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Towards the Development of Traffic Safety Strategies in Developing Countries: Analysis of Road Users' Perspective

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Abstract

The rapid growth of automobile ownership and use in developing countries resulted in an exponential growth in road traffic related fatalities and injuries. It is estimated that 1.25 million road traffic deaths occur in the world every year (WHO, 2015), most of them in developing countries in which more than 51% are vulnerable road users. The complexity and unexpected nature of the traffic accidents put the decision makers confronted with the quandary of forming a particular combination of measures to reduce traffic accidents. Despite this problem, few empirical studies have so far been undertaken to analyze the selection of the traffic safety strategies and to identify key selection measures. This study is designed to fill these research gaps. Two methods: the Customer Satisfaction Index (CSI) and the Analytic Hierarchy Process (AHP) method are proposed to achieve these objectives. The first method aims to collect general views from road users to identify the traffic problems, while AHP method was conducted to prioritize and assign the important weightings for the selected measures.

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Keywords: Traffic Safety Strategies, Accidents, AHP.

1. Introduction

The boom expansion of motor vehicle use in developing countries resulted in a sharp rise in road traffic-related deaths and injuries. It is estimated that 1.25 million road traffic deaths occur in the world every year (WHO, 2015), most of them in developing countries in which more than 51% are vulnerable road users.

According to the statistics of Vietnam, the impact of accident accounted for 2.5-3% GDP (Hung, 2016). Vietnam ranks among the countries with the highest accident rates in the world, including the number of accidents, the number of fatalities and injuries. In 2016, there was 8.685 deaths, 19.280 injures, while traffic accidents continue to be the hottest problem in Vietnam today.

Within these accidents, vulnerable road users, namely pedestrians and two-wheelers are the objects who gain a greater risk of injury and therefore highly in need of protection against such collisions. Among these, pedestrians and cyclists are those most unlikely to inflict injury on any other road user, while motorized two-wheelers, which heavier

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machines and higher speeds, may present a danger to others as well as getting a most severe consequences from accidents.

Therefore, selection of measures and policies for protection of vulnerable road users has become more and more significant during the last decades. Although the recent approaches focus in the areas of infrastructure, urban planning, regulation, education, or combination of these, aim to reduce traffic accident, it still remains at a high level, so it is necessary to find out the effective approaches to identify the appropriate measures.

Customer Satisfaction Index (CSI) and Analytic Hierarchy Process (AHP) have been widely used in many areas of business administration, medicine, industry, and engineering fields, etc. CSI is considered as the primary outcome of a marketer activity (Jamal & Naser, 2002). AHP is a multi-criteria decision making method and is presented by American researcher Satty T. L., professor of operations research. AHP is the subjective judgment of decision makers to quantify the number of forms of expression and processing, through the quantitative data in the form of a combination of qualitative and quantitative analysis to help decision makers make decisions. A review from literature reveals that a combination of CSI and AHP have been mostly investigated in industries (Nabavi et al, 2012; Zhao and Dholakia, 2009; Li et al, 2008; Xi et al, 2015).

The objective of this study is to investigate whether CSI and AHP methods can be utilized to select the traffic safety strategies dealing with traffic accidents. The structure of the paper is as follows: the paper begins with the data and methodology. By using the data collected, CSI and AHP method is analyzed and evaluated. Finally, the results are obtained; the conclusions are made and further investigation direction is pointed out.

2. Methodology

2.1. Data Collection

The sample of this study is narrowed down to Hanoi Capital, Vietnam, which is seriously facing with traffic accident. Hanoi is known to be one of the most motorcycle dominated cities in the world. Currently, motorcycle accounted for more than 65 percent of the total modal share and this significantly influence traffic accidents.

A sample survey was conducted on December 2016 with a sample of 300 public citizens and 15 transport experts. For general public, they were asked to share their experiences on road accidents and how they satisfy with road factors which influence to traffic accidents.

Group discussion was conducted first with transport authorities and experts to identify the criteria and indices influencing road user's satisfaction. The selected factors were found as illustrated in Table 1.

Table 1. Identified the criteria and indices influencing customer satisfaction

	Criteria	Index
Road Users' Satisfaction	1) Road Facility	Road pavements
		Visibility
		Lanes
		Sidewalk width
		Intersection shape
		Traffic signal
		Traffic sign
		Road marking
		Median and guard rails
		Speed hump
	2) Road environment	Pedestrian sidewalk
		Parking
		Crosswalk
		Traffic signal for pedestrian
	3) Traffic safety management system	Traffic safety information
		Traffic safety administrative
		Traffic safety legal system
	4) Safety for motorcycle	Safety for two-wheeled motor vehicles
	5) Traffic safety education and traffic culture	Traffic safety education and promotion

Based on road users' experience gained from customer satisfaction, five strategies and eighteen measures are continued to propose. Then, fifteen experts were invited to rank the importance of each strategy and measure.

Table 2. Identified the criteria and indices influencing customer satisfaction

Strategy	Implementation program
1) Safe road infrastructure (Engineering)	1-1: Intersection traffic measure
	1-2: Road safety facility improvement
	1-3: Pedestrian safety environment improvement
	1-4: ITS based traffic safety enhancement
	1-5: TMS Improvement
2) Safe road environment (environment)	2-1: Establishment of school zone
	2-2: Establishment of silver zone
3) Road user behaviour (Education)	3-1 Tailored transport safety education
	3-2: Training traffic safety experts
	3-3: Effective promotion of traffic safety
4) Traffic safety management (enforcement)	4-1: Sustainable financing of traffic safety
	4-2: Traffic safety database management system
	4-3: Reinforcement of traffic safety organization
	4-4: Reinforcement of traffic safety regulation and enforcement
	4-5: Traffic accident management measures
5) Motorcycle safety	5-1: Relief of human factor for motorcycle accidents
	5-2: Relief of vehicle factor and environmental for motorcycle accidents
	5-3: Training traffic safety specialist

2.2. Customer Satisfaction Index

An analysis of the importance satisfaction of the strategies was conducted by using Customers Satisfaction Index (CSI), which can be calculated as follows:

$$\text{CSI} = \sum_{k=1}^{N} S_k * W_k \qquad W_k = I_k / \sum_{k=1}^{N} I_k$$

Where: S_k : Satisfaction index for each evaluation item
W_k: Represents the importance weigh.
I_k: Evaluation item k

The five-point evaluation was used in order to differentiate levels of satisfaction or importance as shown below. The top two ratings together are defined as satisfied (important) and the bottom two ratings together are defined as dissatisfied (unimportant).

Table 3. Scale of satisfaction and importance

5	4	3	2	1
Very satisfied	Satisfied	Neither satisfied or dissatisfied	Dissatisfied	Satisfied
Very important	Important	Neither important or unimportant	unimportant	Very unimportant

2.3. Analytical Hierarchy Process (AHP)

AHP is one of the multiple criteria decision making methods which are used to decide and choose one out of a number of alternatives regarding the criteria determined by the decision maker (Bowen, 1993). AHP is one of the

best-known and most applied decision making models and a powerful decision making method to determine priorities in cases where there are inconsistent criteria.

The application process of the AHP methods is based on the concept proposed by Vinod Kumar and Ganesh (Kumar & Ganesh,1996). There are totally four steps in the AHP process: Step 1: Systematize the evaluation items and set the evaluation index; Step 2: Weight of the evaluation items; Step 3: Importance and schedule of each implementation program; and Step 4: It was analyzed as the calculation step of evaluation result.

The relative weight is computed from the eigenvalues of the N × N matrices according to the paired comparisons of criteria i and j. The evaluation data set is written according to the following rules:

$$S = \begin{pmatrix} 1 & s_{12} & \cdots & s_{1k} \\ 1/s_{12} & 1 & \cdots & s_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ 1/s_{1k} & 1/s_{2k} & \cdots & 1 \end{pmatrix}$$

In the dual comparisons, the Consistency Index (CI) is used to check consistency for all replies. The closer this CI is to zero, the better the overall consistency in the judgements. Saaty (1980) proposed a CI as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where λ_{max} – the largest Eigen value
n – the number of comparisions

With this study, seven scales are used to make a comparison. For an equal assessment numerical value 1 is presented and for moderately more important 3 is assigned, for strongly more 5 is presented and 7 for extremely more import. 2, 4, 6 are presented for intermediate values of importance and is shown in Table 4 (Virendra et al, 1997).

Table 4. Scale of relative importance

Relative Intensity	Definition	Explanation
1	Equal importance	Two elements are of equal value
3	Moderate importance	Experience slightly favour on element over another
5	Strong importance	Experience strongly favour on element over another
7	Extremely importance	Experience very strongly favour on element over another
2,4,6	Intermediate values between two adjacent judgments	When compromise is needed

The five-point evaluation (5 = Very important, 1 = Not important) of the eighteen implementation programs on the weight of each strategy (Wi) and the short-term (S) = 1.3, and L (long-term) = 1.0 to calculate the total score. The total evaluation value is calculated by summing the weight Wi of the evaluation item and the rating Si of the lower evaluation item index.

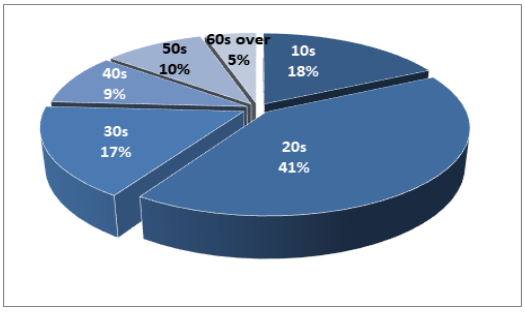
3. Results Analysis and Findings

3.1. General Information of Respondents

The distribution of 300 respondents by age group showed the highest rate in the 20s (41.3%), followed by 17.8% in the teenagers and 16.8% in the 30s. Gender composition ratio is 57% for males and 43% for females

Table 5. Classification of age

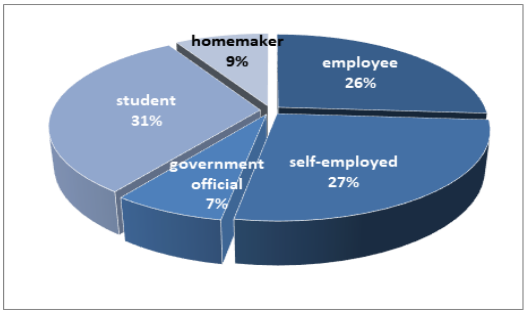
Classification	Frequency	Percent
10s	54	17.8%
20s	125	41.3%
30s	51	16.8%
40s	29	9.6%
50s	29	9.6%
60s over	15	5.0%
Total	303	100.0%



31.4% of the respondents were students, followed by Self-employed (26.7%) and Employee (16.1%).

Table 6. Classification of age

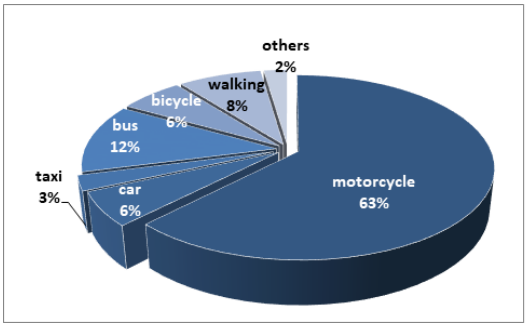
Classification	Frequency	Percent
Employee	79	26.1%
Self-employed	81	26.7%
Government official	22	7.3%
Student	95	31.4%
Homemaker	26	8.6%
Total	303	100.0%



Motorcycle was the most frequent with 62.4%, followed by bus 12.2%, walk 8.3%, and bicycle 6.3%.

Table 7. Classification of age

Classification	Frequency	Percent
motorcycle	189	62.4%
car	18	5.9%
taxi	8	2.6%
bus	37	12.2%
bicycle	19	6.3%
walking	25	8.3%
others	7	2.3%
Total	303	100.0%



3.2. Customer Satisfaction Index

Among elements of safe road infrastructure, road users were least satisfied with sidewalk width (59.4%), medium and guard rails (54.5%), traffic signal (52.8%) and visibility (52.5%).

From road environment perspective, it reveals that almost indices did not fulfill road users' requirement. The level of dissatisfaction reached over 50 percent for almost indices.

In the meantime, road users were most hesitant with traffic safety management system. Over 50 percent of respondents replied with be neither satisfied nor dissatisfied.

Finally, both motorcycle safety and education indices showed the less satisfaction with 49.6% and 43.2% respectively.

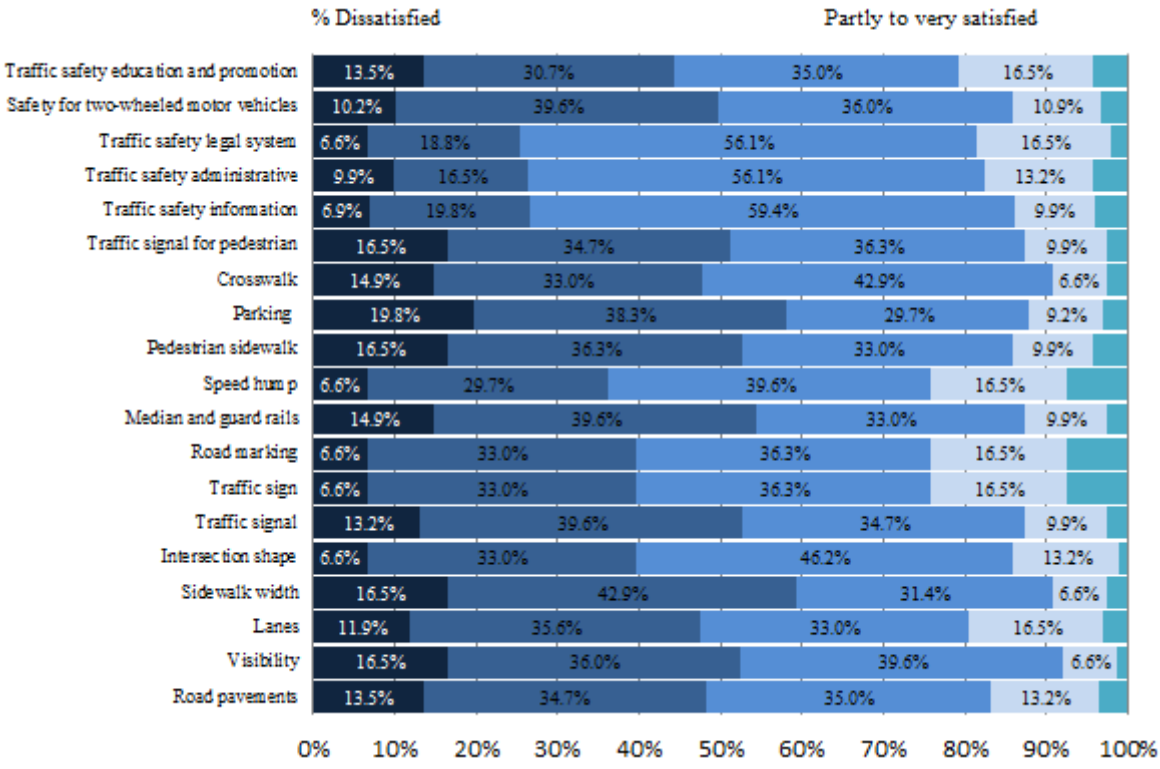


Fig. 1. Customer satisfaction on traffic safety

The following shows the results from analysis of importance and satisfactions with five criteria. As indicated above, road users were most satisfied with traffic safety management but were least satisfied with road environment and safety for motorcycle.

The most importance criterion need to be enhanced to ensure traffic safety is traffic safety education, following by road facility.

Using the importance satisfaction index, the relationship between satisfaction and importance was indicated as in Table 8.

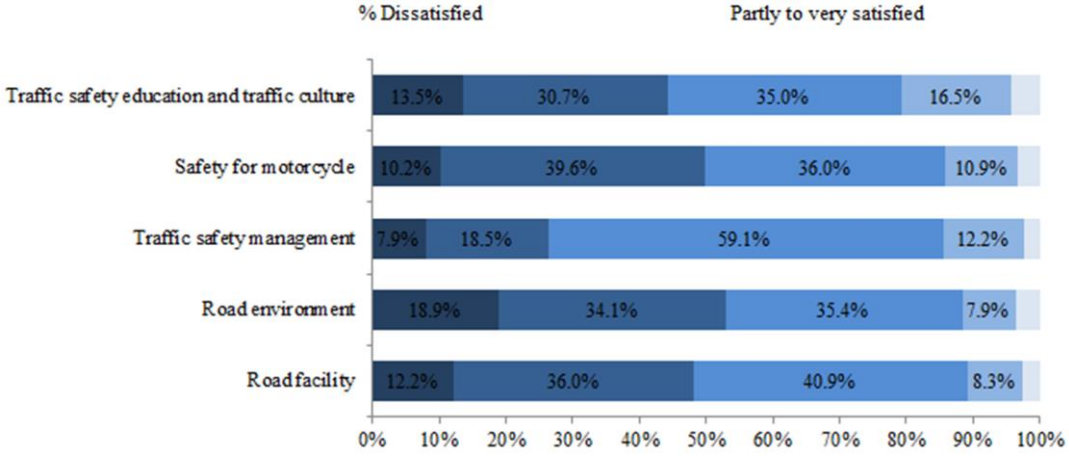


Fig. 2. Level of satisfaction on traffic safety

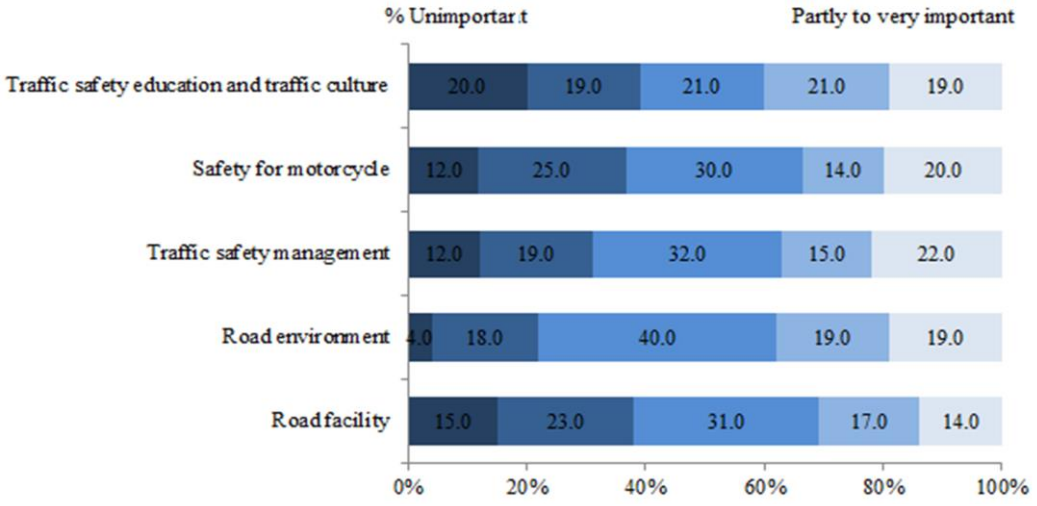


Fig.3. Level of importance of traffic safety criteria

Table 8. Result of importance-satisfaction analysis

	Satisfaction				Importance			
	S	S.E	S-S.E	S+S.E	I	S.E	I-S.E	I+S.E
1) Safe Road Facility	2.53	0.052	2.48	2.58	4.45	0.040	4.41	4.49
2) Road Environment	2.44	0.057	2.38	2.49	4.22	0.048	4.17	4.27
3) Traffic Safety Management System	2.83	0.048	2.78	2.87	3.85	0.051	3.80	3.90
4) Safety for Motorcycle	2.57	0.054	2.52	2.63	4.38	0.041	4.34	4.42
5) Traffic safety education and traffic culture	2.67	0.060	2.61	2.73	4.47	0.047	4.42	4.51

As a result of the analysis, except for the traffic safety management, all of the criteria are at high importance but low satisfaction.

Traffic safety education and traffic culture and and road facility have the highest importance with 4.47 and 4.45, while satisfaction is very low with 2.67 and 2.53

In the same time, the traffic safety management has the lowest importance level of 3.85, but the satisfaction level is 2.83, which is relatively high.

The analysis of Customer Satisfaction Index (CSI) = (Weight Percentage / 5) × 100 = 52.08%, which is an analysis of the importance satisfaction of the five criteria for traffic safety.

Table 9. Result of importance-satisfaction analysis

Criterion	Importance index (I_K)	$W_k = I_k/\sum I$	Satisfaction index	Weight score	Weight percentage	CSI
1) Safe Road Facility	4.45	0.21	2.53	0.53	2.60%	52.08%
2) Road Environment	4.22	0.20	2.44	0.48		
3) Traffic Safety Management	3.85	0.18	2.83	0.51		
4) Safety for Motorcycle	4.38	0.21	2.57	0.53		
5) Traffic safety education and traffic culture	4.47	0.21	2.67	0.56		

3.3. AHP

In order to rank the traffic strategies and measures according to priority and to see whether the right criteria have been selected or not. Firstly, the selection criteria to determine the suitable factors for traffic safety strategies were analyzed. Secondly, the AHP model formed by the criteria and sub-criteria determined in the first step. Criteria have been evaluated by decision makers via linguistic variables that can be expressed in AHP calculator. Then, a degree of proper possibility (scale for pair wise comparisons) is proposed to calculate the weights.

Results of analyses show aggregate opinions of experts that safe road infrastructure is the most important strategy with a weight of 36%, road user behavior ranked second (28%), while the traffic safety management and safe road environment ranked third and fourth with 15.3% and 14.3% weight. Motorcycle safety is the lowest rank with only 6.5%.

Table 10. Weights of the strategy

Weight of strategy		Strategy	Priority
100%	36.0%	Safe road infrastructure	1
	14.3%	Safe road environment	4
	28.0%	Road user behavior	2
	15.3%	Traffic safety management	3
	6.5%	Motorcycle safety	5

Table 11. Priority calculation result

Strategy	Implementation program	Score	Priority
1) Safe road infrastructure (Engineering)	1-1: Intersection traffic measure	41.71	1
	1-2: Road safety facility improvement	34.97	2
	1-3: Pedestrian safety environment improvement	34.93	3
	1-4: ITS based traffic safety enhancement	32.42	4
	1-5: TMS Improvement	30.59	5
2) Safe road environment (environment)	2-1: Establishment of school zone	0.53	0
	2-2: Establishment of silver zone	8.12	12
3) Road user behaviour (Education)	3-1 Tailored transport safety education	24.94	6
	3-2: Training traffic safety experts	19.99	8
	3-3: Effective promotion of traffic safety	23.30	7
4) Traffic safety management (enforcement)	4-1: Sustainable financing of traffic safety	8.08	13
	4-2: Traffic safety database management system	8.78	10
	4-3: Reinforcement of traffic safety organization	7.14	14
	4-4: Reinforcement of traffic safety regulation and enforcement	9.98	9
	4-5: Traffic accident management measures	8.71	11
5) Motorcycle safety	5-1: Relief of human factor for motorcycle accidents	24.94	16
	5-2: Relief of vehicle factor and environmental for motorcycle accidents	23.30	17
	5-3: Training traffic safety specialist	19.99	18

In traffic safety implementation program, if priority is calculated by simple score aggregation without applying the weight of weight, the first rank is safety measure, the second rank is tailored transport safety education, and the third rank is effective promotion on traffic safety.

As a result of prioritizing the overall evaluation based on the final weight, the top ranking is the Safe Road Infrastructure strategy with high priority and the first rank is the Intersection safety measure, the second rank is the Road Safety Facility Improvement, and the third is the Pedestrian Safety Environment Improvement

4. Conclusions

Based on CSI and AHP method, this paper find out the effects of road traffic safety conditions on road users satisfaction, based on this, a list of priority strategies will be suggested to evaluate the effective road conditions influencing customer satisfaction. The results show that among the influencing factors, improvement of road infrastructure and changing road user behavior play the important role in reducing traffic accidents.

As a result of the questionnaire survey of general citizens and traffic safety experts, it was said that the short-term plan needed to improve the traffic safety through intersection maintenance and installation of safety facilities and systematic organization and strengthening of the traffic safety organization.

In the medium term, it is necessary to strengthen the traffic safety regulations and to install the traffic control center and interception system centering that located in traffic police authority. In addition, respondents answered that they should secure continuous traffic safety education and finance.

In the long-term plan, the management and inspection of motorcycles and the establishment of a traffic safety database were required to systematically manage the safety of roads.

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