

Child Presence Detection: Assessment Methodology for ASEAN NCAP

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Abstract – *The introduction of Child Presence Detection (CPD) technology under the Child Occupant Protection (COP) pillar in the New Car Assessment Programme for Southeast Asian Countries (ASEAN NCAP) Roadmap 2021-2025 should come with proper assessment methodology to evaluate the effectiveness of such technologies in a vehicle. This paper gives an overview of CPD systems and Vehicle Reminder Systems (VRS), together with their associated technologies. Most importantly, a comprehensive assessment methodology for CPD and VRS that covers the vehicle preparation, occupants' classifications (i.e., newborn, infant and toddler), assessment procedure, scoring criteria, and implementation plan is also presented. It is hoped that this work could contribute to ASEAN NCAP Roadmap 2021-2025, and gives valuable insights to relevant stakeholders such as the vehicle manufacturers and technology providers.*

Keywords: Child Presence Detection (CPD), Child Occupant Protection (COP), assessment methodology, ASEAN NCAP Roadmap 2021-2025

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1.0 INTRODUCTION

Infant and young children are vulnerable to heat due to their physiological and behavioural characteristics. Globally, small children lose their lives due to being locked in the car under hot weather, either accidentally by the children themselves or forgotten by their guardians. According to Null (2016), an average of 38 children have been killed every year due to heatstroke in a locked automobile in the USA between 1998 and 2014. About half of the cases were due to parents leaving a child unintentionally in the car, while approximately 29 % were due to children amusing themselves in parked vehicles, and another 18 % were due to children being left intentionally by their caretakers. Meanwhile, a news analysis performed by Malaysian Institute of Road Safety Research (MIROS) on the matter found a total of nine cases related to child death in parked vehicles until the end of 2018 (Jawi, 2018); the statistics increased in 2019 with two recent cases, making the number of the total case to 11 (Figure 1).

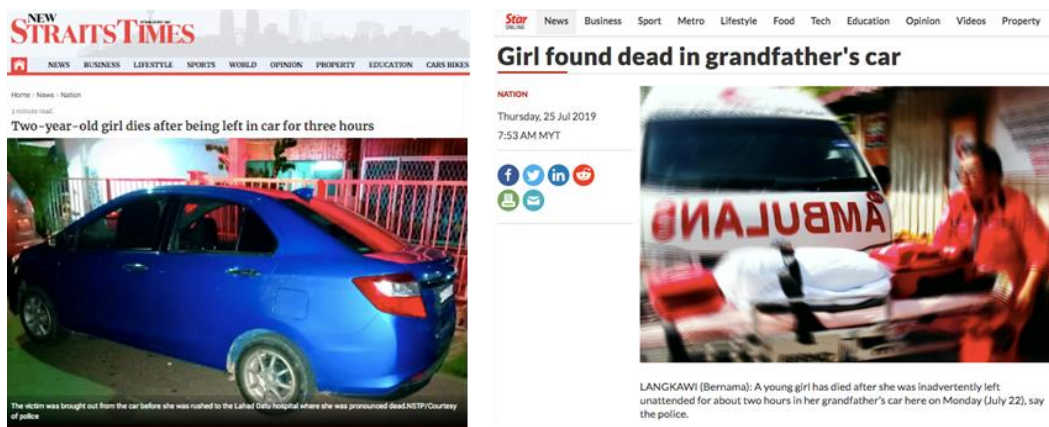


Figure 1: Newspaper clips regarding recent death cases (2019) of forgotten children in Malaysia

These unfortunate events often occur in countries with hot climate; usually caused by a condition called vehicular hyperthermia or vehicular heating, where the heat causes human core body temperature to exceed the normal value of around 37°C. As the core body temperature rises above 40°C, medical emergencies such as convulsions, coma, and ultimately, death can occur as depicted in Figure 2 (Ismail, 2018). Meanwhile, those who survive hyperthermia could experience severe and permanent neuropsychological deficits (Duzinski et al., 2014).

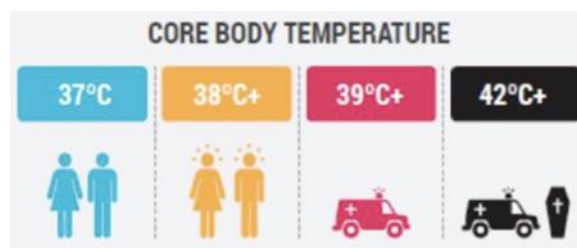


Figure 2: Effects of rising core body temperature (taken from Ismail, 2018)

According to Abu Kassim (2018), 80 % of the increase in vehicle interior temperature happens in the first 10 minutes, while Hwong (2018), a Child Passenger Safety Consultant from Childline Malaysia, reported that a car interior temperature can rise by 16°C within 20 minutes. There are also various studies on temperature increase in vehicles, as summarised by

Grundstein et al. (2010) in Table 1. This information on maximum temperature change rates inside motor vehicles should be useful in educating the public about the dangers of vehicle-related hyperthermia. The information provided by Grundstein et al. (2010) is vital, especially when coupled with temperature data within ASEAN countries. An article published by LivingASEAN in April 2017 outlined the highest recorded temperatures in the ten ASEAN countries (Figure 3). Myanmar recorded 47.2°C in May 2010, followed by Thailand at 44.6°C on April 28, 2016. Vietnam, Cambodia, Laos and the Philippines observed a temperature of around 42°C between 2015 and 2016, while Malaysia recorded 40.1°C at Chuping on April 9, 1998. Indonesia, Singapore, and Brunei all have recorded a maximum temperature above 35°C.

Table 1: A summary of maximum temperature change rates inside motor vehicles by Grundstein et al. (2010)

Study	5 min	10 min	30 min	60 min	Max	Instrument type and location	Parked (h)	Location and dates
Gibbs et al. (1995)	7	16	24	27	60	Electronic; placed on front seat	1.5	New Orleans, LA; 27 Jul 1995; 1430–1600 LT
Grundstein et al. (2009)					76	Electronic; 15 cm below roof center	6	Athens, GA; 1 Apr–31 Aug 2007
King et al. (1981)	19	21	25	25	66	Electronic; 15 cm below roof center	2	Brisbane, Queensland, Australia; summer 1978 and 1979; 1100–1300 LT
Marty et al. (2001)					89	Electronic	12*	Zurich and Chur, Switzerland; Jan 1995–Mar 2000
McLaren et al. (2005)	4–10	7–13	17–18	22–23	47	Electronic; 38 cm above rear seat	1	Freemont, CA; 16 days; 15 May–8 Aug 2002
Roberts and Roberts (1976)			15		45	Liquid in glass; 15 cm above front seat cushion	0.75	Baltimore, MD; Sep 1975; afternoon
Surpure (1982)					78	Liquid in glass; suspended from driver's seat	8	Oklahoma City, OK; first week, Jul 1980; 0800–1600 LT
Zumwalt and Petty (1976)					58	Liquid in glass; back seat	5	Dallas, TX; Jun–Oct 1975; 1200–1700 LT



Figure 3: The highest temperature recorded in ASEAN (LivingASEAN, 2017)

In order to prevent further increase in child death due to vehicular heating, the New Car Assessment Programme for Southeast Asian Countries (ASEAN NCAP) has included the requirement of Child Presence Detection (CPD) technology in its ASEAN NCAP Roadmap 2021-2025 (ASEAN NCAP, 2018). This safety issue is also dealt with in other NCAPs. For instance, Euro NCAP 2025 Roadmap (Euro NCAP, 2017) states that a technological solution would be introduced and shall be employed by 2022 to track a child in a car and notify the owner of the car or emergency facilities should the circumstances become harmful. ASEAN NCAP and Euro NCAP will compensate vehicle manufacturers that provide these solutions as standard. These solutions to detect children or other vehicle occupants may come in different types of technologies and approaches. Each technology performs and functions differently, with varying effectiveness.

This paper aims to establish a proper assessment methodology that covers the assessment procedure, score rating and implementation plan for ASEAN NCAP. Section 2 of this paper briefly outlines the CPD technology and vehicle reminder system, while Section 3 of this paper presents a comprehensive proposal for ASEAN NCAP's CPD assessment methodology. Section 4 presents some recommendations for implementation that could be useful to ASEAN NCAP, vehicle manufacturers and technology providers.

2.0 CHILD PRESENCE DETECTION

As an overview, a Child Presence Detection technology is a safety system designed to assist the driver to prevent the consequences of mistakenly left children in closed parked vehicles especially if the child is sleeping in an obscured position. CPD system may employ different types of technologies, which can be further categorised into three: integrated-in-vehicle; Child Restraint System (CRS)-based; and standalone system.

2.1 Integrated-in-Vehicle CPD Systems

Rosli et al. (2019a) reviewed a number of methods taken to detect a child present in the vehicle. Included in the paper is work conducted by Hashim et al. (2014) which designed a system that detects movements and sounds in a vehicle when a child is locked behind and sends an alert through Short Message Service (SMS). Samant et al. (2015) developed a system that employed a sound sensor to recognize the crying voice of a child, and a temperature sensor to monitor the vehicle temperature. If a child is detected when the temperature of the vehicle is above 35°C, the vehicle alarm will be activated.

Gonçalves (2018) presented a solution to prevent in-car infants' deaths, capitalizing on low-cost technologies that can easily be integrated on a vehicle, including utilisation of motion sensors and vision algorithms. While an integrated system is idealized to optimally recognise the presence of children inside the vehicle, the study suggested a stand-alone application might be viable. IEE, another technology developer, presented VitaSense that uses well-known 24 GHz low-power radio technology detects occupants based on their movements or breathing, even when they are sleeping (IEE, 2018).

The most advanced and commercially available system is Hyundai's Rear Occupant Alert equipped in 2019 Santa Fe for its American market (Hyundai, 2019). The system utilises an ultrasonic sensor to continuously monitor the rear seats after the vehicle is parked and all

doors are locked. Notification will be sent to the driver's phone through its Blue Link apps, while alerts will be provided via horn sounds and lights flash.

2.2 CRS-based CPD Systems

The National Highway Traffic Safety Administration (NHTSA) investigated a number of CRS-based electronic reminder devices that were referred to as Unattended Child Reminder Systems (UCRS). Selected UCRS described in the report (Rudd et al., 2015) are outlined as follows.

Aviso Child-in-Car Alert is an add-on vehicle-based and CRS-based system that interfaces with the vehicle's power and horn. The Aviso provides a detection confirmation tone when a child is placed in the CRS by sensing its weight, issues an end-of-trip convenience reminder when the vehicle power is shut off, and a left-behind alert if the child has not been removed from the CRS after the vehicle power is shut off for certain duration. Other systems using the same weight monitoring are called Forget Me Not, Suddenly Safe 'N' Secure Wireless Child Protection System, True Fit I-Alert, and ChildMinder Elite Pad System. Similarly, to the Aviso, these abovementioned systems rely on a weight sensor placed under the CRS covers to detect the weight of a child. Once the child is seated in the CRS, the sensor detects its presence and continuously monitors the child's presence. The information is delivered to a fob or smartphone through a transmitter module, where an LED flashes on the fob and notification sent to the driver's phone as long as the child's weight is maintained.

Another ChildMinder product is called ChildMinder SoftClip, which employs a retrofit chest clip containing a transmitter and closure switch. Like the ChildMinder Elite Pad System, an LED flashes on the chest clip and the fob as long as the chest clip is fastened. An SOS system (name of another product) is also constructed using the same concept as the ChildMinder SoftClip, with an additional interface to the vehicle's OBD-II port that supplies 12V power and vehicle status data.

2.3 Standalone CPD Systems

One example of standalone CPD is called the OleaVision™, developed by Olea Sensor Networks (2018). This life presence detector includes a wireless, contactless device, which can be installed in the cabin of any vehicles. OleaVision™ is able to detect the presence of a living being in the vehicle cabin, even if the subject is motionless or sleeping.

A different approach to the Child Presence Detection is a Vehicle Reminder System. For instance, General Motors introduced Rear Seat Reminder starting with GMC Acadia in 2016, and to its other models in 2017 and 2018. In 2017, Nissan North America added its Rear Door Alert starting with the 2018 Nissan Pathfinder. Good effort by these vehicle manufacturers; however, the reminder system is still insufficient to perform presence detection functions.

Based on a study conducted by Rosli et al. (2019b), 70 % of parents in Malaysia are willing to pay for the CPD system in the car because they are well aware of the risk relating to vehicular heating. Therefore, implementation of the CPD system may immediately start in Malaysia starting with the vehicle reminder system that should be immediately followed by a full CPD system in the near future – in line with ASEAN NCAP Roadmap 2021-2025. With this information, vehicle manufacturers and suppliers must enhance their effort in developing suitable systems for their products. ASEAN NCAP, on the other hand, should establish an

assessment plan for Child Presence Detection as part of the Child Occupant Protection pillar. A comprehensive proposal is presented in the next section.

3.0 A PROPOSAL FOR CPD ASSESSMENT METHODOLOGY

A comprehensive procedure is proposed for ASEAN NCAP's Child Presence Detection assessment methodology, as summarised in Figure 4. The flowchart describes a laboratory-based simulation to assess the effectiveness of a Child Presence Detection system. The procedure is constructed to assess functionality, repeatability, and effectiveness of the CPD system. An alternative assessment is included for Vehicle Reminder System (VRS). A more detailed procedure is explained as follows.

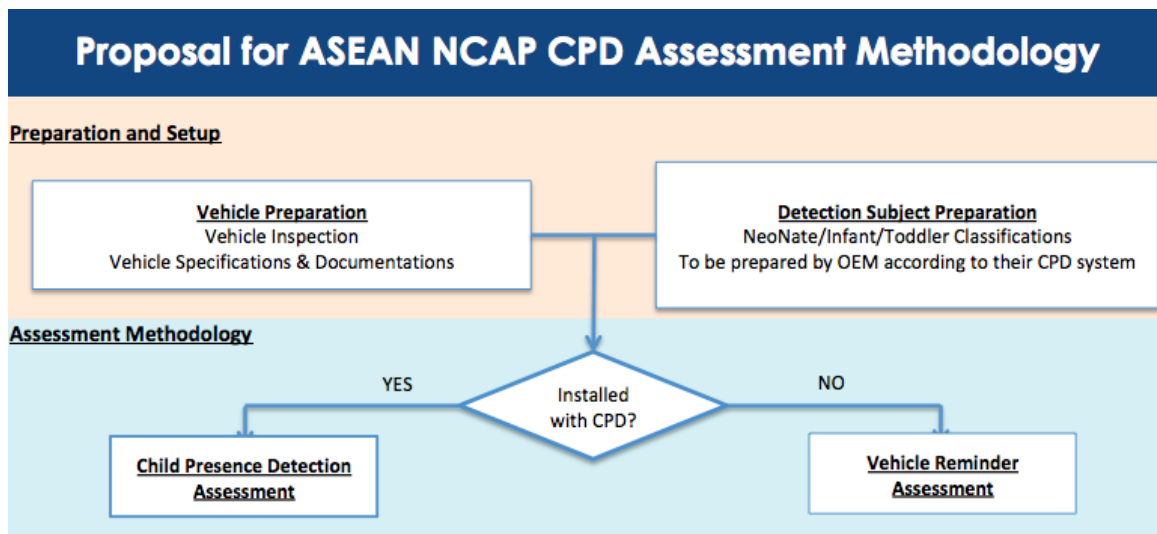


Figure 4: Summary of the proposal for ASEAN NCAP CPD assessment methodology

3.1 Vehicle Preparation

Vehicle preparation is conducted first by recording and confirming that vehicle make, vehicle model, model year, etc., are in compliance with all requirements stated by the vehicle manufacturers. Proper documentation shall be produced and signed by the assessor and witnesses.

3.2 Detection Subjects

The assessment procedure is designed to cover small occupants ranging from sleeping newborns (or neonate) up to children aged five years old. The Detection Subjects are classified according to age group, as detailed in Table 2. The classification is formulated based on the Paediatric Protocols for Malaysian Hospitals (Muhammad Ismail et al., 2018), followed by consultations with a number of Malaysian medical experts.

These Detection Subjects should be secured in suitable CRS accordingly, as stated in Table 3. The manufacturers may prepare a surrogate to represent the Detection Subjects in order to avoid using real children for the assessment. For example, the NHTSA used anthropomorphic test devices (ATDs) in its assessments.

Table 2: Detection subjects' classification

Detection Subject Classification	Age Group
Classification 1: Sleeping Neonate	Birth to 1 month
Classification 2: Infant	> 1 month to 2 years
Classification 3: Toddler	> 2 years to 5 years

Table 3: Detection subjects and CRS installation

Classification	CRS Direction
1 Sleeping Neonate	Rearward Facing (Rwd)
2 Infant	Rearward Facing (Rwd)
3 Toddler	Forward Facing (Fwd)

3.3 Assessment Methodology

As shown in Figure 4, the proposed assessment procedure would consider two situations: (i) a vehicle equipped with an integrated CPD system (Figure 5); and (ii) a vehicle equipped with an integrated reminder system (Figure 6). The assessment methodology for each category is explained as follows.

3.3.1 CPD Assessment Procedure

There are three levels of functions for the CPD assessment, as illustrated in Figure 5:

1. **Function 1: Detection**
The system must demonstrate its ability to detect the presence of children in parked vehicles by means of notifications to phone, fob, etc. that is perceptible by the driver.
2. **Function 2: Alert**
If no action is received from the driver, the vehicle must alert its surroundings by means of horns, hazard lights, alarm, etc. to attract attention.
3. **Function 3: Intervention**
The vehicle should initiate intervention measures (e.g., window down, engine on, etc.) to allow air ventilation into the car cabin if no further action is taken by the car driver.

The CPD assessment must be conducted by positioning the Detection Subject in CRS on each position at rear passenger seats and repeated until all three Detection Subjects are tested. A timeline of 5 minutes is suggested for the whole assessment duration, based on the findings presented by Grundstein et al. (2010) that indicated maximum in-vehicle temperature increase of 4-19°C within 5 minutes under hot weather. Furthermore, the short timeline will ensure that the driver is still in the vicinity of the parked vehicle to take immediate action.

3.3.2 Vehicle Reminder System Assessment Procedure

Similar to the CPD assessment, vehicles with a reminder system will undergo three stages of reminder assessment within 5 minutes, as shown in Figure 6. However, the assessment methodology is more straightforward than the CPD assessment.

1. **Reminder 01** – Shall provide an alert to the driver when the engine is turned off. Reminder alert may be introduced by means of audio or visual display at the car instrumentation panel, etc. that is easily perceptible by the driver.
2. **Reminder 02** – The vehicle must be able to provide a further reminder to the driver by means of notifications to phone, fob, etc. which should be turned off or snoozed by the recipient.
3. **Reminder 03** – If no action is received from the driver, a final reminder with more pronounced audio/visual measures should be introduced to attract the driver’s attention.

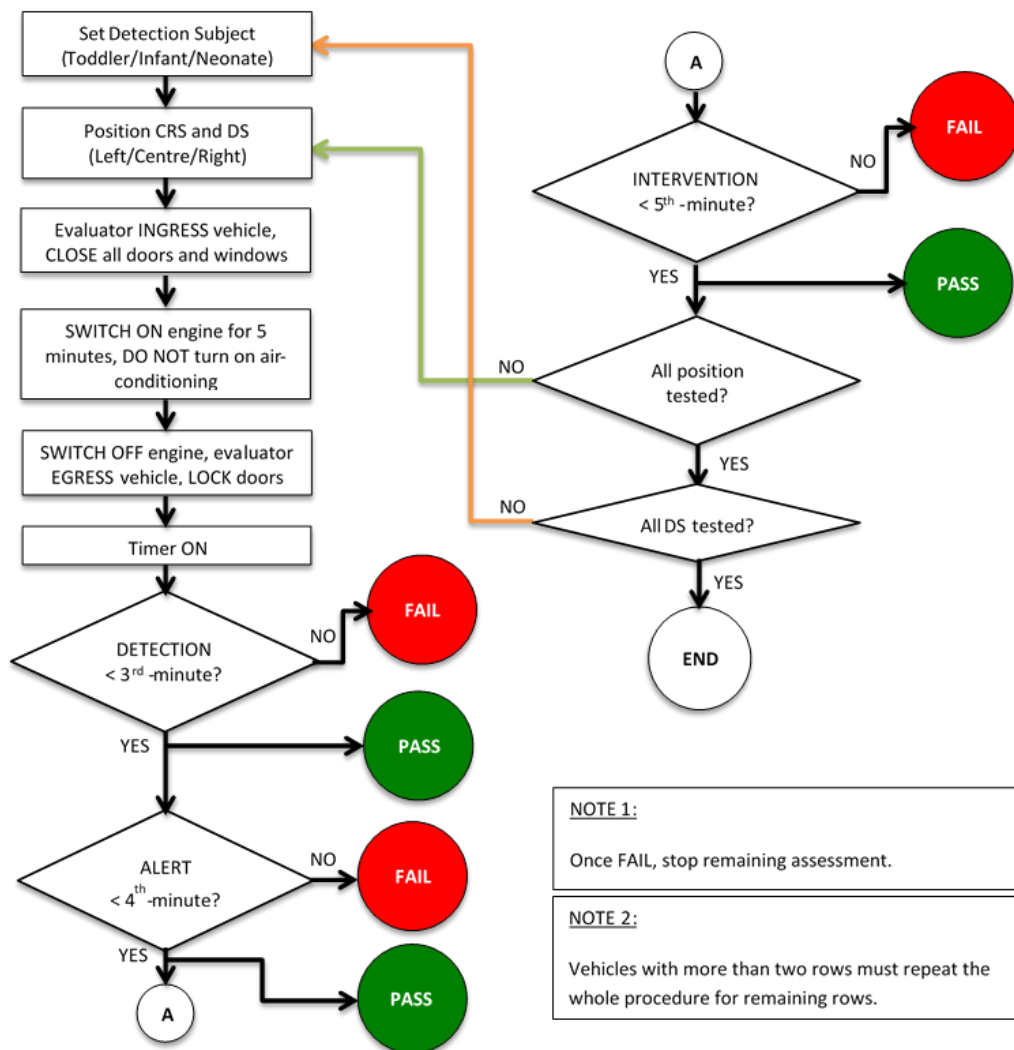


Figure 5: Flow chart of CPD system assessment methodology

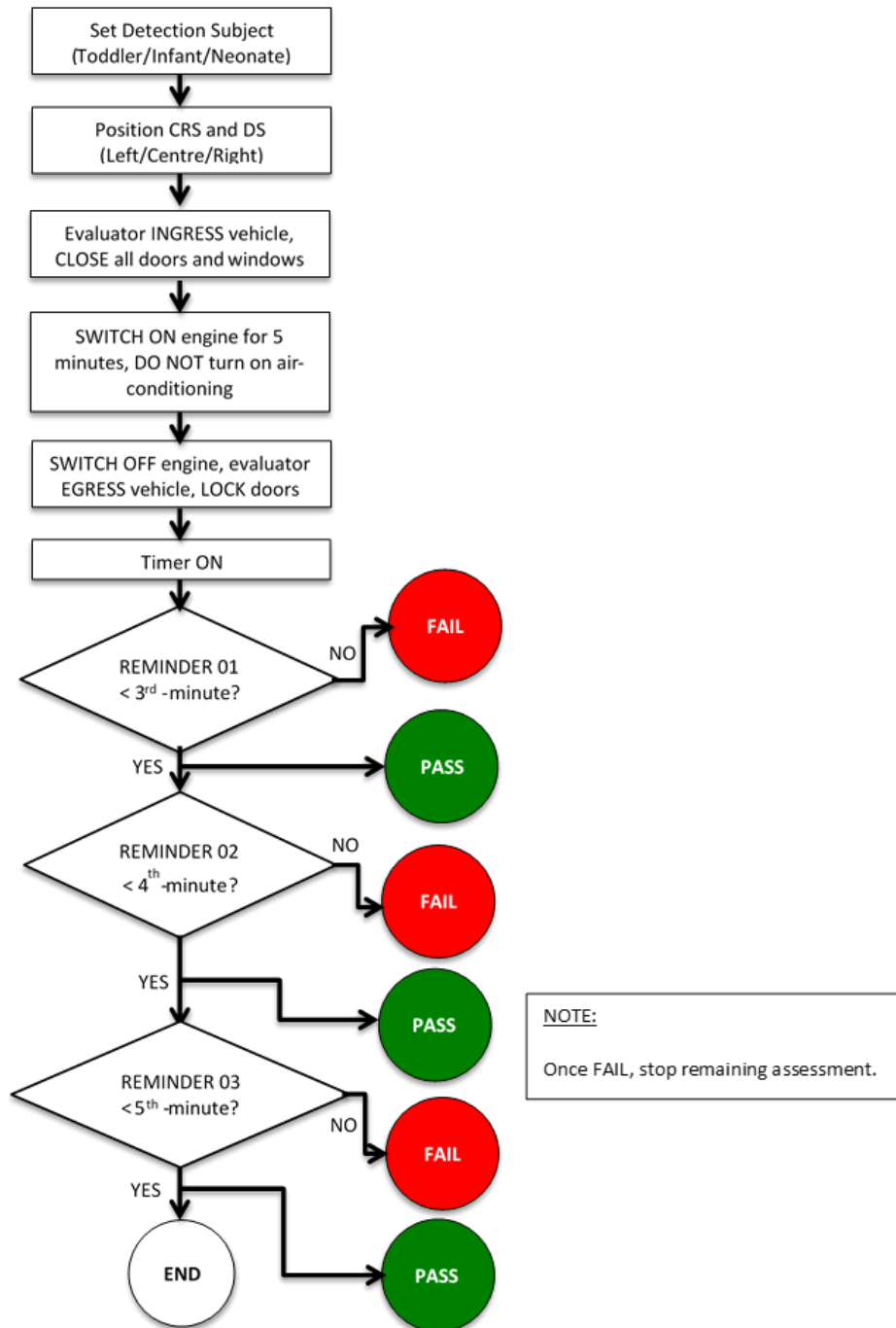


Figure 6: Flow chart of Vehicle Reminder System assessment methodology

3.4 Assessment Matrices and Scoring

Findings from each assessment will be recorded accordingly using the assessment matrices presented in Tables 4 and 5 for the CPD System and Reminder System, respectively. As stated in the flow chart, the assessment shall be concluded whenever it obtains FAIL status. Else, the assessment shall continue until completion.

Table 4: Assessment matrix for CPD system with full score rating

Child Presence Detection Assessment			DETECTION						ALERT						INTERVENTION						Score	Point
			2nd row			3rd row			2nd row			3rd row			2nd row			3rd row				
			Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right		
Classification	CRS Direction																					
1	Sleeping Neonate	Rwd	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	1.00	2.00
2	Infant	Rwd	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	1.00	
3	Toddler	Fwd	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	1.00	

Table 5: Assessment matrix for Vehicle Reminder System with full score rating

Vehicle Reminder System Assessment	REMINDER 01	REMINDER 02	REMINDER 03	Score	Point
	Pass	Pass	Pass	1.00	1.00

Assessment scoring is tabulated in Table 6. CPD system shall carry a full score of two points, while Vehicle Reminder System shall carry a full score of one point only. Scoring examples are given for more clarification of scoring.

Table 6: Assessment matrix for Vehicle Reminder System with full score rating

Assessment	Level	Criteria	Point
CPD	1	Coverage for all passengers – Sleeping Neonate Rearward Facing, Infant Rearward Facing, Toddler Forward Facing	2.00
	2	Coverage for Infant Rearward Facing, Toddler Forward Facing only	1.75
	3	Coverage for Toddler Forward Facing only	1.50
VRS	4	Coverage for Whole Vehicle	1.00

3.4.1 Scoring Examples

Example 1: No CPD system installed; a Reminder System is in-placed; gives reminder two times only within 5 minutes.

Vehicle Reminder System Assessment	REMINDER 01	REMINDER 02	REMINDER 03	Score	Point
	Pass	Pass	Fail	0.00	0.00

Example 2: CPD only detects Toddler within 3 minutes; gives second notification before fourth-minute; gives third notification before fifth-minute.

Child Presence Detection Assessment			DETECTION						ALERT						INTERVENTION						Score	Point
			2nd row			3rd row			2nd row			3rd row			2nd row			3rd row				
			Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right		
Classification	CRS Direction																					
1	Sleeping Neonate	Rwd	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	0.00	1.50
2	Infant	Rwd	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	0.00	
3	Toddler	Fwd	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	1.00	

Example 3: CPD only detects Infant within 3 minutes; gives second notification before fourth-minute; gives third notification before fifth-minute.

Child Presence Detection Assessment			DETECTION						ALERT						INTERVENTION						Score	Point
			2nd row			3rd row			2nd row			3rd row			2nd row			3rd row				
			Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right		
Classification	CRS Direction																					
1	Sleeping Neonate	Rwd	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	0.00	0.00
2	Infant	Rwd	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	Pass	Pass	Pass	N/A	N/A	N/A	1.00	
3	Toddler	Fwd	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	Fail	Fail	Fail	N/A	N/A	N/A	0.00	

4.0 RECOMMENDATIONS FOR IMPLEMENTATION

The proposed methodology is very comprehensive and may not be realizable for the year 2021 implementation. To give ample time for product development and vehicle integration to the manufacturers and product developers, it is recommended for ASEAN NCAP to execute the assessment in stages, with a view for full implementation by end of 2025 in accordance with their 2021-2025 Roadmap. The recommended assessment implementation is as follows:

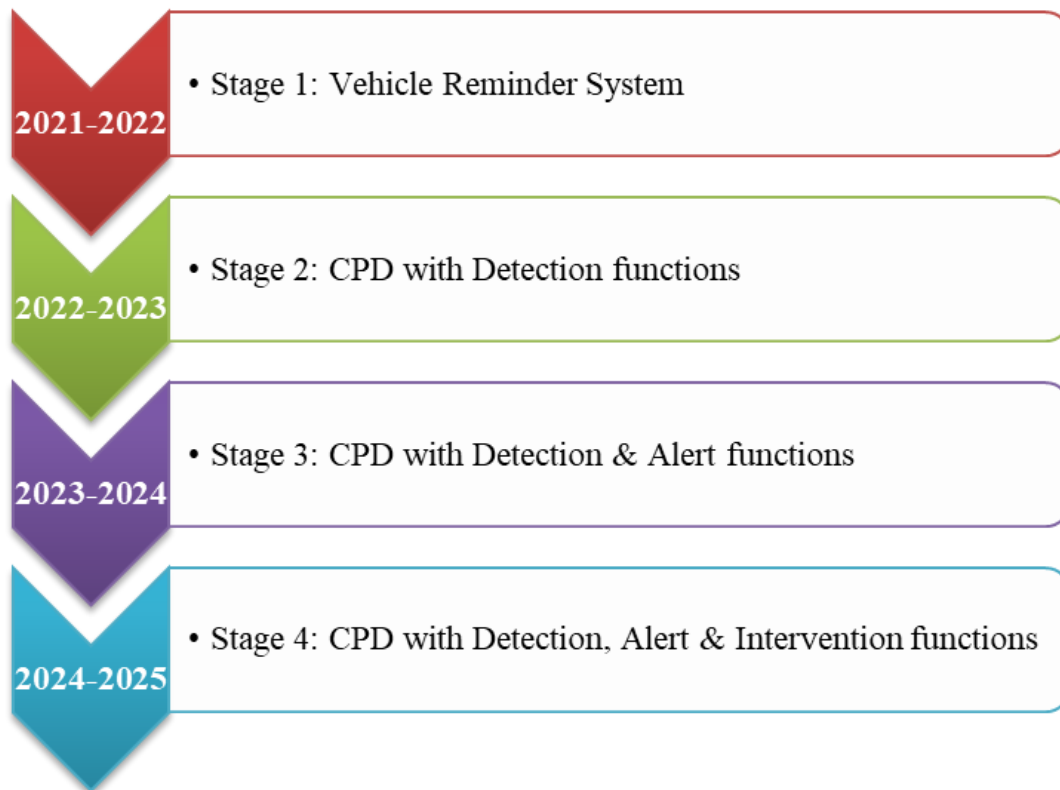


Figure 7: Recommendation for Implementation of CPD Assessment

Furthermore, ASEAN NCAP may want to expand CPD coverage to the elderly in the future. In addition, once the technology has matured enough, stricter scoring criteria could be introduced by assigning weightage to each Detection Subjects classification and also Level of Functions. Moreover, more points should be allocated to Child Presence Detection as the technology progresses.

5.0 CONCLUSION

This paper briefly outlines the significance of having a Child Presence Detection System in vehicles. ASEAN NCAP, as a sensible vehicle safety advocate, acted to the needs by the inclusion of CPD technology requirement in ASEAN NCAP Roadmap 2021-2025. Solutions to detect children or other vehicle occupants may come in different types of technologies and approaches, with varying performance, functions and effectiveness. Hence, a comprehensive assessment methodology that covers the assessment procedure, score rating and implementation plan for ASEAN NCAP is presented.

It is hoped that the methodology proposed in this document could help ASEAN NCAP in accomplishing its roadmap. Furthermore, it should also guide the vehicle manufacturers, product developers, and innovators to bring more robust child safety products to the market.

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