Road Safety Development Evaluation for ASEAN Community Using EWM-GRA-Kmeans

Xiangrun Chen[1,a,*], Gavin Huang[2,b], Zhaokai Luo[3,c], Yunhao Mei[4,d], Beier Sun[5,e], Mingyang Sun[6,f], Guozheng Wang[7,g], Tingrui Zhang[8,h]

* Corresponding author. Email addresses: [a] cxr0523@uw.edu; [b] gavinhuang90@icloud.com; [c] blurrylove7@gmail.com; [d] yunhaom2@illinois.edu; [e] iambellsun@gmail.com; [f] myangsun@outlook.com; [g] gwang35@syr.edu; [h] erzhangtr@outlook.com

[1]Department of Psychology, University of Washington, Seattle, WA 98195, United States
[2]Tsinghua International School, Beijing 100084, China
[3]School of Electrical and Information Engineering, The University of Sydney, NSW 2006, Australia
[4]School of Information Sciences, University of Illinois Urbana-Champaign, Urbana, IL 61801, United States
[5]San Domenico School, San Anselmo, CA 94960, United States
[6]College of Arts and Architecture, University of Pennsylvania, Philadelphia, PA 19104, United States
[7]College of Engineering and Computer Science, Syracuse University, Syracuse, NY 13244, United States
[8]United World College Changshu, Changshu, Jiangsu 215500, China

Abstract: This study develops a one-stop evaluation framework, EWM-GRA-Kmeans, aiming to evaluate road safety development of the ASEAN community over the past decade (2009-2020). The results' comparisons suggest the proposed model's robustness. Overall, this study helps provide policymakers with a reference for policymaking and measures formulation to improve road safety.

Keywords: Road safety development; Numerical computation; ASEAN community; EWM; GRA; K-means

1 Introduction

Road safety is a very significant topic. It takes a great deal of effort on the part of national policymakers to ensure that it is effective and meets the needs of communities. Traffic crashes can result in physical injuries and fatalities, the major share of which is road traffic. An additional 20 to 50 million individuals have non-fatal injuries, resulting in a significant number of them acquiring disabilities as a consequence of their injuries in the ASEAN region [1]. Severe traffic crashes also result in varying degrees of emotional trauma, such as PTSD. This requires a regular evaluation of road safety to support the policy and measures formulation.

However, implementation of the comprehensive evaluation is not easy. Methods for evaluating road safety development require steps such as data collection, normalization, weighting, aggregation, grouping, and robustness analysis [2]. There is no complete and systematic method to accomplish the evaluation task. In addition, most of the existing methods are auxiliary methods, most of which rely on the subjective evaluation of experts. This presents a huge obstacle to decision-makers, policymakers, and practitioners.

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Toward this end, this study develops an evaluation framework, namely Entropy Weight Method (EWM)-Grey Relational Analysis (GRA)-Kmeans. The framework has three components: (1) EWM, an objective weighting method in which the objective weights are determined by the magnitude of the variability of the indicators. (2) GRA, a method for quantitative analysis of the developmental dynamics of the system. It determines whether the link is strong or not by comparing the degree of correlation between the reference data and several comparative data. (3) As an unsupervised machine learning method, K-means aims to group ASEAN countries according to different traffic conditions.

2 Data

2.1 Safety performance indicators (SPIs)

The safety performance indicators (SPIs) selected in this study are based on Al-Haji's study [3] and Chen et al. (2017)'s improvement [4]. It is mainly selected from three major categories: product, people, and system. A total of 20 indicators were selected for analysis, as shown in Figure 1.

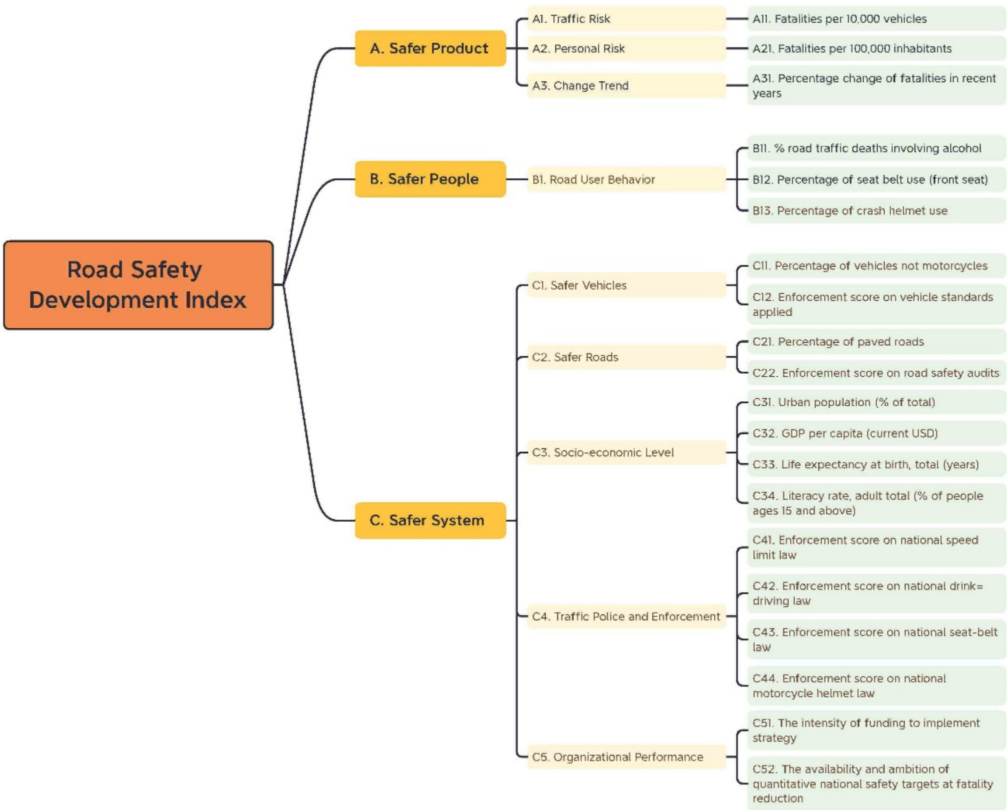

Figure 1 Safety performance indicators used in this study.

2.2 Data collection

2.2.1 Study region

Founded on August 8, 1967, the Association of Southeast Asian Nations (ASEAN)'s objective is to foster economic, political, and security collaboration among its member nations, as well as to enhance regional peace, stability, and prosperity [5]. The ASEAN has 10 member states, namely Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

2.2.2 Data sources

Data was gathered for 11 Southeast Asian nations, including 10 ASEAN countries and Timor-Leste, from the global status report on road safety. In the case of missing data, the paper is supplemented with missing value estimates from SPSS.

3 Method

This study develops a comprehensive model framework that combines the Entropy Weight Method (EWM), Grey Relational Analysis (GRA), and K-means.

Procedure 1: Decision matrix creation.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix} \tag{1}$$

Procedure 2: Decision matrix normalization.

$$b_{ij} = \begin{cases} \dfrac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}}, \text{for positive indicators} \\ \dfrac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}}, \text{for negative indicators} \end{cases} \tag{2}$$

Procedure 3: Indicators' weights calculation.

$$w_j = \frac{(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} \tag{3}$$

where

$$e_j = -\frac{1}{\ln m} \cdot \sum_{i=1}^{m} p_{ij} \cdot \ln p_{ij}$$
$$p_{ij} = b_{ij} \Big/ \sum_{i=1}^{m} b_{ij} \tag{4}$$

Procedure 4: Grey relational coefficients determination.

$$\xi_{ij} = \frac{\min_{i=1}^{m} \min_{j=1}^{n} \left| k_j - b_{ij} \right| + 0.5 \cdot \max_{i=1}^{m} \max_{j=1}^{n} \left| k_j - b_{ij} \right|}{\left| k_j - b_{ij} \right| + 0.5 \cdot \max_{i=1}^{m} \max_{j=1}^{n} \left| k_j - b_{ij} \right|} \tag{5}$$

where $k_j = \max_{i=1}^{m}(b_{ij})$, and $\sigma \in (0,1)$ is often assigned a value of 0.5 in the majority of empirical investigations, serving as the distinguishing coefficient [6, 7].

Procedure 5: Grey relational grade computation.

$$S_i = \frac{1}{n} \sum_{j=1}^{n} w_j \xi_{ij}$$

Procedure 6: According to the correlation coefficient matrix obtained in Step 4.

$$\xi = \begin{bmatrix} \xi_1(1) & \xi_1(2) & \cdots & \xi_1(m) \\ \xi_1(1) & \xi_1(2) & \cdots & \xi_1(m) \\ \vdots & \vdots & \ddots & \vdots \\ \xi_n(1) & \xi_n(2) & \cdots & \xi_1(m) \end{bmatrix}$$

Determin the difference between the minimum and maximum value of each indicator:

$$p_{\max} = \left[\max \xi_i(1) - \min \xi_i(1), \max \xi_i(2) - \min \xi_i(2), \max \xi_i(m) - \min \xi_i(m) \right]$$

The quantile is obtained from the number of clusters k:

$$p_1 = \frac{1}{(k+1)\times 2} \times p_{\max}$$
$$p_2 = \frac{3}{(k+1)\times 2} \times p_{\max}$$
$$\vdots$$
$$p_k = \frac{2k-1}{(k+1)\times 2} \times p_{\max}$$

where k is the number of clusters/groups we want to get. Before running the K-means algorithm, it is necessary to specify the number of clustering centers K. In our case, we intend to divide the 11 evaluation objects into three groups, so we set K to 3. For the 3 clustering results, this paper uses averaging the final clustering centers to rank them. The final samples of the 3 clustering centers are divided into 3 classes. Get the initial clustering centers $a = p_1, p_2, \cdots, p_k$.

Procedure 7: Compute the distance between each sample in the dataset ξ_i and the k cluster centers, then assign it to the class associated with the cluster center that has the shortest distance.

Procedure 8: For each of the groups a_j, re-calculate its cluster center $a_j = \frac{1}{|c_i|}\sum_{x \in c_i} x$ (i.e., the cluster center of all samples belonging to the class).

Procedure 9: Continue executing steps 7 and 8 repeatedly until a specified termination condition is met, for as reaching a certain number of iterations or achieving a minimal change in error.

4 Results

4.1 Ranking

Table 1 presents the ranking of the ASEAN community by the suggested model in terms of road safety progress during the course of four years.

Table 1 Ranking of ASEAN countries over the four years.

Country	ISO	2020		2015		2012		2009	
	code	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Brunei	BN	0.861	2	0.917	2	0.902	2	0.847	3
Indonesia	ID	0.860	3	0.858	4	0.809	6	0.798	7
Cambodia	KH	0.766	9	0.804	9	0.780	8	0.720	11
Laos	LA	0.741	11	0.810	8	0.771	10	0.781	9
Myanmar	MM	0.772	8	0.798	10	0.778	9	0.809	6
Malaysia	MY	0.853	4	0.895	3	0.815	5	0.889	2
Philippines	PH	0.819	6	0.847	6	0.834	3	0.828	5
Singapore	SG	0.914	1	0.926	1	0.918	1	0.940	1
Thailand	TH	0.798	7	0.827	7	0.793	7	0.795	8
Timor-Leste	TL	0.754	10	0.796	11	0.743	11	0.741	10
Vietnam	VN	0.829	5	0.856	5	0.827	4	0.833	4

4.2 Clustering

Table 2 presents the grouping of the ASEAN community by the suggested model concerning road safety progress over the course of four years.

Table 2 Grouping of ASEAN countries over the four years.

Country	ISO Code	2020	2015	2012	2009
Brunei	BN	1	1	1	1
Indonesia	ID	2	2	2	2
Cambodia	KH	3	3	3	3
Laos	LA	3	3	3	2
Myanmar	MM	3	3	3	2
Malaysia	MY	2	2	2	1
Philippines	PH	2	2	2	2
Singapore	SG	1	1	1	1
Thailand	TH	2	2	2	2
Timor-Leste	TL	3	3	3	3
Vietnam	VN	2	2	2	2

5 Discussion

5.1 Comparison of ranking

The ranking results obtained using the EMW-GRA model are contrasted with those derived from more conventional approaches, namely RSR and TOPSIS [8], as shown in Table 3. The results obtained from the GRA model exhibit a high level of consistency with the outcomes generated by the TOPSIS and RSR methods.

Table 3 Ranking comparisons across different methods for the four years.

Country	2020			2015			2012			2009		
	GRA	RSR	TOPSIS	GRA	RSR	TOPSIS	GRA	RSR	TOPSIS	GRA	RSR	TOPSIS
BN	2	1	2	2	1	2	2	2	2	3	4	2
ID	3	4	7	4	5	6	6	6	6	7	8	6
KH	9	9	11	9	9	10	8	9	10	11	11	10
LA	11	11	9	8	8	9	10	8	9	9	7	9
MM	8	8	10	10	10	11	9	10	11	6	5	11
MY	4	2	3	3	2	3	5	4	3	2	1	3
PH	6	7	5	6	6	5	3	3	5	5	6	5
SG	1	3	1	1	3	1	1	1	1	1	2	1
TH	7	5	4	7	7	4	7	7	4	8	9	4
TL	10	10	8	11	11	8	11	11	8	10	10	8
VN	5	6	6	5	4	7	4	5	7	4	3	7

5.2 Comparison of grouping

The ranking results derived from the proposed model are contrasted with those obtained from other conventional approaches, namely HCA and HDI, as shown in Table 4. As can be seen, the results derived from the K-means model are quite consistent with those from TOPSIS and RSR.

Table 4 Grouping comparisons across different methods for the four years.

Country	2020			2015			2012			2009		
	K-Means	HCA	HDI	K-Mean s	HCA	HDI	K-Means	HCA	HDI	K-Means	HCA	HDI
BN	1	1	1	1	1	1	1	1	1	1	1	1
ID	2	2	2	2	3	3	2	2	3	2	2	3
KH	3	2	3	3	3	3	3	2	3	3	2	4
LA	3	2	3	3	3	3	3	2	3	2	2	4
MM	3	2	3	3	3	3	3	2	4	2	2	4
MY	2	3	1	2	2	2	2	3	2	1	3	2
PH	2	2	2	2	3	3	2	3	3	2	2	3
SG	1	1	1	1	1	1	1	1	1	1	1	1
TH	2	3	1	2	2	2	2	3	2	2	2	2
TL	3	2	3	3	3	3	3	2	3	3	2	3
VN	2	2	2	2	3	3	2	2	3	2	3	3

6 Conclusion

This study designs an evaluation model (i.e., EWM-GRA-Kmeans), which was used to rank and group the road safety status of eleven countries in ASEAN plus Timor-Leste. It provides a reference for policymakers from the perspective of data analysis to formulate measures and policies. The framework proposed in this study is a method that completely excludes subjective influence and does not rely on any subjective judgment at all. In addition, our method can accommodate regional diversity as well as universality. It is not only applicable to ASEAN countries but also can be used in other countries and regions and even in other fields of evaluation analysis.

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