

# A CONSIDERATION ON THE OVERALL RATING FOR THE CRASH TEST PERFORMANCE IN KNCAP

**Jaemoon Lim**

Daeduk College  
Korea

**Dongjun Lee**

**Gyuhyun Kim**

**Jaewan Lee**

Korea Automobile Testing & Research Institute (KATRI)  
Korea  
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## ABSTRACT

The Korean New Car Assessment Program (KNCAP) has been carried out by the Korean Ministry of Land, Transportation and Maritime Affairs (MLTM) since 1999 in order to encourage that the auto makers shall launch the safer cars into the domestic market. Various test methods were amended in the KNCAP since 2003. Now, the test procedures in the KNCAP are consisted of 8 fields. It was difficult for consumers to understand the KNCAP results because of various test methods.

The crash safety in the KNCAP consists of the full frontal impact, the offset frontal impact, the side impact, the pole side impact and the whiplash test. The overall rating on the crash safety in KNCAP is to inform test results easily to consumers. Each crash test result is converted into scores. The overall rating system is classified into 5 grades depending on the distribution of scores. From 2010 to 2012, the KNCAP evaluated the occupant protection performance of 34 vehicles from domestic and foreign auto makers. The overall ratings on the crash safety of 34 vehicles were listed and discussed.

## INTRODUCTION

The Korean New Car Assessment Program (KNCAP) has been carried out by the Korean Ministry of Land, Transportation and Maritime Affairs (MLTM) since 1999 in order to encourage that the auto makers shall launch the safer cars into the domestic market.

The full frontal crash test based on the US-NCAP has been adapted to enhance the occupant protection under the frontal crash environment [2]. The full frontal crash test has contributed to the enhancement of the occupant protection performance of domestic vehicles reducing of the head and the chest injuries [3]. However, the full frontal crash test is more or less insufficient for the protection of the lower extremities compared to the offset frontal crash test.

To reduce the social cost by the injuries of the lower extremities, the offset frontal crash test based on the EuroNCAP was added and conducted in the KNCAP in 2009.

The side impact test has been conducted since 2003, and the pole side impact test based on the EuroNCAP was added in 2010. The pole side impact test is additional test by the choice of car maker. The star rating system by the points calculated using the injury criteria of the body parts is used for the crash test.

In 2001, the brake test was added and conducted in KNCAP. And, the rollover test in 2005, the pedestrian test in 2007, and the seat safety test was added and conducted in 2008. So, the KNCAP is consist of eight safety test categories, such as the full frontal impact test, offset frontal impact test, side impact test, pole side impact test, seat safety test, pedestrian test, rollover test, and brake test. It was difficult for consumers to understand the KNCAP results because of various test methods. Therefore, the overall rating method was developed for the consumers [1]. In the first stage, the overall rating on the crash test for full frontal impact, offset frontal impact, side impact, pole side impact and seat safety is carried out. From 2013, the overall rating including pedestrian, rollover and brake test will be carried out. From 2010 to 2012, the overall rating on the crash test performance of 34 vehicles from domestic and foreign auto makers were evaluated by the procedures of the KNCAP [4-6]. In this paper, the results of 34 vehicles for each KNCAP test and the overall evaluation results on crash safety were listed and discussed.

## TEST AND EVALUATION METHOD

### Full Wrap Frontal Impact Test

The full wrap frontal impact test is performed at the velocity of 56 kph [1]. The photo and the schematic view of the full frontal impact test are represented in Figure 1. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head, the chest and the knee, femur of the driver and the passenger dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the full

frontal impact is shown in Table 1.

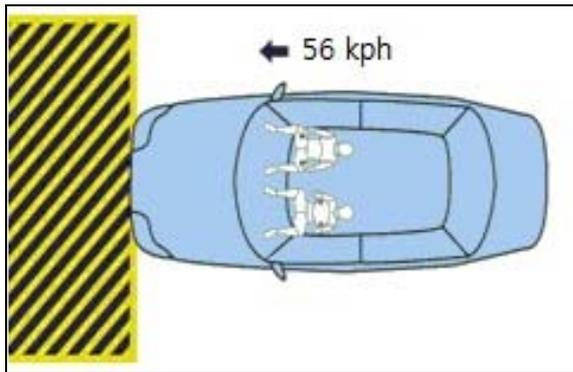


Figure 1. Full frontal impact test.

### Offset Frontal Impact Test

The offset frontal impact test is performed at the velocity of 64 kph [1]. The vehicle is subjected to an offset impact into an immovable block fitted with a deformable aluminum honeycomb face. The photo and the schematic view of the offset frontal crash test are represented in Figure 2. The performance of the vehicle safety is evaluated by the injury rate, the car body deformation, the possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The points are evaluated using the injuries for the head, the neck, the chest, the knee, the femur and the lower leg of the driver and the passenger dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the offset frontal crash is shown in Table 2. Unlike the EuroNCAP, the injury rating is evaluated respectively at the driver and the passenger position in the KNCAP [1].

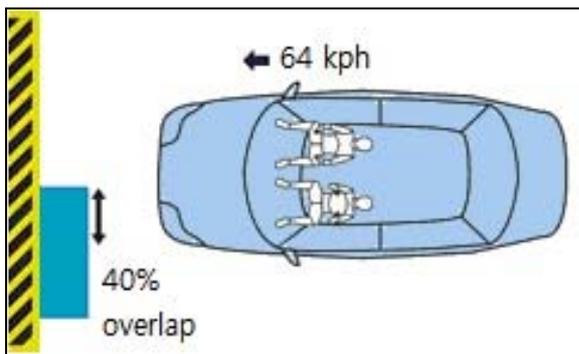


Figure 2. Offset frontal impact test.

### Side Impact Test

The side impact test is performed at the velocity of 55 kph [1]. The moving deformable barrier is subjected to the vehicle with a deformable aluminum honeycomb face. The photo and the schematic view of the side impact test are represented in Figure 3. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the

fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head, the chest, the abdomen and the pelvis of the driver dummies. The modifiers are also applied but the subjective items are excluded. The injury evaluation and rating method for the side impact is shown in Table 3.

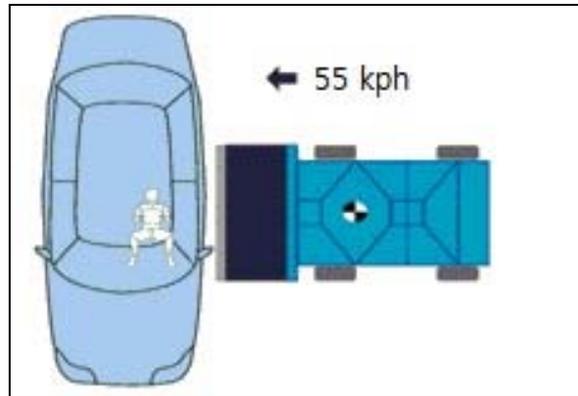


Figure 3. Side impact test.

### Pole Side Impact Test

The pole side impact test is performed at the velocity of 29 kph [1]. The moving carrier with test car is subjected to the pole. The photo and the schematic view of the side impact test are represented in Figure 4. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The injuries for the occupants are evaluated using the points of a serious injury for the head of the driver dummies. The injury evaluation and rating method for the side impact is shown in Table 4.

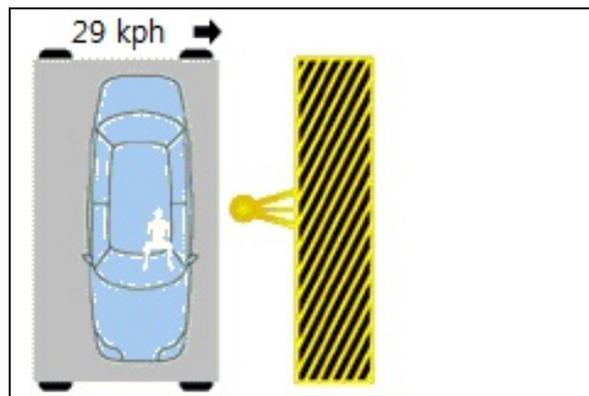


Figure 4. Pole side impact test.

### Whiplash Test

The whiplash test is performed at the velocity of 16 kph [1]. The dynamic performance is assessed using a seat mounted on a sled test. The seat and head restraint dynamic performance is evaluated by the injury rate. The injuries for the occupants are evaluated using the combination results of head

restraint contact time, T1 x-acceleration, upper neck shear force, upper neck tension, head rebound velocity, NIC and  $N_{km}$  of the BioRID and seatback dynamic opening of static test. The injury rating method for the side impact is shown in Table 5.



Figure 5. Whiplash test.

### Overall Evaluation on Crash Safety Test

Total assessment for all KNCAP tests has been studied from 2009 to integrate in a single rating system. So, the overall evaluation for crash safety was added and evaluated in the KNCAP from 2010.

The overall evaluation on the crash safety is evaluated with the full frontal impact test, the offset frontal impact test, the side impact test, the pole side impact test and the whiplash test. Significantly, the side pole impact test is additional (optional) test by car maker. The additional side pole impact test is performed with the lowest model with curtain air bag installed.

The grade of overall evaluation is shown in Table 6. The overall evaluation will be graded 5 level rating, and the first grade will be scored from 47 to 54 point.

### TEST RESULTS AND DISCUSSIONS

Twelve vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Renault Samsung, and three foreign auto makers such as Lexus, BMW and Audi were tested in 2010 [4]. Eleven vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Ssangyong, and three foreign auto makers such as Nissan, VW and Audi were tested in 2011 [5]. Eleven vehicles from four Korean auto makers such as Hyundai, Kia, GM Korea and Renault Samsung, and three foreign auto makers such as Toyota, VW and BMW were tested in 2012 [6]. The test results and star ratings for the vehicles are represented in Table 7 to Table 9. As shown in Table 7 to Table 9, 32 vehicles got 1<sup>st</sup> grade for the overall rating on the crash safety test and 2 vehicles got 2<sup>nd</sup> grade. As shown in Table 8, Hyundai Veloster finally got the 1<sup>st</sup> grade through re-test step.

The whiplash and pole side impact test may not be the main factor that affects the overall ratings on the crash safety. Under the current overall evaluation

system, the overall ratings may be mainly affected by the results of full frontal, offset frontal and side impact test.

The main factor affecting results of the frontal impact test was chest injuries. In the case of light vehicles, the main factor was head injuries.

The main factor affecting results of the offset frontal impact test was injuries of chest and lower legs. In the case of light vehicles, the results were affected by injuries of all the part of the dummy on the driver's seat.

The main factor affecting results of the side impact test was chest injuries.

As shown in Table 7 to Table 9, it is easy to understand that the auto makers have been tried to launch the safer vehicles into the market. However, it is difficult to expect the discrimination of the overall ratings for the tested cars.

### CONCLUSIONS

The overall rating on the crash safety in KNCAP is to inform test results easily to consumers. Each crash test result is converted into scores. The overall rating system is classified into 5 grades depending on the distribution of scores. From 2010 to 2012, the KNCAP evaluated the occupant protection performance of 34 vehicles from domestic and foreign auto makers. 32 vehicles got 1<sup>st</sup> grade for the overall rating on the crash safety test and 2 vehicles got 2<sup>nd</sup> grade. It is difficult to expect the discrimination of the overall ratings for the tested vehicles. In the KNCAP, the overall rating will be performed to a high standard from 2013 and planned to raise the level of each grade gradually in the near future.

### REFERENCES

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- [2] Youn, Y. H., Kim, G. H., Yong, G. J., Kwon, I. S. and Lee, J. H., "Impacts of Recent Korean NCAP Programs in Automotive Safety", Paper No. 65, The 18<sup>th</sup> International Technical Conference on the Enhance Safety of Vehicles (ESV) Proceedings, Nagoya Japan, May 19-22, 2003.
- [3] Ministry of Land, Transportation and Maritime Affairs (MLTM), "A Research on the Offset Frontal Crash Test for the New Car Assessment Program", Final Report, 2008.
- [4] Ministry of Land, Transportation and Maritime Affairs (MLTM), "The Korean New Car Assessment Program 2010", Final Report, 2010.
- [5] Ministry of Land, Transportation and Maritime

**Table 1.**  
**The evaluation method for the full frontal crash test.**

	Injury	Criteria	Points	% AIS3 > 3	
Head	HIC36		0 - 6	5 - 20 (%)	
	Neck	Shear		1.9 - 3.1 (kN)	Significant risk of injury
		Tension		2.7 - 3.3 (kN)	
		Extension		42 - 57 (Nm)	
Chest	Compression	22 - 50 (mm)	0 - 6	5 - 50 (%)	
	Viscous Criterion	0.5 - 1.0 (m/s)		5 - 25 (AIS4)	
Knee, Femur	Femur Compression	3.80 - 9.07 (kN)	0 - 4	5% - Femur fracture	
	Knee Slider Compressive Displacement	6 - 15 (mm)		Cruciate ligament failure	
Injury Rating	★★★★★		13.0 - 16.0 Points		
	★★★★★		10.0 - 12.9 Points		
	★★★		7.0 - 9.9 Points		
	★★		4.0 - 6.9 Points		
	★		0.0 - 3.9 Points		

**Table 2.**  
**The evaluation method for the offset frontal impact test.**

	Injury	Criteria	Points	% AIS3 > 3	
Head	HIC36		0 - 4	5 - 20 (%)	
	Neck	Shear		1.9 - 3.1 (kN)	Significant risk of injury
		Tension		2.7 - 3.3 (kN)	
		Extension		42 - 57 (Nm)	
Chest	Compression	22 - 50 (mm)	0 - 4	5 - 50 (%)	
	Viscous Criterion	0.5 - 1.0 (m/s)		5 - 25 (AIS4)	
Knee, Femur	Femur Compression	3.80 - 9.07 (kN)	0 - 4	5% - Femur fracture	
	Knee Slider Compressive Displacement	6 - 15 (mm)		Cruciate ligament failure	
Lower Leg	Tibia Index	0.4 - 1.3	0 - 4	10% risk of fracture	
	Tibia Compression	2.0 - 8.0 (kN)			
Injury Rating	★★★★★		13.0 - 16.0 Points		
	★★★★★		10.0 - 12.9 Points		
	★★★		7.0 - 9.9 Points		
	★★		4.0 - 6.9 Points		
	★		0.0 - 3.9 Points		

**Table 3.**  
**The evaluation method for the side impact test.**

	Injury	Criteria	Points	% AIS3 > 3
Head	HIC36	650 - 1000	0 - 4	5 – 20 (%)
Chest	Compression	22 – 42 (mm)	0 - 4	5 – 30 (%)
	Viscous Criterion	0.32 – 1.0 (m/s)		5 – 50 (%)
Abdomen	Abdomen Forces	1.0 – 2.5 (kN)	0 - 4	
Pelvis	Lateral Acceleration	3.0 – 6.0 (kN)	0 - 4	
Injury Rating	★★★★★	13.00 – 16.00 Points		
	★★★★	9.00 – 12.99 Points		
	★★★	5.00 – 8.99 Points		
	★★	2.00 – 4.99 Points		
	★	0.00 – 1.99 Points		

**Table 4.**  
**The evaluation method for the pole side impact test.**

	Injury	Criteria	Points	% AIS3 > 3
Head	HIC36	650 - 1000	0 - 2	5 – 20 (%)

**Table 5.**  
**The injury rating method for the whiplash test.**

Injury Rating	★★★★★	4.9 – 6.0 Points
	★★★★	4.0 – 4.8 Points
	★★★	3.1 – 3.9 Points
	★★	2.2 – 3.0 Points
	★	0.0 – 2.0 Points

**Table 6.**  
**The overall evaluation method on the crash safety test.**

Test	Points	
Full frontal impact test	16.0	
Offset frontal impact test	16.0	
Side impact test	16.0	
Pole side impact test	(2.0)	Additional Test
Whiplash test	6.0	
Total Point	54.0	The maximum is 54.0
Overall evaluation rating	1 <sup>st</sup> Grade (Good) 2 <sup>nd</sup> Grade (Acceptable) 3 <sup>rd</sup> Grade (Marginal) 4 <sup>th</sup> Grade (Poor) 5 <sup>th</sup> Grade (Bad)	47.0 – 54.0 Points 40.0 – 46.9 Points 33.0 – 39.9 Points 26.0 – 32.9 Points 0.0 – 25.9 Points

**Table 7.**  
**Test results and star ratings.**

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
GM Matiz	Light	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.1(94%)	14.3(89%)	15.0(94%)	4.8(80%)		49.2(91%)
Renault SM3	Sub -mid	Star	★★★★★	★★★★★	★★★★★	★★★★★		2 <sup>nd</sup>
		Points	12.5(78%)	14.2(89%)	14.1(88%)	4.4(73%)		45.2(84%)
Hyundai Avante	Sub -mid	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.8(99%)	14.8(93%)	15.8(99%)	5.0(83%)	2.0(100%)	53.4(99%)
Kia K5	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.7(98%)	15.0(94%)	15.4(96%)	5.2(87%)	2.0(100%)	53.3(99%)
Renault SM5	Medium	Star	★★★★★	★★★★★	★★★★★	★★★		1 <sup>st</sup>
		Points	13.4(84%)	14.7(92%)	15.8(99%)	3.8(63%)	2.0(100%)	49.7(92%)
Hyundai Sonata	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.2(95%)	15.3(96%)	5.1(85%)	2.0(100%)	53.6(99%)
Kia Sportage	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.2(95%)	14.5(91%)	15.6(98%)	5.3(88%)		50.6(94%)
Hyundai Tucson	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	14.8(93%)	15.2(95%)	15.0(94%)	5.3(88%)		50.3(93%)
Kia K7	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.2(95%)	15.5(97%)	16.0(100%)	5.0(83%)	2.0(100%)	53.7(99%)
Lexus ES350	Large	Star	★★★★★	★★★★★	★★★★★	★★		1 <sup>st</sup>
		Points	16.0(100%)	14.6(91%)	16.0(100%)	3.0(50%)		49.6(92%)
Benz E220	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	12.2(76%)	14.3(89%)	16.0(100%)	4.5(75%)	2.0(100%)	49.0(91%)
Audi A6	Large	Star	★★★★★	★★★★★	★★★★★	★★★		1 <sup>st</sup>
		Points	12.9(81%)	15.1(94%)	15.4(96%)	3.6(60%)		47.0(87%)

**Table 8.**  
**Test results and star ratings.**

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
KIA Morning	Light	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	13.2(83%)	14.0(88%)	15.5(97%)	5.2(87%)	2.0(100%)	49.9(92%)
GM Aveo	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.5(97%)	15.3(96%)	16.0(100%)	5.1(85%)		51.9(96%)
Hyundai Accent	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.6(98%)	13.4(84%)	16.0(100%)	5.2(87%)	2.0(100%)	52.2(97%)
Hyundai Veloster	Sub-mid	Star	★★★★★	★★★	★★★★★	★★★★★		2 <sup>nd</sup>
		Points	14.5(91%)	7.6(48%)	15.8(99%)	5.8(100%)	2.0(100%)	45.7(85%)
Hyundai Veloster	Sub-mid	Star	★★★★★	★★★★★	★★★★★	★★★		1 <sup>st</sup>
		Points	15.7(98%)	13.6(85%)	15.8(99%)	3.8(63%)	2.0(100%)	52.9(98%)
Nissan Altima	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.6(98%)	15.1(94%)	14.9(93%)	4.6(77%)	2.0(100%)	52.2(97%)
Audi A4	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	13.7(86%)	15.0(94%)	16.0(100%)	5.6(93%)	2.0(100%)	52.3(97%)
VW Golf	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	12.0(75%)	15.4(96%)	14.4(90%)	5.1(85%)	2.0(100%)	48.9(91%)
Ssangyong Korando C	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	13.1(82%)	13.4(84%)	15.4(96%)	5.5(92%)		47.4(88%)
GM Orlando	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.3(96%)	16.0(100%)	5.8(97%)		53.1(98%)
GM Alpheon	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.3(96%)	16.0(100%)	5.4(90%)	2.0(100%)	54.0(100%)
Hyundai Grandeur	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.9(99%)	14.8(93%)	5.7(95%)	2.0(100%)	54.0(100%)

**Table 9.**  
**Test results and star ratings.**

Vehicle	Class		Full Frontal Impact	Offset Frontal Impact	Side Impact	Whiplash	Pole Side Impact	Overall Evaluation Results
Kia Ray	Light	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	13.4(84%)	12.6(79%)	16.0(100%)	5.4(90%)	2.0(100%)	49.4(91%)
Kia Pride	Compact	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	14.6(91%)	16.0(100%)	5.6(93%)	2.0(100%)	54.0(100%)
Hyundai i30	Sub-mid	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.2(95%)	14.6(91%)	16.0(100%)	5.4(90%)	2.0(100%)	53.2(99%)
GM Malibu	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.6(98%)	15.8(99%)	5.9(98%)	2.0(100%)	54.0(100%)
Hyundai i40	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.4(96%)	15.4(96%)	16.0(100%)	5.4(90%)	2.0(100%)	54.0(100%)
BMW 320d	Medium	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	14.5(91%)	15.4(96%)	16.0(100%)	4.6(77%)	2.0(100%)	52.5(97%)
Toyota Camry	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.3(96%)	16.0(100%)	4.7(78%)		54.0(100%)
VW CC	Medium (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	13.9(87%)	12.9(81%)	16.0(100%)	5.2(87%)		50.0(93%)
Kia K9	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.2(95%)	16.0(100%)	5.6(93%)	2.0(100%)	54.0(100%)
Renault SM7	Large	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	15.2(95%)	14.3(89%)	15.5(97%)	5.8(97%)	2.0(100%)	52.8(98%)
Hyundai SantaFe	Large (SUV)	Star	★★★★★	★★★★★	★★★★★	★★★★★		1 <sup>st</sup>
		Points	16.0(100%)	15.9(99%)	16.0(100%)	5.7(95%)	2.0(100%)	54.0(100%)