Rearward visibility assessment and a proposed performance scoring for ASEAN NCAP

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Abstract – *Asia has the highest number of registered motorcycles globally and the recent data has shown that motorcycles fatalities has been the major accident and death cases in ASEAN Region. One of the major concerns is the visibility of motorcycles to other vehicles on the road. Thus, in this project, ECE R46 and FMVSS regulations have been referred as the base guidelines to establish a novel test protocols for vehicles rearward visibility assessment. Sixteen cars have been benchmarked and analysed in term of their rear-view mirror (Class I) and external mirror (Class III) performance. Motorcycles visibility to the vehicles' Class I and Class III mirrors also been assessed by converting the measured data into number of motorcycles based on its width. A proposed performance scoring system for ASEAN NCAP has been developed based on that to address the Motorcycle Safety pillar.*

Keywords: ASEAN NCAP, Rearward Visibility, Motorcycle Safety, ECE R46, FMVSS

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1.0 INTRODUCTION

South-East Asia has the second highest regional rate of road traffic death higher than the global rate per 100,000 population after Africa (refer Figure 1) as reported in Global Status Report on Road Safety in 2018 by WHO [1]. It is also mentioned that in South-East Asia, the majority of deaths are among riders of motorized two- and three-wheelers who represent 43% of all deaths. Riders of motorized two- and three-wheelers are more vulnerable because they are less protected than car occupants. This proves the need to look into improving motorcycle conspicuity on the road especially by integrating it in the vehicle designs and technologies.

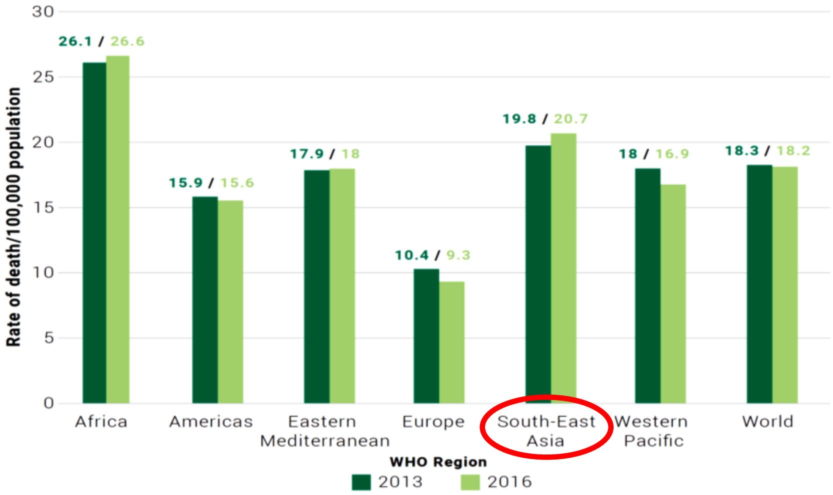

Figure 1 Motorcycle fatalities per 100 000 population [1]

This paper discusses regarding the rearward visibility assessment's methodology and the result's analysis that has been done on sixteen vehicles. A proposed performance scoring system for ASEAN NCAP Roadmap 2021-2025 [2] to address the Motorcycle Safety pillar has been developed based on the analysis.

ECE R46 [3] and FMVSS 111 [4] field-of-view test protocols have been compared in order to establish a novel test protocol for the benchmarking of rearward visibilities. Below are the criteria that were looked into in both protocols:

- Performance requirement
- Manikin positioning
- Test area
- Test sequence
- Test apparatus

For the performance requirement, R46 for Class I is less stringent than FMVSS 111. Figure 2 shows the fields of vision requirement for the ECE R46. As FMVSS 111 is not applicable to ASEAN countries, thus the new protocol will retain R46 requirement. As for Class III, R46 vision is more stringent than FMVSS111.

Both protocols are using the same manikin of SAE-J826. Seating reference point (SRP) is similar where manikin H-point is based on the 95th percentile position (SGRP). FMVSS method requires bigger space, but it is suitable for direct assessment method and can be adapted with R46 performance requirement.

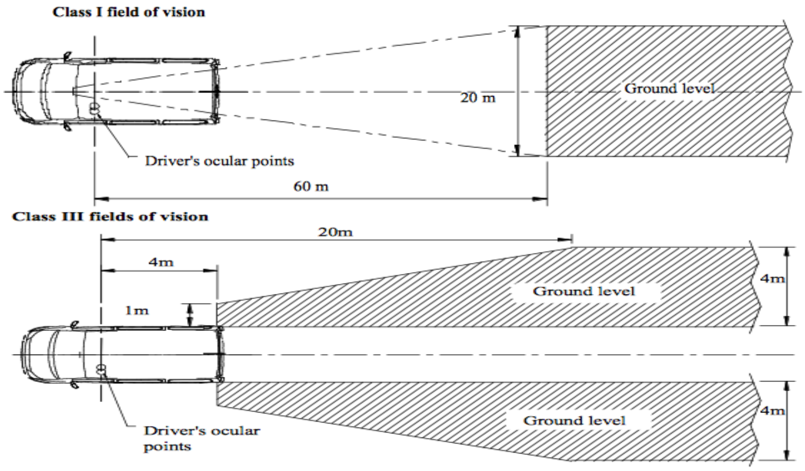

Figure 2 ECE R46 Class I and Class III fields of vision [3]

Comparison of both protocols have indicated slight difference in performance requirement and test sequence. As the manikin is equal and positioned similarly, the performance requirement and test sequence are interchangeable. Thus, ECE R46 will be used as baseline performance limit while FMVSS will be prioritise for test area range, sequence and apparatus.

2.0 REARWARD VISIBILITY ASSESSMENT METHODOLOGY

There are two main parts for the assessment which are Class I (interior rear-view mirror) and Class III (external mirrors) mirrors.

2.1 Vehicle Preparation

The benchmarking activity was done at MIROS PC3 Lab, Melaka. Figure 3 shows the general layout of the vehicle arrangement at the test location. The floor markings at 6-meter, 16-meter, and 20-meter were done for the Class 1 and Class 3 mirror’s measurements purpose.

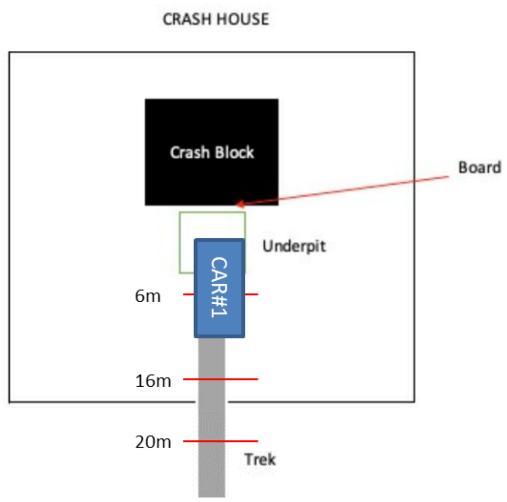

Figure 3 Vehicle arrangement at the test location

Five vehicle markings have been made at the vehicle center, the right side of both front and rear wheel centers and wheel arches by placing roundel at each location. Then, measurements as listed in Table 1 were taken. Figure 4 shows the four measurement points before a manikin was installed at the driver's seat.

Figure 4 Measurement points for points 1 to 4 of Table 1.

Table 1 Measurements taken on the vehicle (pre-manikin positioning)

No	*Measurement point*
1	Front-right wheel center height from ground
2	Front-right wheel arch height from ground
3	Rear-right wheel center height from ground
4	Rear-right wheel arch height from ground

A manikin was positioned at the driver's seat with adjusted seatback angle of 25°. A camera jig was also positioned to according to the seatback angle (Figure 5). Further measurements were done as in Table 2.

Figure 5 A manikin with adjusted seatback angle of 25°.

Table 2 Measurement taken on the vehicle (post-manikin positioning)

No	*Measurement point*
1	Front-right wheel center height from ground
2	Front-right wheel arch height from ground

2.2 Class I (Interior rear-view mirror) test set up

For Class I (interior mirror) test, a horizontal reference line was marked at the board to indicate the line height from the ground. A red tape was used to represent the line (refer Figure 6). The equation below is used to determine the vertical height from ground:

$$Line\ height\ from\ ground = OPh - \left[6 * \left(\frac{OPh}{60}\right)\right]$$

$$OPh = \left((OCz) - (WCz)\right) + WCh$$

Where:

OPh = Ocular Point height

OCz = Ocular Point z-coordinate (from CMM)

WCz = Wheel Centre z-coordinate (from CMM)

WCh = Wheel Centre height (from direct measurement, pre-manikin

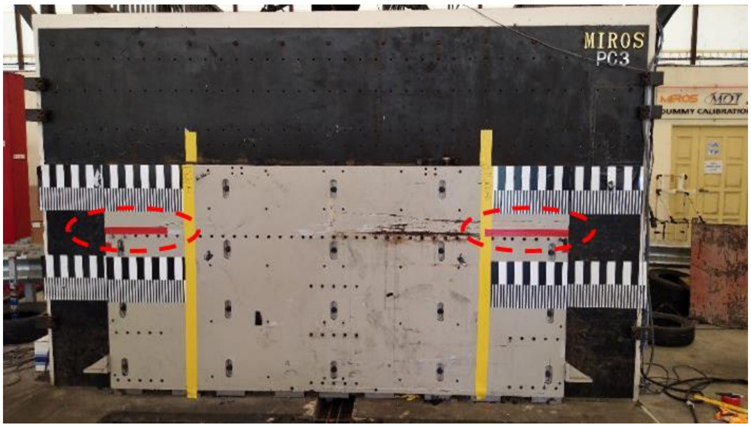

Figure 6 Horizontal reference line marked on vertical board

The test vehicle was pushed into test position at 6-meter mark. The ocular point was also aligned vertically to the 6-meter mark. The camera jig yaw and pitch combined with interior rear-view mirror were adjusted to get the optimum rear view (refer Figure 7). Optimum view criteria:

- Maximum view between C/D-pillars of vehicle
- Maximum view between roof and lower limit (tailgate, parcel shelf, rear seats)
- Horizontal reference line must be always visible

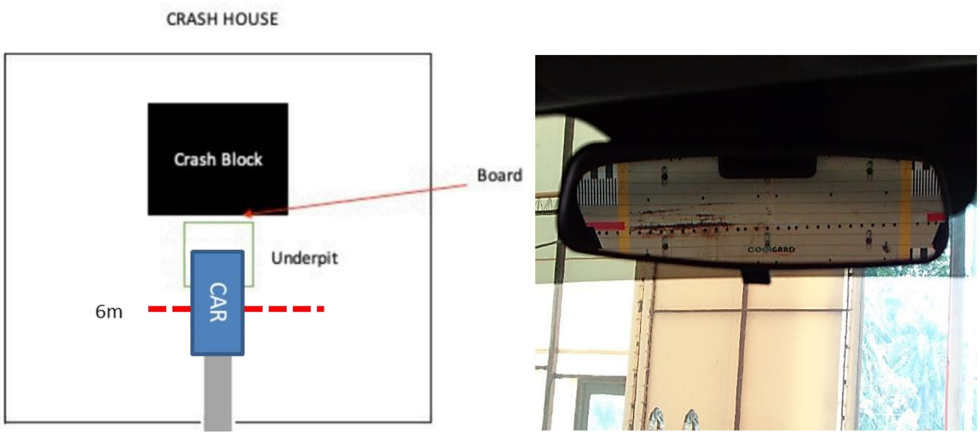

Figure 7 Test vehicle at 6-meter mark and interior rear-view mirror field of view adjustment

Table 3 listed the markings placed on vertical board which correspond to the visible limits of interior mirror (Figure 8). The field of view measurements were taken and recorded for the Class I mirror.

Table 3 Markings required per vehicle in CLASS1 Test.

No.	Markings to be made
1	Limit on horizontal line, RH side
2	Minimum viewable location, RH side
3	Maximum viewable location, RH side
4	Limit on horizontal line, LH side
5	Minimum viewable location, LH side
6	Maximum viewable location, LH side

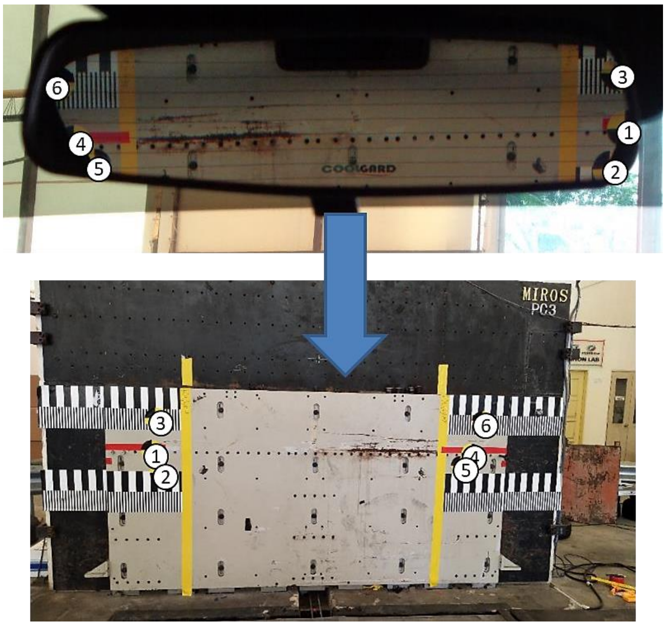

Figure 8 Field of view markings and measurements

2.3 Class 3 (Exterior rear-view mirror) test set up

For the Class III (exterior rear-view) mirror set up, the test vehicle was pushed into test position at 20-meter mark. The ocular point was also aligned vertically to the 20-meter mark. To measure the field of view for Class III mirror, cones have been positioned at 1-meter and 4-meter marks for both right and left side of the test vehicle (Figure 9). The camera and side rear mirror were adjusted until optimum rear view was found. Optimum view criteria:

- Minimum view of vehicle body
- Maximum outboard view of 4-meter and 20-meter cones

Measurements were taken at cones at 4-meter and 20-meter mark between reference cone (orange dots) and maximum view cones (green dots). Measurements were in parallel to reference horizontal lines of 16-meter and 0-meter mark respectively.

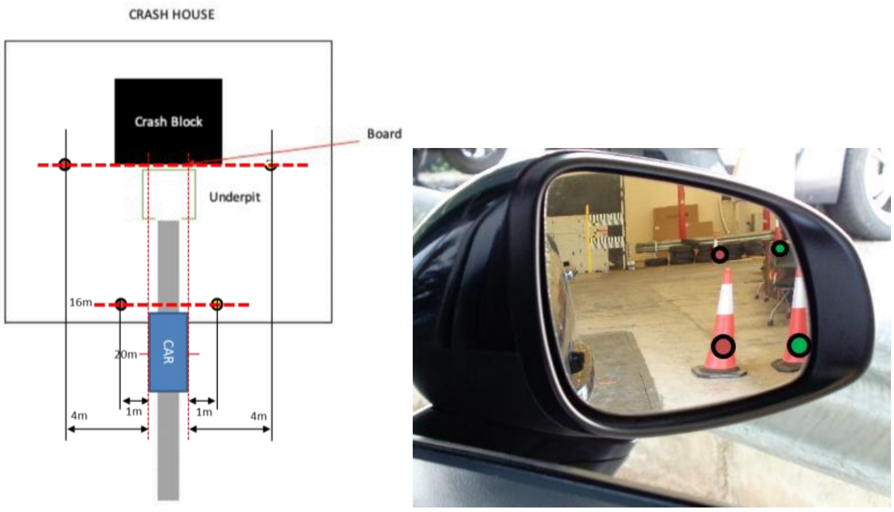

Figure 9 Test vehicle set up at 20-meter point and the cones positioning.

3.0 RESULTS & DISCUSSIONS

3.1 ECE R46 Limit Measurement Data

A total of sixteen vehicles comprising of various categories like pickup, SUV, MPV, family car, and mini car were tested.

Table 4 shows the top five vehicles with widest visibility coverage for vehicle RH and LH respectively for Class I assessment. From the data, all three vehicles from the pickup category are included in the Top 5.

Table 4 Top 5 vehicles with widest visibility (R46 limits)

CLASS 1 RH			
Vehicle	*R46 Limits (width)*	*Widest (width)*	*Smallest (width)*
Ford Ranger	430.0	430.0	425.0
Honda HR-V	305.0	305.0	212.0
Mitsubishi Triton	305.0	308.0	305.0
Nissan Navara	248.0	323.0	248.0
PROTON Saga	222.0	222.0	150.0
CLASS 1 LH			
Vehicle	*R46 Limits (width)*	*Widest (width)*	*Smallest (width)*
Ford Ranger	415.0	415.0	353.0
PROTON Iriz	358.0	420.0	280.0
Nissan Navara	325.0	360.0	325.0
Mitsubishi Triton	250.0	250.0	250.0
PROTON Saga	225.0	225.0	106.0

Table 5 and Table 6 show the top five vehicles with widest visibility (R46 limits) at respective mirror and marker positions indicated for Class III assessment at 4-meter and 20-meter distance.

Table 5 Top 5 vehicles for Class III 4m assessment

4-meter limit	
Vehicle	*RH*
Mitsubishi Triton	1323
Perodua Axia	1129
Nissan Navara	1101
PROTON Saga	1070
Perodua Alza	960
Vehicle	*LH*
Ford Ranger	925
Mitsubishi Triton	890
Perodua Axia	780
Nissan Navara	770
PROTON Saga	740

Table 6 Top 5 vehicles for Class III 20m assessment

20-meter limit	
Vehicle	*RH*
Mitsubishi Triton	6150
Nissan Navara	5628
PROTON Saga	5030
Nissan Xtrail	4650
Perodua Alza	4290
Vehicle	*LH*
Nissan Navara	3530
Mitsubishi Triton	3365
Subaru XV	3085
PROTON Saga	3010
Nissan Xtrail	2890

Statistical analysis has been done on the measured data. Based on the Table 7, the statistics for ALL the datasets are skewed for Class I. It is due to the big gap in performance for PICKUP vehicles in comparison to the NON-PICKUP. When the data is split to the 2 subsets, statistics are comparable. Especially for the *Standard deviation*; which will form the basis for the scoring proposal.

As per the Class I findings, the Class III LH, RH 4m (Table 8) dataset statistic is also skewed when ALL vehicles are factored in. However, for LH the skew is limited only to the *Average* of the datasets. The PICKUP has a significantly higher *Average* than the NON-PICKUP. Unlike RH findings, the LH *Standard deviation* of the NON-PICKUP is significantly higher which indicating of the great variation in performance.

Referring to Table 9, for Class III LH 20m, similar findings to Class III LH 4m are observed which shows skew in *Average* but very different *Standard deviation* of PICKUP and NON-PICKUP. For Class III RH 20m, findings are not similar to Class III RH 4m since RH 20m is skew in *Average* but very different *Standard deviation* of PICKUP and NON-PICKUP.

Due to the above, for all Class I and Class III dataset, the scoring of PICKUP and NON-PICKUP is to be separated.

Table 7 Statistical analysis for Class I LH & RH

CLASS 1	LH			RH		
	ALL	**PICKUP**	**NON-PICKUP**	**ALL**	**PICKUP**	**NON-PICKUP**
Average	179.4	330	144.7	167.7	327.7	130.8
Median	158.5	325	127	158.8	305	138
Variance, Population	11824.4	4550	7061.9	12188.4	5777.6	6401.6
Standard deviation, Population	108.7	67.5	84	110.4	76	80

Table 8 Statistical analysis for Class III 4-meter LH & RH

CLASS III (4m)	LH			RH		
	ALL	**PICKUP**	**NON-PICKUP**	**ALL**	**PICKUP**	**NON-PICKUP**
Average	590.9	861.7	528.4	809.9	1087.3	745.9
Median	582.5	890	540	789	1101	670
Variance, Population	43031.6	4405.6	31118.4	61155.9	39297.6	44345
Standard deviation, Population	207.4	66.4	176.4	247.3	198.2	210.6

Table 9 Statistical analysis for Class III 20-meter LH & RH

CLASS III (20m)	LH			RH		
	ALL	**PICKUP**	**NON-PICKUP**	**ALL**	**PICKUP**	**NON-PICKUP**
Average	2343.4	3245	2135.4	3615.8	5315.3	3223.5
Median	2505	3365	2360	3780	5628	3120
Variance, Population	674855.4	86550	579759.5	1668646	703600.9	1070922.6
Standard deviation, Population	821.5	294.2	761.4	1291.8	838.8	1034.9

3.2 Proposed Performance Scoring Method for ASEAN NCAP

The need for separated assessment of PICKUP and NON-PICKUP, as indicated from the findings of the statistical analysis made, is further apparent when the physical dimensions of the vehicle categories are compared. Due to this, the PICKUP vehicles generally have a bigger rear windscreen. Thus, the Class I visibility can be generally made wider than NON-PICKUP from the onset, as per Figure 10. Similarly, Class III mirrors of PICKUP are designed to match the bigger physical dimension and to have proportionate styling look.

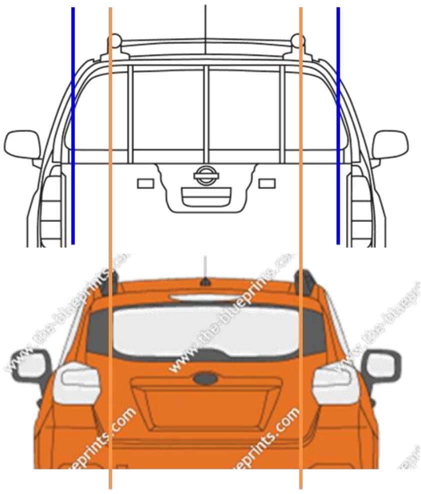

Figure 10 Comparison of rear windscreen Nissan Navara (PICKUP) and Subaru XV (NON-PICKUP).

If the statistical findings are to be used directly, the actual performance gains in real world may not be represented. An increase of 100mm in viewing range may not necessarily increase the conspicuity of a motorcyclist. To avoid this risk, the statistical findings are proposed to be normalized to a width of a motorcycle. For every 1 full width of a motorcycle is achieved, the conspicuity of a motorcyclist to the driver is increased by 100% (refer Figure 11). Although Vehicle B's Class I mirror exceeded the R46 performance requirement, the real-world performance benefit is not as good as Vehicle A.

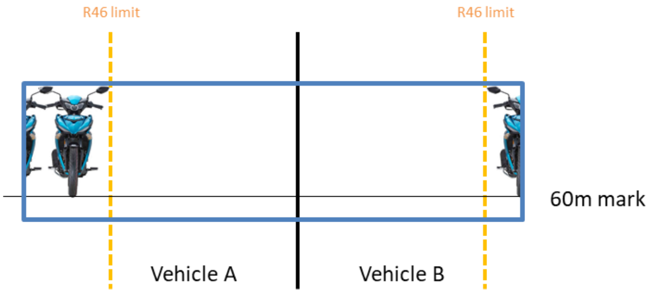

Figure 11 Example of Class I mirror comparison for Vehicle A & B

A standard motorcycle width needs to be established. In line with ASEAN NCAP, underbone type motorcycle for the Blind Spot Detection test is used. A study on the width of the common motorcycles of Malaysia and Indonesia was conducted and indicated that the motorcycle width to be used for the normalization is 731mm. Consistent with ISO17387, which indicated motorcycle width for Blind Spot Detection tests is within 700mm – 900mm. Thus, the normalized statistical findings of the RVB benchmark data are shown below in Table 10.

Table 10 RVB benchmarking data normalized to motorcycle width

	CLASS I				CLASS III 4m				CLASS III 20m			
	LH		RH		LH		RH		LH		RH	
	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
Average	5	2	4	2	1	1	1	1	4	3	7	4
Standard deviation, Population	1	1	1	1	0	0	0	0	0	1	1	1

For each performance parameter, vehicle is scored as;

- Below average: 0point
- Average to (Average + Standard deviation): 1point
- Above (Average + Standard deviation): 2points

Where Standard deviation is 0 (zero), the performance is scored as;

- Below average: 0point
- Above Average: 2points

The above scoring method is summarized in Table 11 below.

Table 11 The performance limits per assessment category for scoring

	CLASS I				CLASS III 4m				CLASS III 20m			
	LH		RH		LH		RH		LH		RH	
	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
Lower limit	5	2	4	2	0	0	0	0	0	3	7	4
Upper limit	6	3	5	3	1	1	1	1	4	4	8	5

For the performance scoring proposal, *Average* is selected as the lower performance limit as it represents the "norm" of the performance of each vehicle group (PICKUP or NON-PICKUP). The *Average + Standard deviation* is set as the upper performance limit of each group as it is a fair value to represent the truly large rearward visibility of each vehicle group. Figure 13 shows the simulation of the performance limit for Class I rearwards visibility; orange is *Average*, blue is (*Average + Standard deviation*) and green is above (*Average + Standard deviation*). CLASS III performance limit follows same principle.

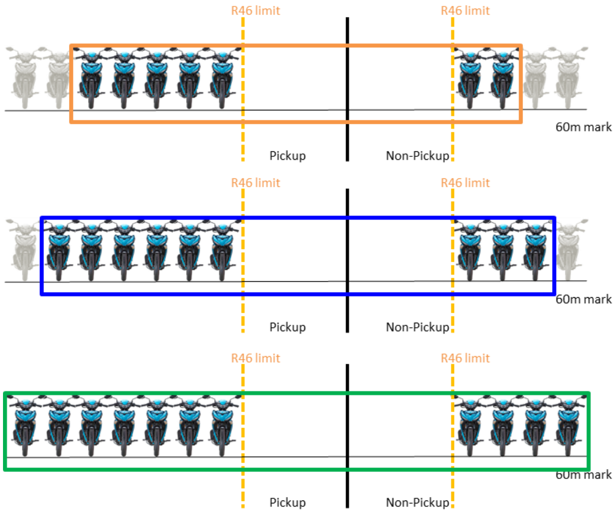

Figure 12 Simulation of the performance limit for Class 1

In simplifying the score calculation, two scoring templates as Table 12 are generated which are for PICKUP and NON-PICKUP categories. Figure 13 below shows the proposed process for the vehicle assessment for rearwards visibility performance and scoring.

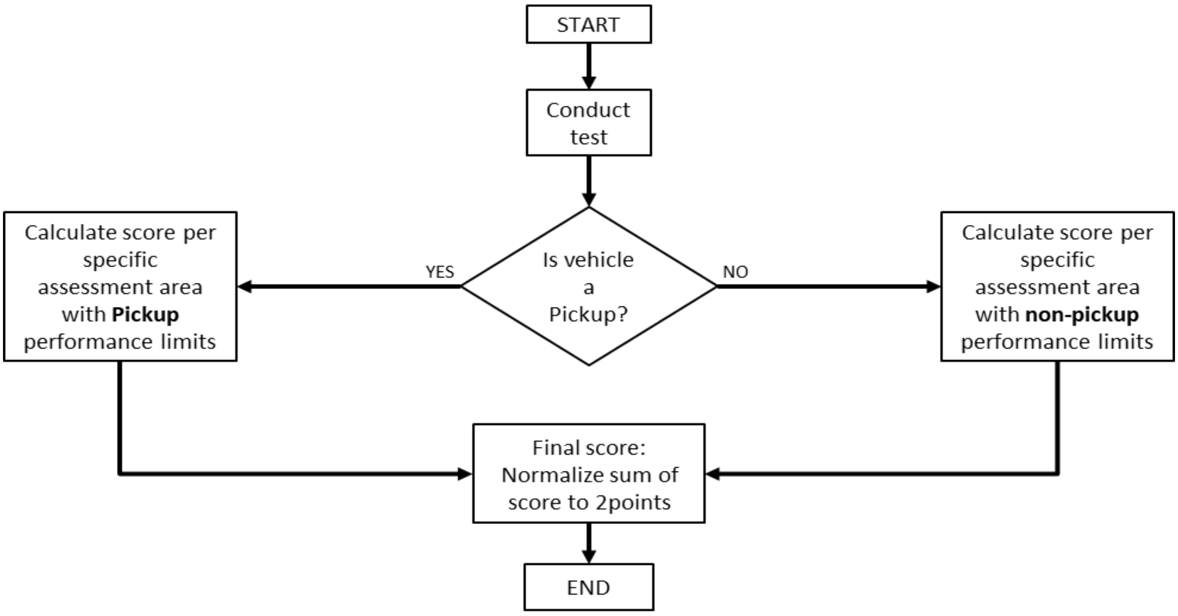

Figure 13 Process flow for vehicle rearwards visibility performance and scoring

Table 12 Example of performance scoring templates

ASEANNCAP Rearwards Visibility 2021 - 2025

				Nissan Navara	
	Assessment Area	**Injury**	**Units**	**Measured**	**Unit Score**
Pickup	CLASS I	LH	mm	325	0
		RH	mm	248	0
	CLASS III	LH, 4-meter	mm	770	2
		RH, 4-meter	mm	1101	2
		LH, 20-meter	mm	3530	2
		RH, 20-meter	mm	5628	1
Overall score				**1.17**	

ASEANNCAP Rearwards Visibility 2021 - 2025

				Perodua Alza	
	Assessment Area	**Injury**	**Units**	**Measured**	**Unit Score**
Non-Pickup	CLASS I	LH	mm	33	0
		RH	mm	168	1
	CLASS III	LH, 4-meter	mm	540	0
		RH, 4-meter	mm	960	2
		LH, 20-meter	mm	2000	0
		RH, 20-meter	mm	4290	2
Overall score				**0.83**	

CONCLUSION

In finalizing the proposal for ASEANNCAP's rearward visibility assessment for the Motorcyclist safety pillar of ASEANNCAP 2021-2025, the following are recommended:

- Given the data trends, performance limits for scoring needs to be split for PICKUP and NON-PICKUP vehicles.
- Based on the statistical assessment, performance limits for scoring should be normalized to per motorcycle width in order to increase real world benefit gain in increasing motorcyclist conspicuity.

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