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# 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 have been the main road death category in the Southeast Asian region. One of the major concerns is the visibility of motorcycles to other vehicles on the road. Thus, in this project, UN R46 and FMVSS regulations have been referred to as the base guidelines to establish a novel test protocol for vehicles rearward visibility assessment. Sixteen cars have been benchmarked and analysed in terms 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 several 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, UN R46, FMVSS

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## 1.0 INTRODUCTION

Southeast Asia has the second-highest regional rate of road traffic death higher than the global rate per 100,000 populations after Africa (refer Figure 1) as reported in Global Status Report on Road Safety in 2018 (WHO, 2018). It is also mentioned that in Southeast 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 vehicle designs and technologies (Meor Said et al., 2020).

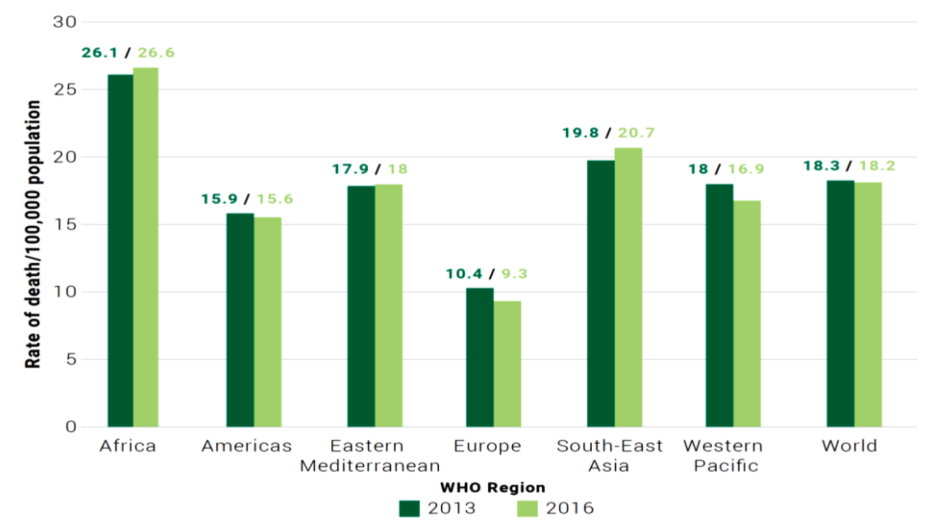


**Figure 1**: Motorcycle fatalities per 100,000 populations (WHO, 2018)

This paper discusses 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 to address the Motorcycle Safety pillar has been developed based on the analysis (ASEAN NCAP, 2018). UN R46 (UN, 2013) and FMVSS 111 (NHTSA, 2018) field-of-view test protocols have been compared to establish a novel test protocol for the benchmarking of rearward visibilities. The followings are the criteria that were looked into in both protocols: (i) performance requirement; (ii) manikin positioning; (iii) test area; (iv) test sequence; and (v) test apparatus.

For the performance requirement, UN R46 for Class I is less stringent than FMVSS 111. Figure 2 shows the fields of vision requirement for UN R46. As FMVSS 111 does not apply to ASEAN countries, thus the new protocol will retain the UN R46 requirement. As for Class III, the UN R46 vision is more stringent than FMVSS 111. Both protocols are using the same manikin of SAE-J826. Seating Reference Point (SRP) is similar where manikin H-point is based on the 95$^{th}$ percentile position (SgRP). FMVSS method requires a bigger space, but it is suitable for the direct assessment method and can be adapted with the UN R46 performance requirement.

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A comparison of both protocols has indicated a 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, UN R46 will be used as a baseline performance limit while FMVSS 111 will be prioritised for test area range, sequence, and apparatus.

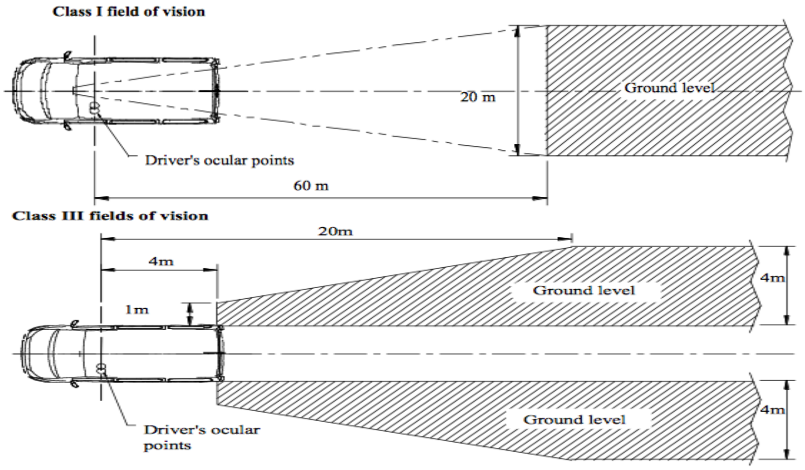


**Figure 2**: UN R46 Class I and Class III fields of vision (UN, 2013)

## 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 the MIROS PC3 Lab, Melaka. Figure 3 shows the general layout of the vehicle arrangement at the test location. The floor markings at 6-metre, 16-metre, and 20-metre were done for the Class 1 and Class III mirror's measurements purpose. Five vehicle markings have been made at the vehicle centre, the right side of both front and rear wheel centres 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.

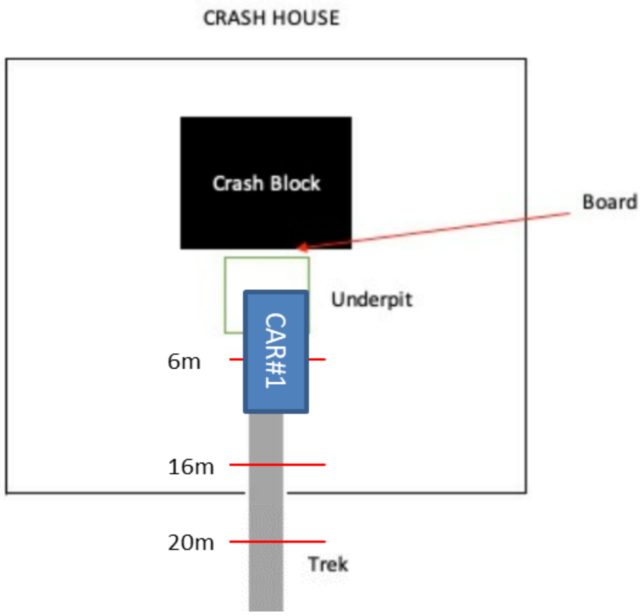


**Figure 3**: Vehicle arrangement at the test location

**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 |


**Figure 4**: Measurement points for points 1 to 4 of Table 1

A manikin was positioned at the driver's seat with an adjusted seatback angle of 25°. A camera jig was also positioned 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 the Class I (interior mirror) test, a horizontal reference line was marked at the board to indicate the line-height from the ground. Red tape was used to represent the line (refer Figure 6). The vertical height from the ground is determined from Equation 1 and Equation 2 below.

$$Line\ height\ from\ ground = OP_h - \left[6 \times \left(\frac{OP_h}{60}\right)\right] \quad (1)$$

$$OP_h = (OC_z - WC_z) + WC_h \quad (2)$$

Where:

$OP_h$ = Ocular point height

$OC_z$ = Ocular point z-coordinate (from CMM)

$WC_z$ = Wheel centre z-coordinate (from CMM)

$WC_h$ = Wheel Centre height (from direct measurement, pre-manikin)

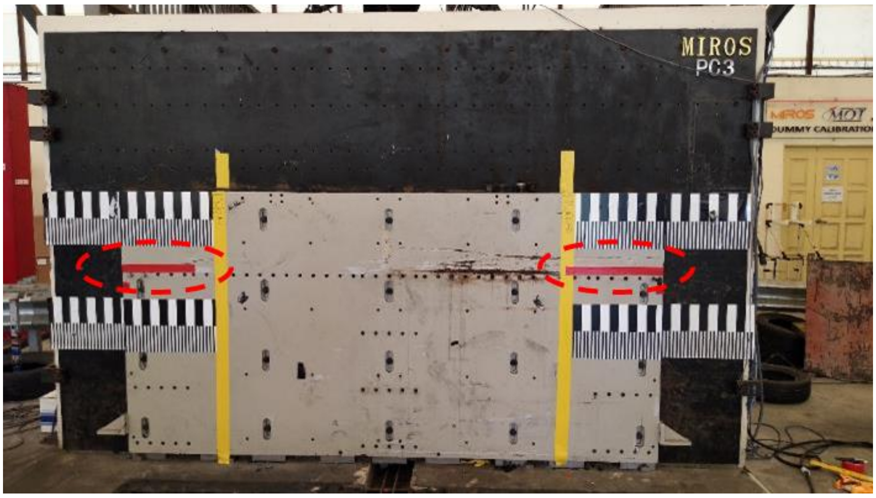


**Figure 6**: Horizontal reference line marked on vertical board

The test vehicle was pushed into the test position at the 6-metre mark. The ocular point was also aligned vertically to the 6-metre mark. The camera jig yaw and pitch combined with the interior rear-view mirror were adjusted to get the optimum rear view (refer Figure 7). The optimum view criteria are: (i) maximum view between C/D-pillars of the vehicle; (ii) maximum view between the roof and lower limit (tailgate, parcel shelf, rear seats); and (iii) horizontal reference line must be always visible.

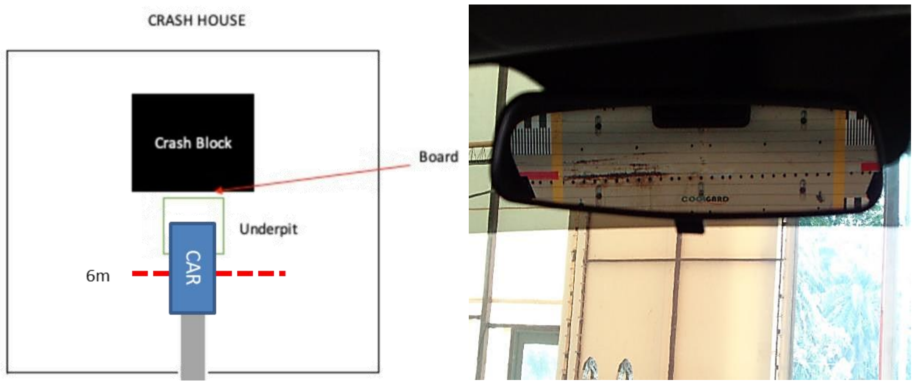


**Figure 7**: Test vehicle at 6-meter mark and interior rear-view mirror field of view adjustment

Table 3 listed the markings placed on the vertical board which corresponds to the visible limits of the 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 Class I 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 |

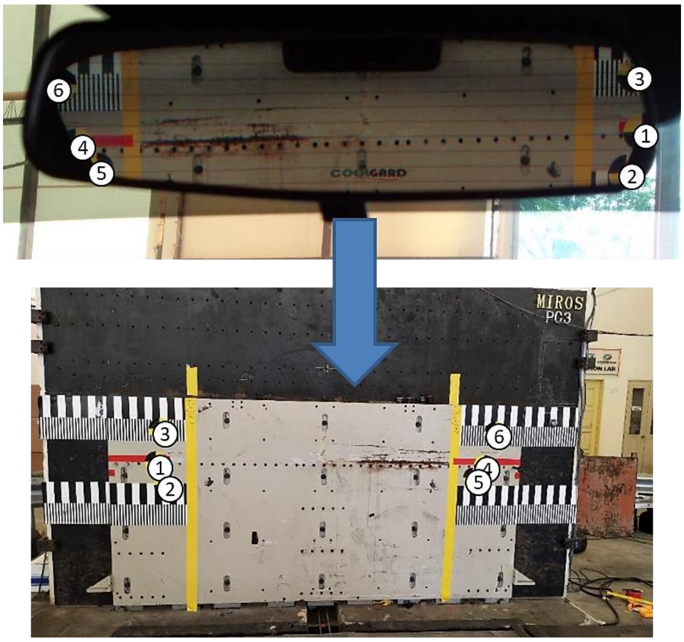


**Figure 8**: Field of view markings and measurements

## 2.3 Class III (Exterior Rear View Mirror) Test Set-Up

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

The optimum view criteria are the minimum view of the vehicle body and maximum outboard view of 4-metre and 20-metre cones. Measurements were taken at cones at 4-metre and 20-metre mark between reference cone (orange dots) and maximum view cones (green dots). Measurements were in parallel to reference horizontal lines of 16-metre and 0-metre mark respectively.

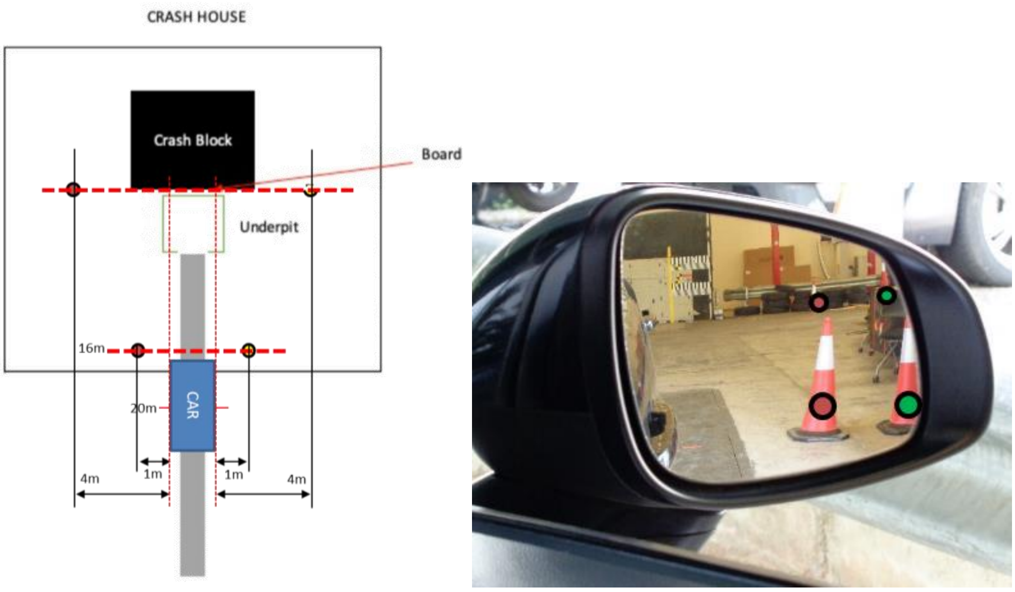


**Figure 9**: Test vehicle set up at 20-metre point and the cones positioning

## 3.0 RESULTS AND DISCUSSION

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

**Table 4**: Top five vehicles with the widest visibility (UN R46 limits)

| CLASS 1 RH | | | |
|---|---|---|---|
| **Vehicle** | **UN 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** | **UN 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**: Top five vehicles for Class III 4-metre assessment

| 4-metre 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 five vehicles for Class III 20-metre assessment

| 20-metre limit | |
|---|---|
| **Vehicle** | **RH** |
| Mitsubishi Triton | 6150 |
| Nissan Navara | 5628 |
| Proton Saga | 5030 |
| Nissan X-Trail | 4650 |
| Perodua Alza | 4290 |
| **Vehicle** | **LH** |
| Nissan Navara | 3530 |
| Mitsubishi Triton | 3365 |
| Subaru XV | 3085 |
| Proton Saga | 3010 |
| Nissan X-Trail | 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 into the two 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 I | 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 a proportionate styling look.

If the statistical findings are to be used directly, the actual performance gains in the 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.

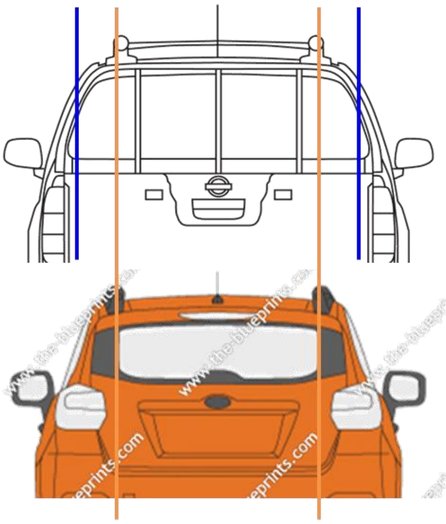

**Figure 10**: Comparison of rear windscreen Nissan Navara (PICKUP) and Subaru XV (NON-PICKUP)

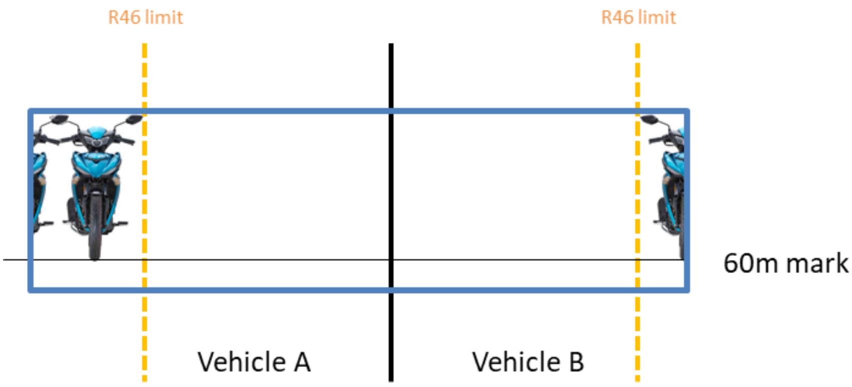


**Figure 11**: Example of Class I mirror comparison for Vehicle A & B

A standard motorcycle width needs to be established to produce Rearward Visibility Blockage (RVB) benchmarking data. In line with ASEAN NCAP, the underbone type motorcycle for the Blind Spot Detection (BSD) test is used (Abu Kassim et al., 2019). A rough estimate 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 ISO 17387, which indicated motorcycle width for BSD tests is within 700mm – 900mm. Thus, the normalized statistical findings of the RVB benchmark data are shown below in Table 10.

For each performance parameter, vehicle is scored as: (i) below average: 0 point; (ii) average to (Average + Standard Deviation): 1 point; and (iii) above (Average + Standard Deviation): 2 points. Where Standard Deviation is 0 (zero), the performance is scored as: (i) below average: 0 point; and (ii) above Average: 2 points. The above scoring method is summarized in Table 11.

**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 |

**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 12 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 the same principle.

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.

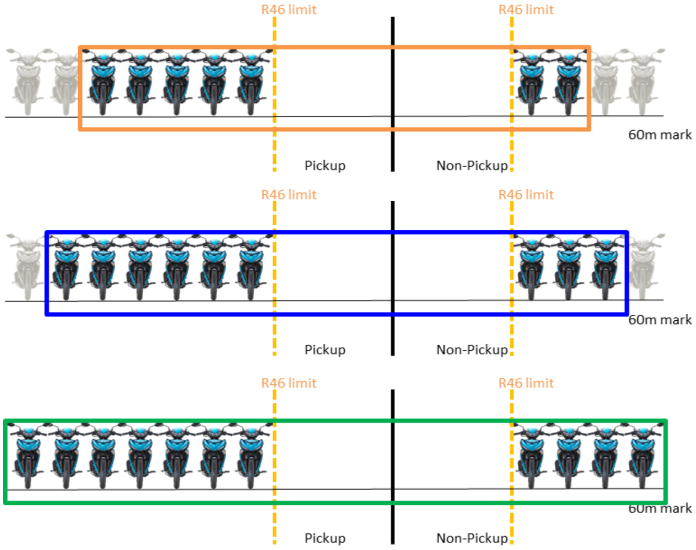


**Figure 12**: Simulation of the performance limit for Class 1

**Table 12**: Examples of performance scoring template

## 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

| | | | | Nissan Navara | |
|---|---|---|---|---|---|
| | **Assessment Area** | **Injury** | **Units** | **Measured** | **Unit Score** |
| **Pickup** | CLASS I | LH | mm | 325 | 0 |
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| | 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** | |

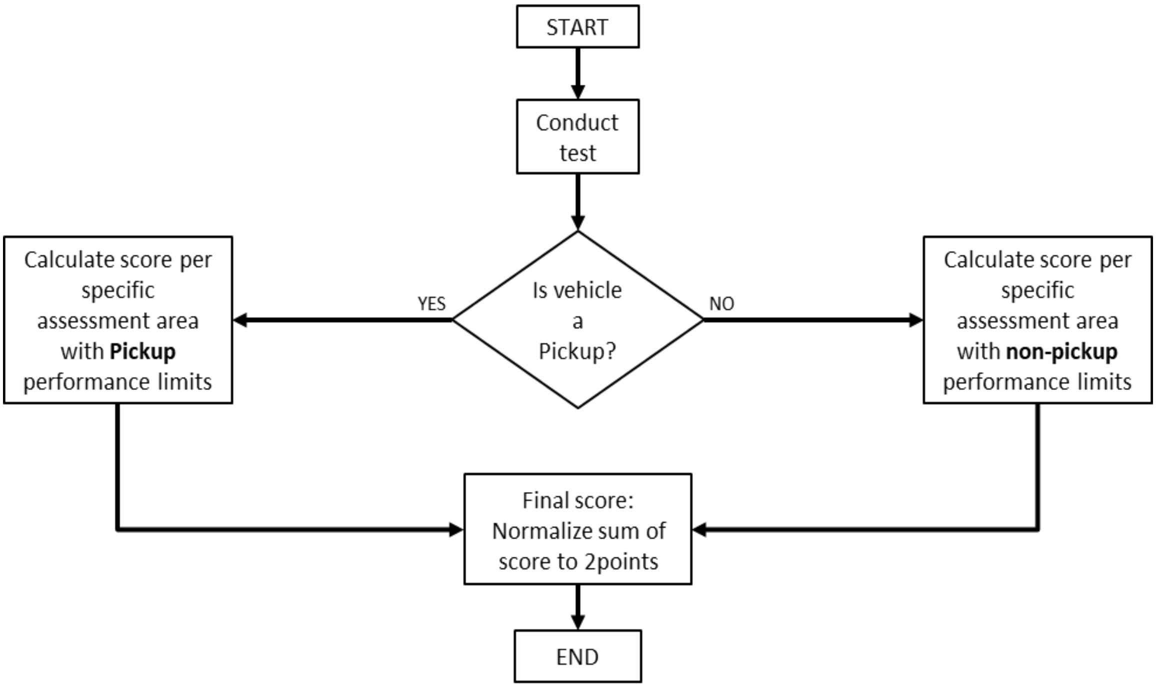


**Figure 13**: Process flow for vehicle rearwards visibility performance and scoring

## 5.0 CONCLUSION

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

- Given the data trends, performance limits for scoring need 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 to increase real-world benefit gain in increasing motorcyclist conspicuity.

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