

Road safety development evaluation in the ASEAN region

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Abstract. Benchmarking, detecting progress and then readjusting interventions is a valuable process for achieving continuous improvement in road safety. This study developed a systematic and validated methodology, the entropy-TOPSIS-RSR method, to evaluate road safety development in Southeast Asia. In this study, 20 indicators from 11 countries in Southeast Asia were normalized by constructing a decision matrix, then weights were derived and finally countries were ranked and grouped. This approach helps to build capacity for sustainable security management in Southeast Asian countries and to develop better policies for improved livelihoods.

Keywords: Road safety, ASEAN, matrix normalization, Rank-sum ratio.

1. Introduction

The number of road traffic deaths on the world's roads remains unacceptably high of 1.35 million in 2016. Despite the increase in absolute numbers, the rate of road traffic deaths has remained fairly constant at around 18 deaths per 100,000 population over that last 15 years (World Health, 2018). Road traffic injuries cost governments approximately 3% of GDP (World Health, 2015). However, it is still insufficient to combat this global challenge. The risk of traffic deaths is unevenly distributed across countries and strongly correlated with income levels, which is more than three times higher in low-income countries than in high-income countries. Southeast Asia has the second highest traffic safety death rate of all regions among the world, which is 2.5/100,000 higher than the global average death rate (World Health, 2018). Traffic accidents are the leading cause of death among people aged 5-29. Therefore, this is going to be a big burden for Southeast Asia.

In such a severe situation, a regular evaluation of the national or regional road safety situation is of great importance to the government or relevant authorities in formulating policy guidelines for road safety. However, a scientific and systematic approach for the entire Southeast Asia region does not exist at present. It is therefore essential to develop a road safety assessment methodology that can be adapted to all the countries in Southeast Asia.

In this paper, we propose the entropy-TOPSIS-RSR method, a system of evaluation methods that integrates weighting, aggregating, and grouping. This study contributes to the research and industry communities in two ways. Firstly, we propose a system of assessment methods adapted to the situation in Southeast Asian, providing policy makers, government personnel, and managers in ASEAN Member countries with a system of assessment methods to measure road safety developments. Secondly, our findings provide a relevant basis for the development of policies or action programmes to improve the road safety situation in Southeast Asia.

2. Data

2.1. Safety performance indicators (SPIs)

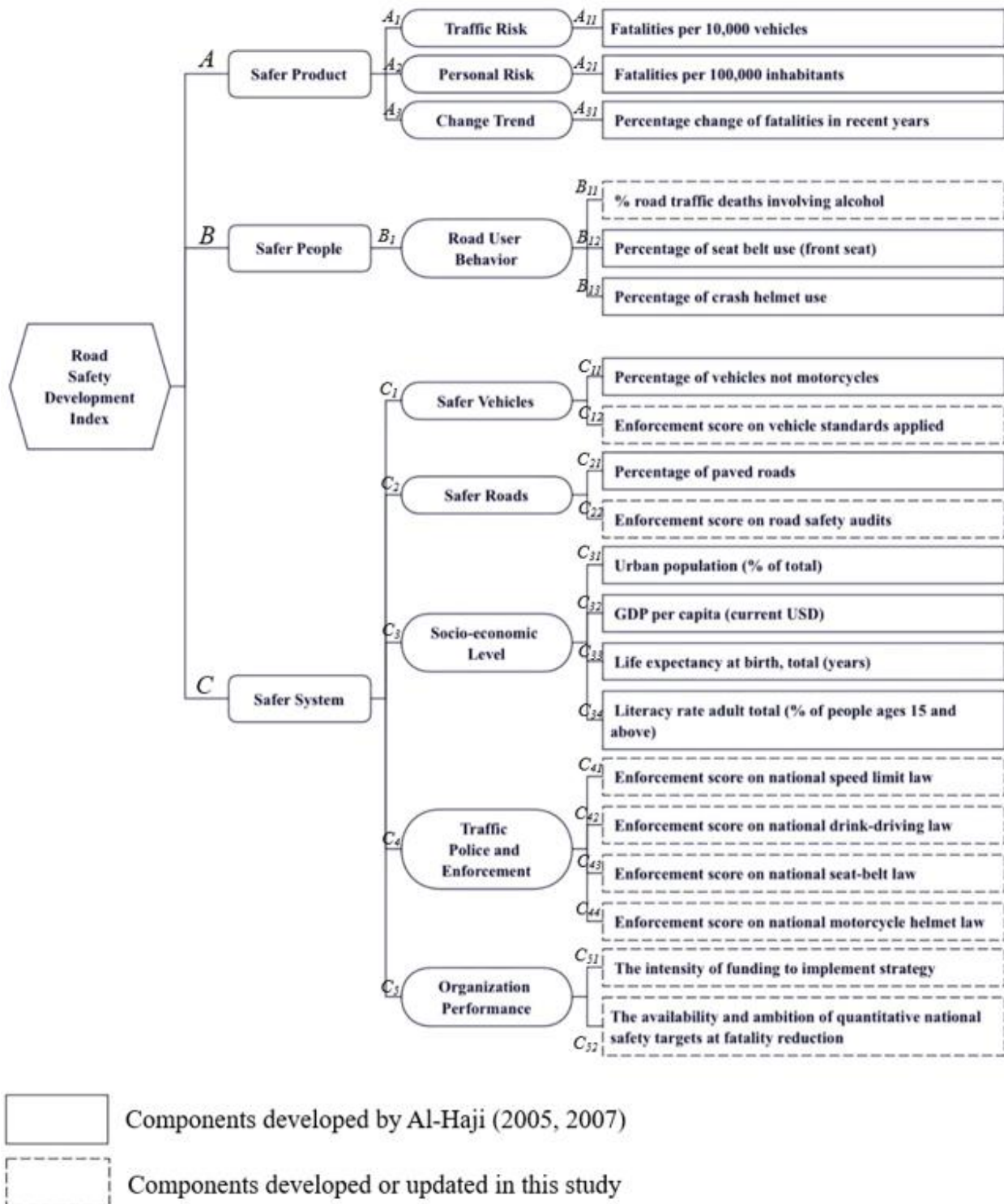


Fig 1. The set of road safety development index (RSDI) used in this study.

We needed a set of indicators to evaluate the traffic safety system, so the Fig1 evaluation system was created. This system is divided into three main categories, Safer Product, Safer People and Safer System. These three categories are subdivided into twenty sub-categories. Of these 20 sub-categories, 11 are developed by Al-Haji, which are Fatalities per 10,000 vehicles, Fatalities per 100,000 inhabitants, Percentage change of fatalities in recent years, Percentage of seat belt use (front seat), Percentage of crash helmet use, Percentage of vehicles not motorcycles, Percentage of paved roads,

Urban population (% of total), GDP per capita (current USD), Life expectancy at birth, total (years), Literacy rate, adult total (% of people ages 15 and above). The other 9 categories are developed updated in this study, which are % road traffic deaths involving alcohol, Enforcement score on vehicle standards applied, Enforcement score on road safety audits, Enforcement score on national speed limit law, Enforcement score on national drink-driving law, Enforcement score on national seat-belt law, Enforcement score on national motorcycle helmet law, The intensity of funding to implement strategy, and The availability and ambition of quantitative national safety targets at fatality reduction.

2.2. Data collection

The data set of the road safety development index (RSDI) as presented in Fig. 1, along with the Human Development Index (HDI), was gathered for 11 Southeast Asian countries, which are Brunei (BN), Indonesia (ID), Cambodia (KH), Laos (LA), Myanmar (MM), Malaysia (MY), Philippines (PH), Singapore (SG), Thailand (TH), Timor-Leste (TL), Vietnam (VN).

The RSDI data is collected from the four years (i.e. 2009, 2012, 2015, and 2018), compiled from several international databases and recent publications; more specifically, for A11, A21, A31, C11 (World Bank, 2018; World Health, 2009, 2013, 2015, 2018), B11, B12, B13, C41, C42, C43, C44 is directly extracted from the Global Status Report on Road Safety published by the WHO (World Bank, 2018; World Health, 2009, 2013, 2015, 2018), C21 (ESCAP, 2016; Central Intelligence Agency, 2016; International Road Federation, 2010), C31, C32, C33, C34 (World Bank, 2015), C12, C22, C51, C52 (World Bank, 2018; World Health, 2009, 2013, 2015, 2018), the Human Development Index (HDI) values are derived from the annual Human Development Report published by the United Nations Development Programme (UNDP) (see UNDP, 2018, 2015, 2013, 2009). For any missing data, we used SPSS for missing value estimation.

3. Methods

3.1. Entropy

The entropy method is an objective weighting method. In the specific use process, the entropy method uses information entropy to calculate the entropy weight of each indicator according to the degree of variation of each indicator, and then corrects the weight of each indicator by the entropy weight, so as to arrive at a more objective weight of the indicator (Hainmueller, 2017).

3.2. TOPSIS

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multiple criterion decision analysis method (Hwang & Yoon, 2012). It was first developed by Ching-Lai Hwang and Yoon in 1981. TOPSIS is a method to sort the limited alternatives according to their proximity to the ideal target, which is to evaluate the relative advantages and disadvantages of the existing alternatives (Assari, Mahesh, Assari, & Technology, 2012). TOPSIS method is a kind of ordering method that approximates to ideal solution, which only requires that each utility function has monotonically increasing (or decreasing) property. TOPSIS method is a common and effective method in multi-criterion decision analysis. Its basic principle is to sort by detecting the geometric distance between the evaluation alternative and the positive ideal solution (PIS) and the negative ideal solution (NIS). If the evaluation object is closest to the PIS and furthest away from the NIS, it is the best. Otherwise, it is not optimal. The index value of the PIS reaches the positive ideal value of each evaluation index. The index value of the worst solution reaches the negative ideal value of each evaluation index (Assari et al., 2012).

3.3. RSR

Rank-sum Ratio (RSR) is a statistical analysis method proposed by Professor Tian Fengdiao in 1988, which combines the advantages of classical parametric statistics and modern nonparametric

statistics (Wang, Dang, Xing, Li, & Yan, 2015). The basic idea of RSR is to obtain dimensionless statistic RSR in a matrix of n rows (n evaluation objects) and m columns (m evaluation indexes or grades) through rank transformation, and sort the merits and defects of evaluation objects by RSR value. Then, according to the number of comparison groups, the classification process (large number of comparison groups) or the RSR square root arcsine transform value confidence interval processing (small number of comparison groups) is carried out (Wang et al., 2015).

3.4. Entropy-TOPSIS-RSR

Step 1. Construct the decision matrix.

Assume an MCDM problem has m alternatives, each including n main criteria. Let a_{ij} denote the value of alternative i ($1 \leq i \leq m$) with respect to criteria j ($1 \leq j \leq n$). Therefore, the MCDM problem can be expressed in matrix format as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

Step 2. Transform each indicator to be in the same direction

For the positive indicators (B12, B13, C11, C12, C21, C22, C31, C32, C33, C34, C41, C21, C43, C44, C51, C52 in this case study):

$$x_{ij} = a_{ij}; \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (2)$$

For the negative indicators (A11, A21, A31, and B11 in this case study):

(a) If the value is a relative number at intervals of [0, 1] (B11 in this case study), use the difference method:

$$x_{ij} = 1 - a_{ij}; \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (3)$$

(b) If the value is an absolute number or a multiple (A11, A21, A31 in this case study), it will be transformed to its reciprocal number:

$$x_{ij} = \frac{1}{a_{ij}}; \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (4)$$

Then the transformed decision matrix is:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (5)$$

After transformation, higher values of the indicator values in the decision matrix X represent better value in terms of road safety.

Step 3. Normalize the decision matrix

At this point, the indicators still have different attribute dimensions (e.g. scales or units). This step transforms various attribute dimensions of the indicators into non-dimensional attributes, in order to mix them together. The idea is to make all the indicators acquire the same magnitude, which allows comparisons across criteria. The normalized value Y_{ij} is calculated as:

$$Y_{ij} = \frac{X_{ij}}{\sqrt{\sum_{k=1}^m (X_{kj})^2}} ; i = 1, 2, \dots, m ; j = 1, 2, \dots, n \quad (6)$$

Step 4. Assign the weights of the indicators
 Calculating weight by entropy weight method:

$$w_j = \frac{(1 - E_j)}{\sum_{j=1}^n (1 - E_j)} ; j = 1, 2, \dots, n \quad (7)$$

Where

$$E_j = -k \sum_{i=1}^m p_{ij} \cdot \ln p_{ij} ; i = 1, 2, \dots, m ; j = 1, 2, \dots, n \quad (8)$$

$$(k = \frac{1}{\ln m}, \text{ if } p_{ij} = 0, \text{ then } p_{ij} \cdot \ln p_{ij} = 0) \quad (9)$$

And

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^m r_{ij}} ; i = 1, 2, \dots, m ; j = 1, 2, \dots, n \quad (10)$$

Then we can calculate the weights matrix W:

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (11)$$

Step 5. Constructing the weighted normative matrix

$$C_{ij} = w_j \cdot Y_{ij} ; i = 1, 2, \dots, m ; j = 1, 2, \dots, n \quad (12)$$

Step 6. Calculating positive and negative ideal solutions

$$C^+ = (\max C_{i1}, \max C_{i2}, \dots, \max C_{in}) \quad (13)$$

$$C^- = (\min C_{i1}, \min C_{i2}, \dots, \min C_{in}) \quad (14)$$

Step 7. Calculate the distance of each solution to the positive ideal solution and the negative ideal solution

$$D_i^+ = \sqrt{\sum_{j=1}^n (C_{ij} - C_j^+)^2} ; i = 1, 2, \dots, m \quad (15)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (C_{ij} - C_j^-)^2} ; i = 1, 2, \dots, m \quad (16)$$

Step 8. Calculate the proximity of each evaluation object to the optimal solution

$$f_i = \frac{D_i^-}{(D_i^- + D_i^+)}; \quad i = 1, 2, \dots, m \quad (17)$$

Step 9. Ranking of the countries

Countries are ranked according to the calculated f_i value from largest to smallest. The larger the f_i value, the higher the ranking of the country.

Step 10. Calculate the RSR distribution for each country with the corresponding probit value

$$RSR_i = \frac{\sum (R_{ij} \cdot w_j)}{m}; \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (18)$$

Where

$$R_{ij} = 1 + (m - 1) \times \frac{X_{j\max} - X_{ij}}{X_{j\max} - X_{j\min}}; \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (19)$$

Then calculate f , $\sum f$, R , \bar{R} , $\left(\frac{\bar{R}}{m}\right) \times 100\%$ (the last is $\left(1 - \frac{1}{4m}\right) \times 100\%$), and Probit according to the Standard Normal Distribution Table.

Step 11. Calculating the linear regression equation

The linear regression equation was calculated with the probit as the independent variable and the RSR value as the dependent variable.

$$RSR = a + b \times probit \quad (20)$$

Step 12. Grouping countries

4. Results

4.1. Ranking

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

Table 1. Four-year ranking of the Road Safety Development Composite Index for 11 Southeast Asian countries.

By combining these 20 indicators and based on the proposed model, the final four-year ranking of the Road Safety Development Composite Index for 11 Southeast Asian countries has been derived. As can be seen from the table, the ranking of the countries in Southeast Asia has been relatively stable

over the four years, with Singapore, Brunei and Malaysia in the top three, and Laos, Cambodia and Myanmar in the bottom three.

4.2. Grouping

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

Table 2. The final grouping results for 11 Southeast Asian countries.

The final grouping results also showed a stable trend, and the grouping results were the same in four years without any fluctuations. Singapore and Brunei are always in the first group, Myanmar is always in the last group, and all other countries are in the second group. This may be due to the large gap between rich and poor countries in Southeast Asia, making it difficult for developing countries to catch up with developed countries. Therefore, while some countries are improving every year, they are still struggling to catch up with developed countries like Singapore.

5. Discussions

5.1. Comparison of ranking

Country	TOPSIS	RSR	HDI
Brunei	2	2	2
Indonesia	6	6	6
Cambodia	10	10	10
Laos	9	9	9
Myanmar	11	11	11
Malaysia	3	3	3
Philippines	5	5	5
Singapore	1	1	1
Thailand	4	4	4
Timor-Leste	8	8	8
Vietnam	6	6	6

Table 3. Comparison of ranking of traffic safety in 11 southeast Asian countries by using TOPSIS, RSR and HDI methods in 2018.

Country	TOPSIS	RSR	HDI
Brunei	2	2	2
Indonesia	6	6	6
Cambodia	10	10	10
Laos	9	9	9
Myanmar	11	11	11
Malaysia	3	3	3
Philippines	5	5	5
Singapore	1	1	1
Thailand	4	4	4
Timor-Leste	8	8	8
Vietnam	7	7	7

Table 4. Comparison of ranking of traffic safety in 11 Southeast Asian countries by using TOPSIS, RSR and HDI methods in 2015.

Country	TOPSIS	RSR	HDI
Brunei	2	2	2
Indonesia	6	6	6
Cambodia	10	10	10
Laos	9	9	9
Myanmar	11	11	11
Malaysia	3	3	3
Philippines	5	5	5
Singapore	1	1	1
Thailand	4	4	4
Timor-Leste	8	8	8
Vietnam	7	7	7

Table 5. Comparison of ranking of traffic safety in 11 Southeast Asian countries by using TOPSIS, RSR and HDI methods in 2012.

Country	TOPSIS	RSR	HDI
Brunei	2	2	2
Indonesia	6	6	6
Cambodia	10	10	10
Laos	9	9	9
Myanmar	11	11	11
Malaysia	3	3	3
Philippines	5	5	5
Singapore	1	1	1
Thailand	4	4	4
Timor-Leste	8	8	8
Vietnam	6	6	6

Table 6. Comparison of ranking of traffic safety in 11 Southeast Asian countries by using TOPSIS, RSR and HDI methods in 2009.

The four tables above respectively show the ranking of traffic safety in 11 southeast Asian countries by using TOPSIS, RSR and HDI methods in 2009, 2012, 2015, 2018. Rankings obtained by these three methods are exactly the same, and the rankings of countries have little change from year to year. The ranking of 2018 is the same as that of 2009. The 2015 ranking is the same as 2012.

Due to the large gap between rich and poor countries in Southeast Asia, and the improvement of the index in recent years, the overall ranking has not changed much.

5.2. Comparison of grouping

Country	RSR	CA	PCA	HDI
Brunei	1	1	1	1
Indonesia	2	2	2	3
Cambodia	2	3	3	3
Laos	2	3	3	3
Myanmar	3	3	3	3
Malaysia	2	2	1	1
Philippines	2	2	1	3
Singapore	1	1	1	1
Thailand	2	2	1	2
Timor-Leste	2	3	3	3
Vietnam	2	2	2	3

Table 7. Results of grouping in 11 Southeast Asian countries by using RSR, CA, PCA, and HDI methods in 2018.

Country	RSR	CA	PCA	HDI
Brunei	1	1	1	1
Indonesia	2	2	1	3
Cambodia	2	3	3	3
Laos	2	3	3	3
Myanmar	3	3	3	3
Malaysia	2	2	1	2
Philippines	2	2	2	3
Singapore	1	1	1	1
Thailand	2	2	2	2
Timor-Leste	2	3	3	3
Vietnam	2	2	1	3

Table 8. Results of grouping in 11 Southeast Asian countries by using RSR, CA, PCA, and HDI methods in 2015.

Country	RSR	CA	PCA	HDI
Brunei	1	1	1	1
Indonesia	2	2	2	2
Cambodia	2	3	3	2
Laos	2	3	3	2
Myanmar	3	3	3	3
Malaysia	2	2	2	1
Philippines	2	2	1	2
Singapore	1	1	1	1
Thailand	2	2	2	2
Timor-Leste	2	3	3	2
Vietnam	2	2	2	2

Table 9. Results of grouping in 11 Southeast Asian countries by using RSR, CA, PCA, and HDI methods in 2012.

Country	RSR	CA	PCA	HDI
Brunei	1	1	1	1
Indonesia	2	2	2	2
Cambodia	2	3	3	2
Laos	2	3	2	2
Myanmar	3	3	2	2
Malaysia	2	2	1	1
Philippines	2	2	2	2
Singapore	1	1	1	1
Thailand	2	2	2	2
Timor-Leste	2	2	3	3
Vietnam	2	2	2	2

Table 10. Results of grouping in 11 Southeast Asian countries by using RSR, CA, PCA, and HDI methods in 2009.

The four tables above show the results of grouping four years of data for each country using four different grouping methods (i.e. RSR, CA, PCA, and HDI). Among them, Singapore and Brunei, which are ranked first and second, are always in group 1, 11th-Myanmar is basically in group 3, and other Southeast Asian countries are basically in group 2. Malaysia, which is ranked third, is sometimes in group 1 and sometimes in group 2. Therefore, the correlation between ranking and grouping is relatively large, no matter which grouping method is used. The results obtained by the four grouping methods are also not much different.

6. Conclusion

This study uses the entropy-TOPSIS-RSR method to assess the development of road safety in Southeast Asia. Through this method a ranking of the different countries in Southeast Asia is obtained, as well as a grouping of the different countries in Southeast Asia. Singapore, Brunei and Malaysia are ranked relatively high and Myanmar is ranked relatively low.

This new approach enriches the system of assessment methods. We have used this methodology to derive a ranking and grouping of countries in Southeast Asia in terms of traffic safety. These results can provide some reference for policy or programme development in ASEAN countries. Also, this evaluation indicator system can provide a basic framework for future road safety development assessments in ASEAN.

However, the shortcoming is that some data were found to be missing when we collected the data. For the data that did we used SPSS to estimate the missing values, which may have affected our results.

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