Identifying Black Spots Based on Safety Potential – A Suitable Approach to Accident Reduction in Developing Countries

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Abstract: In improving road safety, identifying black spots based on safety potential is also known as identifying locations with potential saving in accident costs. Such identification is an attempt to make the selection of black spots which are most suitable to treat out of the identified ones. This paper intends to introduce an approach to identifying locations with potential saving in accident costs. In such approach, the key parameter used to assess the safety performance of road spots is the safety potential. This approach enables the identification of the black spots for which safety improvement measures are expected to have the greatest economical effectiveness. As a result, the approach is of great use to accident reduction in developing countries facing limited budgets for road safety improvement.

Keywords: black spots identification, safety potential, accident cost saving, black spot management, identifying black spots

1. INTRODUCTION

Road traffic accident is most important negative impact of road networks. The problem of accident is a very acute in road transport due to complex flow pattern of vehicular traffic, presence of mixed traffic along with pedestrians. Road traffic accident leads to loss of life and property.

Road planners and engineers in the highly motorized countries have learnt from the mistakes made in the past and realized the potential of road safety conscious planning and design. However, most of their counterparts in developing countries are often still preoccupied with the problems of road construction, maintenance and increasing the network capacity. Thus, all too frequently, roads and road systems are being built or upgraded with little consideration given to road safety. As a result, black spots and black links are created and many road users are being killed or injured regrettably.
Many lives could be saved and many accidents avoided, if the existing road infrastructure was managed according to the best practice of safety engineering. Action needs to be taken on the selection of black spots on the basis of local accident records. Therefore, the purpose of this paper is to introduce a new approach to identify black spots based on safety potential which can both identify and prioritize black spots efficiently. With such dual function, the approach can assist developing countries to overcome the shortage of funds for black spot identification and treatment – the two basic stages of black spot management.

2. CHALLENGES OF BLACK SPOT MANAGEMENT IN DEVELOPING COUNTRIES

The developing world has been facing a numbers of challenges in terms of black spot management which can be described as follows.

2.1 Challenges associated with the accident database system

Developing countries have been experiencing a seriously insufficient road traffic accident database system which cannot meet the requirements of the road network safety management. Such insufficiency can be felt in such aspects as poor systemization, low accessibility, low reliability and poor adequateness of data. Another important aspect is the under-reporting of road accidents. Specifically, approximately 50 percent of fatal accidents are under-reported such as Vietnam, Thailand (see World Health Organization [WHO], 2013). Thus, one of the major challenges of road safety improvement in developing countries is how to improve the road traffic accident database system efficiently.

2.2 Challenges associated with the road environment

The first challenge is that of road design and planning. Motorcycles are considered the majority vehicle in developing countries but most of the existing road networks in these countries were designed in compliance with the standards employed in developed countries where motorcycles are considered a minority vehicle. As a consequence, many motorcycle accidents have occurred in the developing world (WHO, 2013). Motorcycle users are relatively more affected by characteristics of the road environment in terms of crash causation and severity of injury outcome than other road users (Haworth, 2012).

Another challenge for countries with high aspirations for road safety is how to provide – in an affordable and feasible manner – a road infrastructure that is forgiving for motorcycle riders and still functions well for other road users.

2.3 Challenges associated with the safety work budget

Implementing safety measures is costly, but in theory, all measures generating a positive net-benefit should be implemented (Geurts and Wets, 2003). Moreover, in developing countries there are so many requirements for road network safety improvement, especially for the black spot treatment. However, the funds available for safety work are always scarce. This leads to a limitation of sites which can be effectively treated. Thus, there is a challenge of how to use the limited funds effectively to both treat all of the black spots and solve other related road safety issues.

2.4 Challenges associated with the knowledge constraints
Motorcycle accidents made up a large proportion of the total number of road accidents in developing countries. The cases of Thailand (60%) and Vietnam (approximately 70%) are good cases in point (Nguyen, 2013). There should be more incorporation of motorcycle safety into the black spot safety management program of such countries. Such incorporation requires good knowledge about motorcycle safety, mobility and a number of local factors to which motorcycle accidents are attributable. However, most of the research into the safety and mobility of motorcycles comes from the developed world (Association des Constructeurs Européens de Motocycles [ACEM], 2004; Hurt et al., 1981), with the exception of some studies of helmet use from Asia (Haworth, 2012) and a large-scale motorcycle crash study from Thailand (Kasantikul, 2002).

Furthermore, much of the research focuses on aspects of motorcycles as a minority vehicle, with much riding being for recreation (Haworth, 2012). While motorcycles serve as the means of transport in developing countries. This fact suggests that there is a severe shortage of research into motorcycles as a majority vehicle in the developing world.

3. POTENTIAL ACCIDENT REDUCTION vs. POTENTIAL SAVING IN ACCIDENT COST

Traditional methods of black spot identification are based on numbers of accidents as the main indicator. As a result, the expected improvement is weighted by the reduction in numbers of accidents only, almost ignoring other important aspects such as severity and economical effectiveness. Therefore, it is necessary to integrate these factors as indicators in identifying black spots. Such integration can be found in a new approach to black spot identification based on accident costs as a ‘master indicator’. This approach enables the identification of the black spots whose treatment can bring the optimal economical effectiveness. In order to have better view of this approach, it is vital to tell the difference between potential accident reduction and potential saving in accident cost.

3.1 Potential accident reduction

![Figure 1. Definition sketch of the potential accident reduction](source.png)

Locations with potential accident reduction are locations where the recorded number of accidents is bigger than the expected number which is determined by using safety
performance functions (SPF). These locations exhibit a potential accident reduction known as potential for safety improvement (Kononov, 2002).

Potential accident reduction is defined as the difference between the predicted crashes frequency determined by Empirical Bayesian estimation and the crashes frequencies predicted by the safety performance function, as shown in Figure 1 (Tegge et al., 2010).

3.2 Potential saving in accident cost

Locations with potential saving in accident costs are locations where the actual accident costs are higher than the expected accident costs which are estimated based on real accident data. These locations exhibit a potential saving in accident costs known as safety potential (Ganneau and Lemke, 2008).

Safety potential is defined as the difference between actual accident cost and basic accident cost (expected accident cost) as shown in Figure 2. It describes the potential savings in accident costs that could be reached by remedial measures (Federal Highway Research Institute - Germany [Bast] and Roads and Motorways Engineering Department - France [Sétra], 2005).

4. ANALYTICAL FRAMEWORK FOR IDENTIFYING BLACK SPOTS BASED ON SAFETY POTENTIAL

4.1 The aim of the approach

The aim of the 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 in accident costs in order to provide a priority list of spots to be treated.

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 in accident costs, allowing the ranking of measures by their cost–benefit ratio.
4.2 Analytical framework for identifying black spots based on safety potential

The identification of back spots based on safety potential can be divided into five steps as shown in Figure 3.

Figure 3. Reference framework diagram for identifying black spots based on safety potential

4.2.1 Step 1 - Data collection and statistical analysis of accidents

The data collection is supposed to come up with the quantitative statistics of the following three sets of data:

- Accident data by severity and location;
- Accident unit cost by accident severity;
- Traffic data (AADT or ADT); and
- Basic accident cost rate of the road networks.

The process of collecting such data may pose these two common issues – (1) the inaccessibility of basic accident cost rate, and (2) the decision as to which crash period to select. However, there are applicable solutions for both of the two issues.

- If the data on basic accident cost rate is insufficient, a specific percentile (e.g. 15%) of the overall distribution of the accident cost rates can be used (Bast and Sétra, 2005).
The crash period of three to five years is the best choice for the sake of data validity and reliability.

Actually, a number of experts of road safety present the support of this point of view. First, Elvik (2008) claims that the length of the period used to identify black spots varies from 1 year to 5 years, a period of 3 years is used frequently. Next, research by Cheng and Washington (2005) shows that the gain in the accuracy of black spot identification obtained by using a longer period of three years is marginal and declines rapidly as the length of the period is increased. There is little point in using a longer period than 5 years.

Additionally, Land Transport New Zealand [LTNZ] (2004) stressed out that a 3-year crash period could be used in heavily trafficked networks or areas where road changes are recent or ongoing. A three-to-five-year period is preferred because:

- It is long enough to provide a sufficient number of crashes for meaningful results;
- It is short enough to limit the number of traffic and environmental changes that may bias results;
- It helps remove statistical fluctuation and reduce the impact of the regression-to-the-mean effect;
- It provides a consistent base for before and after comparisons.

4.2.2 Step 2 - Identification of spots by dividing the roads into sections and spots

In the road safety engineering, the following different calculation models should be distinguished: (1) sections with similar alignment - models for certain road sections, and (2) transitions (single elements) - models for spots. According to Bast and Sétra (2005), there are two possible ways of dividing the road into sections and spots.

(1) Dividing the road into sections and spots on basis of the network structure: This method of dividing is appropriate if a visualization of the accident occurrence on the road network is not available or the accident occurrence is to be analyzed in interaction with other influencing parameters (e.g. road improvement standard, accessibility, traffic) in the road network.

(2) Dividing the road into sections and spots on basis of the accident occurrence: This method of dividing appropriate if a visualization of the accident occurrence is available and no other section demarcations are required on the basis of a joint consideration of various influencing parameters.

Ogden (1994), Southeast Michigan Council of Governments [SEMCOG] (1997), and Transportation Research Board [TRB] (2009) pointed out that spots should be defined to include the area of influence of the features in question. For example, driver behavior can be influenced as far as 150 metres from a curve and 76 metres from an intersection (or further with severe congestion and queuing). Considering an influence area of at least 150 metres...
from both ends of a non-intersection spot location also helps ensure that a larger share of relevant crashes are properly identified, given typical uncertainties and errors in reporting crash position.

### 4.2.3 Step 3 - Identifying high accident frequency locations

This step is aimed to identify the list of high accident frequency locations within the sample of locations established according to the dividing of the road into sections and spots as in Step 2. Such identification is based on the threshold value of observed numbers of injury accidents at every site in the sample in three consecutive years. The simplest way to select the threshold value for the sample is the following:

\[
\text{Threshold Value} = \text{Max} [\bar{x}, m]
\]

in which,

- \( \bar{x} \): the average value, and
- \( m \): the median value of the sample.

Any site with observed number of accidents higher than the threshold value is listed as a high accident frequency location. Sites that have more accidents than the mean value plus one standard deviation should be the first to be singled out for further consideration (Baguley, 1995).

### 4.2.4 Step 4 - Statistical tests

As crashes are rare and random, the number of reported accidents will change from one time period to another even if the expected average crash frequency remains the same (Elvik et al., 2009). To make sure that the 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 accidents with the expected number of accidents of that spot and the determination of the importance of the deviation by calculating the confidence interval of the observed values (Bast and Sétra, 2005).

Furthermore, the Poisson test can be used to determine whether a recent increase in accidents at a site was due to random fluctuation only (Baguley, 1995). What is mentioned above can be illustrated by means of an example.

**Example:** Propose that the injury accident figures observed at a site are as shown in Table 1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Observed accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>3</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
</tr>
<tr>
<td>2013</td>
<td>5</td>
</tr>
</tbody>
</table>
The statistics show that the observed numbers of accidents fluctuated over the years with the sharp increase in the year 2013 as a noticeable case (see Table 1). This fact poses the question of whether such increase was due to random variation only. To answer this question it is necessary to calculate the confidence interval of the observed accidents and then consider the relation between the number of observed accidents of the year 2013 and the confidence interval.

- If the interval encompasses the observed values, there is no random variation. That means the change in the number of the observed accidents is a real one.
- If the interval does not encompass the observed values, there is a random variation. That means the change in the number of the observed accidents is not a completely real one.

Specifically, for the case of this example, the confidence level of 95% corresponds to the confidence interval of from 0.76 to 5.24 accidents as shown in Table 2. This means that accidents may systematically happen in the range of 1 – 6. In other words, the increase in 2013 is real because the corresponding observed number is 5.

The Poisson cumulative probability that there are more than 6 accidents with the long-term average (μ) being 3.0 is 0.0335 or 3.35%. This indicates that the random variation of accident count at the site is 3.35 percent.

4.2.5 Step 5 - Calculation of safety potential and ranking of spots

This step is aimed to (1) calculate the safety potential of the spots identified in Step 3 and verified in Step 4, and (2) rank these spots according to the established safety potential. The calculation of the safety potential is done using the following accident parameters: annual average accident cost, accident density, accident cost density, accident rate, accident cost rate, and basic accident cost rate are shown in Eqs. (3) to (9) in Table 3. Then, the spots of
the road network are ranked on the basis of the magnitude of the safety potential. Such ranking is of great use to further detailed studies so as to determine possible improvement measures. The higher the safety potential, the more societal benefits can be expected from improvements to the roads.

Briefly, the analytical framework for identifying locations with potential saving in accident costs or safety potential is described as in Figure 3.

Table 3. Accident parameters for determination of safety potential of spots

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AC_a$</td>
<td>$AC_a = \frac{\sum nA(c_i) \times MCA(c_i)}{t}$ (3)</td>
</tr>
<tr>
<td>$AD$</td>
<td>$AD = nA/t$ (4)</td>
</tr>
<tr>
<td>$ACD$</td>
<td>$ACD = AC/(1000 \cdot t)$ (5)</td>
</tr>
<tr>
<td>$AR$</td>
<td>$AR = 10^6 \cdot nA/(365 \cdot AADT \cdot t)$ (6)</td>
</tr>
<tr>
<td>$ACR$</td>
<td>$ACR = 1000 \cdot AC/(365 \cdot AADT \cdot t)$ (7)</td>
</tr>
<tr>
<td>$bACD$</td>
<td>$bACD = \frac{bACR \times ADT \times 365}{10^6}$ (8)</td>
</tr>
</tbody>
</table>

Where,
- $AC_a$: annual average accident cost [USD/year]
- $nA(c_i)$: number of accidents of specific accident category $c_i$, in $t \geq 3$ years
- $MCA(c_i)$: mean cost per accident of accident category $c_i$ [USD/accident]
- $t$: period of time under review [years]
- $AD$: accident density
- $nA$: number of accidents
- $t$: time period [years]
- $ACD$: accident cost density [1000 USD/year]
- $AC$: accident cost
- $t$: time period [years]
- $AR$: accident rate
- $nA$: number of accidents
- $AADT$: average annual daily traffic
- $t$: time period [years]
- $ACR$: accident cost rate [USD/1000 veh]
- $AC$: accident cost
- $AADT$: average annual daily traffic
- $t$: time period [years]
- $bACD$: basic accident cost density [1000 USD/year]
- $bACR$: basic accident cost rate
- $ADT$: average daily traffic
5. PRACTICAL IMPLEMENTATION

In order to provide a detailed description of analysis steps in identifying black spots based on safety potential, an urban district named Phu-Nhuan in Ho Chi Minh City (HCMC) was selected as the study area. Before identifying the expected locations, some amount of a priori knowledge about the safety performance of the road network is required. This knowledge was compiled in an extensive data set describing various characteristics of accident distribution profiles as shown in Table 4. This data set was compiled for all types of urban roads over a period of 3 years and contains 40 different parameters related to accident occurrence, such as accident type, severity, and roadway conditions. The set represents a source of a priori knowledge base required for accidents mapping and the estimating of basic accident cost rate.

Table 4. Normative values of various accidents characteristics

<table>
<thead>
<tr>
<th>Categories</th>
<th>Description</th>
<th>Quantity</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Severity-based accident types</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS1: Accidents with fatalities</td>
<td>11.11%</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>AS2: Accident with seriously injured</td>
<td>57.82%</td>
<td>307</td>
<td></td>
</tr>
<tr>
<td>AS3: Accident with slightly injured</td>
<td>23.16%</td>
<td>123</td>
<td></td>
</tr>
<tr>
<td>AS4: Accident with serious material damage</td>
<td>0.94%</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>AS5: Accident with material damage but with driving while intoxicated</td>
<td>6.21%</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>AS6: Accident with material damage but without driving while intoxicated</td>
<td>0.75%</td>
<td>4</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td><strong>Consequences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persons killed</td>
<td>N/A</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Persons injured</td>
<td>N/A</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>Property damage with motorcycles</td>
<td>N/A</td>
<td>943</td>
<td></td>
</tr>
<tr>
<td>Property damage without motorcycles</td>
<td>N/A</td>
<td>186</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Special circumstances</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accidents with motorcycles are involved</td>
<td>92.84%</td>
<td>493</td>
<td>493/531</td>
</tr>
<tr>
<td>Accidents with bicycles are involved</td>
<td>3.58%</td>
<td>19</td>
<td>19/531</td>
</tr>
<tr>
<td>Accidents with pedestrians are involved</td>
<td>8.66%</td>
<td>46</td>
<td>46/531</td>
</tr>
<tr>
<td>Drink-driving accidents</td>
<td>3.39%</td>
<td>18</td>
<td>18/531</td>
</tr>
</tbody>
</table>
### Motorcycle-related accident types

| Motorcycle Accidents (caused by a motorcycle) | 432 | 81.36% |
| Non-Motorcycle accidents (not caused by a motorcycle) | 99 | 18.64% |

### Intersection-related accident types

| Intersection accidents (occurring at intersections) | 216 | 40.68% |
| Non-intersection accidents (occurring at a location other than intersections) | 315 | 59.32% |

### Time-based accident types

| Day-Time Accidents | 167 | 31.45% |
| Night-Time Accidents | 364 | 68.55% |

### Conflict-based accident types

**AC1:** Driving Accidents (caused by loss control of the vehicle without influence of other road users)
- 30 | 5.65%

**AC2:** Turn-off Accidents (caused by a collision between moving vehicles with other road users during a turn-off maneuver at junctions)
- 18 | 3.39%

**AC3:** Turn-into/Crossing Accident (caused by a collision between moving vehicles with other road users having right of way during a turn-into or crossing maneuver at junctions)
- 138 | 25.99%

**AC4:** Accident With Crossing Pedestrian (caused by a collision between a vehicle and a pedestrian crossing the road)
- 49 | 9.23%

**AC5:** Accident With Parked Vehicle (caused by a collision between moving vehicles with parked or stopped ones)
- 16 | 3.01%

**AC6:** Accident with Longitudinal Direction (caused by a collision between road users which drive in the same or opposite direction)
- 254 | 47.83%

**AC7:** Other Accidents (not classified as any of the six types above)
- 26 | 4.90%

### Direction-based accident types

**AD1:** Collision between a moving vehicle with a vehicle that has just started, is stopped, or parked
- 9 | 1.69%

**AD2:** Collision with a vehicle which drivers in front or has stopped
- 113 | 21.28%

**AD3:** Collision with a vehicle which drives parallel in the same direction
- 42 | 7.91%

**AD4:** Head-on collision
- 143 | 26.93%

**AD5:** Collision with a vehicle which turns into or crosses
- 136 | 25.61%

**AD6:** Collision between a vehicle and pedestrian
- 51 | 9.60%

**AD7:** Collision with an obstacle on the road
- 5 | 0.94%

**AD8:** Run-off accident (right)
- 11 | 2.07%

**AD9:** Run-off accident (left)
- 10 | 1.88%

**AD10:** Other accident
- 11 | 2.07%

### Road conditions

| Dry road | 449 | 84.56% |
| Wet road | 19 | 3.58% |
| Unknown road condition | 63 | 11.86% |

**Total Accidents** | 531 |

**Total Number of Locations** | 108 |
5.1 Stage 1 - Accident data collection, statistical analysis, and mapping accidents

Accident data collection and statistical analysis are the prerequisites for identifying locations based on safety potential. However, it was only possible to access a limited amount of raw road accident data from the local authorities. Accordingly, by means of the analysis of the raw data, a set of intermediate input data was established – the 3-year accident pin board of the period 2009-2011 as shown in Figure 4. The three-year accident pin board (3-year APB) serves as an accident map with the detailed information in the following aspects:

- Location of accidents;
- Severity-based accident types;
- Conflict-based accident types; and
- Special accident circumstances.

The locations of accidents are marked on the GIS-based map. The severity-based accidents are marked by pin sizes. The conflict-based accidents are marked by pin colors. Special circumstances of accidents are marked by colored triangles as shown in the legends of 3-year APB (see Figure 4).

![Figure 4. Three-year Accident Pin Board of study area](image)

5.2 Stage 2 - Dividing the road network into spots and sections based on 3-year APB

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This stage was aimed to identify locations where accidents have clustered with the visual support of the 3-year APB (see Figure 4). Collectively, 108 accident spots were identified, and coded, and the total number of accidents at each of which was also determined. Such intermediate data not only established the divisions of the road network into spots and sections but also facilitates the identification of high accident frequency locations in the next step.

5.3 Stage 3 - Identifying high accident frequency locations

To identify high accident frequency locations, the data on 108 identified accident spots in Step 2 are statistically processed. As a result, the statistical sample of number of injury accidents in three years is established. This sample has an average value of 5.93, median value of 5, and standard deviation of 3.34. Accordingly, the suitable threshold value of number of accidents should be 6. Any spot with more than 6 recorded injury accidents was considered a high accident frequency location (see Table 5). With this threshold as the criterion for identification, a total of 32 high accident frequency locations were determined with 302 injury accidents in three years, accounting for 52.86 percent of all injury accidents in the study area.

5.4 Stage 4 - Statistical test for high accident frequency locations

This stage was intended to estimate the percentage of random and systematic variation in accident count at each identified location from Stage 3. In order to have such estimation, it is necessary to calculate the confidence interval of the particular sample of accident count at each spot. The changes in observed accident numbers within the confidence interval form the systematic variation. The changes in observed number of accidents beyond the confidence interval form the random variation.

The occurrence probability of an observed accident value that is higher than the maximum value of the confidence interval can be calculated by using Poisson probability formula. The percentage of random variation of accident count at a spot is calculated by Poisson cumulative probability as shown in Table 5 and Figure 5.

The calculation method applied to the case of Spot S.002 as a typical one serves as the explanation for the calculation method applied to all other cases of identified high accident frequency locations. The year-based numbers of recorded injury accidents at this spot in the years of 2009, 2010 and 2011 were 3, 4, and 3 respectively. These figures form a sample of 3-year accident count whose long-term average value equals 3.33. The 95% confidence interval of the sample was determined with 1.90 as the minimum value, and 4.77 as the maximum value. The determined interval indicates that the change in number of observed accidents from 2 accidents to 5 accidents is the real change or systematic variation. This systematic variation makes it possible to estimate the quantity of random variation of observed accidents at this spot by considering the year-based numbers of observed accidents were distributed pursuant to Poisson probability distribution. Specifically, for the case of a random variable X with the mean number of successes (μ) being 3.33, the cumulative probability P(X≥6,3.33)
would be 0.1207 or 12.07%. This value is the very random variation of observed accidents (see Table 5 and Figure 5).

Exact calculations of random variation in accident count at a spot require a complicated process. In order to simplify the process, the calculation method which is based on the confidence interval and the year-based numbers of observed accidents is a suitable choice. This method enables the quantitative estimation of the random variation in accident counts at a given spot. On the basis of this estimation the high accident frequency locations can be detected more easily.

![Figure 5. Percentage of random and systematic variations of accident counts at 32 selected spots](image)

**Table 5. Statistical test for four typical high accident frequency locations**

<table>
<thead>
<tr>
<th>No.</th>
<th>Spot ID</th>
<th>Observed Injury Accidents</th>
<th>Long term Average</th>
<th>95% Confidence Interval</th>
<th>Poisson Cumulative Probability P(X=x,μ)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S.002</td>
<td>3 4 3 10</td>
<td>3.33</td>
<td>1.90 4.77</td>
<td>P(X=6.33)</td>
<td>0.1207</td>
</tr>
<tr>
<td>2</td>
<td>S.010</td>
<td>5 4 3 12</td>
<td>4.00</td>
<td>1.52 6.48</td>
<td>P(X=8.40)</td>
<td>0.0511</td>
</tr>
<tr>
<td>3</td>
<td>S.011</td>
<td>4 2 3 9</td>
<td>3.00</td>
<td>0.52 5.48</td>
<td>P(X=7.30)</td>
<td>0.0335</td>
</tr>
<tr>
<td>4</td>
<td>S.012</td>
<td>2 3 3 8</td>
<td>2.67</td>
<td>1.23 4.10</td>
<td>P(X=6.27)</td>
<td>0.0544</td>
</tr>
</tbody>
</table>

5.5 Stage 5 - Calculating safety potential and ranking of spots

The results of calculating safety potential and ranking spots according to their safety potential are shown in Figure 6 and Table 6, in which the spots in were ranked by their safety potential in order to provide a priority list of spots to be treated.

The Figure 6 shows that safety potential of a spot is the difference between actual accident cost and its expected accident cost of the spot. This expected value depends on the basic accident cost rate for a best-practice design. In this research, the value of basic accident cost rate was estimated from 15 percent of the overall distribution of accident cost rate of every specific spot type.

The highest value of safety potential in Figure 6 is 116,240 U.S. dollars per year. This means that each year at the spot, accident cost could be saved 116,240 USD if it had a best-
practice design. Therefore, if the cost of the safety countermeasure at the spot is given, the benefit-cost ratio of the safety improvement project can be identified.

Figure 6. Safety potentials of 32 selected spots within the road network (2009-2011)

Table 6. Calculating safety potential for the top ten spots with highest safety potential

<table>
<thead>
<tr>
<th>Spot ID</th>
<th>ADT</th>
<th>Accidents (2009–2011)</th>
<th>ACa</th>
<th>AD</th>
<th>AR</th>
<th>ACD</th>
<th>ACR</th>
<th>bACR</th>
<th>bACD</th>
<th>SAPO</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.050</td>
<td>13,500</td>
<td>4 7 3 0</td>
<td>125,900</td>
<td>4.67</td>
<td>0.95</td>
<td>125.90</td>
<td>25.55</td>
<td>1.96</td>
<td>9.66</td>
<td>116.24</td>
<td>1</td>
</tr>
<tr>
<td>S.105</td>
<td>14,400</td>
<td>2 10 2 1</td>
<td>102,759</td>
<td>4.67</td>
<td>0.89</td>
<td>102.76</td>
<td>19.55</td>
<td>2.93</td>
<td>15.40</td>
<td>87.36</td>
<td>2</td>
</tr>
<tr>
<td>S.090</td>
<td>18,200</td>
<td>3 4 2 0</td>
<td>86,664</td>
<td>3.00</td>
<td>0.45</td>
<td>86.66</td>
<td>13.05</td>
<td>1.96</td>
<td>13.02</td>
<td>73.64</td>
<td>3</td>
</tr>
<tr>
<td>S.048</td>
<td>11,150</td>
<td>2 6 4 0</td>
<td>79,843</td>
<td>4.00</td>
<td>0.98</td>
<td>79.84</td>
<td>19.62</td>
<td>1.96</td>
<td>7.98</td>
<td>71.87</td>
<td>4</td>
</tr>
<tr>
<td>S.093</td>
<td>10,183</td>
<td>1 10 0 0</td>
<td>81,052</td>
<td>3.67</td>
<td>0.99</td>
<td>81.05</td>
<td>21.81</td>
<td>2.84</td>
<td>10.56</td>
<td>70.50</td>
<td>5</td>
</tr>
<tr>
<td>S.061</td>
<td>8,083</td>
<td>2 6 2 0</td>
<td>78,472</td>
<td>3.33</td>
<td>1.13</td>
<td>78.47</td>
<td>26.60</td>
<td>2.84</td>
<td>8.38</td>
<td>70.09</td>
<td>6</td>
</tr>
<tr>
<td>S.034</td>
<td>11,650</td>
<td>1 9 4 0</td>
<td>77,722</td>
<td>4.67</td>
<td>1.10</td>
<td>77.72</td>
<td>18.28</td>
<td>1.96</td>
<td>8.33</td>
<td>69.39</td>
<td>7</td>
</tr>
<tr>
<td>S.010</td>
<td>4,983</td>
<td>1 8 3 0</td>
<td>70,965</td>
<td>4.00</td>
<td>2.20</td>
<td>70.97</td>
<td>39.01</td>
<td>3.31</td>
<td>6.02</td>
<td>64.94</td>
<td>8</td>
</tr>
<tr>
<td>S.043</td>
<td>28,050</td>
<td>1 8 2 0</td>
<td>70,280</td>
<td>3.67</td>
<td>0.36</td>
<td>70.28</td>
<td>6.86</td>
<td>1.25</td>
<td>12.80</td>
<td>57.48</td>
<td>9</td>
</tr>
<tr>
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<td>6,033</td>
<td>2 3 3 0</td>
<td>60,942</td>
<td>2.67</td>
<td>1.21</td>
<td>60.94</td>
<td>27.67</td>
<td>2.84</td>
<td>6.25</td>
<td>54.69</td>
<td>10</td>
</tr>
</tbody>
</table>

Furthermore, with the ranking of spots by safety potential, it is easy to decide which and how many spots to be treated depending on the financial resources. This fact adds new aspects to the concept of black spots and increases the flexibility of the selection of black spots to be treated by means of the prioritization which is based on economical effectiveness.

6. SUMMARY

This research presents a new black spot identification method which is expected to result in economic as well as societal benefits. In order to ensure these benefits, this new methods takes safety potential as its key parameter. With this key parameter, the method facilitates not only the identification but also the prioritization of black spots. Such facilitation, in its turn,
enables the suitable selection of which black spots to treat first depending on the particular financial conditions of the given region or country.

In order to avoid unexpected shortcomings in the implementation of the method, it is important to pay special attention to the following two aspects.

First, safety potential is the very difference between the actual accident cost and the expected accident cost conforming to the best-practice design standard. The expected accident cost depends on the basic accident cost rate. In ideal circumstances this expected accident cost contains no influence of the infrastructure on the accidents any more but represents the accident cost caused only by the other two components of the transport system – vehicle and road users. The best way to estimate the target values would be to calculate the accident cost rate for a sample of spots with best practice design. Another possibility would be to use a specific percentile of the overall distribution of the accident cost rates.

Second, statistical tests must be done to make sure that the random variation is not the decisive factor in the process of identifying the high accident frequency locations. Random variation in accident count at the identified locations can be estimated by Poisson probability distribution.

In conclusion, the method proposed in this research introduces a new aspect in black spot management by integrating prioritization into the identification. In this way, the method can optimize the black spot treatment with limited financial resources which are facing most developing countries. Still, the benefits are considerable in terms of economic efficiency. Therefore, the method is expected to be a satisfactory solution for accident reduction in developing countries.

7. REFERENCES


Federal Highway Research Institute (Bast), Bergisch Gladbach, Germany, and Road Safety Director, Roads and Motorways Engineering Department (Sétra), Bagneux, France, (2005) Network safety management – NSM, 08.06.2005.