

Road safety development evaluation for the ASEAN countries by TOSPSI-RSR

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Abstract. This study develops a systematic methodology, TOPSIS-RSR, to assess road safety development in an integrative manner for ASEAN (Association of Southeast Asian Nations) countries. Using other methods and measures as references, 11 countries are ranked based on their overall road safety performance over the past ten years (2009-2018) and divided into several classes. This provides government officials and policy makers in all ASEAN member countries with a flexible tool to comprehensively assess road safety developments. Providing the ability to identify delays in the implementation of action plans and to proactively reallocate resources to more effective actions when needed. It helps ASEAN member countries to build capacity for sustainable safety management and supports them in developing future strategies.

Keywords: TOSPSI-RSR, ASEAN countries, Road safety.

1. Introduction

Road traffic crashes result in the deaths of approximately 1.3 million people around the world each year and leave between 20 and 50 million people with non-fatal injuries. Developing economies record higher rates of road traffic injuries, with 93% of fatalities coming from low- and middle-income countries. In addition to the human suffering caused by road traffic injuries, they also incur a heavy economic burden on victims and their families. More broadly, road traffic injuries have a serious impact on national economies, costing countries 3% of their annual gross domestic product.

Most ASEAN countries are developing countries and see a high growth rate of vehicles. It is estimated that about 75,000 road deaths and over 4.7 million injuries (many resulting in permanent disability or serious injury) occurred in the region in 2003. Huge economic losses are now incurred annually in ASEAN countries as a direct result of traffic accidents, and most research suggests annual losses across the region are now in excess of \$15 billion per year. These losses inhibit economic and social development and can contribute to the perpetuation of poverty.

Under the above background, a systematic all-around evaluation method will play an important role in the periodical evaluation of the road safety situation in ASEAN countries, furthermore, provide a scientific basis for decision-makers to take necessary actions to improve the road safety situation.

There are statistical evaluation methods available for other social events, but a well-fitted systematical method with regard to road safety, especially focusing on ASEAN countries with their unique social and economic features in consideration, is still in demand. In this paper, we develop a new evaluation system to give a comprehensive evaluation by applying classical mathematical methods such as Entropy, TOPSIS, and RSR. The method adapts itself to ASEAN countries' situations and yields persuasive results. It refines and improves the currently available methods and will be a powerful tool to assist decision-making in improving road safety development in ASEAN.

2. Data

2.1 Safety performance indicators (SPIs)

An ideal indicator should reflect the unsafe conditions and factors contributing to road fatalities and injuries, and then be able to report the national performance and development in road safety in the specific region over time.

Based on the framework developed by (Al-Haji, 2005, 2007; Chen et al., 2017), a set of 20 SPIs with high data availability and acceptable qualities is selected, as shown in Fig. 1.

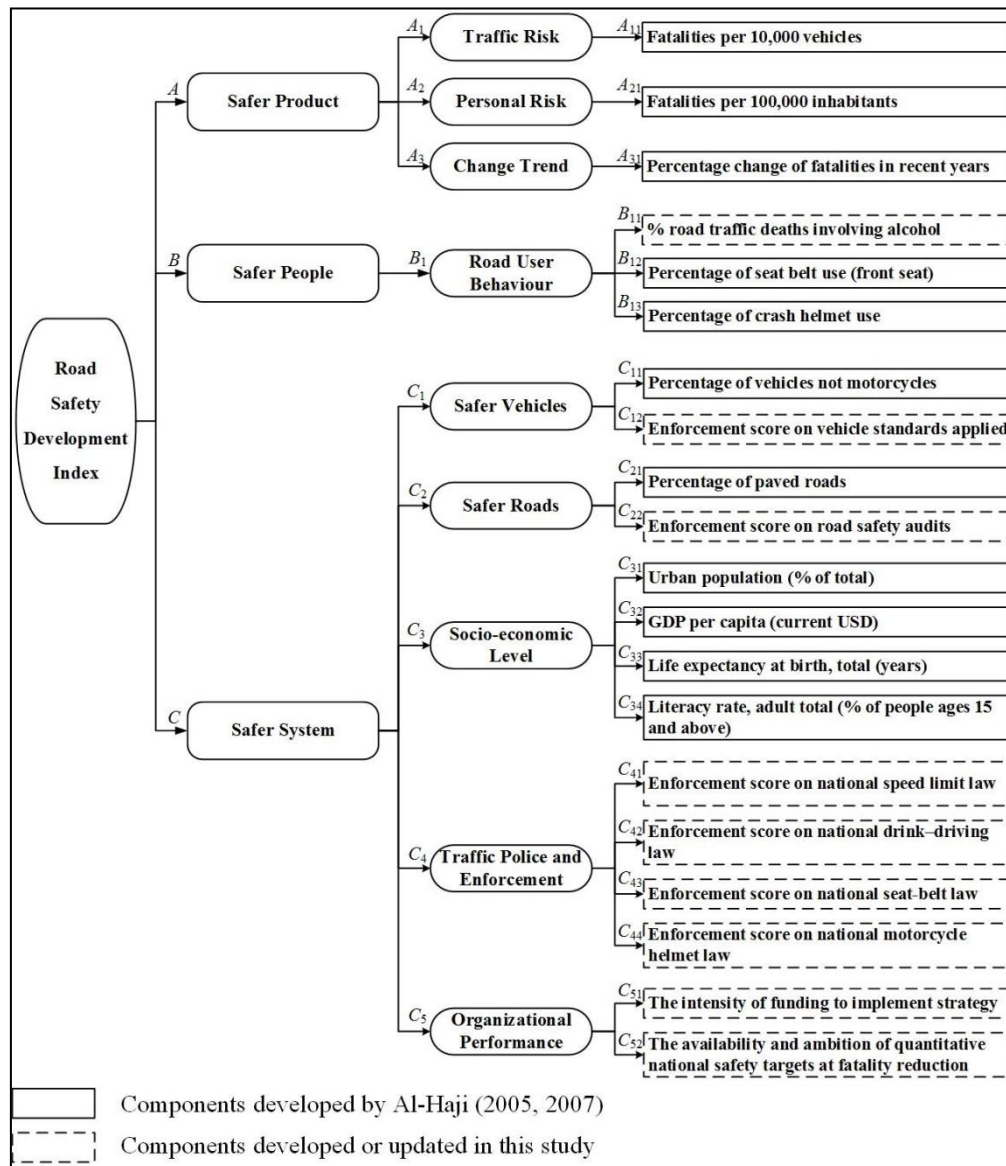


Fig. 1 Road safety development index (Derived from (Chen et al., 2017)).

2.2 Data collection

The dataset of the above 20 SPIs for the 11 ASEAN countries is collected for the years of 2018, 2015, 2012, and 2009 from various international organizations and local governments, including the World Health Organization (WHO), United Nations Economic and Social Commission for Asian and the Pacific (ESCAP) and World Bank. Additionally, the Human Development Index (HDI) from United Nations Development Program is collected and listed.

2018		Traffic Risk	Personal Risk	Change trend (%)	Deaths involving alcohol (%)	Percentage of seat belts use (%)	Percentage of helmets use (%)	Vehicles not motorcycles (%)	Enforcement score on vehicle standards applied	Paved Roads (% of total)	Enforcement score on Road safety audits	Urban population (%)	GDP per capita (ppp US\$)	Life expectancy at birth	Adult literacy (%)	Enforcement score on speed limit law	Enforcement score on drink driving law	Enforcement score on seat belt law	Enforcement score on helmet use law	Funding to study	Safety targets	HDI
Burundi	BN	0.7	6.3	75.00	12.33	73.30	98.00	97.48	1	93.68	3	77.63	618.39	72.4	96.2	6	6	6	7	3	0	0.853
Indonesia	ID	2.4	11.8	81.70	17	69	71	16.83	0	60.45	4	55.33	116.45	69.4	95.4	8	9	8	9	3	1	0.694
Cambodia	KH	4.9	11.4	70.30	13	28	57	13.67	0	17.37	4	23.39	425.9	69.3	96.2	5	5	7	6	3	0	0.582
Laos	LA	5.9	16.0	112.00	50	47	71	23.96	0	15.45	1	35.00	77.5	67.0	96.2	5	3	2	7	3	1	0.601
Myanmar	MM	7.7	9.3	45.20	21	7	32	15.51	0	24.03	4	30.58	45.75	66.7	96.2	6	6	7	6	0	1	0.578
Malaysia	MY	2.6	22.1	100.00	0	48	91	54.16	2	76.58	4	76.04	282.40	75.5	96.2	6	4	4	4	3	1	0.802
Philippines	PH	10.8	9.4	96.50	1	80	70	48.78	0	94.42	4	46.51	87.21	69.2	96.2	5	6	6	6	4	2	0.699
Singapore	SG	1.5	2.5	71.60	6	50	56	85.24	0	100.00	4	100.00	1005.81	82.9	97.0	8	8	8	9	3	0	0.922
Thailand	TH	5.8	32.1	89.70	14	58	51	41.68	1	74.11	3	49.95	185.30	75.5	96.2	5	6	6	6	3	1	0.755
Timor-Leste	TL	4.8	5.4	37.80	17	7.5	70	26.05	0	43.05	1	30.58	31.68	69.2	96.2	5	4	2	7	3	0	0.625
Vietnam	VN	1.7	8.9	37.50	34	47	81	6.98	0	70.92	4	35.92	77.60	76.5	96.2	7	8	6	8	3	1	0.694
2015																						
Burundi	BN	0.8	7.0	78.30	9	72	98	99.12	1	93.52	3	76.66	625.41	77.0	88.5	5	4	5	7	3	0	0.852
Indonesia	ID	3.7	15.3	122.60	21	80	90	16.83	0	60.52	4	53.31	102.47	69.0	95.2	5	5	8	8	4	1	0.686
Cambodia	KH	10.7	17.5	145.10	15	1	64	14.16	0	11.29	4	22.19	339.9	68.6	88.5	4	4	5	5	3	1	0.571
Laos	LA	6.7	10.0	123.00	50	53	73	23.26	0	15.68	2	33.11	61.68	68.3	84.7	4	2	2	7	3	1	0.593
Myanmar	MM	25.1	20.3	438.70	21	53	50	16.34	0	25.11	4	29.86	40.05	66.5	75.6	5	4	5	5	1	1	0.569
Malaysia	MY	3.0	24.0	103.70	23	77	97	54.02	1	76.58	4	74.21	248.02	75.1	93.7	6	5	4	5	4	1	0.795
Philippines	PH	13.5	10.6	149.50	1	80	51	46.90	0	88.62	4	46.28	71.87	69.0	88.5	5	1	5	6	4	2	0.693
Singapore	SG	1.8	3.3	102.10	11	50	56	85.06	0	100.00	4	100.00	869.75	82.7	96.8	8	8	8	9	3	0	0.929
Thailand	TH	7.5	36.2	176.10	26	58	52	42.27	0	81.20	0	47.69	158.22	75.1	92.9	3	6	6	6	3	1	0.741
Timor-Leste	TL	31.3	16.6	247.40	21	7.5	70	24.25	0	43.05	4	29.49	29.13	68.6	88.5	5	4	2	6	3	0	0.630
Vietnam	VN	5.5	24.5	203.30	34	53	96	5.27	0	63.79	4	33.81	61.03	76.1	88.5	6	5	6	9	3	1	0.684
2012																						
Burundi	BN	1.3	11.5	85.20	9	72	98	98.3	1	93.07	3	75.66	837.89	76.8	96.1	6	9	6	10	3	0	0.852
Indonesia	ID	4.3	13.0	188.70	25	80	93	19.1	0	56.15	3	51.28	100.67	68.5	92.8	4	5	8	8	1	1	0.675
Cambodia	KH	11.0	12.8	108.90	15	0	65	13.9	1	10.65	4	21.84	30.46	67.5	78.1	7	3	5	6	3	1	0.553
Laos	LA	7.8	12.7	120.40	50	53	75	22.0	1	14.90	3	31.26	52.89	65.2	58.3	6	3	2	8	3	1	0.569
Myanmar	MM	10.6	5.1	150.40	25	53	50	12.8	0	21.50	4	29.27	37.83	65.8	87.4	5	5	6	6	3	1	0.549
Malaysia	MY	3.4	24.2	109.40	23	77	76	53.4	1	78.28	3	72.28	234.78	74.6	87.4	5	4	4	5	3	1	0.781
Philippines	PH	10.5	7.4	585.70	1	80	87	44.8	1	88.52	2	45.71	66.15	68.6	96.4	3	0	8	5	4	2	0.677
Singapore	SG	2.0	3.8	90.20	41	50	56	85.2	1	99.88	4	100.00	830.02	82.0	96.4	7	9	8	9	3	0	0.920
Thailand	TH	4.8	20.0	110.20	26	61	53	39.8	1	88.77	0	45.45	154.88	74.4	93.7	3	5	6	6	3	1	0.731
Timor-Leste	TL	78.7	6.8	155.10	25	7.5	70	23.7	2	43.05	3	28.43	24.83	67.8	87.4	4	3	2	5	1	0	0.599
Vietnam	VN	3.3	12.6	86.20	34	53	90	5.2	1	66.26	4	31.75	535.9	75.5	87.4	7	3	7	9	3	0	0.670
2009																						
Burundi	BN	1.8	13.8	143.80	4	70	98	99.0	0	84.16	0	74.61	782.99	76.7	96.1	7	6	7	9	1	1	0.842
Indonesia	ID	2.6	7.1	198.20	16	85	93	21.6	1	56.94	0	49.13	80.22	68.0	92.6	4	5	7	7	3	1	0.656
Cambodia	KH	10.8	11.5	165.60	10	0	21	10.3	0	6.72	0	19.93	22.99	66.0	73.9	1	5	1	2	3	1	0.521
Laos	LA	10.7	11.2	298.10	48	56	77	19.7	0	13.74	4	29.48	35.39	63.9	88.4	5	3	4	6	0	2	0.539
Myanmar	MM	15.7	3.4	176.80	36	56	60	18.1	1	28.59	4	28.78	26.77	64.8	88.4	5	5	4	6	2	2	0.519
Malaysia	MY	3.7	23.6	109.30	23	70	90	53.0	2	79.96	4	70.00	197.93	74.0	93.1	6	6	6	6	4	2	0.765
Philippines	PH	21.1	1.3	165.50	1	52	34	48.5	0	75.15	4	45.37	52.68	68.2	95.4	3	5	3	6	2	2	0.659
Singapore	SG	2.5	4.8	101.57	7	50	56	84.1	0	99.88	4	100.00	661.49	81.2	95.9	8	8	8	9	4	2	0.884
Thailand	TH	4.9	19.6	250.30	4	56	27	36.3	0	79.29	0	42.54	121.91	73.6	96.4	2	5	5	4	4	2	0.718
Timor-Leste	TL	18.4	4.2	165.60	16	56	70	28.0	0	43.05	2	27.39	17.84	67.0	58.3	0	0	0	5	3	1	0.610
Vietnam	VN	5.6	14.6	45.90	34	56	85	5.0	2	64.70	4	29.76	395.3	74.9	93.5	6	3	3	7	3	1	0.656

Fig. 2 The Human Development Index (HDI)

3. Methods

3.1 Entropy

Entropy weight method (EWM) is a commonly used weighting method that measures value dispersion in decision-making (Shannon, 1948). The entropy value e_j for each indicator is calculated. The smaller the value, the greater the degree of dispersion, the greater the degree of differentiation, and more information can be derived. Meanwhile, higher weight should be given to the indicator and vice versa.

In this paper, EWM is adopted to determine the weight of each indicator, which is calculated as follows: m is the number of countries, n is the number of indicators, a matrix of the dataset is set as:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

p_{ij} , the weight of indicator w_j is calculated as:

$$p_{ij} = \frac{r_{ij}}{\sum_{k=1}^m r_{kj}}$$

its entropy value e_j is calculated as:

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln p_{ij}$$

then the indicator will be given a entropy weight as:

$$\omega_j = \frac{(1 - e_j)}{\sum_{k=1}^n (1 - e_k)}$$

3.2 TOPSIS

TOPSIS is for Technique for Order Preference by Similarity to an Ideal Solution. It is a multi-criteria decision analysis method (Hwang & Yoon, 1981). It compares a set of alternatives based on a pre-specified criterion. The chosen alternative should have the shortest geometric distance from the best solution and the longest geometric distance from the worst solution. Such methodology allows finding trade-offs between criteria when a poor performance in one can be canceled by a good performance in another criterion. This provides a pretty comprehensive form of modeling because we are not excluding alternative solutions based on pre-defined thresholds. In this paper it works as the following Figure:

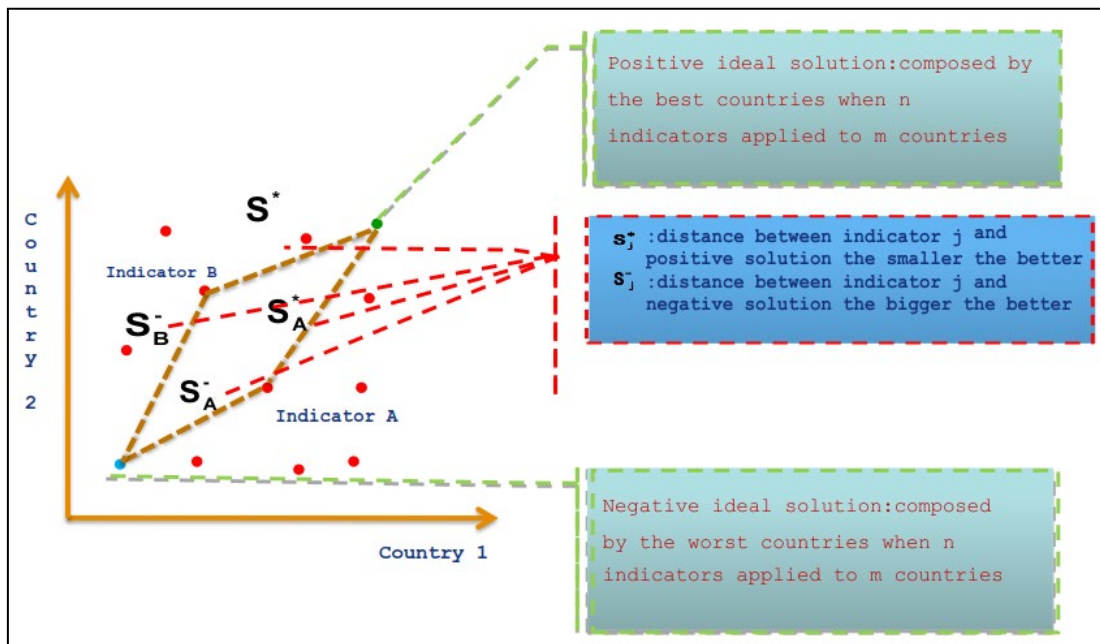


Fig. 3 The TOPSIS

First, we create an evaluation matrix $B = (b_{ij})_{m \times n}$, which consists $m=11$ countries and $n=20$ indicators, by the following operation based on the entropy weights we get:

$$w = [w_1, w_2, \dots, w_n]^T$$

$$c_{ij} = w_i \cdot b_{ij}$$

Second, we determine the best and worst country for each indicator by finding the maximum and minimum value of each indicator among all countries, as:

$$C^+ = (\max c_{i1}, \max c_{i2}, \dots, \max c_{in})$$

$$C^- = (\min c_{i1}, \min c_{i2}, \dots, \min c_{in})$$

Third, we find the distance between the target country and the best/worst country by calculating the geometric distance between the value of each indicator for a given country and the best/worst value of such a metric among all countries:

$$D_i^+ = \sqrt{\sum_{j=1}^n (c_{ij} - c_j^+)^2}; i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

$$D_i^- = \sqrt{\sum_{j=1}^n (c_{ij} - c_j^-)^2}; i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

At last, for each country we calculate the similarity to the worst country.

$$f_i = \frac{D_i^-}{D_i^+ + D_i^-}; i = 1, 2, \dots, m$$

3.3 RSR

RSR is for Rank Sum Ratio (Tian, 1988). It is a comprehensive evaluation method by calculating the rank of each element in a dataset matrix of countries and indicators, then calculating the ratio of the sum of ranks of each country to the dimension value (m x n). It gives us the dimensionless statistics value RSR; The RSR score would be used to make statistical parameter analysis such as distribution analysis or simple sort & ordering to make a comprehensive evaluation of the evaluation objects.

Then we calculate RSR score as:

$$RSR_i = \frac{\sum_{k=1}^n R_{ik}}{m \times n}$$

By summing up the rank values country-wise and divide it by (m*n). After sorting and ordering, we have the RSR rank.

4. Results

4.1 Ranking of countries

The rankings of countries based on TOPSIS-RSR in the four years (2018, 2015, 2012, and 2009) are presented in Table 1.

Table 1. Ranking of countries in the four years.

	2018	2015	2012	2009
Brunei	2	1	2	4
Indonesia	4	5	5	6
Cambodia	9	11	9	11
Laos	11	8	8	8
Myanmar	8	10	11	5
Malaysia	1	2	4	2
Philippines	7	6	6	7
Singapore	3	3	1	1
Thailand	5	7	7	9
Timor-Leste	10	9	10	10
Vietnam	6	4	3	3

Countries Brunei, Malaysia, and Singapore are constantly in the top 3 or 4, proving constant good behavior. Countries Laos, Myanmar, and Timor-Leste are constantly in the last 2 or 3, needing huge improvement.

Laos, Myanmar, and Timor Leste should take countries like Vietnam, Philippines as examples to improve their road safety. The countries that are in the middle are in a good place and should keep their road safety enforcement.

4.2 Grouping of countries

The groupings of countries based on TOPSIS-RSR in the four years (2018, 2015, 2012, and 2009) are presented in Table 2.

Table 2. Grouping of countries in the four years.

	2018	2015	2012	2009
Brunei	1	1	1	1
Indonesia	2	2	2	2
Cambodia	3	3	3	3
Laos	3	3	3	2
Myanmar	3	3	3	2
Malaysia	2	2	2	1
Philippines	2	2	2	2
Singapore	1	1	1	1
Thailand	2	2	2	2
Timor-Leste	3	3	3	3
Vietnam	2	2	2	2

In order to see how countries can improve in their road safety, we decided it was appropriate to divide the thirteen countries into 3 groups. Furthermore, the countries in each group should look forward to the country that is placing first in their individual first and the firsts in each group should look forward to the group above or keep their placement. The countries were divided into groups because it does not seem practical for the last countries to adopt methods used by the top country because of territorial issues.

The countries of Brunei and Singapore are constantly in the first group and should strive to maintain their placement.

Indonesia, Malaysia, the Philippines, and Thailand are in the second group and these countries should use Malaysia as a role model. Countries Cambodia, Laos, Myanmar, and Timor-Leste are in the third group, and Laos and Myanmar are placing higher in this band.

5. Discussions

5.1 Comparison of countries' ranking

The ranking results derived from TOPSIS are compared to those from RSR and HDI, as shown in Table 3.

Table 3. Comparison of ranking for the four years.

	2018			2015			2012			2009		
	TOPSIS	RSR	HDI	TOPSIS	RSR	HDI	TOPSIS	RSR	HDI	TOPSIS	RSR	HDI
BN	2	2	10	1	1	10	2	2	10	4	3	10
ID	4	4	5	5	4	6	5	5	6	6	5	5
KH	9	9	2	11	10	2	9	9	2	11	11	2
LA	11	11	3	8	8	3	8	8	3	8	9	3
MM	8	8	1	10	11	1	11	11	1	5	6	1
MY	1	3	9	2	3	9	4	4	9	2	2	9
PH	7	7	7	6	6	7	6	6	7	7	7	7
SG	3	1	11	3	2	11	1	1	11	1	1	11
TH	5	6	8	7	7	8	7	7	8	9	8	8
TL	10	10	4	9	9	4	10	10	4	10	10	4
VN	6	5	6	4	5	5	3	3	5	3	4	6

As can be seen in Table 3, the ranking results derived from the proposed method (TOPSIS) are highly consist with that from the RSR model and HDI, verifying the credibility of the ranking.

5.2 Comparison of countries' grouping

The grouping results derived from RSR are compared to those from CA, as shown in Table 4.

Table 4. Comparison of grouping for the four years.

	2018		2015		2012		2009	
	RSR	CA	RSR	CA	RSR	CA	RSR	CA
BN	1	1	1	1	1	1	1	1
ID	2	2	2	2	2	2	2	2
KH	3	3	3	3	3	3	3	3
LA	3	3	3	3	3	3	2	3
MM	3	3	3	3	3	3	2	2
MY	2	2	2	2	2	2	1	1
PH	2	2	2	2	2	2	2	2
SG	1	1	1	1	1	1	1	1
TH	2	2	2	3	2	3	2	3
TL	3	3	3	3	3	3	3	3
VN	2	2	2	2	2	2	2	2

As can be seen in Table 4, the grouping results derived from the proposed method (RSR) are highly consist with that from the cluster analysis (CA), verifying the reliability of the grouping.

6. Conclusion

This paper introduces a new method of Entropy-TOPSIS-RSR using weighting, ranking, and grouping to produce data that is proved suitable and acceptable for reporting accounting the road safety development for ASEAN countries. The method outcomes assist government officials and policymakers in planning and implementing successful road safety policies to decrease the number of traffic-related deaths in ASEAN countries. The analysis of the comparison of data produces valuable references for individual countries, providing insight into different road safety situations across countries.

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