Safety-Potential-Based Black Spot Safety Management Approach: A Case Study in Ho Chi Minh City

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Abstract: Black Spot Safety Management (BSM) employs identification and treatment of black spots as the two basic stages. Traditionally, these two stages base themselves mainly on recorded accidents rather than safety potential (SAPO). This paper intends to introduce an innovative BSM approach called SAPO-Based BSM which developed is based on the *Network Safety Management* (BASt & Sétra, 2005). There are two basic stages in this approach: *SAPO calculation* and *accident pattern analysis*. The innovation lies in the fact that SAPO-Based BSM approach takes SAPO as the main indicator of black spots; and SAPO is determined by means of the traffic volume and the severity of accidents. In order to illustrate the effectiveness of SAPO-Based BSM approach, this paper provides an empirical investigation in which SAPO-Based BSM is practically applied to the local road traffic situations in Ho Chi Minh City (HCMC).

Keywords: Black Spot Safety Management, Safety Potential Based Approach, Black Spot Treatment, SAPO-Based BSM

1. INTRODUCTION

Black Spot Safety Management (BSM) approach was proven to be a very efficient method in improving road traffic safety. However, the traditional BSM approaches rely mainly on the recorded number of accidents, critical values, and the sliding window method to identify black spots. Therefore, the set of hazardous road locations identified will contain both true and false positives. This leads to the fact that the analysis may include a number of sites which are not true black spots; and a number of sites with false negatives may go undetected. This research introduces a new BSM approach which is based on the SAPO in identifying and ranking black spots in order to maximize the effectiveness of safety improvement measures.

2. BACKGROUND

This section discusses some problems related to the reality of road traffic safety in HCMC and the potential limitations of the traditional BSM approaches which make it necessary to do further research so as to solve or minimize such problems and limitations.

2.1 Practical Background

HCMC is an important transport hub of Vietnam, linking the Southern areas with the other parts of the country as well as with foreign countries. The demand for the city's transport is rapidly growing. However, the transport infrastructure, especially road sector, remains very poor and fails to keep in pace with the development growth.

2.1.1 Under-reported Road Traffic Accidents in HCMC

Table 1 shows the difference in quantity of road traffic accidents reported by the two sources. This means that a considerable number of accident cases are under-reported. Actually, the number of serious injury and fatality cases recorded by HCMC Health Inspection Division is much higher than that by HCMC Traffic Police.

Table 1. Comparison between two accident data sources in HCMC (2010-2011)

Data source	Year 2010				Year 2011			
	No. of Accidents	Fatalities[1)]	Serious Injuries[2)]	Slight Injuries[3)]	No. of Accidents	Fatalities[1)]	Serious Injuries[2)]	Slight Injuries[3)]
[1]	10,928	1,058	536	9,651	8,641	1,028	557	8,565
[2]	-	1,685	3,889	8,669	-	2,030	4,797	8,565

- Not available; [1] Data from HCMC Traffic Police; [2] Data from Health Inspection Division; [1)] Refers to cases of death within 24 hours from arrived at hospital; [2)] Refers to cases of injury which require 30 days of treatment or over; [3)] Refers to cases of injury which require one day of treatment or less

2.1.2 Accidents According to Road Types

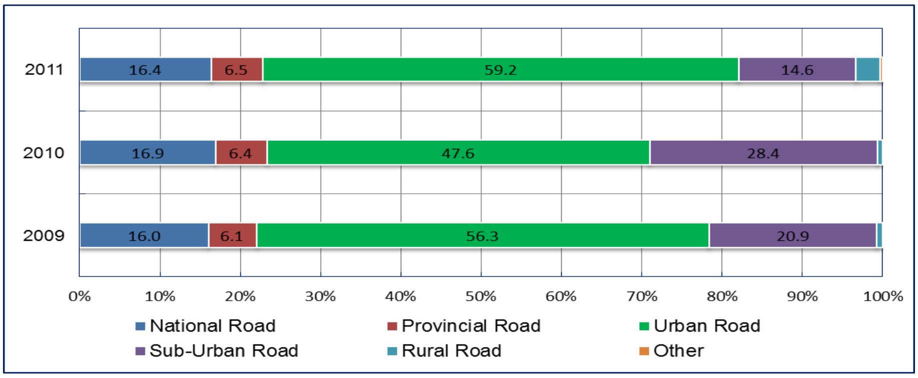


Figure 1. Road traffic accidents according the type of roads (2009-2011)

Owing to heavy traffic with strong conflict between vehicles of different sizes and speeds, the percentage of road accidents happening on urban roads is relatively higher than that of accidents happening on sub-urban roads and national roads. The distribution of road accidents according to road types in the city in the period from 2009 to 2011 is illustrated as in the Figure 1.

2.1.3 Accidents According to Vehicle Types

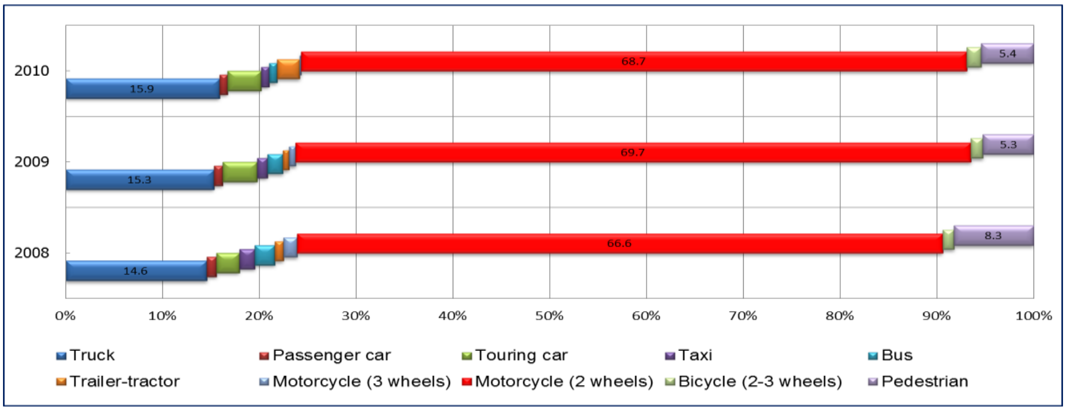


Figure 2. Road traffic accident according to type of vehicles (2008-2010)

The prominent feature of vehicle types in HCMC is that motorcycles account for 90% of the total number of vehicles. As a result, this type of vehicles takes up 90% of the road traffic capacity of the city. 70% of the road accidents are caused by motorbikes, 15% by taxis and 5% by lorries. The remaining 10% are caused by other types of vehicles such as trailers, buses, coaches, and so on. The distribution of road accidents according to vehicle types in the city in the period from 2008 to 2010 is illustrated as in the figure 2.

2.1.4 Accidents According to Crash Types

Most of the road accidents are crashes between motorcycles, accounting for a percentage of approximately 60%. Next comes, the case of between motorcycles and cars, accounting for a percentage of 18%. The remaining 22% are the cases of car-car accidents, motorcycle-pedestrian accidents, and so on. The distribution of road accidents according to crash types in the city in the 2010 is illustrated as in the figure 3.

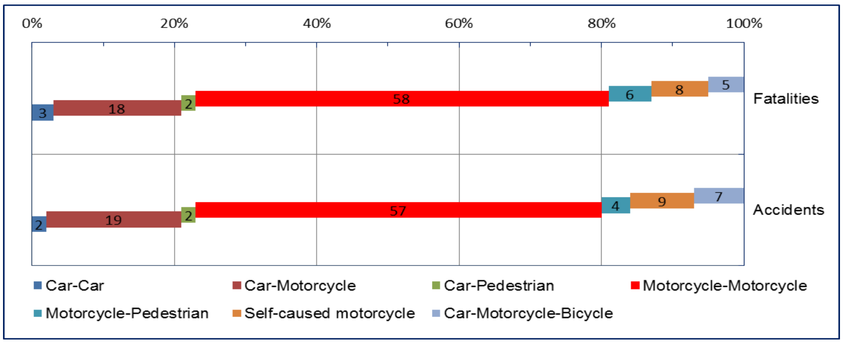


Figure 3. Road traffic accidents according to crash types (2010)

2.1.5 Accidents According to the Age of Road Users

According to the statistics for road accidents in 2010, most of the accidents are caused with the involvement of road users of the age between 19 and 40. The distribution of road accidents according to the age of road users in the 2010 is illustrated as in the figure below.

Figure 4 shows that most of cases of death and serious injury in road accidents in HCMC happen to people who are still at the age of labor. These people are often the breadwinner in their families and also the main labor force the society.

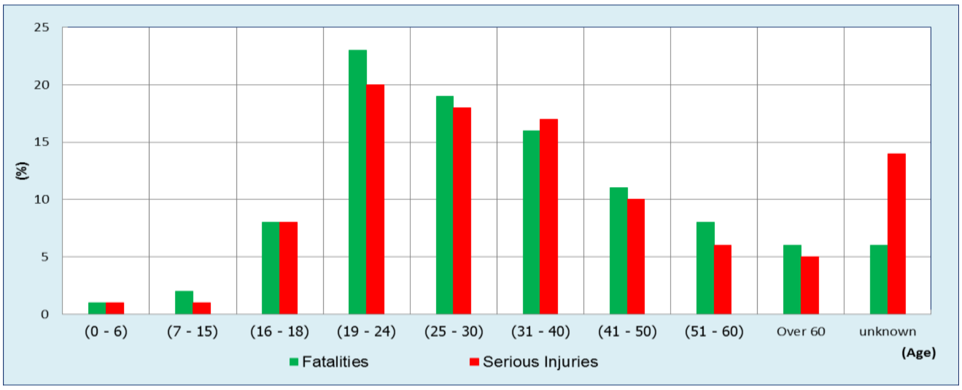


Figure 4. Road traffic accidents according to age of road users in the year 2010

2.2 Theoretical Background

2.2.1 Overview of Road Traffic Safety Methods and Road Safety Analysis Applications

(1) Application of Road Safety Methods

Figure 5 shows the five instruments of the road infrastructure safety management and their scope of application according to the number of accidents which have been occurring on the road network.

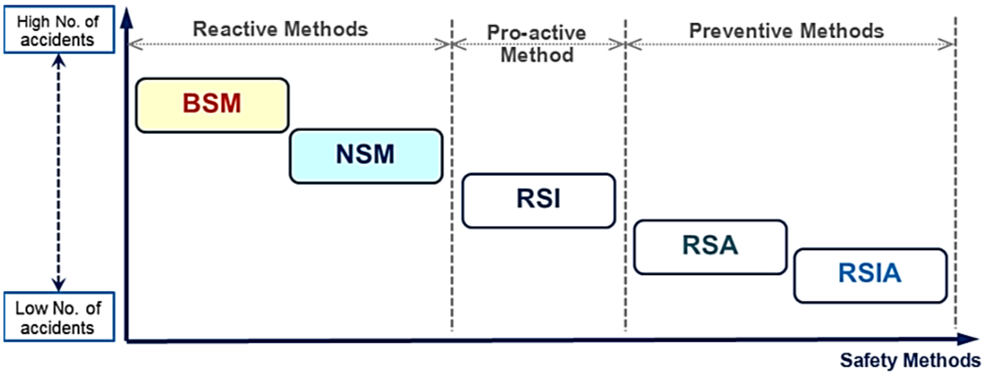


Figure 5. Application of road safety methods

CEDR (2008) claimed that the infrastructure safety management focuses on the five instruments: Road Safety Impact Assessment (RSIA), Road Safety Audits (RSA), Road Safety Inspection (RSI), Network Safety Management (NSM), and Black Spot Safety Management (BSM). These five instruments can be basically defined as follows.

The RSIA is a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network, at the initial planning stage before the infrastructure project is approved. The RSA is an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation as to identify, in a detailed way, unsafe features of a road infrastructure project. RSI is a systematic, periodic, objective and proactive safety review of a road in operation. The objectives of RSI are to identify and eliminate hazardous conditions, faults and deficiencies in order to improve the road safety for the road users. NSM is used to manage the existing road network or the parts of the road network with the aim to identify, localize and rank road sections according to their potential savings in accident costs. BSM is the reactive investigation and implementation of remedial measures at single localized (e.g. curves, junctions), short road segments or sites with a high number of injury accidents. BSM and NSM are reactive approaches to improve the safety performance of road infrastructure during operation.

According to CEDR (2008) when many accidents of the same type happened at more or less the same place, BSM is certainly the first method to apply for the road manager. When black spots are eradicated, NSM can be processed and will be a very efficient method to identify road stretches with a high safety potential. When there are no concentrations of accidents on the road anymore, RSI can be processed as a pro-active approach.

(2) Application of Road Safety Analysis

Analysis of road safety is an important field of road engineering in order to provide quantitative results for the evaluation of safety efficiency of road safety countermeasures. Brannolte and Munch (2009) pointed out four levels of safety analysis as shown in Figure 6. The process of these four safety analysis levels can be described as follows.

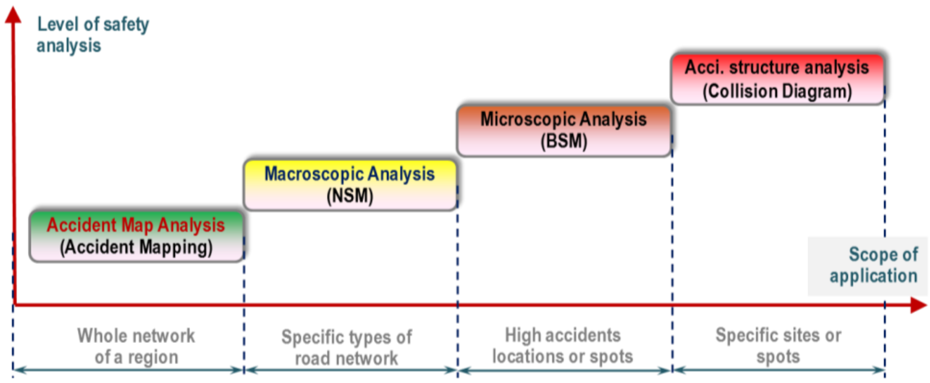


Figure 6. Road safety analysis applications

First, a general view on the whole road network will be provided by accident mapping analysis. Mapping accidents (i.e. location, categories, types, circumstances, road users, etc.) is an essential prerequisite for drawing sound conclusions with regard to accident countermeasures. This lowest level of safety analysis helps us to find out which particular locations in a specific region should be considered to improve road traffic safety.

Second, macroscopic level of safety analysis (NSM) focuses on identifying, analyzing and classifying parts of the existing road network according to their potential for safety development and accident cost saving. It also helps the road administrations in detecting the sections within the network with the highest safety potential, i.e. where an improvement of the infrastructure is expected to be highly cost efficient.

Third, BSM goes up to microscopic level of safety analysis with the aim to identify, analyze, and rank the high accident concentration sections or spots within the road network which have been in operation for more than three years and upon which a large number of fatal accidents in proportion to the traffic flow have occurred.

The highest level of safety analysis is the collision diagram analysis with focus on the concentrations and similarities of accidents at black spots selected. After black spots are identified, the accident data at those spots can be analyzed in order to find common patterns in accidents. A visit of the black spot site is usually part of the process of analysis. Collision diagram can be used in investigation of conflict situations on local spots. On the other hand, collision diagrams have been proven as very useful tools for detecting safety deficits easily.

2.2.2 Limitations of Traditional BSM Approaches

(1) Limitations in Identifying Black Spots

Traditional approaches only rely on the recorded number of accidents for identification of black spots. Any value of the recorded number of accidents at a site during a certain period always is a sum of two values, the first value is the very systematic number, and the second value is random number. Because of this, if a value of recorded number is used as a critical value in identifying black spots, then the identified black spots will be a set of true and false black spots.

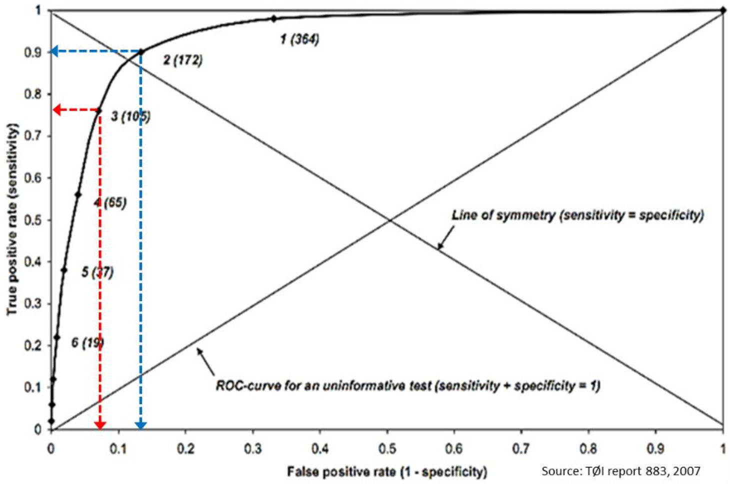


Figure 7. ROC-curve for detecting road accident black spots. Simulated data

Indeed, Elvik (2008) used expected number of accidents and simulated data to point out the limitations and pitfalls of identifying road accident black spots in terms of the recorded number of accidents only. Based on the analysis we may now define four categories of sites as follows.

①. <u>*Correct positives*</u>: if E ≥ [c] and R ≥ [c];
②. <u>*False positives*</u>: if E < [c] and R ≥ [c];
③. <u>*Correct negatives*</u>: if E < [c] and R < [c];
④. <u>*False negatives*</u>: if E ≥ [c] and R < [c].

Where:
E denotes the expected number of accidents; [c] denotes the selected critical value; and R denotes the recorded number of accidents at a site during a given period of time.

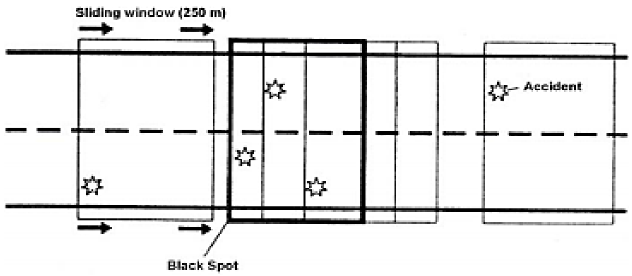
"The performance of the various criterion values can be assessed quantitatively in terms of screening performance criteria developed in epidemiology (Deeks, 2001; Rothman and Greenland, 1998). Two of the most common criteria for diagnostic tests are *sensitivity* and *specificity*," (cited in Elvik, 2008, p. 26). They are defined as follows:

$$Sensitivity = \frac{Number\_of\_correct\_positives}{Total\_number\_of\_positives} \quad (1)$$

$$Specificity = \frac{Number\_of\_correct\_negatives}{Total\_number\_of\_negatives} \quad (2)$$

The total number of positives equals the number of correct positives plus the number of false negatives, and the total number of negatives equals the number of correct negatives plus the number of false positives.

The performance of different values for the critical number of accidents used to identify a black spot can now be assessed in terms of a *receiver operating characteristic curve* (ROC-curve). Such a curve, derived from the simulated data, is shown in the Figure 7. The false positive rate is plotted along the abscissa. This is equal to 1 minus specificity. The true positive rate (sensitivity) is plotted on the ordinate. If the diagnostic test discriminates well, the ROC-curve will rise steeply, close to the ordinate and flatten out near the top of the diagram. If the diagnostic test is uninformative, the ROC-curve will follow the diagonal line indicated in Figure 7.



Source: Austrian guidelines for black spot identification

Figure 8. Identification of road accident black spots in Austria by sliding window approach

With regard to the sliding window method, Elvik (2008) had two important conclusions. One is that using this method artificially inflates the number of black sections, and makes each section look blacker than it really is (i.e. having a higher recorded number of accidents); the other is that sliding window has the advantage of identifying more correct positives, but the disadvantage of identifying more false positives.

(2) Limitations in analyzing black spots

Traditional approaches employ only recorded number of accidents to identify black spots. As a consequence, any set of identified hazardous road locations will contain both true and false positives. This may lead to the discrimination of true and false positive sites. This section summarizes some results from past studies in order to highlight the limitations in black spot analysis of traditional approaches.

Danielsson (1988) showed that "one commonly used criterion for identifying a truly hazardous road location, namely the over-representation of a particular type of accident is vulnerable to regression-to-the-mean-bias, because over-representation could be attributable mainly to chance," (cited in Elvik, 2008, p. 30).

"A commonly applied criterion to discriminate between true and false black spots is the presence of a dominant accident pattern. A dominant accident pattern is characterized by the over-representation of a particular type of accident," (cited in Elvik, 2008, p. 31). It is therefore of some interest to probe whether there is any difference in the regression-to-the-mean effect between hazardous road locations that have a dominant accident pattern and those that do not. In order to test this, Elvik (2006) conducted a study on regression-to-the-mean at hazardous road sections with and without a dominant accident pattern and came to the conclusion that the presence of a clearly identifiable pattern of accidents characterized by the dominance of a particular type of accident may not effectively separate true from false black spots.

Harwood *et al.* (2002) pointed out that “some sites with a high number of accidents do not have readily identifiable accident pattern. A given deficiency in highway design or traffic control can contribute to accidents at one site, while at another site with similar deficiency, there are no accidents or no clear pattern of accidents associated with the deficiency,” (cited in Elvik, 2008, p. 32). Finally, a given deficiency can contribute to different accident types. This suggests that an analysis of accidents designed to identify true black spots must go beyond merely identifying a dominant accident pattern. Thus, an approach to accident analysis is needed that provides clearer criteria for identifying true black spots, recognizes the possibility that analysis might be inconclusive, and minimizes the role of analyst expectancies.

3. SAPO-BASED BSM APPROACH

Virtisen (2002) stated that “high-risk sites are targeted with aim of improving safety on the road network through remedial treatment of the sites. Any achieved positive effects of safety measures at accident hot spots are denoted the benefits of the implemented measures. Implementing safety measures is costly, but in theory, all measures generating a positive net-benefit should be implemented. However, the restricted funding for hot spot safety work does put a limit to the number of sites that may be treated. Therefore, it is necessary to prioritize between sites and safety measures in order to utilize the limited funds as effectively as possible,” (cited in Geurts and Wets, 2003, p. 11). The general aim of prioritizing may be described as:

$$\underset{Y}{Max} \frac{B(Y)}{C(Y)} \qquad (3)$$

where,

Y represents a portfolio of safety measures, and C(Y) and B(Y) denote the corresponding overall cost and benefit of Y.

3.1 The Aims of SAPO-Based BSM Approach

The aim of new BSM approach is to enable road administration to:

(1) Determine spots within the road network with a poor safety performance based on accident data and where deficits in road infrastructure have to be suspected;

(2) Rank the spots by potential savings (safety potential) in accident costs in order to provide a priority list of spots to be treated by road administrations.

The accident structures of the spots are then analyzed in order to detect abnormal accident patterns, which can lead to possible improvement measures. Finally, this offers the possibility of comparing the costs of improvement measures to the potential savings (safety potential) in accident costs, allowing the ranking of measures by their cost – benefit ratio.

3.2 Advantage of SAPO-Based BSM Approach

SAPO-Based BSM approach is developed based on the *Network Safety Management* (BASt & Sétra, 2005). The methodology employed in the approach focuses on the traffic volume and the severity of accidents at spots and the evaluation of the accidents on the basis of accident cost rates. The comparison of actual accident cost with a hypothetical estimated base accident cost provides information on SAPO of spots.

The advantage of the SAPO compared to the classic accident parameters is that it allows assessing different road types and roads with different volumes at the same time. Furthermore, as the SAPO is given in accident cost, it can be related to the cost of the improvement measures.

Brannolte & Munch (2009) claimed that SAPO is the most important parameter to identify black spots on which safety improvement measures are expected to have the greatest effects.

3.3 Basic Values for Determination of SAPO

The development of the SAPO-Based BSM Approach is based on the calculation of accident rates and accident cost rates. Thereby, the following different calculation models should be distinguished:

- Sections with similar alignment: models for certain road sections;
- Transitions (single elements): models for spots.

3.3.1 Accident Cost

When analyzing accidents of different categories together, the numbers of accidents are weighted by the accident severity. Accident Costs (AC) are, therefore, used to describe the combined effect of number and severity of the accidents.

Annual Average Accident Cost (AC_a) [USD/year] is calculated with the formula (4) as follows.

$$AC_a(F+SI+LI+PDO) = \frac{A(F)\times MCA(F) + A(SI)\times MCA(SI) + A(LI)\times MCA(LI) + A(PDO)\times MCA(PDO)}{t} \quad (4)$$

where,

A is number of accidents; MCA is the mean cost per accident [USD/acci]; and t is the period of time under review [year].

Table 2 shows the mean cost per accident for four different levels of severity in the road network in Vietnam. These accident unit costs are calculated based on the Human Capital Method.

Table 2. Mean cost per accident for various severities (Price level 2008)

Severity Description	Cost per Accident [USD/acci]
Fatal (F)	31,777
Serious Injury (SI)	9,488
Light Injury (LI)	1,071

Property Damage Only (PDO)	354

Source: JICA & NTSC (2009), *Study on Master Plan of Road Traffic Safety in Vietnam up to 2020*

3.3.2 Accident Density

The density of accidents represents the incidence of accidents on a road section within a defined time period. The accident density makes it possible to determine areas with a significant number of accidents. They are calculated based on the number of accidents/casualties or accident costs.

- Accident Density (AD): average number of accidents or casualties within either a road section of one kilometre length or a defined spot within a defined time period (number/year).
- Accident Cost Density (ACD): average of the economic costs for either a road section of one kilometre length or a defined spot within a defined time period (costs/year).

Due to the mentioned definitions the density is calculated with the formulas in Table 3.

Table 3. Formulas of Accident Density (AD) and Accident Cost Density (ACD)

Spots		Sections	
$ACD = AC/(1000 \cdot t)$	(5)	$ACD = AC/(1000 \cdot L \cdot t)$	(6)
$AD = nA/t$	(7)	$AD = nA/L \cdot t$	(8)

ACD = density of accident costs; AD = density of accident; nA = number of accidents; L = length of road section; t = time period.

3.3.3 Accident Rate

Accident Rates represent a road user's risk of being involved in an accident. Like the densities, rates are calculated for numbers of accidents as well as for accident costs.

- Accident Rate (AR): average number of accidents at a traffic volume of one million vehicles and one kilometre section length (for spots only one million vehicles)
- Accident Cost Rates (ACR): average of economic costs at a traffic volume of one million vehicles and one kilometre section length (for spots only one million vehicles).

The rates for number of accidents or rather for accident costs are calculated with formulas in the Table 4 as follows:

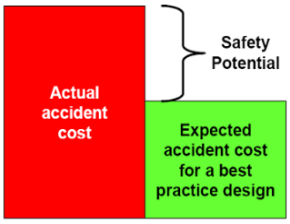
Table 4. Formulas of Accident Rate (AR) and Accident Cost Rate (ACR)

Spots		Sections	
$ACR = 1000 \cdot AC/(365 \cdot AADT \cdot t)$	(9)	$ACR = 1000 \cdot AC/(365 \cdot AADT \cdot t \cdot L)$	(10)
$AR = 10^6 \cdot nA/(365 \cdot AADT \cdot t)$	(11)	$AR = 10^6 \cdot nA/(365 \cdot AADT \cdot t \cdot L)$	(12)

ACR = accident cost rate, AR = accident rate, AADT = average annual daily traffic, nA = number of accidents, L = length of road section, t = time period.

3.3.4 Safety Potential

It is an important task of road administrations to determine the road sections and spots that have poor safety properties which could be improved by changes in the roadway, its equipment, and traffic operation.



Source: Transport Research Arena Europe 2006, Kerstin Lemke BASt, Germany

Figure 9. Diagrammatic views on the safety potential defined as the difference between actual accident costs and the assumption of expected basic accident costs refering to best practice road design

As resources are limited, those sections and spots where improvements can be expected to have the highest cost–benefit ratio have to be treated first. Therefore, information is needed on the accident costs per kilometer (or at a given location or spot) and the SAPOs for possible remedial measures.

The SAPO is defined as the amount of accident costs per kilometre road length (cost density) that could be reduced if a road section would have a best-practice design.

The higher the SAPO, the more societal benefits can be expected from improvements to the road. The SAPO (refers to Figure 9) is calculated as follows:

$$SAPO = ACD - bACD \quad (13)$$

The Basic Accident Cost Density (bACD) represents the anticipated average annual number and severity of road accidents per kilometre, which can be achieved by a best-practice design at the given average daily traffic. It can be calculated as the product of bACR and the Average Daily Traffic (ADT):

$$bACD = \frac{bACR \times ADT \times 365}{10^6} \quad (14)$$

The main idea is to define bACR for many different types of roads and intersections which are derived from the detailed assessment of existing accident cost rates. The bACR includes only that share of all accidents which could not be avoided by a very good design on regulations conforming to standards.

3.4 Statistical Test

Table 5. Formulas for calculation of expected number of accidents (eA)

Spots		Sections	
$eA = \frac{365 \cdot \overline{AR} \cdot ADT \cdot t}{10^6}$	(15)	$eA = \frac{365 \cdot \overline{AR} \cdot ADT \cdot L \cdot t}{10^6}$	(16)

$\overline{AR}$ = Average accident rate [A/(10^6 veh . km)], ADT = Average daily traffic in t years [veh/24h], L = Length of road section [km], t = Period of time under review [years].

According to *Network Safety Management* (BASt & Sétra, 2005) to make sure that the road sections or spots identified as hazardous are not merely the result of random variation in accident counts, statistical tests are performed. The test consists of the comparison of the observed number of accident A with the expected number of accidents eA of that section or spot and the determination of the importance of the deviation by calculating the confidence interval of the observed values (Poisson law).

3.5 Procedure of SAPO-Based BSM Approach

The SAPO-Based BSM Approach can be subdivided into five work steps as shown in the Table 6:

Table 6. Typical stages in SAPO-Based BSM Approach

Work Steps	Epigraphs	Descriptions
Basic data	Accident Pin Boards establishment	1-year & 3-year Accident Pin Boards (APBs) have to be established
1st	Identification of sites with high accident frequency	Identification of sites with high accident frequency based on the selected critical values and APBs
2nd	Ranking of sites	Ranking of high accident sites by SAPO
3rd	Accident pattern analysis and Local accident investigation	Pre-analysis based on collision diagrams and on-site inspection to determine safety countermeasures
4th	Treatment of identified BSs	Implementation of treatment including immediate measures, medium term & long term measure
5th	Evaluation	Before-and-after evaluation of effect of treatment

3.6 Required Data

Figure 10. Typical example of Accident Pin Board (APB) of the area under study

Following basic data is required for identification and treatment of black spots:

- Accident data (1-year and 3-year Accident Pin Boards (APBs), refers to Figure 10);
- Geometric data of the road network;
- Traffic volume of the road network.

In the Accident Pin Boards (APBs) accident type is marked by the colour of pins, accident category is marked by the size of pins, and some special accident circumstances are marked by coloured triangle such as pedestrians are involved, motorcycles are involved, alcohol, etc. as shown in the Figure 10.

4. FROM SAFETY POTENTIAL TO MEASURE – A CONCRETE EXAMPLE

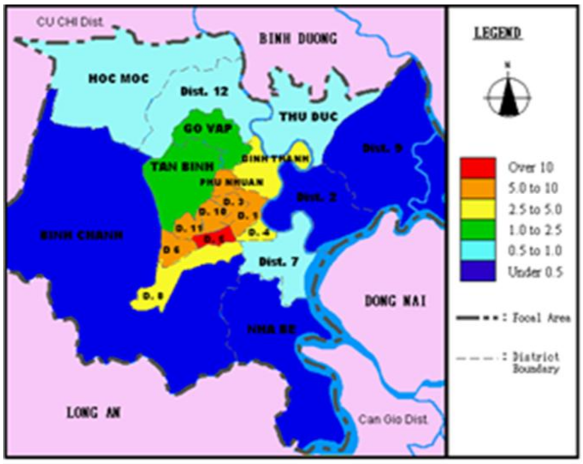
4.1 Introduction of Study Area

Phu Nhuan (Figure 11), an urban district in HCMC, was selected as the study area with the following details.

- Land use type: Urban area
- Area: 5 km^2
- Population: 180,000 peoples (statistic data 2009)
- Road density: 5.16 km/km^2 (Figure 12)

Source: HCMC Department of Transportation, 2011

Figure 11. Perspective image of Phu Nhuan District (from North to South)



Source: HOUTRANS, 2008

Figure 12. Road network densities in Ho Chi Minh City

4.2 Process of Black Spots Identification and Treatment Based on SAPO

As mentioned in the sub-section 3.5, SAPO-Based BSM can be subdivided into five work steps as in Figure 13. This sub-section shows more details with description and required data of each step.

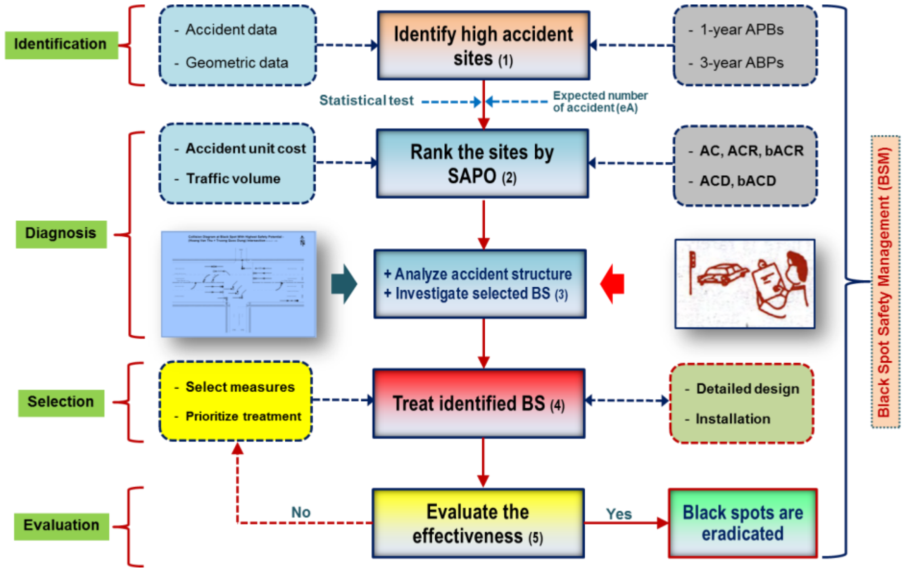


Figure 13. Process of SAPO-Based BSM Approach which identifying and ranking black spots based on potential savings in accident cost

4.3 Accident Data Analysis - Preliminary Results

Between 2009 and 2011, 531 accidents with casualties or serious material damage were recorded within the study area. 489 accidents with casualties include 59 accidents with fatalities, 307 accidents with seriously injured, and 123 accidents with slightly injured as shown in the Figure 14. In consequence of these accidents 61 persons were killed, 397 seriously and 275 slightly injured. Furthermore in the same time period 42 accidents with serious material damage happened as well.

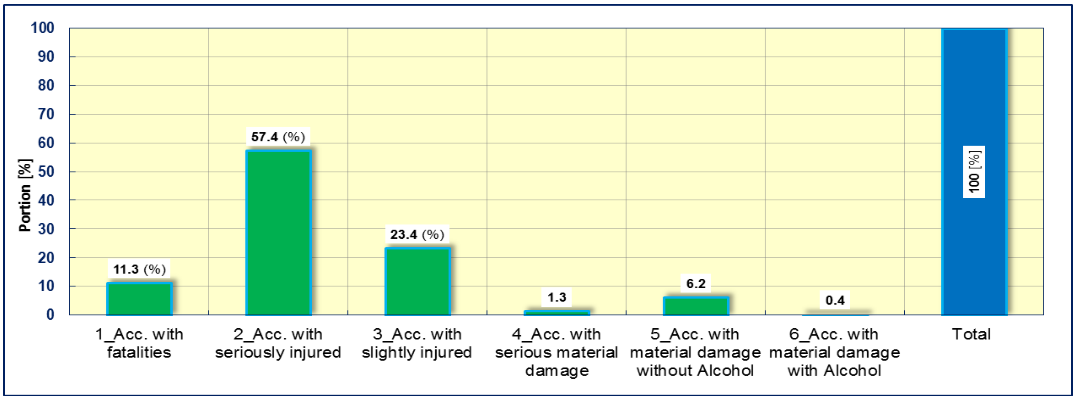


Figure 14. Distribution of accident categories (total number 531)

The accident type 6 (accidents in longitudinal direction), and type are the most frequent accident types with 48% and 26% portions of the total number of accidents as shown in the Figure 15. The remaining accidents are attributed to accidents in pedestrian accidents (type 4), single accidents (type 1), parked vehicle accidents (type 5), and other accidents. The definition of *accident types* is based on the conflict situation which has caused the accident.

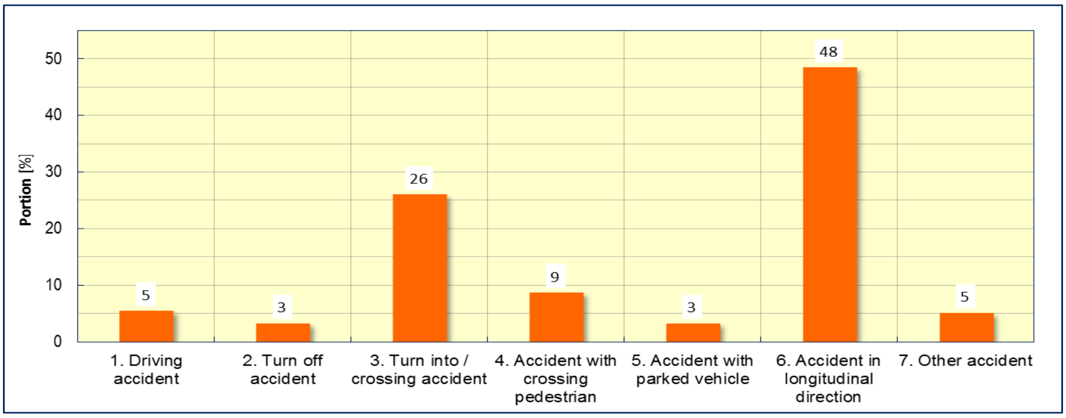


Figure 15. Distribution of accident types (total number 531)

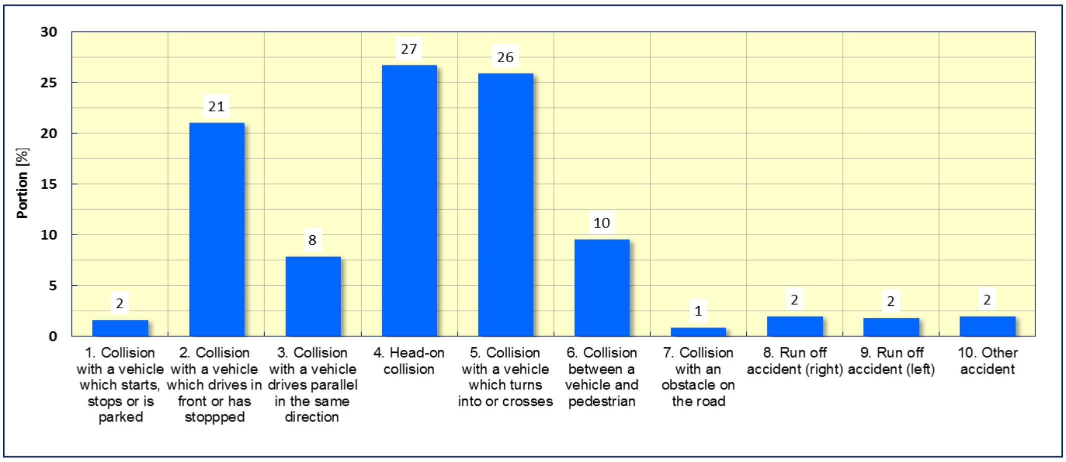


Figure 16. Distribution of accident kinds (total number 531)

Statistics show that accident type 6 has highest portion of serious injuries and fatalities. A more detailed analysis of accident type 6 is given in Figure 16 which shows the distribution concerning accident kinds. The *kind of accidents* is defined by the moving direction of the involved vehicles at the time of the first collision. If there was no collision the first mechanical effect is important.

Accidents in longitudinal direction such as head-on collisions while overtaking (highest percentage 27%) are characterized by a high severity. Such accidents often result in fatal head-on collisions with serious consequences and might be the reason for the increased accident cost unit rates.

4.4 Determination of Threshold Value in Identifying Sites with High Accident Frequency

Table 7. Calculation of statistical parameters of at-site recorded accidents

Year	Total no. of Acci.	No. of Sites	Acci. per site (Avg.)	Variance	Standard deviation	C.o.f of Variation	Confidence interval at significance level 1%	
							Min. value	Max. value
2011	191	79	2.69	2.14	1.46	0.54	2.267	3.113
2010	176	68	2.72	3.49	1.87	0.69	2.136	3.304
2009	164	62	2.61	3.34	1.83	0.70	2.011	3.209

The three 1-year APBs are used to determine critical value for identification of high accident location within road network in the study area. The statistical parameters of at-site recorded number of accidents are calculated in the Table 7.

Based on the results as shown in Table 7, a value of 3-severe-accidents per year was proposed as a threshold value to identify sites with higher accident frequency within the study area. All of sites which have recorded number of accidents equal or higher than threshold value will be selected to do statistical test and calculate the SAPOs.

4.5 Safety performance assessment of selected critical value

The safety performance of selected threshold value can be assessed by using *Receiver Operating Characteristic Curve* (ROC-curve) as shown in the Figure 7. Based on this curve 3-accident critical value has true positive rate (sensitivity) is 0.75 and false positive rate (1-Specificity) is 0.07.

4.6 Calculation of SAPO

The SAPOs of the 18 identified locations within study area which have high accident frequency are calculated based on accident data and accident unit costs of the year 2011 as shown in Figure 17. The highest value of SAPO is 122×10^3 [USD/year], this means that in terms of economic, in the year 2011, an amount of 122,000 USD of accident cost could be saved if the spot would have a best practice design.

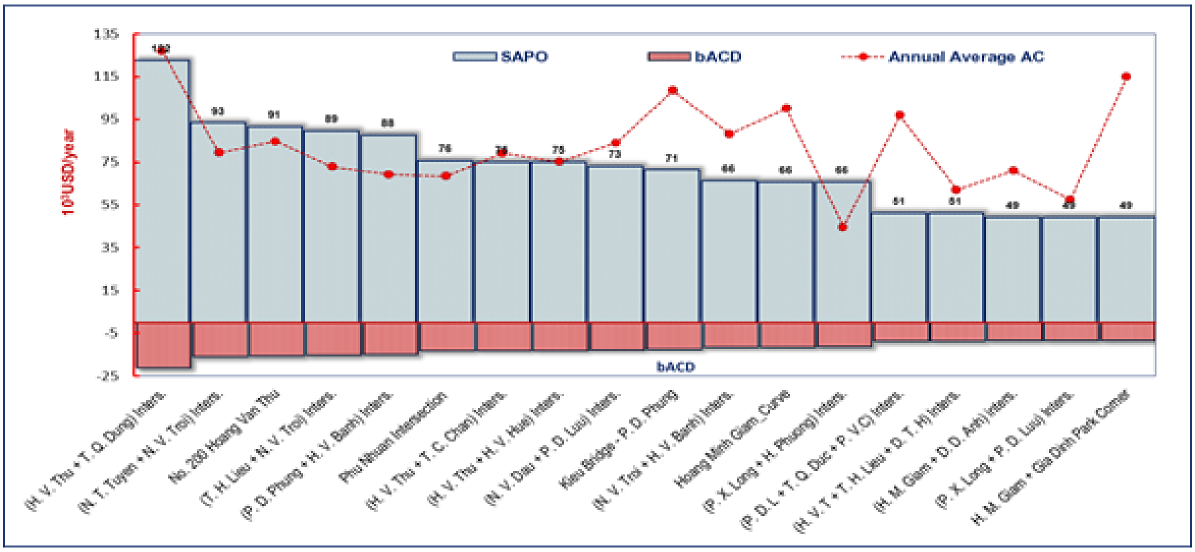


Figure 17. Ranking of the 18 identified black spots by SAPOs of the year 2011

In this research the basic accident cost rate (bACR) is calculated by using a specific percentile, 15% of the overall distribution of the accident cost rates.

4.7 Accident Pattern Analysis

The location with the highest SAPO of the 18 identified locations was selected to be the place whose accident pattern was analyzed by means of collision diagram as shown in Figure 18.

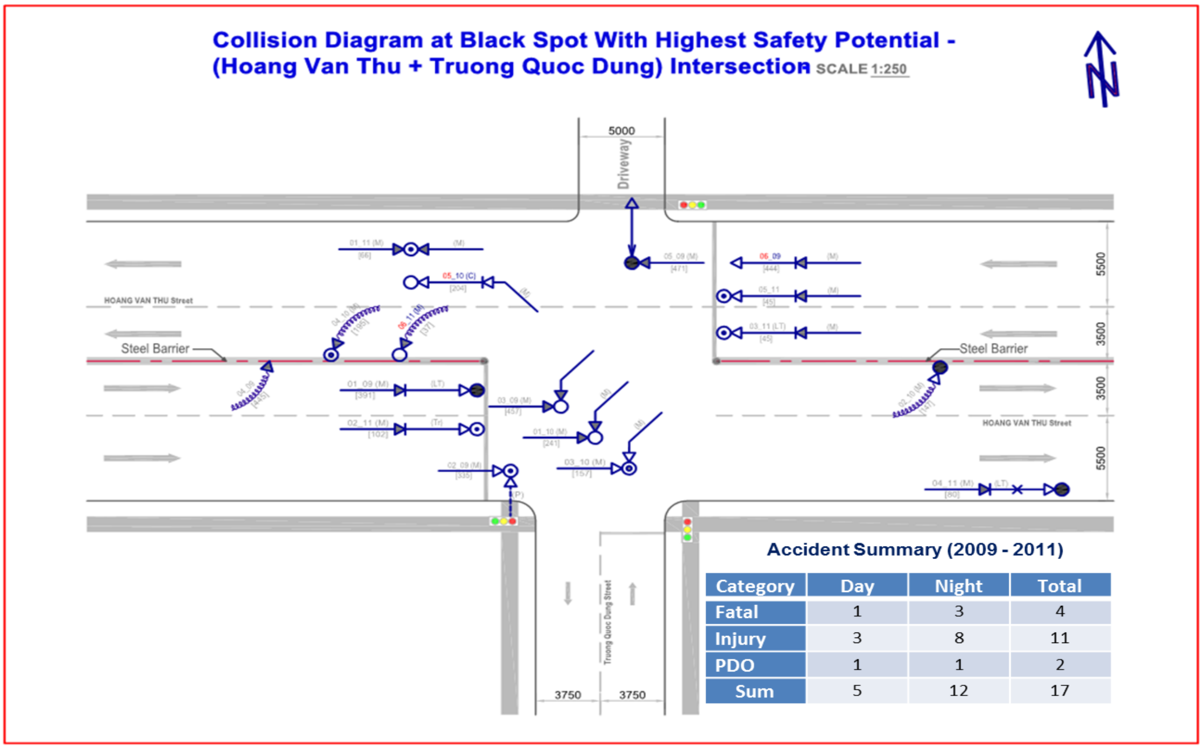


Figure 18. Collision diagram of black spot which has highest SAPO

❑ Searching for a dominant accident pattern using stick diagram

There were 12 accidents during the hours of darkness, 6 accidents of rear-end collision, 4 accidents of single vehicle running off the road, 3 accidents of left-turn heading, and 4 accidents with excessive speed as shown in the Figure 19.

Accident No.	1/09	2/09	3/09	4/09	5/09	6/09	1/10	2/10	3/10	4/10	5/10	1/11	2/11	3/11	4/11	5/11	6/11	Sum
Severity	F	SI	U	PDO	F	PDO	U	F	SI	SI	U	SI	SI	SI	F	SI	U	-
Single vehicle running off the road				x				x		x							x	4
Left-turn heading			x				x		x									3
Right-turn heading																		0
Right angle collision					x													1
Head-on collision												x						1
Rear-end collision	x					x					x		x	x		x		6
Pedestrian-Vehicle collision		x																1
Parked or stopped vehicle collision															x			1
Darkness	■		■	■	■	■	■			■			■	■	■	■	■	12
Wet surface																		0
Excessive speed	■							■		■					■			4

Figure 19. Stick diagram of black spot which has highest SAPO

❑ Identifying risk factors contributing to accidents and countermeasures

Brude and Larsson (1982) claimed that “the accident analysis together with on-site inspection should enable us to decide whether a high recorded number of accidents is due to chance or to deficiencies in design or traffic control,” cited in Elvik, 2008, p. 33.

Table 8. Potential causal factors and possible countermeasure

No.	Accident types	Potential causal factors	Possible countermeasures
1	Night-time accidents	➢ Inadequate roadway lighting	❑ Improve street lighting
2	Rear-end collision	➢ Large number of turning vehicles ➢ Poor visibility of traffic signal ➢ Inadequate signal timing ➢ Unwarranted signal ➢ Slippery pavement ➢ Crossing pedestrians	❑ Provide right-turn phase ❑ Provide turn lane ❑ Provide adequate drainage ❑ Groove pavement ❑ Adjust phase change interval ❑ Zone protection
3	Single vehicle running off at the junction	➢ Inadequate signal timing ➢ Inadequate advance warning signs ➢ Slippery pavement	❑ Provide signal actuation with dilemma ❑ Overlay pavement ❑ Provide red clearance interval
4	Left-turn heading	➢ Restrict sight distance ➢ Excessive speed ➢ Inadequate signal timing ➢ Large traffic volume	❑ Remove sight obstruction ❑ Reduce speed with enforcement ❑ Provide progression ❑ Add lane

5. CONCLUSIONS

The traditional criterion for identifying a true black spot based on a dominant pattern of accidents has turned out to be of inadequate validity. Analysis of accidents at black spots is best viewed as a means of developing hypotheses regarding potential contributing factors to the accidents.

The new BSM approach is based on the SAPO in identifying and ranking black spots. The SAPO identifies network spots on which safety improvement measures are expected to have the greatest effect, but it requires a reliable basic data system. The basic data such as accident pin board (APBs) or accident maps, road network data, and traffic volume play the key role in identifying, ranking and treating black spots.

The New BSM approach is expected to fill the gaps left in traditional approaches in identifying and analyzing black spots; and to give satisfactory remedies for the problems of road safety suitable for the local traffic conditions of HCMC.

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