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A Systematic Review on the Autonomous Emergency Steering Assessments and Tests Methodology in ASEAN

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Abstract – *Safety should be the top priority for any automaker - because traffic accidents roughly killed 1.4 million people worldwide, ranking tenth on the World Health Organization's list of leading causes of death. Two decades ago, the focus was on passive safety, where it helps vehicle occupants to survive the crash. However, the frontier in safety innovation has moved beyond airbags and side-impact protection. Today, the frontier is active safety for preventing collisions before they occur. In Euro NCAP 2025 Roadmap, this active safety frontier falls under the primary safety and has become one of the overall safety rating initiatives toward safer cars. The primary safety features four technologies to be assessed, including driver monitoring (2020), automatic emergency steering (2020, 2022), autonomous emergency braking (2020, 2022), and V2x (2024). However, this initiative is partially encapsulated in the ASEAN NCAP Roadmap 2021-2025 under – 'Safety Assist' technological feature. For instance, in the new roadmap, ASEAN NCAP only focuses on Auto Emergency Braking (AEB) technology. This AEB is a feature to alert drivers to an imminent crash and help them use the car's maximum capacity. Therefore, as benchmarked to the EURO NCAP, this paper comprehensively reviews the AES demand, assessments, control, and testing methodology and can be further developed to consolidate for the ASEAN NCAP safety rating schemes.*

Keywords: Active safety, autonomous emergency steering, assessment scenario, ASEAN NCAP, front collision avoidance.

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1.0 INTRODUCTION

Safety should be the top priority for any automaker - because traffic accidents roughly killed about 1.4 million people worldwide, ranking tenth on the World Health Organization's list of top causes of death (World Health Organization (WHO), 2018). The crude death rate is even higher in countries with lower income (3 casualties per 10000 population) than countries with middle and upper income (2 casualties per 10000 population). Meanwhile, the traffic accident does not make it to the top 10 causes of death in high-income countries. These statistics show that the cause of death may relate to the absence of technology due to low purchasing ability. In this case, the technology that can improve road safety, such as smart traffic lights, traffic control systems, artificial intelligence, the use of telematics, and automotive technology (UNITAR, 2019). Vehicles with advanced safety technology can decrease the major traffic accidents that can lead to death, which this technology is affordable to people of high-income countries.

Two decades ago, the focus was on passive safety, where it helps vehicle occupants to survive the crash. Nevertheless, the frontier in safety innovation has moved beyond airbags and side-impact protection in which today, the frontier is active safety for preventing collisions before they occur. In Euro NCAP 2025 Roadmap, this active safety frontier falls under the primary safety and has become one of the overall safety rating initiatives toward safer cars (Euro NCAP, 2017). The primary safety features four technologies to be assessed, including driver monitoring (2020), automatic emergency steering (2020, 2022), autonomous emergency braking (2020, 2022), and V2x (2024). However, this initiative is partially encapsulated in the ASEAN NCAP Roadmap 2021-2025 under – 'Safety Assist' technological feature. For instance, ASEAN NCAP only focuses on Auto Emergency Braking (AEB) technology in which a feature to alert drivers to an imminent crash and help them use the car's maximum capacity (New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP), 2018). Therefore, as benchmarked to the EURO NCAP, this paper comprehensively reviews the AES demand, assessments, control, and testing methodology and can be further developed to consolidate for the ASEAN NCAP safety rating schemes.

2.0 METHODOLOGY

Information search is conducted in September 2020 using several search engine platforms, such as Google, Google Patent, and Web of Science (WoS). In Google search and Google Patent search, the keywords used are "autonomous emergency steering assessment." Meanwhile, in WoS, the searched keyword "autonomous emergency steering assessment" is accompanied by "assessment," "demand," "control," and "testing." Finally, the ten most relevant and recently published works related to the AES demand, assessments, control, and testing methodology were selected to be discussed in this paper.

3.0 RESULT

Article search using the Google search platform resulted in 3 articles from the industry, such as Eckert et al., (2011), CAN Newsletter (2014), Nissan Global (2012), and ZF (2015) that discussed the AES feature on passengers' cars. Different terms are used other than AES, such as Emergency Steering Assist (ESA) and Emergency Steering Control (ESC). However, the principle is the same, which is to automate the steering to avoid a collision. There are also research papers by Nilsson (2014), Yanagisawa et al. (2017) and Jeong & Oh (2017), which discussed the AES development and its implication for safety.

The top three patent search results come from BWI (Hac & Dickinson, 2004), TRW (Carsten et al., 2016), and Continental Teves AG (Hartmann et al., 2014). They explained that the AES research is the continuation of the AEB research since early 2000. AES's general idea is to predict the escape route based on the vehicle surrounding, sometimes based on the obstacle surrounding. Here, AEB will increase the time to collision for AES to predict the escape route before avoiding the crash.

The WoS platform's search results show that research on AES's assessment and demand aspects is still few compared to AES's control and testing aspects. Using keywords of “assessment” and “demand” in addition to “active emergency steering” resulted in 9 articles and three articles, respectively. Meanwhile, an additional keyword of control resulted in 61 articles, and the keyword of testing resulted in 22 articles. The search result makes sense because it should be well developed first before somebody can do an assessment. After that, the AES technology assessment output can give insight into common people when purchasing a vehicle. Selected three papers that cover assessment, demand, control, and testing aspects of AES, such as works by Kovaceva et al. (2020), Liu et al. (2018), Zakir et al. (2017), are further discussed in this paper.

4.0 DISCUSSION

This section is divided into four sections: assessment, demand, control, and testing aspects of AES.

4.1 AES Assessment

One of the control technologies related to safety features that are currently being developed is AES. Precise control quickly based on adequate surroundings to handle critical situations requires a must to have a good AES. According to Euro NCAP, AES is a technology in its infancy. Changes to legislation expected in 2022 are deemed necessary to allow full exploitation of its potential. AES shall automatically steer from the technology viewpoint to help avoid accidents when a potential collision is detected, which is advantageous compared to a safety system with AEB. Moreover, the AES system could potentially be part of an advanced driver-assistance system (ADAS) towards future automated driving or autonomous vehicles. Many researchers have reported their progress in AES vehicles (Jeong & Oh, 2017; Liu et al., 2018; Nilsson, 2014; Zakir et al., 2017). However, very few automatic steering intervention systems are currently offered, lacking specific assessments and effective measures. Appropriate assessment is necessary to anticipate the technology before being distributed in the market – for instance, the safety rating of a new car in the ASEAN NCAP.

Assessment transition is necessary from a technology-based approach (e.g., test for AES and/or AEB only) to more scenario-based assessments that allow various types of interventions (e.g., braking and steering) (ASEAN NCAP, 2018). The evaluation should be ready whatever the technology that will come up in the future. An example of a technology-based approach has been proposed by researchers (Liu et al., 2018; Zakir et al., 2017). A novel emergency steering control strategy is based on hierarchical control architecture consisting of decision-making and motion control layers. The proposed control strategy has improved effectively to perform an emergency collision avoidance maneuver. Emergency steering assist (ESA) systems and their technologies have been developed for the past ten years (CAN Newsletter, 2014). For instance, a giant automotive supplier, Continental, has launched its ContiGuard ESA system already in 2010. Two years later, a Japanese automaker Nissan has presented the idea of a self-developed assistant, which steers in emergencies on its own. In contrast, TRW Automotive has developed since some years of driver-assist systems based on radar and video camera systems. It is anticipated that the technology will be ready for production in 2017 for 2018 model year applications.

4.2 AES Demand

Safety and comfort are features embedded in many modern vehicles to meet market demands of reducing road accidents. Combination of steering and pedal control to ensure safety and comfort is inseparable (Morando, 2019). From these activities came various safety technologies, such as Advanced Driver Assistance Systems (ADAS), Adaptive Cruise Control (ACC), Forward Collision-Avoidance (FCA), (LDWS) Lane Departure Warning System (Guo, Hu, & Wang, 2016). Researchers and automotive companies still debate about the safety system's effectiveness because system failure is dangerous for the driver. However, this is a great opportunity to sell the product and build trust with the buyers if the safety system assessment shows that it can run with fewer errors (Victor et al., 2018). Crashes or collisions are caused by human error, such as the driver's delayed reaction due to an obstacle's sudden appearance. The current AEB system shows the potential to avoid or mitigate many crashes. Still, AES, although technically more demanding, may deliver a further significant reduction in collisions and casualties, in particular scenarios for a single vehicle and small overlap crashes and accidents involving vulnerable road users, such as cyclists and pedestrians (Kovaceva et al., 2020).

4.3 AES Control System

AES is a lateral safety system that controls the steering rotation in emergency due to potential collision (Eckert et al., 2011). The system employs complex vehicle models and rigorous mathematics. However, the main idea is to avoid the obstacle by rotating the steering, preventing a collision. AES control, in particular, is developed to solve collision avoidance problems in a high-speed scenario (highway traffic) (Liu et al., 2018; Zakir et al., 2017), where AEB control only is more suitable for slow-speed scenario (urban traffic) (Hartmann et al., 2014; Nissan Global, 2012). The longitudinal distance to the obstacle is less in high-speed scenarios; thus, it is not suitable to avoid the crash using AEB. However, it does not mean that AES works alone without AEB; instead, the combination of both systems is compulsory. When a potential collision is detected, the driver must make several judgments and decisions, such as "What is the obstacle type?" "When should I break or steer?" "Where to escape?" and so on. There is so much information to be processed in a split time second, which then delays the driver's reaction. Here, ADAS, which integrates both the AES and AEB, helps the driver alarm the driver, brake the vehicle, and turn the steering. First, the system alarms the driver about potential collisions ahead. If the driver does not respond until the last point to brake or the collision is imminent, then AEB is activated to decrease the vehicle speed in lane, allowing more driver reaction time. If the driver still fails to react until the last point to steer (Nissan Global, 2012) or they have a reaction, but the steering torque is not enough (ZF, 2015), then AES is activated to avoid the crash by performing automatic lane change. The decision on when to initiate the AES assist probably in a crucial split-second, and the optimum braking distance that ensures the effectiveness of the AES is still an open issue, and it requires further assessments.

In Figure 1, the flow of the collision avoidance system is started from scanning the surrounding situation, such as the obstacle type (big or small) (Zakir et al., 2017), vehicle or pedestrian (Kovaceva et al., 2020), static or dynamic (Liu et al., 2018), the lane type (Hartmann et al., 2014), road type (Hac & Dickinson, 2004), and traffic conditions (Jeong & Oh, 2017). In terms of obstacle type, the system should be concerned about the dimension. Failure to assess the dimension will increase the probability of edge collision. (Zakir et al., 2017) use an invisible rectangular to increase the dimension of the obstacle, thus creating more safe escape routes.

The lane type, road type, and traffic information narrow the optimal escape route options. An optimal escape route should not be a pedestrian sidewalk, lane occupied by oncoming vehicles, or a damaged road (Jeong & Oh, 2017). Commonly used sensors for the scanning process are cameras, radar, and LIDAR (CAN Newsletter, 2014; Nissan Global, 2012; ZF, 2015). At least one sensor must generate environmental information about the obstacle ahead (Carsten et al., 2016). Communication between two vehicles can also help to enrich the information. Meanwhile, electronic maps can also obtain environment information in a wider area but less accurately in smaller regions than direct sensors on vehicles. Finally, after determining the optimal escape route, the system tracks the escape route trajectory with a small error by applying AES and AEB.

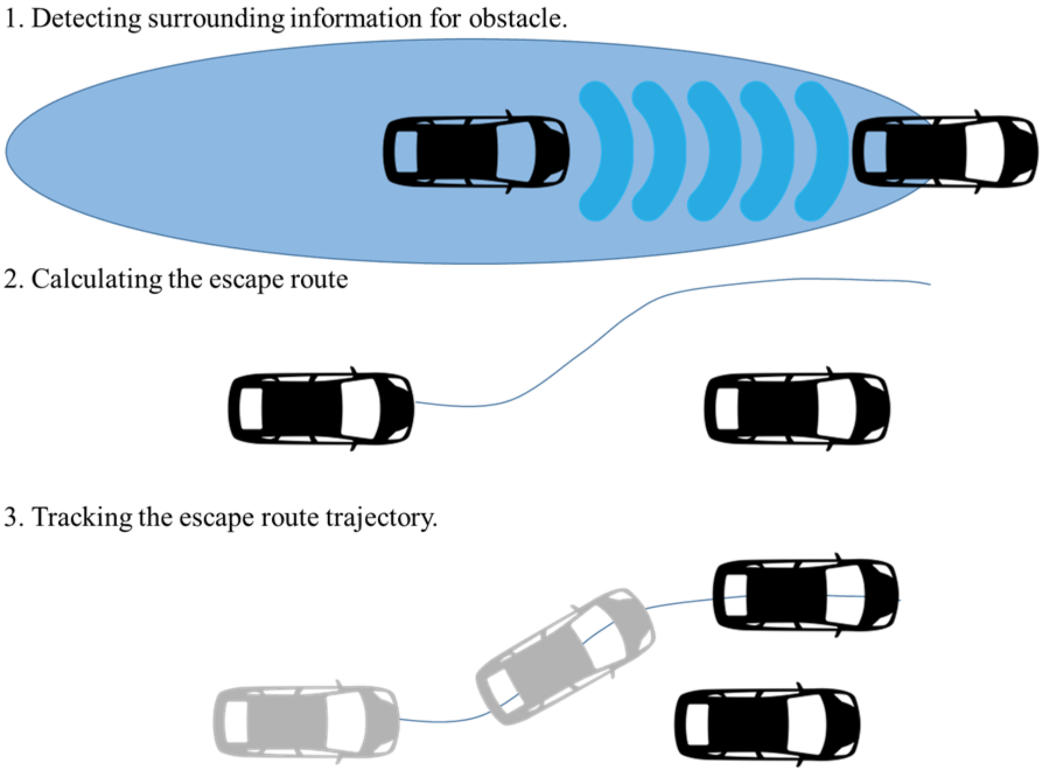

Figure 1: Algorithm flow of collision avoidance system by applying AEB and AES to track the escape route trajectory

4.4 Testing Methodology of AES

Common approaches to test the developed AES control are experiment and simulation. Both methods have advantages and disadvantages. The experiment is the most appropriate way to verify the driving system (Nilsson, 2014), where AES implementation is conducted in a real situation. Although the result is more certain to be valid, the challenge is the collision scenario's fabrication. For instance, (Eckert et al., 2011) demonstrated the fabrication of collision scenarios in a closed circuit. Besides ensuring the driver's safety issue during the test, the researcher also had to ensure that the driver can feel the real situation during collisions in the experiment. Eckert et al. (2011) manipulate the shock caused by the sudden obstacle appearance by not saying anything about it to the test vehicle's driver. The experiment's testing numbers are limited, making the conclusion drawn from the experiment not be generalized.

Meanwhile, the simulation approach allows multiple scenario testing in a short time with less effort and less risk (Yanagisawa et al., 2017). However, the reliability of simulation results is very dependent on the verification and validation of models with measurable idealization. Real-world data should drive the scenario cases, which ensures the validity of the testing result. Therefore, a combination of both methods will ensure the testing result's validity, as demonstrated by (Kovaceva et al., 2020).

When doing the testing, a high number of scenarios are more preferred than a small number. Variation of the surrounding situation (obstacle, lane, and road type) creates multiple scenarios. A list of testing scenarios from literature reviews is summarized in Table 1. Common scenarios, as shown in Figure 2, Figure 3, and Figure 4, respectively, are (1) the vehicle coming into the obstacle whether the obstacle is static or moving, (2) sudden obstacle appearance from the side, and (3) incoming obstacle from opposite vehicle's lane crossing the lane. The vehicle to escape from the lane is compulsory but returning to the lane after avoiding the collision is optional. The most important thing is that the system should ensure that no other vehicle is on that lane when escaping the lane. As for the record, statistics have shown that about 20 percent of Killed and Seriously Injured (KSI) originate from loss of control (UK Road Accidents Safety Data, 2015). Frontal collisions with a small overlap account for around 15 percent of all car accidents and 25 percent of all car accidents involving a frontal collision (Kuehn et al., 2013). This situation amounts to approximately 10 percent of KSI in small overlap crashes, while vulnerable road users KSI account for 36 percent. Thus, considering all the scenarios is paramount and will facilitate AES's development and fitment, especially for automakers.

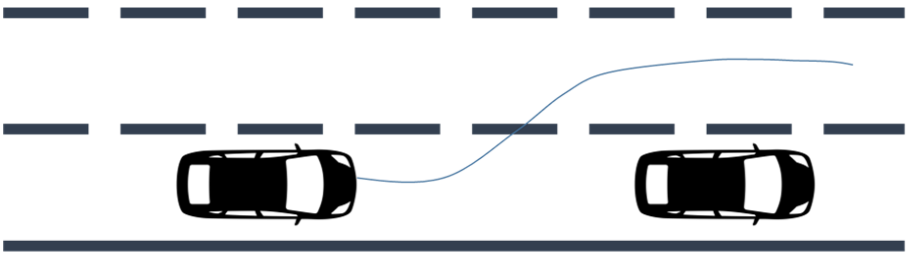

Figure 2: Common scenarios for AES testing: in the front static or moving obstacle

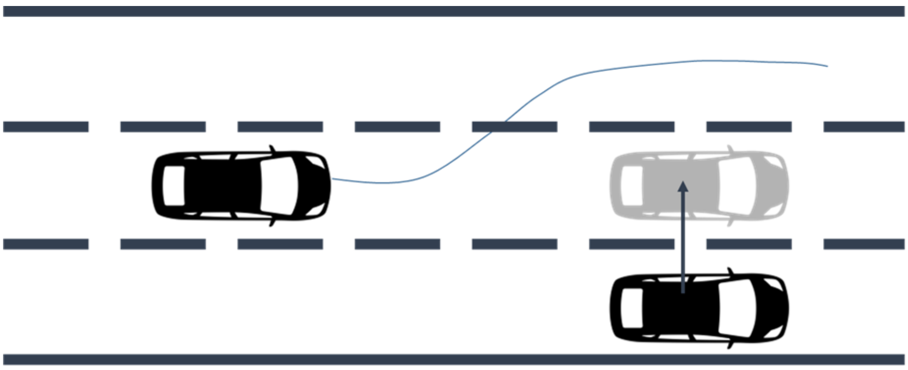

Figure 3: Common scenarios for AES testing: the sudden appearance of obstacles from the side lane

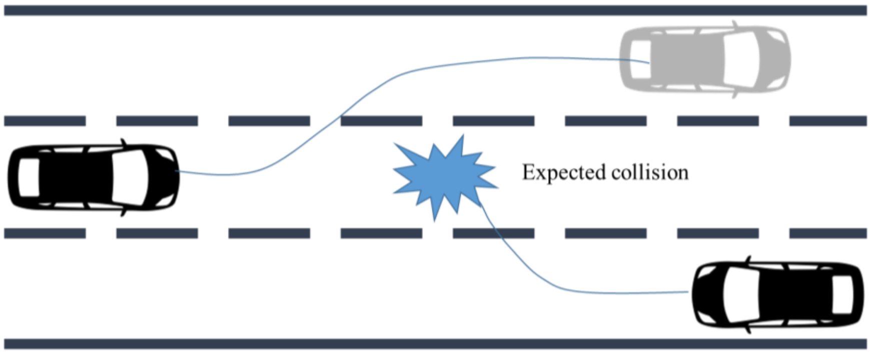

Figure 4: Common scenarios for AES testing: incoming obstacle crossing the lane

Table 1: List of the testing scenario of AES

Previous Works	Scenario	Scoring parameter
(Nissan Global, 2012)	1. In the front moving obstacle, the vehicle escapes the lane. 2. Sudden obstacle from the right side, vehicle moves to escape the lane. 3. Incoming moving obstacles from the opposite lane, the vehicle escapes the lane.	Unreported.
(Kovaceva et al., 2020)	1. Slow obstacles coming from the right and left, when vehicles turn right, left, or going straight in an intersection.	- Crash avoided or mitigated. - If mitigated, what is the speed reduction?
(Liu et al., 2018)	In the front moving obstacle, the vehicle escapes the lane.	- Error to reference trajectory
(Zakir et al., 2017)	1. In front of one static obstacle, vehicles escape the lane then return to the lane after avoidance. 2. Two static obstacles in front of the vehicle, vehicles escape the lane. 3. Two static obstacles in front of the vehicle, vehicles escape the lane then return after each crash avoidance. 4. In the front moving obstacle, vehicles escape the lane then return to the lane after avoidance.	- Error to reference trajectory. - The calculation time of AES. - Time to collision during AES activation.
(Yanagisawa et al., 2017)	1. Sudden obstacle from the right side, vehicle moves to escape the lane. 2. Incoming moving obstacle from the opposite lane, vehicle moves to escape lane	- The numbers of collision cases. - Pedestrian's injury degree.

The scoring systems are divided into two categories: avoidance occurrence and trajectory tracking error. Avoidance occurrence is suitable for assessing the AES's functionality. At the same time, trajectory tracking error is ideal for determining the AES control performance. In the case of the ASEAN NCAP safety rating, the scoring system based on avoidance occurrence is more preferred to be implemented because it explicitly tells us the system's benefit. For example, the percentage of collision occurrence when using the AES. and the degree of injuries when AES mitigates the collision involving pedestrians (Jeong & Oh, 2017; Yanagisawa et al., 2017).

5.0 CONCLUSION

In this paper, the assessment, demand, control, and testing aspects of an AES have been discussed. AES is designed to help the driver avoids collisions in a split-second emergency by turning the steering automatically. The safety technology is predicted to be launched soon in the future, according to Euro NCAP. Despite that, the necessary assessment framework is still absent, probably caused by very few automatic steering intervention systems currently offered to be assessed. Previous research works had shown several scenarios that are used to test the developed AES. The most common scenarios are the front static or moving obstacle and the sudden appearance of obstacles from the side lane. These scenarios can be adopted to design a scenario-based assessment framework for the future ASEAN NCAP safety rating scheme. Avoidance occurrence is then suggested as the scoring method. A high percentage of collision occurrence and a low degree of injury due to collision mitigation means a high score or rating.

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