

Ratio of incidence of frontal collision and side collision resulting in death in Japan is almost 2:1 as shown in Figure 9. When accidents that have resulted in serious injury are added, the ratio becomes almost 7: 3 as shown in Figure 10.

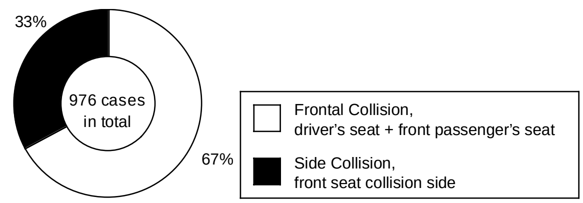


Figure 9 Percentage of accidents resulting in death of persons using seatbelts by kinds of collisions (Statistics for 1996-1998 by The National Police Agency)

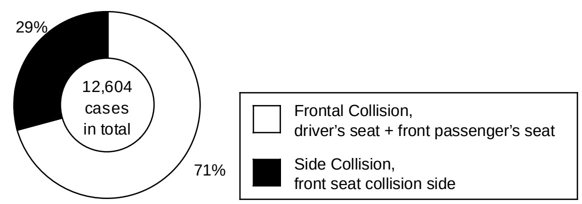


Figure 10 Percentage of accidents resulting in death or serious injury of persons using seatbelts by kinds of collisions (Statistics for 1996-1998 by the National Police Agency)

Ratio of the full- frontal collision to offset frontal collision is 1:1 as shown in Figure 11. Above statistics indicate that probability of passengers' encountering an accident resulting from three modes of collision is the same. Considering the accident data, we have judged it reasonable to weight the full-frontal collision, offset frontal collision and side collision as 1: 1: 1 (coefficient W_i for each mode of

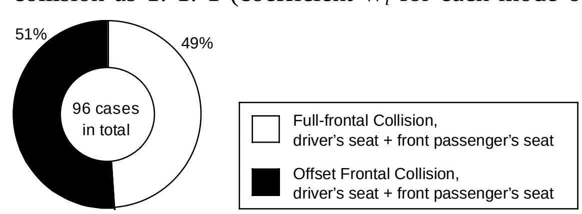


Figure 11 Percentage of injuries AIS3 or more for persons using seatbelts by kinds of frontal collision (Automobile Accident Investigation Data of the Ministry of Land, Infrastructure and Transport and ITARDA data in 1993-1999)

collision is 1.0, 1.0 and 1.0).
The weighting functions for individual portions on the human body and that for each mode of collision are summarized in Tables 8 to 10.

Table 8 Weighting factor for each body portion in frontal collision

	wj
Head	0.923
Neck	0.231
Chest	0.923
Legs	0.923

Table 9 Weighting factor for each body portion in side collision

	wj
Head	1.000
Chest	1.000
Abdomen	0.500
Pelvis	0.500

Table 10 Weighting factor for each collision test

	W_i
Full-wrap Frontal Collision	1.0
Offset Frontal Collision	1.0
Side Collision	1.0

6.COMPARISON WITH SCORES OF EURO-NCAP

Figure 12 compares the score rates obtained by individual cars in Euro-NCAP (published data on Japanese cars) and in the new overall assessment method. In our new assessment, scores in the full-frontal collision, offset frontal collision, and side collision are added. Scores in Euro-NCAP are calculated based on offset frontal and side collisions

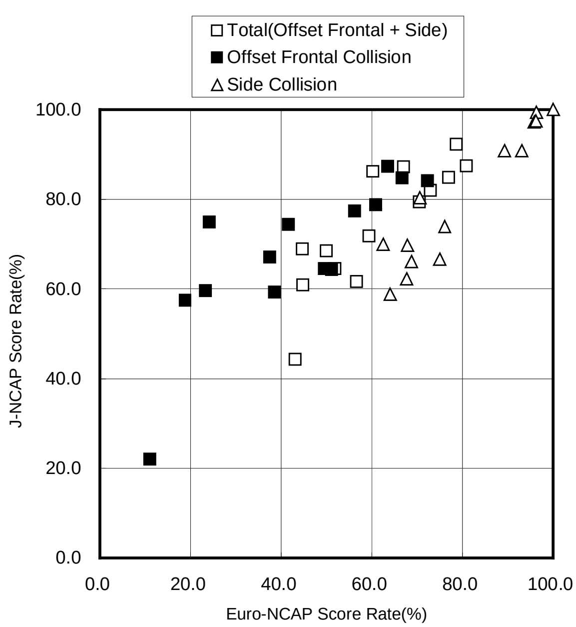


Figure 12 Comparison of score rates

alone since they do not employ the full-frontal collision.
Comparison between the new overall assessment (JNCAP) and the assessment by Euro-NCAP indicates that JNCAP tends to generate a higher score rate than Euro-NCAP in the offset frontal collision. In the side collision, the score rate of JNCAP and Euro-NCAP is considered similar. For the overall score calculated by combining the offset frontal collision and side collision, JNCAP tends to rate higher. Setting minor differences in ranking of individual cars aside, there is no significant conflict between the two assessment methods in the overall ranking. Those cars that scored high in Euro-NCAP are also high scorers in the new overall assessment.
Figure 13 shows score rates being calculated from results of IIHS offset collision by use of the Euro-NCAP assessment method and that of JNCAP.
Although there are some variations in the results of the two assessments due to differences in the injury standard employed as well as the weighting, these variations become less significant with higher scoring cars. This figure also indicates that those cars that obtain high scores in Euro-NCAP also get high marks in JNCAP.

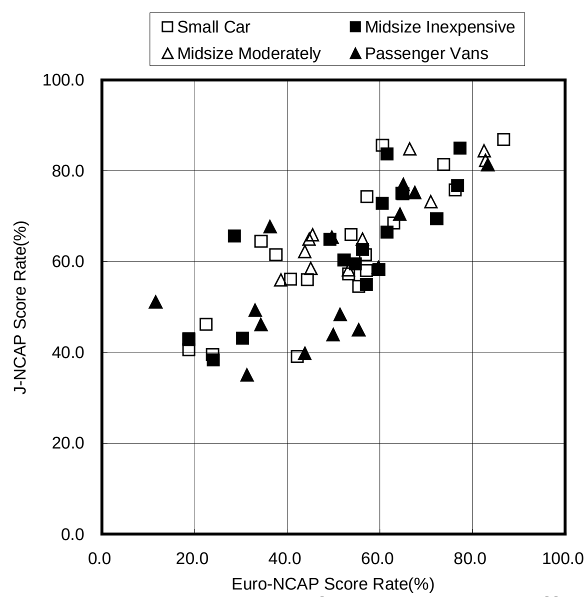


Figure 13 Comparison of score rates in offset frontal crash test

7.OVERALL RATING

Assessment of each portion on the dummy, assessment of each mode of collision and results of the overall assessment are indicated.
Results of assessment of each portion on the dummy is classified into five grades and indicated by different colors (or results of the measurement alone).

Results of assessment of each collision mode broken down by the seat are also classified into five grades. In the overall assessment in which results are indicated with alphanumerical characters, targets of the assessment are the driver's and front passenger's seat and the assessment results are broken down by these seat positions. In the overall assessment of the driver's seat, data obtained from the full-frontal collision, offset frontal collision, and side collision is used. For the overall assessment of the front passenger's seat, data obtained from the full-frontal collision and side collision (data on the driver's seat is used again) is used. Assessment is made out of 12 scores in each mode and in total 36 scores (the front passenger's seat is assessed in two modes, a total of 24 scores).

In the overall assessment, the basic score (the score obtainable by every car) is set first. This score is subtracted from the score obtained by each car and then the remaining score is classified according to the five-grade system. Ranking in the five-grade system of individual scores will be indicated by the numbers of stars. This procedure is planned so that differences among cars may be clearly indicated.

If a car has received a zero score in the assessment of respective portions on the dummy except the legs, some kind of symbol will be indicated on the car concerned in the overall assessment space. (It does not, however, apply when the zero score results from subtraction of the car deformation).

8.CONCLUSION

(1) From 2000JNCAP has employed the full-frontal crash test, offset frontal crash test, and side impact test. It has developed a new overall assessment method to cope with current situations of accidents in Japan. In developing this new method, JNCAP has referenced the methods currently employed or studied in USA-NCAP Euro-NCAP, TUB-NCAP, and other organizations.

(2) The basic concept employed for developing the assessment method was to mainly use injury parameter on the dummy for the assessment. For the portions of the body not replaceable by the dummy, data on car deformation was added in the assessment. The injury standard applicable to the dummy used was prepared referencing the test methods employed by overseas countries and the standard used by NCAPs. The conversion functions used to convert dummy responses into scores are set, referencing bioengineering data on dummy response as well as assessment functions used by USA-NCAP and Euro-NCAP.

(3) The assessment is switched from the current synthetic probability-based approach to the scoring method where dummy responses are once converted to corresponding scores.

(4) Scores converted from dummy responses are weighted by the portion of the body as well as by mode of collision. Weighting functions are decided taking into consideration the incidence of accidents in Japan and anticipated economic loss resulting from accidents.

(5) The overall assessment developed through the above procedures was compared to that of Euro-NCAP. This comparison has determined that the two methods are fairly well correlated as a whole though minor differences in ranking of individual cars are contained.

(6) The final rating is made separately for the driver's seat and front passenger's seat and the score remaining after subtracting the base score from the overall assessment score is rated according to the five-grade system. The latter arrangement is employed to enable the indication of differences among cars to be made more clearly.

(7) This overall assessment method will be updated utilizing advancement in measuring technologies and SARAC's analysis of correlation between the assessment results and sufferers of actual traffic accidents.

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