Towards Sustainable Transportation: The Role of Black Spot Analysis in Improving Road Safety

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Abstract: Sustainable transportation goals include an improvement in the level of road safety worldwide. It is well known that traffic accidents are one of the major causes of death worldwide. Black spots are road locations with a higher than statistically expected number of accidents. Remedying black spots would decisively improve road safety. A literature review of black spot identification methods, i.e., accident numbers, accident rates related to exposure, severity of accidents, Poisson and quality control methods, is presented within the framework of this paper. The various approaches adopted by key European and other countries are also summarized and evaluated. An important parameter is the unit length of a road, where accidents are referred. The quality of accident records is also critical. It is concluded that the coupling of statistical and accident severity index methods can contribute to assessing road infrastructure in a more holistic way and, therefore, in providing more reliable results with regard to the road safety level. The design and implementation of effective road safety strategies, based on black spot analysis, can be of great value for the decision makers and decision takers who are involved in the development of a sustainable transportation system.

Keywords: black spots; road safety; safety indicators; comparative analysis; threshold values

1. Introduction

The "Global status report on road safety 2018", released by the WHO [1] in December 2018, brings attention to the fact that the yearly count of fatalities resulting from road accidents has reached 1.35 million. These incidents now rank as the primary cause of death for individuals between the ages of 5 and 29. Pedestrians, cyclists, and motorcyclists, especially those residing in developing nations, shoulder a disproportionate share of this burden [2]. For all ages, road accidents have become the eighth highest cause of death globally and that ranking is expected to rise in the coming decades. Furthermore, the socioeconomic cost of road accidents is classified as by far the most significant among all other human activities [3]. Therefore, every action for road safety improvement should be considered urgent and important. The first step is to realize that driving, in its own right, constitutes the most complex and dangerous daily action every person carries out. There is no other daily action that is so widespread which puts life and physical integrity at stake.

Particularly in Greece, an average of 10,000 road accidents took place during the 2014–2018 period. A total of 3800 people died, almost half of them inside urban areas. During the same period, 80,000 people were injured. From a national population of 10 million, 12,000—the equivalent of a whole town—are killed or injured yearly. A rate of 80 deaths per million inhabitants was the mean figure for the 2014–2018 period, whilst in the EU, the rate averages at 50 and in pioneer countries, like in Scandinavia, the relevant rate has fallen below 30 [4]. Table 1 presents the accident time-series in Greece. In recent years, Greece made some progress in the field of road safety, yet it is still well above the European Union average both in terms of road accidents and road fatalities [5].

However, there is still a great deal of work to be carried out to enhance road safety and make our cities sustainable. Cities are constantly evolving and the same applies for mobility systems. Mobility, along with information and communication technologies (ICT) and energy, is a main pillar of the smart cities concept, which has gained a large amount of attention during recent years [6]. It is expected that ICT can significantly contribute to improving road safety through monitoring traffic in real time and providing appropriate messages to road users [7]. In the framework of smart cities, new mobility services and concepts also arise. One of these concepts that has attracted significant research attention is Mobility as a Service (MaaS), where offerings from various mobility service providers are gathered and provided to end-users through a single digital channel [8]. Such innovative services and concepts can contribute to enhancing road safety, but they can also create new challenges by modifying the supply of transportation services [9,10].

The identification of defects, with regard to road safety, in cities' transportation systems is of great importance, and it also continues to have an essential role in this new era that arises with the appearance of innovative mobility services. As such, the detection of black spots (also referred to as hot spots, hazardous locations, and high accident concentrations) is always at the core of road safety. Black spots are characterized as road locations or sections where the recorded number of accidents is higher than the stochastic expected value during a certain period of time [11,12]. Because driver behavior and vehicle factors are constants throughout a country, this accident concentration could occur due to a variety of reasons, which may be connected to infrastructure defects like poor geometric alignment or local risk factors like traffic or weather; as shown in Figure 1 in such cases (road factors) is attributed a high percent of road accidents. In international fieldwork, there is no common unanimity about the definition and the methods of finding black spots [13–16]. However, especially in countries with high accident records, the identification and treatment of road black spots would be of outmost importance for road safety improvement. The most productive approach seems to be to concentrate on a project level, i.e., on a specific road corridor, identify specific causes and patterns of accidents, and act to heal them (reactive approach) [17].
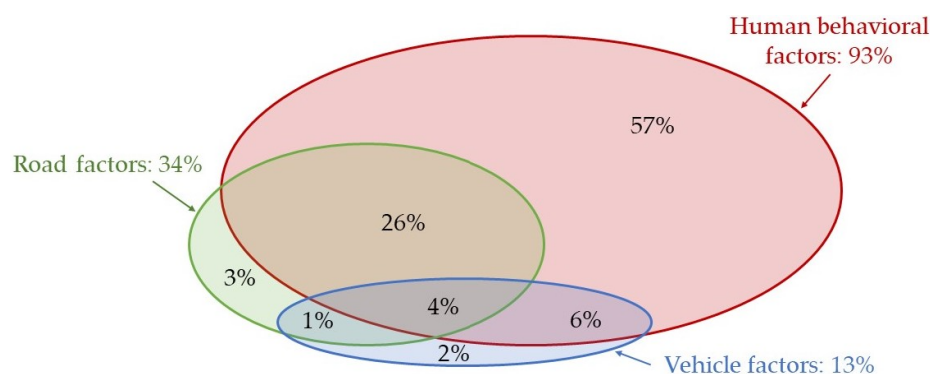

Figure 1. Road accident contributing factors [17].

In this article, the most tested and widespread methods of identifying black spots are presented. National practices in certain EU countries are also presented and compared to each other. By presenting the important differences in black spot determination within EU countries, the need for a more uniform approach is emphasized. For instance, considering the severity of the accidents is crucial in spotting black spots and cannot be ignored. Moreover, a brief comparison between the probabilistic and accident gravity black spot determination approaches is presented, making possible the formation of more holistic methods for black spot detection through the proper combination of the abovementioned approaches. In this direction, a proposal for a simple, efficient, and objective combination of relevant methods is made for the case of Greece.

Table 1. Rounded number of road accidents in Greece [18].

Year	Accident	Deaths	Total No of Accidents
2000		1450	17,000
2001		1700	20,000
2002		1450	17,000
2003		1400	15,500
2004		1350	15,500
2005		1300	16,500
2006		1350	15,500
2007		1300	14,500
2008		1400	13,500
2009		1300	13,500
2010		1150	15,000
2011		1000	13,500
2012		900	12,500
2013		800	12,000
2014		750	11,500
2015		800	12,000
2016		750	12,000
2017		800	11,500
2018		750	11,500

2. The State of the Art of Road Black Spot Identification Methods

Historically, efforts to relate traffic accidents to independent variables are as old as 70 years, pioneered by R.J. Smeed [19] in his milestone study "Some statistical aspects of road safety research". The equation that was described in this research, known as the Smeed equation, has the following form:

$$D/P = 0.0003 \ (N/P)^{0.33} \tag{1}$$

or

$$D/N = 0.0003 \ (N/P)^{-0.67} \tag{2}$$

wherein:

D is the number of reported road deaths in a year;

N is the number of registered vehicles;

P is the population of the country to which the Smeed equation is applied.

D is the dependent variable and both the number of vehicles and the population of the country are the independent ones. The two equations above, which indicate that the fatality rate of road accidents in a country is directly related to the rate of increase in using motor vehicles, are considered primitive nowadays.

In fact, the first step to determine road black spots is to agree on a measure of the exposure to road incidents and risks. The best procedure is to use the vehicle-kilometers travelled as the denominator of a relevant ratio. This is a hard-to-find datum; thus, most researchers compromise with the second-best numbers: either traffic volume or the length of the road network. As the nominator of the ratio, a variety of expressions for accidents may be used. The number of accidents is simply not enough because a spot prone to serious accidents should draw more attention, as highlighted by previous studies including the one by Washington et al., which proposes a method for black spot identification by incorporating crash severity [20]. A measure of accident gravity is necessary. There are of course simpler approaches which rank black spots according to accidents per year. Even if an objective and infallible procedure for black spot determination can be agreed

upon, there would always be cases where a specific spot displays heavy accident records simply by chance. On-site inspections need to become a part of the process. During these inspections, all factors that contribute to the increase in road hazards need to be identified. These encompass construction flaws, inadequate road design, insufficient maintenance, improper or insufficient traffic signage, reduced visibility, and slippery surfaces, among others. Following this procedure, unitary road sections that were shown hazardous (by the methods of finding black spots), but nothing in the road infrastructure suggests them to be dangerous, are excluded from blac spots.

In short, to identify black spots, it is necessary to adhere to the subsequent steps [21]:

1. Data collection about traffic and accidents along the road network;
2. Data processing to find road sections with a high number of accidents by using one or more vigorous methods;
3. Accident analysis and in situ inspection at each one of these places. In cases where the causes of most of these accidents are attributed to infrastructure, these positions are named as black spots.

Afterwards, methods of treatment in each location are proposed in order to improve road traffic safety. Finally, dangerous locations are categorized and evaluated based on the method and expense of restoration; this approach is utilized to prioritize the required interventions [11].

The most common and widely used methods of finding black spots are the following:

- The method of accident rate;
- The method of gravity rate (index);
- The method of random Poisson distribution;
- The Bayes method;
- The method of quality control.

2.1. Accident Rates

There are many types of accident rates in use. In general, accident rates are the deduction of the number of accidents (or fatalities or serious-injury accidents) in relation to a specific parameter (denominator) [22]. These parameters (as mentioned earlier) may encompass metrics such as the total vehicle-kilometers traveled, the count or cost of accidents per vehicle-kilometer or per registered vehicle, the population size, the road network length, the total vehicle count, or a combination thereof. All these parameters are a measure of the exposure to possible accidents. A typical accident rate (A) is expressed by the formula (3):

$$A = Z \times 10^6 / (QLT) \tag{3}$$

wherein:

Z is a number measuring accidents;
Q is the traffic volume;
L is the length of the road network under consideration;
T is the time period covered by the study.
The multiplier 10^6 is used to avoid an extract with many decimal points.

In general, any method should be applied in road sections with similar geometric and traffic features, or the reliability of the analysis falls. Each one of the road sections is divided into unitary ones with a certain length. Inevitably, this elementary length constitutes a function of the accurate recording of road accidents; this length may vary from 100 m to 1 km for rural roads.

In the accident rate method, by far the simplest of all, there is a comparison between the number of accidents in each unitary road section and the (per unit length) accident rate of the road network under consideration.

Although a variety or a combination of accident types can be expressed with Z, the main disadvantage of this method is that the actual severity of road accidents is not considered, so, for this reason, it receives criticism.

2.2. Accident Gravity Rates

To overcome accident rate deficiencies, each accident type should be appointed a level of gravity [23]. Clearly, a spot prone to serious accidents should receive urgent treatment in comparison with a spot with lighter accidents, even if these are greater in number. A typical formula used for accident gravity rates is similar to the previous one (3), but the term Z is expressed explicitly as follows:

$$Z = D \times g_1 + I \times g_2 \tag{4}$$

wherein:

D is the number of deaths;

I is the number of injuries;

g_1 and g_2 are gravity coefficients.

In the most complex form of (4), a gradation among deaths, serious injuries, light injuries, and only damage can be introduced in case reliable and analytical accident data are available. Based on financial features, a gravity coefficient p_1 between 10 and 100 for deaths is usually used and the coefficient for injuries is p_2 between 5 and 10 [13].

In both the accident rate and accident gravity rate methods, an average value for the dependent variable A is obtained. This value refers to the unit length used, most commonly per kilometer of the road network under review. The main question is which unit road length would be considered black, i.e., the one with an accident rate above the average. The threshold is estimated by multiplying the mean rate by an incremental coefficient (usually around 2). Road sections whose accident rates or accident gravity rates are greater than the incremental mean value for the whole relevant network are referred to as black spots. The exact value for the multiplier is a matter of study, but one can work in reverse: grade all road sections in the network in a descending order and extend the number of the black spots in which the authority would upgrade the safety level until budget depletion.

By using the severity of road accidents, accident gravity methods provide an answer to the critical opinions for simple accident rate methods. However, there is the possibility that a position where a random, single, very serious, multi-death road accident occurs could be called hazardous by achieving a very high severity score, without there being a consideration of the objective dangerousness (i.e., road features). Finally, accident gravity methods require data of good quality and detailed injury records.

2.3. Poisson Distribution

The appropriate multiplier previously mentioned is in fact of a statistical nature and a method using random analysis for road accidents should be introduced.

According to the Poisson method, traffic accidents are considered random incidents following a Poisson distribution [24–26]. Thus, the value of A, the mean number of accidents per unit length of the road network, is calculated. Inevitably, there are unitary road sections with a greater or smaller number of observed accidents comparing with the expected value of accidents. With a specified level of confidence, it is possible to estimate the suitable critical count of accidents for an individual road segment. This count establishes the threshold, the exceedance of which signifies that the accidents occurring in that road section are not statistically random. Instead, they can be ascribed to a systematic issue. In this way, road sections where the number of accidents overruns the threshold are found; these sections are considered black spots. Despite the fact that this method is statistically excellent, it is complicated to consider the gravity of accidents, and this is a certain disadvantage.

2.4. Bayes Method

The Bayes method is based on the fact that the accident number along a road network during a specific time period is based on the Poisson distribution, but the expected distribution along the road network follows the gamma distribution. The purpose is to evaluate

the effectiveness of traffic safety works scheduled to improve specific black sections and to accordingly prioritize the works. It is a complex and sophisticated method which requires reliable and long-term data obtained through similar safety improvement works. Such data are not available for Greece or for many EU countries; hence, the Bayes method has limited use, but remains a vigorous research tool [27–29].

2.5. Quality Control

Another common method which is used to determine hazardous road positions is quality control [30,31]. In this method, again, the mean of accidents per kilometer is calculated for each road section with the same traffic volume and geometric features. Based on a table of the Poisson probabilities, the lowest level for a certain confidence interval (i.e., 95%) is found; after that, the critical rate of accidents is calculated:

$$Ri = Ra + k \times \sqrt{(Ra/M + 1/2M)} \tag{5}$$

wherein:

Ri is the critical threshold accident rate (i.e., accidents per road network kilometer);

Ra: the mean average accident rate for all the road sections with similar features considered;

k: the probabilistic parameter set by the desirable statistical confidence interval for Ri. The confidence levels which are usually used are those of 95%, 98%, and 99%, for which K takes the rounded values of 1.6, 2, and 2.6, respectively;

M: kilometers of the road network (or any other reference parameter for the network, like travelled vehicle-kilometers).

In this method, if the number of accidents in a road sector is higher than the Ri, then this event may not be based on a random incident, but on the objective infrastructure hazardousness. Relevant in situ inspection should be scheduled. The severity of the accidents is not normally considered in the quality control method. It can be taken into consideration in rather complicated variations of the method.

3. The State of the Art of Road Black Spot Identification Procedures Used in the EU

The different black spot identification methods mean that the number and location of highlighted black spots would depend on the method which an agency follows. Although the most prominent black spots would be highlighted by any method, experience shows that important differences may exist. As described, the methodology of black spot identification varies from simple or complex to a sophisticated combination of methods. To start from the beginning, there is a wide range both for the length of the road unit subsection used and the accident critical threshold values. For example, the subsection length in Greece is 1000 m; in England, it is 300 m (1000 ft); and in Belgium, it is 100 m. The accident threshold value is 12 accidents in England, whilst in Norway, it is only 4 accidents [32]. Hence, it would be quite interesting to present and compare the various practices followed in certain EU countries and Switzerland.

In Austria, according to [12], scenes of accidents receive two grades: that of hazardous locations and that of black spots, depending on their recorded accident history. A hazardous location is upgraded to a black spot if one of the following two criteria is met:

1. Three or more similar injury accidents within 3 years and a relative coefficient A of at least 0.8. The value of this coefficient is calculated as follows:

$$A = U/(0.5 + 7 \times 10^{-5} \times AADT) \tag{6}$$

wherein:

U the number of injury accidents within 3 years;

AADT is the Annual Average Daily Traffic (vehicles/24 h).

2. At least five accidents (including property damage only) within one year.

For the above purpose, a sliding window with a length of 250 m is used along the roads, as described by Aziz and Ram (2022) [12]. The critical value of 0.8 of the relative coefficient A will be reached if, for example, there are three injury accidents in 3 years and the AADT is up to 10,000 vehicles/24 h, there are four injury accidents in 3 years and the AADT is up to 17,000 vehicles/24 h, etc.

It should be noted that, due to the rather short road unit section of 250 m, the set criteria are quite difficult to be met. In fact, many countries adopt the strategy of setting strict black spot identification criteria so as to hold the number of potential improvement works and immediately materialize them.

Croatia: In this country, as happens in many countries all over Europe, there is not a unique methodology to determine black spots. In Croatia, black spot identification is based on the ranking of the number of traffic accidents in specific locations [33]. This approach ignores an important parameter: that of the existence of a problematic feature in the infrastructure at black spot locations. For the hierarchically higher road network, that supervised by the authority of Croatian Roads, there are certain criteria. First, the sliding window is either 300 m or 1 km, depending on the road type and the accuracy of the records. The goal is to restrict the length to 300 m with the help of in situ inspections. Second, three criteria are set; any of them are enough to determine a subsection as a black one:

- Twelve or more accidents with at least injuries in the past 3 years;
- Fifteen or more accidents, regardless of consequences, during a recent 3-year period;
- Three or more identical accidents in the same moving direction and with similar conflict area characteristics.

Denmark: In Denmark, the definition of black spots relies on a detailed classification of the road system into different types of road sections (motorways or other dual carriageways in urban/rural environments) and various types of intersections. In this country, data refer to a period between 3 and 5 years, and Poisson distribution is used in order to define black spots (the adopted confidence level is 95%). The average daily traffic volume is the main factor used to calculate the normal expected number of accidents (instead of the length of a similar road network or the number of travelled vehicle-kilometers).

In Denmark, a black spot is a site with a reported number of accidents which is:

- Higher than a fixed minimum number (four accidents during a 5-year period);
- Higher by the mentioned confidence level coefficient than the normal mean expected number of accidents for that type of roadway element.

Flanders: In this region of Belgium, a hazardous segment refers to a road section 100 m in length where there at least three accidents have been observed during a 3-year period. Based on an accident severity evaluation procedure, a subset of these hazardous sections receives the denomination of a black spot if their severity index (S) is greater than (or equal to) a fixed number (currently 15) for a 2-year period. This index is calculated as shown in Equation (7):

$$S \geq LI + 3 \times SI + 5 \times D \tag{7}$$

wherein:

LI is the total number of people lightly injured;

SI the total number of people seriously injured;

D the number of deaths for this 3-year period.

It should be noted that fatal accidents have lower gravity compared to other accident severity gradings.

Germany: In Germany, there are individual definitions for black spots, black sections, and black areas (the last one mainly refers to urban areas), primarily relying on contrasts between the accident count in these spots and predefined critical thresholds, usually spanning over periods of 1, 2, or 3 years. A significant factor in this process is the recognition of locations with analogous accident types and comparable levels of accident severity, including fatalities, severe injuries, minor injuries, substantial material damage, and other forms of damage. Thus, severity is considered when defining black spots by reducing the

critical threshold values in serious-injury accidents and injury accidents. It is a sophisticated procedure, requiring extensive and good-quality accident records.

Hungary: In this country, a differentiation is made between urban and interurban regions. Initially, the individual road segment must not be more than 1 km outside urban areas and should be limited to 100 m within them. Black spots are designated as locations where a minimum of four accidents occur within a span of 3 years. Subsequently, traffic volume plays a role in the classification of these black spots.

Norway: In Norway, a distinction is also made between black spots and black sections. A black spot is defined as a road segment of up to 100 m in length, wherein a minimum of four injury accidents have occurred over the past 5 years. On the other hand, a black section is a road segment with a maximum length of 1 km, where a minimum of 10 injury accidents have been recorded during the same 5-year period. Accidents are pinpointed on the road network, and both hazardous spots and sections are identified using the aforementioned sliding window approach. Often, hazardous sections comprise multiple hazardous spots located in close proximity, typically warranting a consolidated remediation strategy. Accident severity is considered by estimating accident costs and potential savings.

Portugal: In Portugal, there are two ways of defining black spots. In the initial approach, black spots refer to road segments with a maximum length of 200 m, where a minimum of five or more accidents have occurred. Furthermore, the severity index (S) must surpass a predetermined value of 20 during the analysis period. This severity index is calculated as shows in Equation (8):

$$S \geq LI + 10 \times SI + 100 \times F \tag{8}$$

wherein:

LI the number of people lightly injured;
SI the number of people seriously injured;
F the number of fatalities.

Contrary to Belgium's approach, in Portugal, they consider the loss of human lives very grievously. A single fatal accident is enough to designate a black spot.

In the second method, a black area is a geographical area where the expected accident frequency is undoubtedly higher than in similar areas because of specific road characteristics (i.e., mountainous areas). In this approach, there is a differentiation between intersection and non-intersection places. In the first case, the minimum length should be 250 m for single carriageway roads and 500 m for dual carriageway roads; furthermore, the road network is classified into six classes, and in each class, a different unique accident prediction model (and threshold values) is fitted. In these models, the most significant reference variable is the average daily traffic volume.

Switzerland: In this central European country, black spot is a road subsection where the number of accidents is significantly higher than the number of accidents at comparable sites. There is a certain procedure for finding these comparable sites separately for road subsections and intersections. The length of a subsection varies according to the road type (between 100 m and 500 m, depending on the importance of the road). Accident sites are those where the number of accidents exceeds the estimated expected number of accidents based on normal accident rates and on Poisson distribution analysis. These sites are compared to threshold values in order to find out whether they are black spots or not. The threshold values also vary, depending on the road type, and they refer to a period of 2 years.

Scotland: In this part of the United Kingdom, a black spot is a position where three or more accidents with casualties have taken place within 3 years in a 100 m radius (practically 200 m in length). In England, there are a variety of black spot identification criteria which have been set by local authorities.

Greece: In the far south of Europe, Greece is among the countries with the worst traffic safety records in the EU. Aggressive driver behavior and a lack of policing have been mentioned as the principal causes. Black spot identification practices are not standard. A

specified procedure does not exist, although recently published guidelines specify more than one acceptable approach [34]. Both Poisson and quality control methods seem to take the lead.

4. Discussion

The identification of black spots is a highly crucial point in road safety, and it has been proved that black spot programs are very effective, contributing to a reduction in accident rates and to financial benefits [35]. In Table 2, a concise summary of black spot identification practices in Europe is presented.

Table 2. A concise summary of road black spot identification practices.

Country	Sliding Window	Threshold of Accidents	Accident Severity Considered	Length of Period
Austria	250 m	Min. three/five (by traffic volume)	Somehow	3 years
Croatia	300 m	12	Somehow	3 years
Denmark	Variable length	Statistical test, Min. four	No	5 years
England	1000 ft	Min. three	Set by local authorities	3 years
Flanders (Belgium)	100 m	Min. three	Yes	3 years
Germany		Min. three or five	Yes	1 or 3 years
Hungary	100 m spot or 1 km section	Min. three	No	3 years
Norway	As above	Statistical test, Min. four (spots) or ten (sections)	Estimating accident costs	5 years
Portugal	200 m	Min. five	Yes	1 or 5 years
Scotland	200 m	Min. three	No	3 years
Switzerland	100/500 m	Statistical and critical values	Somehow	2 years

In this table, many serious differences can be seen. First is the length of the sliding window, varying from 100 m to 1 km. Clearly, if similar accident threshold values are applied for both extremes, the number of road sections identified as black ones would vary by a factor of around two. A unit road length of 100 m requires very precise spatial accident data. A unit road length of 1 km may obfuscate the inherent hazards of a spot. In situ inspections would reduce the ambiguity and are, in any case, necessary. A 200 m sliding window is probably a good compromise between precision and the extent of data. In Greece, a longer unit length (that of 500 m or of 1 km) is probably better to overcome poor and inexact accident reports. The different sliding windows among these EU countries are attributed to historic approaches, accident data quality, and available funds and resources. Also, it should be noted that the same variety of procedures and sliding windows are applied in most developed countries around the world.

In addition, quite important differences are visible in the accident threshold numbers for black spot identification. Sophisticated accident analysis and relevant methods are not a strong point in many EU countries. Also, half the examined countries do not consider the severity of accidents. Thus, a road spot prone to light accidents may come above another where serious and fatal accidents happen, simply because they are in lesser numbers. This is obviously a serious limitation and should be addressed.

Regarding the years over which the analysis extends, it seems that 3 years is the favored number. The range lies between 1 and 5 years. It should be noted that 1 year is a very short time to draw safe conclusions.

To sum up, what would be the best approach to identify black spots? A probabilistic one or one based on accident gravity factors? Quite different results may arise according to the selected approach. The performance of the different approaches is usually assessed through various criteria; for instance, Cheng and Washington propose that black spot identification methods should be assessed in terms of the reliability of results, ranking consistency, as well as the consistency and reliability of false identification [36]. A previous research attempt examined and compared various approaches for black spot identification; its results show that an empirical Bayes estimate provides the most accurate results, while accident rates which are commonly used in practice are not very accurate [37]. Yet, it cannot be taken for granted that the different approaches have the same performance in all different contexts.

The probabilistic approach is fundamentally more correct, since, even at black spots, accidents are stochastic events. But the gravity of accidents should be considered in order to evaluate and grade the spots. However, accident gravity requires limits, otherwise a single serious accident (with many fatalities) can make a point dangerous (black spot) by itself. The experience gained from the prolonged use of the probabilistic accident approach gave reliable accident threshold values according to road type and traffic volumes. If these thresholds are exceeded, the unitary road section can be considered dangerous. By using thresholds, the procedure of black spot identification is simpler. Also, repeatable and reproducible accident analysis can be achieved in different countries. It should be noted that many countries actually adopt the strategy of setting strict black spot identification criteria so as to restrict the number of potential improvement works and immediately materialize them.

Considering the above, it is advised that each EU country applies a variety of black spot identification methods and elaborates the outcomes on the basis of the extension of the resultant remedial works. The priorities and the available funds with regard to the remedial works should be carefully considered. According to a standardization of the cost of remedial works for each occasion, a two-year remedial schedule should be derived. The appropriate black spot identification method is, for each country, the one which results in a two-to-three-year remedial work schedule.

In Greece, there has been extensive research in recent years to make up for the urgent safety problems along the road network. As far as black spot treatment is concerned, many relevant projects are under construction. For the methodology of black spot identification, it seems that a combination of a Poisson distribution or quality control analysis with a low confidence interval (such as 90%) with an accident gravity rate is the prevailing trend, as black spots are determined as 0.5 or 1 km long road sections or individual junctions highlighted in both the probabilistic and gravity identification procedures [21].

Author Contributions: Conceptualization, I.K. and A.K.; methodology, I.K., A.K. and G.B.; formal analysis, I.K., A.K. and G.B.; investigation, A.N. and S.B.; resources, S.B.; writing—original draft preparation, I.K., A.K., G.B., A.N. and S.B.; writing—review and editing, A.K., A.N. and S.B.; supervision, A.K., G.B. and S.B. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

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