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Assessment of Road Safety Performance for Southeast Asian Countries

A. K. Jameel[*1,2] and H. Evdorides[2]

[1]Highway and Transportation Department, Faculty of Engineering, Mustansiriyah University, P.O. Box 14022, Waziriya, Baghdad, Iraq
[2]University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom

[*]*Corresponding author: akj308@bham.ac.uk*

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Abstract – *The aim of this research is to assess the road safety performance in Southeast Asian countries to measure to what extent the new vision "safe system" is considered in the national road safety strategies. For this, a road safety index RSAI(ESA) is developed to use as a tool of assessment. The theoretical framework is based on the main pillars of safe system principles: safer roads and mobility, safer vehicles, and safer road users. A set of indicators are selected based on specific criteria. Each indicator is weighted, normalised, then aggregated using a simple linear additive aggregation method to construct the RSAI(ESA). This index is used to assess the performance of road safety in Southeast Asian countries, and then to rank the countries accordingly. The results show that the countries which have high rate of road crashes have started to take action to solve road safety problems, while some countries need to take further steps to apply the recommendations of the DARS 2011-2020. The setting of the minimum vehicle safety standards regulated by the United Nations (UN) is the most critical element that all the countries in this region should consider in their road safety strategies.*

Keywords: Road safety, safe system, Asian countries

1.0 INTRODUCTION

Road safety is widely recognised as an important issue. Road crashes kill around 1.25 million people annually worldwide of which 316,000 are in the World Health Organization's (WHO) Southeast Asia Region, accounting for 25% of the global rate (WHO, 2013, 2015a, 2015b). This rate is greater by approximately 18.5% than the rate of road deaths and injuries in European countries, which have the lowest rates of road fatalities (Jackisch et al., 2015).

Global organisations, such as the United Nations (UN) and the WHO, recognise this issue and have set plans with targets to control the increasing road crash rate. The Decade of Actions on Road safety 2011-2020 (DARS 2011-2020) plan is an example of a global plan to reduce the rate of road fatalities by around 5 million by 2020. The setting of a target to reduce road fatalities by 50% by 2030 in the 2030 agenda of the UN's sustainable development goals (SDG) is another example. These global organisations recommend taking lessons from countries that have achieved significant declines in road fatalities and injuries (WHO, 2013, 2015a) such as Sweden and the Netherlands (Wegman et al., 2006; Belin et al., 2012). These countries have produced a new vision, which considers that the road transport elements – road infrastructure and vehicles – should be designed to accommodate road users' needs and mistakes. This vision corrects the traditional view, which considered that road user behaviour was the main cause of road safety issues (International Transport Forum, 2016; Wooley et al., 2018).

The new vision, which is called the safe system, is highly recommended by the UN and the WHO as a way to improve road safety levels. The actions recommended in DARS 2011-2020 are based on the safe system concept (WHO, 2011). The concept of the safe system is based on four pillars: safer road infrastructure; safer speed management; safer vehicles, and safer road-user behaviour (International Transport Forum, 2016; Wooley et al., 2018).

Regarding safer road infrastructure, policies based on the safe system recommend providing formal and regular road audits and inspections for both new and existing roads. It is also recommended to promote a safe system in designing roads by incorporating the standards of 'forgiving' road design, which considers the mistakes of road users, and of 'self-explaining' roads, which consider the needs of road users. Setting a minimum safety rating for road mobility using rating programmers is suggested in order to set quantifying targets. In addition, it is recommended to promote walking, cycling, and using public transportation as alternatives to using passenger cars, in order to reduce the mobility size of motorised vehicles. Furthermore, it is recommended to protect vulnerable road users by promoting separated roads. Safer speed limits are suggested, which should be set according to the class of roads, especially where there is a high density of pedestrians and cyclists. This is essential to reduce the impact of energy in crash events and therefore reduce the severity level of crashes (WHO, 2011, 2015a).

For safer vehicles, the recommendations of the safe system policies focus on providing crash avoidance technologies, such as Electronic Stability Control (ESC) and Anti-lock Braking System (ABS), as well as crashworthiness technologies such as seat belts and seat belt anchorages. It is recommended also to consider vulnerable road users in the layout design. Since the New Car Assessment Programme (NCAP) provides a valid assessment methodology which considers crash avoidance and crash-worthiness in layout design and supports this with innovated technologies (Lie & Tingvall, 2002; van Ratingen, 2017; Euro NCAP, 2017), this programme is recommended for use in rating the safety of vehicles (WHO, 2011, 2015a).

For safer road user behaviour, it is recommended to enhance the road safety laws with safer measures regarding speed limits and maximum blood alcohol content (BAC) to prevent crashes and reduce the severity of their consequences. It is also recommended to set laws and evidence-based standards for seat belts, child restraints and helmets, which could also reduce crash severity levels. Furthermore, it is suggested that consuming drugs or using mobile phones while driving should be considered carefully, as the rate of road crashes involved with these two factors is increasing.

1.2 The Aim and Objectives of the Research

The question raised in this paper is whether the safe system is considered in national road safety strategies in Southeast Asian countries. To find an answer to this question, an assessment is needed.

This paper aims to assess the performance of road safety in the Southeast Asia region. The objectives set to achieve this aim include defining the indicators of road safety performance based on the safe system concept, developing a mathematical model of assessment, and applying the developed model to data from the countries in this region.

1.2 Literature Review

In this section, road safety studies are reviewed according to the indicators that are used for assessing road safety performance. This discussion is focused on the indicators of the safe system components.

Regarding the indicators of the safer road infrastructure, the European Transport Safety Council study (European Transport Safety Council, 2001) considers the percentage of roads fitting the standards of road safety design and the percentage of roads fitting in the road network hierarchy as the most comprehensive indicators of safer road infrastructure. The SafetyNet project has made a new proposal for the indicators of road safety performance (Vis, 2005; Vis & van Gent, 2007; Hakkert et al., 2007). It uses the European Road Assessment Programme (EuroRAP) as a valid methodology for assessing the safety of road infrastructure design. EuroRAP, which is the European version of the Road Assessment Programme (RAP), indicates the safety level of road infrastructure in terms of star ratings: five-star ratings are given to safer roads, while one-star ratings indicate those that are the least safe. This methodology considers crash avoidance and crash-worthiness measures in assessing road safety (Turner et al., 2009; Harwood & Mclnerney, 2011; Lynam, 2012). Al-Haji (2007) and Chen et al., (2017) conducted a study to construct a composite of indicators of road safety performance in Asian countries. The indicator that these studies use to reflect the safety of a road's infrastructure is the percentage of the road that is paved. This indicator is selected based on the available data and not on a full reflection on the factors of road infrastructure safety. Hermans (2009) conducted a study for European countries, selecting the infrastructure network density as the indicator, which was based on the availability of relevant data. The selection of indicators by Shen (2012) and Tešić et al. (2018) was also based on data availability. They select the percentage of the motorway length and the motorway density to measure the road infrastructure hierarchy. The percentage of a road separated for walking and cycling is selected by Shen (2012), as the recent policies recommend to consider vulnerable road users and separate their road infrastructure.

Regarding safer speed management, no study has identified indicators related to setting speed limits. However, the RAP methodology considers the speed limit as one of the indicators for identifying the star ratings of road sections (Turner et al., 2009; Harwood & Mclnerney, 2011 Euro NCAP, 2017).

Regarding safer vehicles, the European New Car Assessment Programme (Euro NCAP) (the European version of NCAP) is used to indicate vehicle safety by some European studies (European Transport Safety Council 2001; Koornstra et al., 2002; Vis, 2005; Vis & van Gent, 2007; Hakkert et al., 2007; Wegman et al., 2008). Like Euro RAP, Euro NCAP indicates the results of its assessments in the form of star ratings (Lie & Tingvall, 2002; van Ratingen, 2017;

Euro NCAP, 2017). The output of the Euro NCAP methodology is disaggregated into four types of star ratings: adult occupants; child occupants; pedestrians, and safety assistants. These four scores are then aggregated into one overall star rating. Therefore, some studies use the disaggregated indicators of Euro NCAP star ratings as indicators of vehicle safety (Shen, 2012; Bax et al., 2012). European studies have incorporated indicators related to the age of a vehicle to refer to the vehicle's safety level (Koornstra et al., 2002; Vis, 2005; Vis & van Gent, 2007; Hakkert et al., 2007; Wegman et al., 2008). Other studies use the age of a vehicle as the unique indicator of its safety (Herman, 2009; Shen, 2012; Tešić et al., 2018). However, these studies are based on the traditional view that a newer vehicle is safer than an old vehicle. Recent studies have demonstrated that newer vehicles are safer because they are equipped with technologies that improve crash avoidance and crashworthiness (Hermans et al., 2009; Gitelman & Vis, 2007). This is already considered by Euro NCAP (Shen, 2012; Bax et al., 2012). Vehicle composition is another indicator selected in some studies (Koornstra et al., 2002; Al-Haji, 2007; Wegman et al., 2008; Shen, 2012; Lynam, 2012) to reflect the vehicle compatibility. However, there has been no valid methodology developed to measure vehicle compatibility.

Regarding the indicators of road user behaviour, they are those most often selected in previous studies because the traditional vision focused on road user behaviours as the only causes of road crashes (WHO, 2015a). Table 1 shows a summary of the indicators of road user behaviour that are selected in the reviewed studies. Exceeding the speed limit, drinking alcohol, and wearing seat belts are the most selected indicators in the previous studies. Using child restraints and using helmets are also considered by some studies, where there is available data related to these two indicators.

Table 1: The indicators of road user behaviour which are selected in the previous studies

The authors / **The individual indicators**	**The selected indicators of the road user behavior**								
	ETSC (2001)	SafetyNet (Vis, 2005; Vis & van Gent, 2007; Hakkert et al., 2007)	AL Haji (2007)	SUNflower (Koornstra et al., 2002; Wegman et al., 2008)	Hermans (2009)	Bax et al. (2012)	Shen (2012)	Chen et al., (2017)	Tešić et al. (2018)
% drivers driving above legal limit	X	X			X	X	X		X
% > BAC limit (0.05 for general drivers and 0.02 for young/novice and commercial drivers) *	X				X		X		X
% of fatalities involving alcohol and drug consumption		X		X			X	X	
Roadside police alcohol tests per 1,000 population						X			
% wearing seat belts	X		X		X				X
% wearing seat belt by drivers and front seat occupants, % wearing seat belt by rear seat occupants		X		X		X	X	X	
% of children using child restraints in front and rear seats	X						X		
Rate of wearing helmets by two-wheeled vehicle occupants (drivers and passengers)		X	X					X	

2.0 METHODOLOGY

To achieve the aim of the research, the following steps will be carried out:

1. Selecting indicators related to the safe system concept and can be measured by the available open-access data in southeast Asian countries.
2. Developing an aggregation model to construct the composite indicator of road safety performance assessment.
3. Using the developed composite indicator to assess the road safety performance of the selected countries.
4. Ranking the countries according to the developed composite indicator.
5. Ranking the countries according to the real crash rate.
6. Comparing the two rankings to test the validity of the developed composite indicator in assessing road safety performance.

2.1 Selecting the Indicators of Road Safety Performance

A set of indicators are suggested in this research based on the recommendations of the policies based on the safe system and based on the selected indicators in the reviewed studies. These suggested indicators are evaluated in this section according to specific criteria: the relevancy to the safe system concept; comprehensiveness; measurability; independency, and data availability (Booysen, 2002; Ledoux et al., 2005; Al-Haji, 2007; Tešić et al., 2018). Table 2 shows the results of the evaluation of the suggested indicators.

Table 2: The evaluation of the suggested indicators

The thematic indicators	**The individual indicators**	**The criteria for selecting indicators**				
		Relevant to Safe System	Measurable	Comprehensive	Independent	Data Available
Safer road infrastructure	% of roads meeting design standards	X		X		
	% of the paved roads per total network	X	X			X
	EuroRAP scores	X		X		
	% of roads with vehicle occupants RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads with motorcyclists RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads with pedestrians RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads with bicyclists RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads fitting in road network hierarchy	X		X		
	% of motorways in total length		X			X
	Infrastructure network density		X			X
	Motorway density		X			X
	% of separated walking and cycling infrastructure *	X	X			
	% of roads with RAP star rating ≥ 3 stars*	X	X	X		X
	Road audit and inspection effectiveness score	X	X	X		
Safer speed	% of urban roads with max speed limit < safer speed*	X	X			X
	% of rural roads with max speed limit < safer speed*	X	X			X
	% of motorways roads with max speed limit < safer speed*	X	X			X
	% of vehicle awarded 5 stars*	X	X	X		X
	% of roads with vehicle occupants RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads with motorcyclists RAP star rating ≥ 3 star * **	X	X	X	X	X
	% of roads with pedestrians RAP star rating ≥ 3 star * **	X	X	X	X	X

The thematic indicators	The individual indicators	The criteria for selecting indicators				
		Relevant to Safe System	Measurable	Comprehensive	Independent	Data Available
	% of roads with bicyclists RAP star rating ≥ 3 star * **	X	X	X	X	X
Safer road user behavior	% drivers driving above legal limit	X	X	X	X	X
	Effective score of speeding enforcement* **	X	X	X	X	X
	% > BAC limits which are 0.05 for general drivers and 0.02 for young/novice and commercial drivers	X	X	X		
	% of fatalities involving alcohol and drug consumption	X	X	X		X
	Effective score of drinking-driver enforcement * **	X	X	X	X	X
	Road-side police alcohol tests per 1,000 population	X	X			X
	Effective score of drug enforcement*	X	X	X	X	
	% wearing seat belts, % wearing seat belt by drivers and front seats occupants, % wearing seats by rear seat occupants	X	X		X	X
	Effective reinforcement score of wearing seat belt* **	X	X		X	X
	% of children using child restraints in front and rear seats	X	X		X	X
	Effective reinforcement score of child restraints***	X	X		X	X
	Rate of wearing helmets by two-wheeled vehicle occupants (drivers, passengers, or all)	X	X		X	X
	Effective reinforcement score of using helmets* **	X	X		X	X
	% of drivers using mobile phones while driving (hand-held and hands-free)	X	X	X	X	X
	Effective reinforcement score of using mobile phones*	X	X	X	X	
Safer vehicle	% of cars awarded overall 5 stars *	X	X	X	X	
	Enforcement score on vehicle standard applied	X	X			
	% of cars awarded 5stars on car occupants	X	X			
	% of cars awarded 4 stars on child restraints	X	X			
	% of cars awarded 3 stars on pedestrian protection	X	X			
	Is the pedestrian protection set for new cars sold? **	X	X			X
	Are the vehicles equipped with effective seat belts? * **	X	X			X
	Are the vehicles equipped with seat belt anchorages? * **	X	X			X
	Are the vehicles equipped with child restraint systems? * **	X	X			X
	Are the vehicles designed with safer frontal and side impact standards? * **	X	X			X
	Are the vehicles equipped with effective electronic stability control? * **	X	X			X
	Are the vehicles equipped with anti-lock braking systems? * **	X	X			X
	% of heavy vehicles		X		X	X
	% cars < 6 years		X			
	% of old vehicles > 10 years		X			
	Renewal rate of passenger cars,		X			
	Median age of the passenger car fleet		X			
	% of two-wheeled vehicles		X			X
	% of vehicles in the total vehicle fleet		X			X
	Vehicle fleet composition		X			X
	% of vehicles not motorcycles		X			X

* The indicators which are suggested based on the recommendations of the DARS 2011-2020
** The selected indicators for this research

To assess the road infrastructure, the percentage of road lengths awarded three stars or more for vehicle occupants, pedestrians, motorcyclists and cyclists are suggested, because a three-star rating is the target set by the UN and the WHO, in addition to the national road safety agencies, to achieve the target of the SDG and DARS 2011-2020 (European Transport Safety Council 2001; WHO, 2011; The International Road Assessment Programme, 2017). These indicators are also selected to assess safer speed since one of the input indicators of RAP is the speed limit of the road section (The International Road Assessment Programme, 2017). The EuroRAP score is not selected because this would require finding a valid methodology of aggregating the RAP score for a whole road network. The other indicators are not selected because they are irrelevant to the safe system policy or dependent on other indicators. For example, the indicators related to paved roads and separated walking and cycling road layouts are considered already by the RAP methodology. Therefore, they are considered dependent on the RAP indicator. The indicators of motorway length and density are examples of indicators that do not have direct relevance to the safe system concept.

For safer road user behaviour, the selected indicators are not considered comprehensive unless they are viewed together, because each indicator refers to a measure of road user behaviour. Other indicators reflect the programmes related to road user behaviour, such as the effectiveness score of enforcement programmes, but their selection would overlap with the selected indicators. Therefore, we suggest considering these indicators in case there are no data available to measure the selected indicators. By reviewing the available data related to the suggested indicators, it is noted that the data related to the effectiveness scores of enforcement programmes are available and openly accessible for most of the south-east Asian countries, but the data related to the other suggested indicators are available for only some of them (WHO, 2013, 2015a, 2015b; Wismans et al., 2016).

To assess vehicle safety, the most comprehensive indicator is the one related to the NCAP star rating. The percentage of vehicles awarded five stars is the indicator selected in this research to reflect the recommendation of the DARS 2011-2020 policy to consider crashworthiness and crash-avoidance measures. Although ASEAN NCAP is introduced by Malaysia to assess vehicle safety in Southeast Asian countries (Jawi et al., 2013; ASEAN NCAP, 2017); data regarding car volume, disaggregated by make and model, would need be available. Therefore, alternate indicators are suggested based on the DARS 2011-2020 recommendations and the available data. These indicators represent the seven international standards that are accepted as basic minimum standards for vehicle manufacture (WHO, 2013, 2015a, 2015b). These are: setting effective seat belts; anchorage seat belts; child restraint systems; safe frontal and side impact standards; effective electronic stability control; anti-lock braking systems, and pedestrian protection standards. These indicators are considered less comprehensiveness than NCAP and also dependent on NCAP because they are covered in the methodology of NCAP assessment. However, the indicators related to the NCAP rating are not selected; therefore, the selected indicators are considered independent.

The indicators related to the age of vehicles are not selected because of a lack of openly available data. The indicators related to the composition of the vehicle fleet are not considered because there is no valid methodology to assess the road safety level based on the composition of roads; therefore, they are considered immeasurable.

2.2 Developing the Aggregation Model

The simple linear additive aggregation method is used to develop the model of constructing the composite indicator of road safety performance (Munda & Nardo, 2003; Joint Research Centre-European Commission, 2008). Equation 1 shows the general form of aggregation by this method. The parameters of the model contain the variable of the indicator i *(Vi)* and its weight. Sixteen parameters form the model, representing the sixteen selected indicators.

$$CIj = \sum_{i=1}^{n} W_i V_i \quad (1)$$

Where:

CIj = the composite aggregated indicator of case j;
j = 1, 2…, m, = case number; m = number of cases;
Wi = the weight of indicator i, $0 \leq Wi \leq 1$, $\sum_{i=1}^{n} Wi = 1$;
Vi = the normalised variable of indicator I;
i = 1, 2…n = indicator number; n = number of indicators.

Regarding the weighting of indicators, it is assumed that each thematic group of indicators, the thematic indicators that represent a component of the safe system has the same weight. This means that the indicators of safer road infrastructure and speed, of safer road user behaviour, and of safer vehicles have equal weights. This is based on the concept of the safe system, which considers all these components to have the same significance in improving road safety.

According to this, the weights will be assigned to the individual indicators as shown in Table 3. Equation 1 is therefore developed into Equations 2 and 3.

$$RSAI(SEA)j=SRM+SRU+SV \quad (2)$$

$$RSAI(SEA)j = 0.25RAP3V + 0.25RAP3M + 0.25RAP3P + 0.25RAP3B + 0.20ESP + 0.20EDD + 0.20ESB + 0.20ECHR + 0.20EH + 0.14VPP + 0.14VSB + 0.14VSBA + 0.14VCHR + 0.14VSF + 0.14VSS + 0.14VES \quad (3)$$

Where RSAI (SEA) j is the road safety assessment index for the south-east Asian country j.

Table 3: Assigning weights to the individual indicators

The Thematic Indicators	The Individual Indicators	The Weights
Safer road infrastructure and speed (SRM)	% of roads with vehicle occupants RAP star rating ≥ 3 star (RAP3V)	0.25
	% of roads with motorcyclists RAP star rating ≥ 3 star (RAP3M)	0.25
	% of roads with pedestrians RAP star rating ≥ 3 star (RAP3P)	0.25
	% of roads with bicyclists RAP star rating ≥ 3 star (RAP3B)	0.25
Safer road user behavior (SRU)	Effective score of speeding enforcement (ESP)	0.20
	Effective score of drinking-driver enforcement (EDD)	0.20
	Effective reinforcement score of wearing seat belt (ESB)	0.20
	Effective reinforcement score of child restraints (ECHR)	0.20
	Effective reinforcement score of using helmets (EH)	0.20
Safer vehicle (SV)	Is the pedestrian protection set for new cars sold? (VPP)	0.14
	Are the vehicles equipped with effective seat belts? (VSB)	0.14
	Are the vehicles equipped with seat belt anchorages? (VSBA)	0.14
	Are the vehicles equipped with child restraint systems? (VCHR)	0.14
	Are the vehicles equipped with safer frontal standards? (VSF)	0.14
	Are the vehicles equipped with side impact standards? (VSS)	
	Are the vehicles equipped with effective electronic stability control? (VESC)	0.14

2.3 Applying the Developed Model

The results of applying the developed model in the Southeast Asian countries are shown in Appendix I. Two sources are used to collect the needed data: the WHO website, which provides the data related to the SRU and SV variables, and the iRAP site (The International Road Assessment Programme, 2017), which is used to collect the data needed for the SRM variables. These data are classified into three types according to the form of data: percentage form, which is used for the variables of SRM indicators; out-of-ten form, which are used for the variables of the SRU indicators, and yes/no form, which are measured by binary (1/0) values to measure the variables of the SV indicators.

It is noted that not all of the ten countries selected to apply the RAP methodology in assessing their roads. Therefore, there are missing data regarding the SRM indicators for the Maldives, Timor-Leste, Sri Lanka, Myanmar, and Bangladesh. The data for only two of the variables are found for Bhutan. Therefore, the missing data are substituted with zero, assuming that there is no regular rating assessment of roads. It is also noted that the minimum vehicle safety standards are not required by most of the Southeast Asian countries. India requires two of the seven priority standards, and Thailand applies only one. The enforcement systems of road safety laws related to speeding, drinking alcohol, wearing seat belts, and wearing helmets are applied in all countries, but the child restraints system is applied in only one country. Since these data have different forms and units, they are normalised by dividing the value of Vi of country j by the maximum Vi as shown in Equation 4.

$$The\ normalised\ value\ of\ Vi\ for\ country\ j = \frac{Vij}{MaximumVi} \quad (4)$$

The sample countries are ranked according to the developed RSAI(SEA) and according to the real crash rate per 100,000 populations, which is estimated by the WHO [2]. The rankings are shown in Table 4. The RSAI(SEA) is then converted to star ratings by identifying the star rating bands. The interval of each band is computed using Equation 5 and shown in Table 5.

$$The\ interval\ length\ of\ the\ SR\ band = \frac{Ideal\ score - minimum\ score}{the\ number\ of\ intervals} \quad (5)$$

Table 4: The ranking of countries according to the RSAI(SEA) and according to the estimated crash rate per 100,000 population

Countries	RSAI(SEA)	SR	real crash rate per 100,000 population	SR
Thailand	1.35	3	36.20	1
Indonesia	1.31	3	15.30	3
India	1.19	2	16.60	3
Nepal	1.11	2	17.00	3
Maldives	0.61	2	3.50	5
Bhutan	0.60	1	15.10	3
Timor-Leste	0.59	1	16.60	3
Sri Lanka	0.57	1	17.40	3
Myanmar	0.24	1	20.30	3
Bangladesh	0.21	1	13.60	4

Table 5: The Star Rating (SR) bands

SR	RSAI(SEA)	Real crash rate per 100,000 population
1	0 to ≤ 0.6	+28.96
2	0.6 to ≤ 1.2	21.72 to ≤28.96
3	1.2 to ≤ 1.8	14.48 to ≤ 21.72
4	1.8 to ≤ 2.4	7.24 to ≤14.48
5	2.4 to ≤ 3.0	0.00 to ≤7.24

Where the ideal score is obtained when all the variables have full scores. The minimum score is shown when all the variables equal to zero. The number of intervals is set at five, as it is known that there are five possible levels of star ratings. The same equation is used to find the SR band for the estimated crash rate, assuming the maximum score is equal to the maximum crash rate and the minimum is equal to zero.

3.0 RESULTS AND DISCUSSION

According to the results of the ranking using RSAI(ESA), Thailand has the highest rank despite having a lower rank according to the real crash rate. On the other hand, Bangladesh has the lowest RSAI(ESA) score, but it is grouped within the four-stars rating according to the real crash rate. It is also noted that, when the RSAI(ESA) star rating is low, the SR according to the real crash rate is high. This means that countries that are benchmarked as low-ranked according to the real crash rate have started to take action to improve road safety. This demonstrates that benchmarking and ranking countries plays a significant role in encouraging them to make decisions and take actions to improve road safety.

Regarding the application of the RAP methodology in assessing road infrastructure and mobility, only five countries out of the ten in the south-east Asian region have applied this methodology. Overall, Thailand has the highest rate of roads that have been assessed and awarded at least three stars.

The enforcement of road safety laws relating to speeding, drink-driving, wearing seat belts, and wearing helmets are weak across this region. Only Timor-Leste, however, does not apply a law requiring child restraints. It is recommended that using mobile phones while driving and driving under the influence of drugs also should be considered for strengthening the road safety laws in this region.

Setting minimum standards of vehicle safety also needs to be improved. Only two countries consider one or two of these standards, while the UN regulations recommend that all seven proposed standards should be set.

4.0 CONCLUSION

The developed RSAI(ESA) is aimed at assessing road safety performance in Southeast Asian countries. It is based on the recommendations of the DARS 2011-2020 plan, which promotes the safe system concept. The indicators selected for this index are: the percentage of roads awarded at least a three-star rating using the RAP methodology; the enforcement score on road safety laws regarding the five risk factors of speeding, drink-driving, wearing seat belt, wearing helmets, and using child restraints; and application of the minimum safety standards of vehicles as regulated by the UN.

The results show that benchmarking and ranking countries play a role in raising awareness and encouraging them to take action to solve road safety problems; that is, the countries that have a high rating for risk have started to consider the safe system principles in their national road safety strategies and follow the recommendations of the DARS plans. However, vehicle safety is still a critical element of the road safety pillars. Therefore, more efforts are needed to apply the UN regulations in this area. Timor-Leste, Sri Lanka, Myanmar, and Bangladesh must take further steps to reduce the rate of road crashes.

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Appendix I. The normalized variables for RSAI(SEA)

Countries	RAP3V	RAP3M	RAP3P	RAP3B	ESP	EDD	ESB	ECHR	EH	VPP	VSB	VSBA	VCHR	VSF	VSS	VES
Thailand	0.49	0.78	1.00	0.67	0.43	0.60	0.75	0.00	0.60	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.52	1.00	0.30	1.00	0.71	0.50	1.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.28	0.67	0.42	0.88	0.43	0.40	0.50	0.00	0.40	0.00	1.00	1.00	0.00	0.00	0.00	0.00
Nepal	1.00	0.14	0.23	0.35	1.00	0.90	0.63	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maldives					0.86	1.00	0.50	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bhutan			0.22	0.11	0.71	0.50	0.38	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Timor-Leste					0.71	0.40	0.25	1.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sri Lanka					0.57	0.60	1.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar					0.71	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh					0.43	0.20	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00