Technical note 3

REGIONAL BLACK SPOT MANAGEMENT GUIDELINES

TRACECA Regional Road Safety Project

Safety Engineering Team

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EU funded road safety project

For

Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan

PREFACE
TO THE DRAFT REGIONAL BLACK SPOT MANAGEMENT GUIDELINES FOR TRACECA COUNTRIES

Black Spot Management (BSM) is one of the first road safety tools used for improving the dangerous locations and sections on roads. Despite many years of black spot improvement work, experience from developed and developing countries shows that BSM is still a highly effective and cost effective engineering tool in order to improve the safety of roads.

The identification, analysis and treatment of Black Spots is a well proven method for reducing the number and severity of crashes on the road network. Low cost remedial treatments can offer first year rates of return of several hundred percent and black spot treatments are amongst the most cost-beneficial investments a Road Authority can undertake.

Since there is no universally applicable definition of what should be regarded as a black spot, Project team jointly with concerned stakeholders have proposed a suitable unique definition of Black Spot for use in TRACECA Countries. The proposed definition of a Black Spot for the purposes of this manual is defined as "Any location on a road with a maximum length of 300 meters, at which at least four fatal* crashes have been recorded during the last three years".

Special attention has been given to making the Guidelines user friendly and the Project Team are building on existing good practice and examples from the Region. Throughout these guidelines, the word "crash" is used instead of "accident" to emphasize that these events are preventable and avoidable and not some inevitable event outside of human control.

These Black Spot Identification and Treatment Guidelines have six chapters followed by an Appendix. They draw, as necessary, upon best international practices and manuals available in use around the world. The authors of these guidelines would like to acknowledge their indebtedness to such manuals and their authors – the key ones of which have been listed in the references.

These guidelines have been developed to provide a recommended methodology for Black Spot management to the TRACECA region countries. The main purpose of these guidelines is to provide the reader with a clear overview of the necessary steps for Black Spot elimination.

** A fatal crash is where at least one person has been killed*

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Abbreviations and acronyms

ADB	Asian Development Bank
BSM	Black Spot Management
EC	European Commission
EIB	European Investment Bank
ETSC	European Transport Safety Council
EU	European Union
GLONASS	Global Navigation Satellite System
IBRD	International Bank for Reconstruction and Development
IDS	In-depth Studies
IFI	International Financing Institutions
MoIA	Ministry of Internal Affairs
MoI	Ministry of Interior
MoTC	Ministry of Transport and Communications
NGO	Non-governmental organization
NP	National (Country) Program
PIARC	World Road Association (PIARC actually means Permanent International Association of Road Congresses but this name is rarely used)
PRI	La Prévention Routière Internationale a.s.b.l.
RIA	Road Impact Assessment
RSA	Road Safety Audit
RSI	Road Safety Inspection
SEETO	South-East Europe Transport Observatory
TL	Team Leader
ToR	Terms of Reference
TP	Traffic (Road) Police
TRACECA	Transport Corridor Europe-Caucasus-Asia
WE-WC	Western Europe – Western China International Transit Corridor
WHO	World Health Organization

1. INTRODUCTION

Road crashes are now widely recognized as a serious social and economical problem. And different measures and programs were devised to reduce the blood toll on roads. On the international level, United Nations, World Health Organization, European Commission, International financing organization (especially World Bank, ADB, EIB, IBRD, Islamic Bank,...) and some specialized NGO (PIARC, ETSC, PRI, SEETO, ...), are now working to improve global road safety. In autumn 2009, ministers and stakeholders from all over the world met in Moscow (First Global ministerial conference on Road Safety) and called upon the United Nations to take leadership of this global problem affecting all nations. This issue was discussed at United Nations and a worldwide decade for road safety was announced in 2011. The international community of United Nations Regional Economic Commission, WHO, development banks, major road safety research institutes; Global companies and NGOs are now cooperating to address this global problem.

One of the popular misconceptions is that the faults or bad behaviour of a driver are alone in almost all cases, the cause of road traffic crashes[1]. As result of a basic research project, it is evident (Figure 1.1.), that in every third crash the road environment has at least some influence (road environment factors 34 %) on the occurrence of a crash.

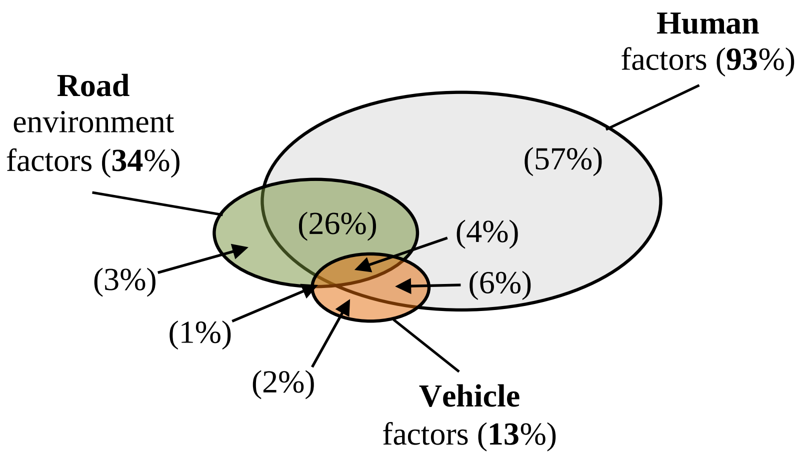

Figure 1.1. The contribution of crash factors
(Source: Road Safety Manual, PIARC, 2003)

As a consequence of recognition that most crashes have multiple contributory factors, Road Safety Management was developed as the best way to decrease the total number of crashes in a country.

The identification, analysis and treatment of Black Spots is a well proven method for reducing the number and severity of crashes on the road network. High effective and low cost remedial treatments can offer first year rates of return of several hundred percent. Black Spot treatments

[1] This is partly because police reporting of crashes tend to focus on blaming and as a consequence the vast number of crashes appear to involve human factor / driver error. However, what is often not explored by police or recorded in statistics is why the driver made that error (e.g. was it because of misleading information, missing signs or even unsafe elements of road design or the vehicle.)

are amongst the most cost-effective investments a Road Authority can undertake.

With its Directive of the European Parliament and of the Council no. 2008/96 on road infrastructure safety management, published in October 2008, the European Union made a clear decision that the BSM should be mandatory for the trans-European Road Network in the following years.

In the mentioned EU directive, the BSM is part of a package road safety measures as follows:

- Road safety impact assessment (RIA),
- Road safety audit for the design stages of roads (RSA),
- **Safety ranking and management of the road network in operation, including management of high risks road sections (BSM),**
- Road safety inspections for existing roads (RSI) and
- In-depth crash analysis (IDS).

The introduced measures are an integral part of the wider road safety management system, and they are shown at Figure 1.2.

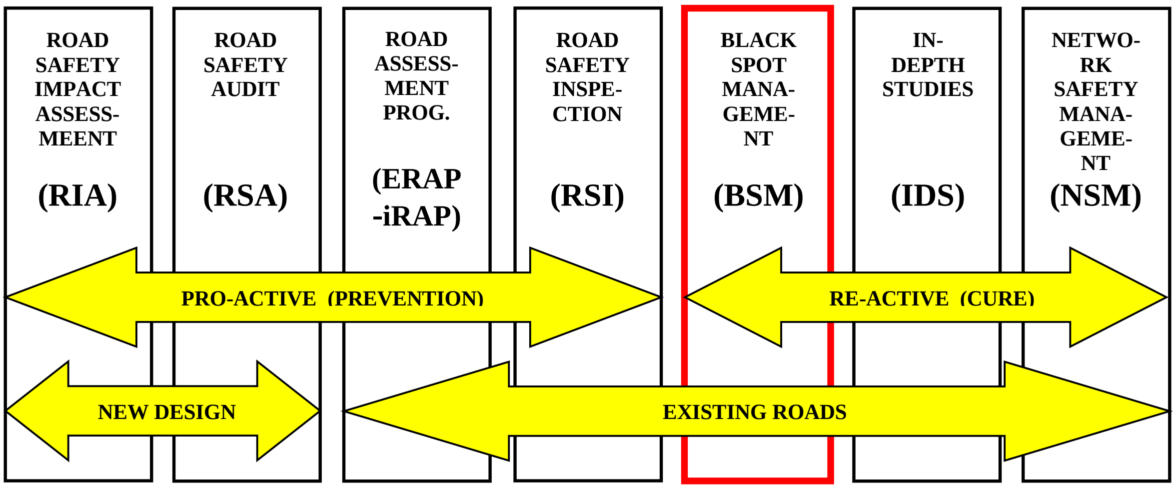

Figure 1.2. The BSM as part of the Road Safety Management
(Source: Road Safety Audit Manual, SEETO, 2009)

It can be easily seen from Figure 1.2. that BSM represents re-active procedure that should be undertaken on existing roads.

The output of BSM is normally a proposal of countermeasures which will decrease the risk of crashes at the treated locations.

The Black Spot identification and treatment Guidelines are based on best international practice and special attention is given to the harmonization of black spot management approaches in TRACECA Countries.

2. INTRODUCTION TO BLACK SPOT MANAGEMENT

2.1. What is Black Spot Management? (Definition)

Black Spot management presents a systematic approach for identification, analysis, treatment and evaluation of countermeasures used at hazardous locations on the road network. The basis for Black Spot identification is statistical data analysis of road crash record and mapping of crash locations. Therefore, an adequate crash database is an essential and necessary tool for effective Black Spot work.

Output of BSM is improvement dangerous road locations, with usage of optimal measures which will prevent occurrence of future crashes and increase the total level of road safety of network.

The database should include most precise information about crash site location (preferably done by GPS/GLONASS coordinates), details about the type of crash, collision diagram, details of drivers and if it is a fatal or a crash with injuries, information about the casualties. Information about vehicles and roads involved, as well as weather conditions, when the crash occurred are other important facts useful for crash analysis.

There is no unique definition of what should be regarded as a Black Spot. Researchers generally agree that Black Spot could be defined as a **location which has a higher expected number of crashes than similar locations, as a result of local risk factors**. However, this is not an easy definition for practical work.

Jointly with concerned stakeholders in different TRACECA Countries, the project team proposes a suitable and common definition for Regional usage. The proposed definition of Black Spot is defined as **"Any location on a road with a maximum length of 300 meters, at which at least four fatal crashes have been recorded during the last three years".**

Furthermore, a Black Road Section is defined as **"any road section with a maximum length of 1000 meters, at which at least six fatal crashes have been recorded during the last three years".**

The above proposed definitions belong to the class of Numerical definitions, and they are suggested for use during the initial period of Black Spot Management. Main reasons why Project proposed unified definition is to have a single common depiction instead of having 10 different local definitions. This will help to harmonize Black Spot Management in the Region as well as fast level up of black spots all over the important transport corridors which are crossing the Region. Proposed approach will also help IFI in their transport and road safety projects and most important will help drivers in region to easily recognize the black spots on the road due to harmonized signalization and possible web based database of black spots (initiative of some NGO for such a project already exists).

All suggested variables in black spot definitions should be tested and if they provide useable and logical output (*for example*: ***total number of identified black spots in country are between 50-150***), they should be applied. It should be noticed that definition could be corrected in future, when most (at least 2/3) of identified dangerous locations are treated (improved).

In future, some of more complex models could be used. For example, analysis of the spatial distribution of road crashes (which relies on modern GIS tools) allows more accurate identification of crash location with accumulation of crashes. Alternatively given that the observed road crashes have different casualties, each crash could be assigned with a weight index based on the degree of severity. Weight indices are based on the costs of crashes suggested by World Road Association (PIARC) and as follows:

- crash with minor (slight) physical injuries should be multiplied by the weight index of 1,
- crash with serious physical injuries should be multiplied by the weight index of 10 and
- crash with fatalities should be multiplied by weight index 85.

In this way, for each of the Black Spots, could be provided so-called “crash weight index” which represents every Black Spot with one unique number. Upon this number, ranking of Black Spots could be developed and a number of dangerous locations selected for improvement, in accordance with the budget available.

2.2. Methodology used for Black Spot Management

Guidelines have been developed based on EU financed research work (RIPCORD - ISEREST), project team experiences and in close cooperation with concerned counterparties, this.

The flowchart for the Black Spot process is made having in mind international best practice as well as specific needs of TRACECA Countries. It is recognized that huge changes in organization of involved institutions, as well as highly complex models, will not be possible to implement, so proposed Black Spot management methodology is a combination of minimal functional requirements for modern black spot management in Region.

Proposed flowchart for the Black Spot process is given in Figure 2.2.1.

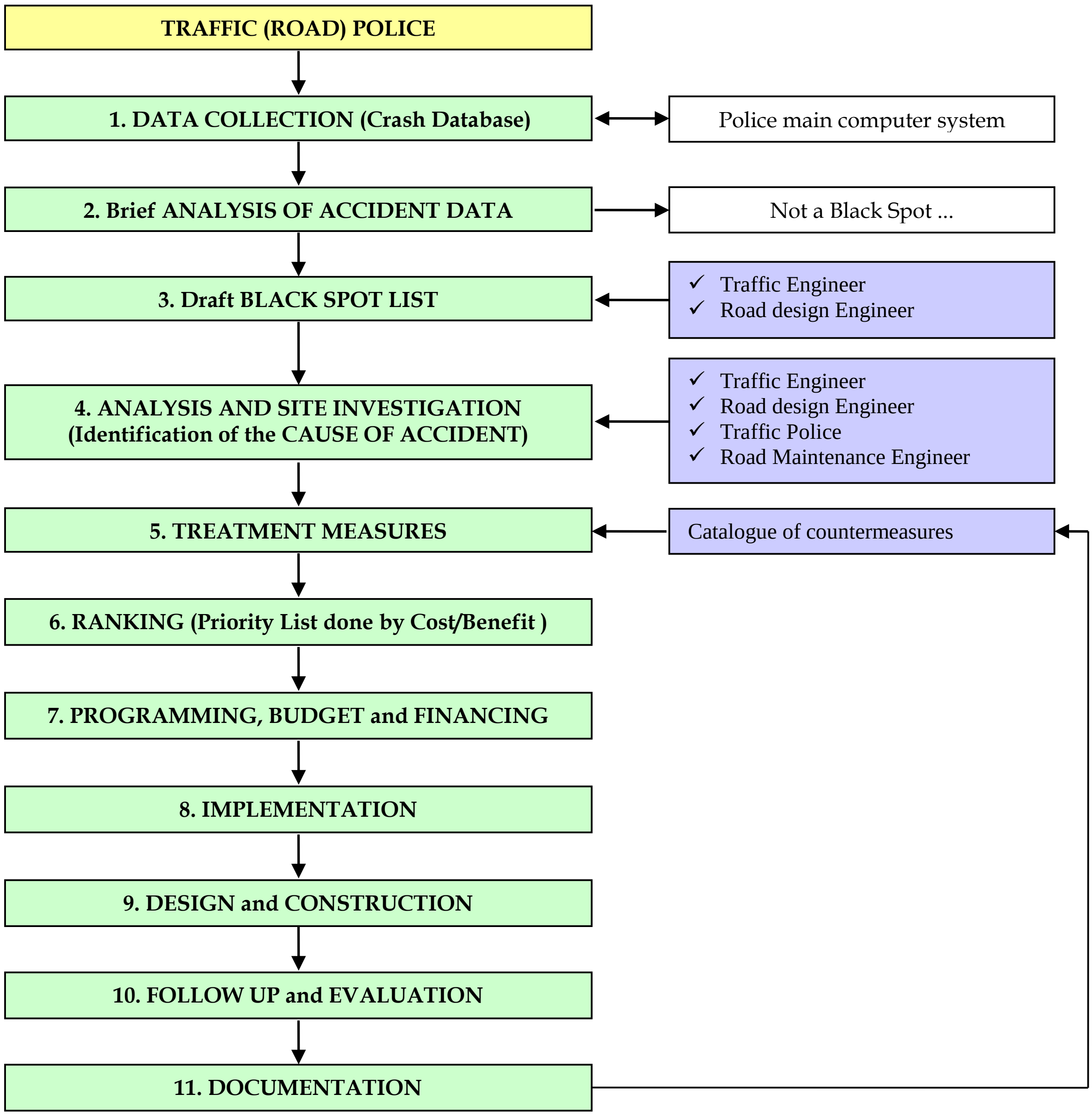

Figure 2.1.1. Flowchart for the proposed Black Spot process
(Source: EU funded Project RIPCORD-ISEREST, 2007)

2.3. Structure of the Guideline

This manual is divided into six chapters as follows:

The first Chapter introduces BSM concepts and explains the need for the BSM procedures to be applied.

Chapter 2 presents basics about BSM. This Chapter contains answers to the following questions: What is BSM?, What is its Definition? and Methodology used for Black Spot Management.

Chapter 3 discusses the BSM process. Detailed explanations are provided for all steps: Data Collection (Reporting and Database), Analysis of Crash Data, Identification (Preparation of Black Spot Lists), Analysis of the Causes of Crashes (in office and on site), Determination of Black Spot Treatment, Ranking (Priority Listing upon cost/benefit analysis), Programming, Budget and Financing, Implementation of Treatment measures, Follow up and Evaluation and Documentation. The chapter also discusses a detailed methodology used for conducting BSM.

Chapter 4 presents a typical Black Spot with most frequently observed road safety deficiencies. All examples used in Guidelines are collected in TRACECA Countries.

Chapter 5 contains the most commonly used countermeasures with specified crash savings.

Chapter 6 presents the literature used.

3. BLACK SPOT MANAGEMENT PROCESS

3.1. Data Collection (Reporting and Database)

Existence of quality and available road crashes database is the most important prerequisite for managing the Black Spots. Without adequate road crash database, it is not possible to identify and monitor Black Spots on a road network. Even, if there is an existing crash database, but it is not made easily available (for further analyses by specific organizations, police), the process of establishing a system of BSM will not be successful. Crash data does not belong to the police but in a resource that has to be made available (once confidential information of driver an vehicle details is removed) to all key stakeholders, such as road engineers, so that further more detailed analyses can be undertaken of the most hazardous locations.

Usually Ministry of Internal Affairs (or Interior) through Traffic Police possesses the crash database that can be used as a basis for BSM. From the Project Inception period visits the Project Team is aware that crash databases exist in each TRACECA Country but in some of them important improvements need to be undertaken, and in some cases, the data needs to be made available for successful BSM usage. The following data could improve the quality of police crash data systems:

- adding of **collision diagram**,
- introducing of **GPS/GLONASS coordinates**,
- adding location whether inside or outside of settlements
- adding information about nearby schools or other public and private services
- surrounding characteristics of interurban roads (desert, agriculture, forests, mountains)
- adding of **weather information,**
- introducing the **posted speed limit, etc.**

Specially designed integrated databases with data about roads, traffic counting and traffic crashes enable high-quality inputs for BSM. This kind of database output would provide adequate spatial and time analysis of crash and enabled increased reliability the understanding of basic causes and circumstances of traffic crashes. There are also other sources, which can be used for improving the quality of the integrated database, such as reports of injuries from hospitals, court records, records from insurance companies, etc. However, data from these sources are often hard to provide and to integrate.

Until now, there seems to be only minimal systematic analysis of crash data with BSM procedures. One of the reasons has been the fast development of road networks with no inclusion of road safety topics. Other, more technical reasons could be that there is no use of Geographic information systems (GIS) and GPS/GLONASS data about crash locations which makes BSM more complex (it is not easy to identify and analyse Black Spots just by looking at long tables without the possibility to see them on the map). The result of that situation is that very little effective BSM analyses have been carried out in the past.

However, by using available information from the Police, Road Authority can improve some of the identified road locations. Without clear definition of Black Spot and of outdated crash database continue to be used, this work is rather time consuming. As a consequence, identification, analysis and treatment of black spots has up to now, not been done systematically and has not been managed in a modern way in TRACECA Region.

Based on BSM international best practice there are two mostly methods used for collecting and preparing the data:

- First method is based on the analytical procedure to enable the list of crashes on different roads. Usually, output is spreadsheet with sorted crash data. In this way, the most dangerous locations can be identified.
- Second one is based on more sophisticated procedure and relies on GIS. This means that all crashes are presented on geo-coded maps. Using GIS, it is easy to identify Black Spots visually from the displayed data.

For both methods, one of most important prerequisite is knowing the exact location of the road crash. For this purpose, road km poles are often used to identify the location. This is good way, but it has few disadvantage:

- Sometimes km poles are missing which complicates the work of the police,
- If road length was change (changing of road alignment, creating the by-pass) there is a problem with km signs and
- All crash data (the part about location) should be transformed into X, Y (or North/South) coordinates, so that they can be used in a GIS road database (which is in the phase of preparation).

Therefore, the usage of “Global Positioning System” (GPS) or “Global Navigation Satellite System” (GLONASS) instruments is strongly recommended for the location of crashes from the beginning. The Traffic Police should enter the GPS/ GLONASS location in the “Road Crash Form” under “Location of the traffic crash”.

Beside data about GPS Location, it is important that crash data includes information on the events and manoeuvres that led to the crash (collision diagram). This information can be also added by the police officers, if it is known.

In this way more quality data will be collected for future BSM work.

According existing data collection in all TRACECA Countries, the Traffic (road) Police is responsible for filling the crash form and import in it into the centralized computer system. In most countries, from time to time, police have meetings with Road Authority (if Road Safety Unit exists) and exchange data about dangerous places. In some of countries, specific Institutes exist and they also receive crash data from the police. These Institutes can be used as a first step in processing the data for BSM.

Traffic (Road) Police preferably or in some cases specialized road safety research Institutes, can perform brief analysis of crash data and prepare draft Black Spot lists.

3.2. Analysis of Crash Data

The black spot can be either an intersection or a section of a road. Generally there are two methods in most common use:

Method based on crash statistics

Based on crash statistics (from police database) in early development of BSM activities, Traffic (Road) Police or specific Institute should make brief analysis of crash data and prepare a draft list of Black Spots in accordance with the adopted definition. The list could include both intersections and road sections and constitute the basis for further Black Spot investigation and processing which will be done inside Road Authority (Road Safety Unit if such exists). Later on, as methods are improved, Traffic (Road) Police or a specific Institute can use a weighted index based on the type of consequence as follows:

- crash with minor (slight) physical injuries should be multiplied by the weight index of 1,

- crash with serious physical injuries by the weight index of 10 and
- crash with the fatalities by weight index 85.

This gives ratio 1:10:85 and is broadly based on the principle that the more serious crashes result in more serious casualties and higher costs to society. Hence, fatal crashes should be given much more priority and importance than light injury crashes. [Note this particular one does not put any weight on damage only crashes but some other systems also include weighting for damage only crashes].

All black spots can be ranked based upon crash weight index. This list should then be sent to Road Authorities (at state and community level) for further analysis of potential improvements at those locations.

Method based on "Pin map"

Another possibility of crash data analysis could be the usage of a "Black Spot Pin Map" (Figure 3.2.1.) as a tool for Black Spot identification. Geo coded road maps can be produced and used for adding the road crashes on it. Each road crash should be marked on the map by a pin. The pins should have different colours to indicate different types or severities of crashes (e.g. crashes with fatal – black colour, crashes with severe injuries – read colour and crashes with slight injuries – blue). The map should be continuously updated with all new crashes as the data becomes available.

Crashes from previous years should be also marked on the map, so that annual trends of number of crashes could be easily visible. In that case, the map would show the number and type of crashes over a period of several years. The situation at year end can be photographed as a record of the data for the year and plotting of locations can continue.

A visual interpretation of the Black Spot pin map provides a good presentation of potential Black Spot locations. If GIS are used, more sophisticated analysis could be provided. Based on the pin map and adopted definition, a preliminary Black Spot list could be drafted easily upon different criteria. The list could include both intersections and road sections and serve as a basis for further Black Spot investigation and processing inside the Road Authority.

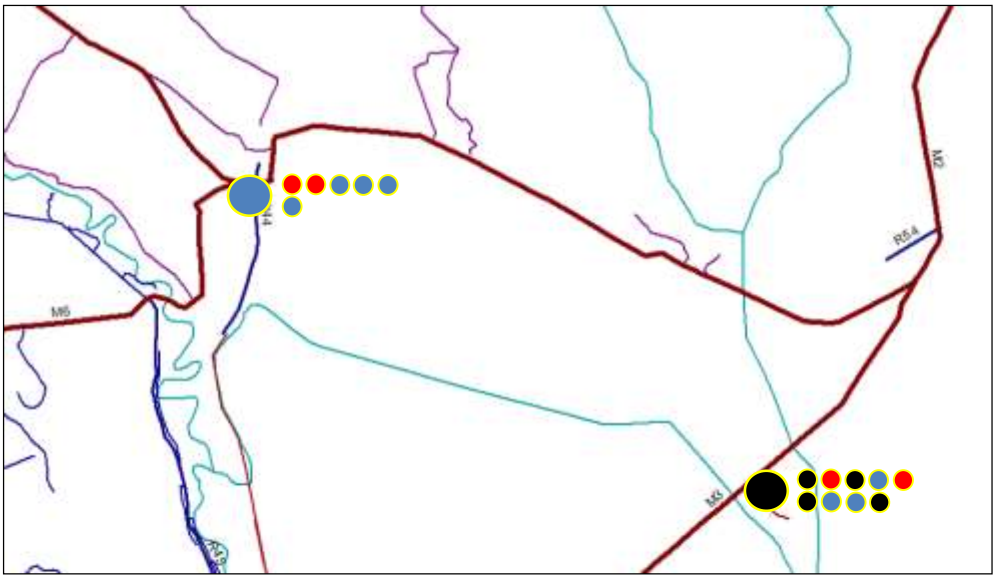

Figure 3.2.1. Example of typical Black Spot Pin Map

3.3. Identification (Preparation of Black Spot Lists)

The draft Black Spot list is prepared in accordance to the adopted definition. Later on, when the system starts to work, the list could be improved by use of a weighted index. The draft list serves as a basis for further investigation and analysis.

The preparation of initial Black Spot list could be carried out by Traffic (Road) Police (or specific Institute if such exists). Data about all single vehicle crashes in defined Black Spots should be double checked and reviewed. There should not be mistakes in crash data forms data which can influence the total statistics and conclusions. If it is necessary, more data about specific crash should be requested from police. In this way, quality of collected data will be improved.

Special attention should be given to the preparation of the collision diagram (if it does not exist inside police crash report), because it presents the easiest way to understand why and how the crash happened.

The final Black Spot list should consist of newly identified Black Spots and Black Spots which have already been analysed, but not yet treated in the past. Black Spots with the highest number of fatal crashes (or with highest weight index) should be given the highest priority to be analysed in-depth.

3.4. Analysis of the Cause of Crash (in office and on site)

The aim of the analysis of the cause of crash is to understand the chain of events which directly lead to the crash. Many factors contribute to an crash, which means that it is not easy to get a full understanding. Therefore, it is important to carry out the analysis systematically using all known facts. Proposed analysis could be done inside Road Authority (and Road Safety Unit if such exists). Usually there are two types of analysis: in office and on site.

3.4.1. In office analysis - Collecting and processing of crash data

In order to carry out a proper analysis, at least the following data are required for in office analysis:

- Crash data,
- Traffic data,
- Road data and
- Supplementary data.

Crash data

Basic data on the crash scene is recorded by the traffic (road) police. Their report and follow up file includes all important data for crash analysis including statements of witnesses and those directly involved in the crash.

Traffic data

In order to choose an optimal countermeasure, additional data would be needed, such as:

- the traffic volume, by vehicle type, direction and time,
- average speeds at that location, if it is available from automatic traffic counters,

- the volume of specific groups of road users or modes of transport normally passing through that location,
- any changes in the traffic structure during the study period, including volume and vehicle type, etc.

Often this information can be collected from different Institutions like Road Authority, local communities and people who are living nearby.

Road Data

Apart from photos a sketch of the crash site is very useful. The sketch should show the final location of vehicles involved, all traffic facilities and obstacles contributing to the crash. The sketch should, if possible, to scale and as detailed as possible and should contain information about the location and road such as:

- Dimensions and layout of the carriageway, lanes, shoulders, medians, curve radius, super elevation and skid resistance,
- Structures and fixed hazards,
- Contours of surrounding terrain,
- Cyclist or pedestrian lanes,
- Existing guardrails and or barriers,
- Delineator posts, signs and lighting (including poles),
- Road markings and pavement markers (including pedestrian crossing),
- Road signs,
- Connecting roads with dimensions and surface type,
- Type of surface layer (carriage way/shoulder),
- Estimated traffic flow/type of traffic/traffic speed,
- Traffic Islands and dimensions,
- Trees, houses and private roads/entries, etc

Supplementary data and information

Sometime it will be useful to collect additional information about the road crash and location, such as dominant vehicle types using the road, signed speed as well as average speed, specific road conditions, obstacles on or nearby the road, etc. This information could be obtained from the local Road Agency, the local Police, from people living near the crash site location and from other sources.

Collected data could be used to draw the Collision diagram (Figure 3.4.1.1). and a Crash summary table (Figure 3.4.1.2.).

Collision diagram

The collision diagram is a schematic representation of all crashes that have occurred at the hazardous location. The characteristics of the crash are shown using the manoeuvre illustration. The movements involved in the crash are graphically explained using arrows, which represent the preliminary collisions parties. The following data are also shown in the collision diagram:

- the exact location of each crash within the junction or section of road.
- the travel direction of each vehicle
- the manoeuvres of each vehicle (straight ahead, turning, loss of control);
- the type of collision (right angle, rear-end, etc.).

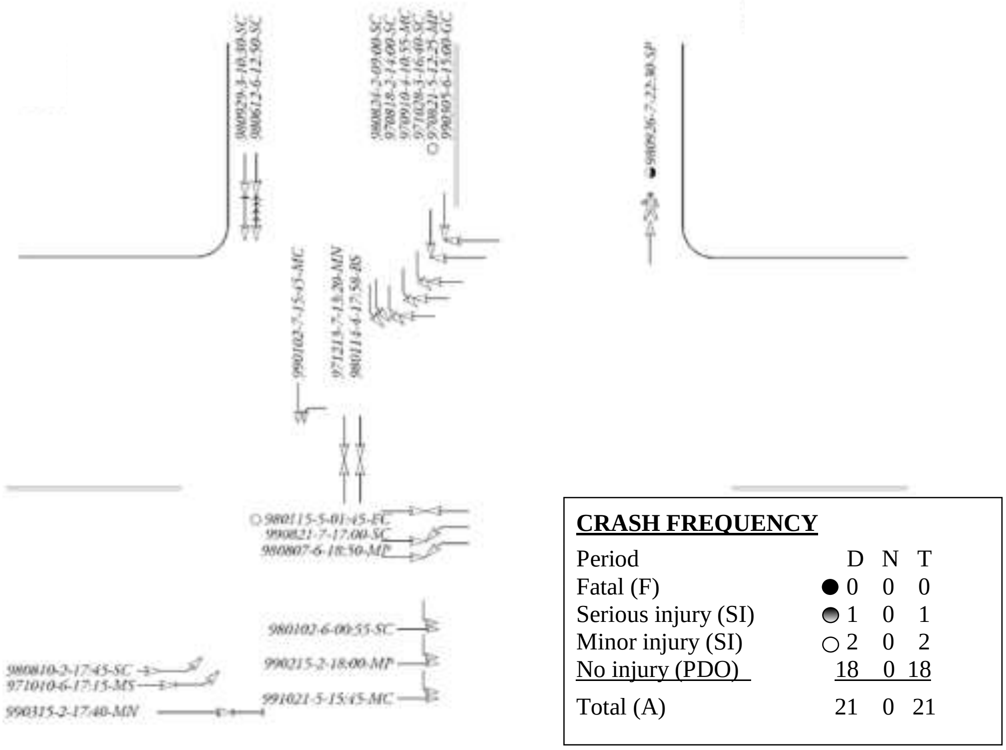

Figure 3.4.1.1. Example of a typical collision diagram

The collision diagram makes it easier to recognize the most frequent crash types and their concentration and given insights into the potential problems and manoeuvres at that location.

Summary tables of crashes

The crash summary tables contains the most important data available for the several crashes that have happened at a single location. From this table it is easy to understand the most common factors and circumstances for all crashes occurring at that location.

	ACCIDENT NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Year	00	99	00	98	99	99	00	98	00	99	98	98
Month	02	03	07	04	01	04	04	12	05	04	09	10
Day of week	SUN	FRI	MON	SUN	TUE	SAT	SAT	TUE	MON	FRI	SUN	SAT
Time	1615	0210	1240	1750	1520	1125	1430	2200	1825	0910	0500	0940
Severity		●				○				○		
Crash Type												
Surface Condition D – dry W-wet	D	D	W	W	W	D	W	D	D	W	D	W
Lighting	N	D	D	N	D	D	D	N	D	D	D	N

Figure 3.4.1.2. Example of a typical crash summary table

3.4.2. Crash analysis

Dominant crash types

If a collision diagram is available, it should be used at the beginning of the analysis process. Through this diagram an initial grouping of crashes will already have already been carried out showing exact location of each crash, travel direction of each vehicle and manoeuvres of each vehicle (type of crash).

The type and location of the crash generally provide the most important information for crash analysis. From the collision diagram, the dominant crash types can be deduced. A crash type is considered dominant when occurring in a cluster of 4 crashes or more. Other types of crashes, not belonging to a dominant group, are not significant enough for crash analysis and cannot lead to conclusions based on common characteristics.

It must be noted that crashes of different characteristics may have the same cause. If an intersection is not easy noticeable, this can lead to both give-way crashes (reacting too late to traffic with priority crossing) and rear-end crashes (reacting too late to the car in front slowing/stopping, standing still and waiting to give way). This means that all crashes should be thoroughly considered.

At a location with relatively few crashes, for example 3 crashes in 3 years, a dominant crash type could be hard to identify. At such locations, dominant crash characteristics (direction of approach, time, light and so forth) will facilitate the analysis better than the crash type.

With low numbers of crashes percentages should not be used when formulating conclusions, because this could provide inappropriate and misleading interpretation. For example: "3 out of 4 crashes occur in the dark" illustrates the actual situation better than "75% occur in the dark" and gives information on the small sample size.

Dominant characteristics

The analysis is initially carried out per dominant crash type. Within this group of crash similarities with other characteristics are required.

With a dominant crash type and a large number of crashes further analyses could be done. For example, if 12 of a cluster out of 20 single crashes turn out to have occurred in the dark, a separate further analysis of these 12 crashes is needed to disclose other similarities (e.g. driver's age, alcohol, etc.).

In addition to determination of dominant crash types and/or characteristics, the remaining part of the analysis can best be carried out using a "question and answer" technique. Two main questions should be asked:

- Does the similarity have any significance?
- What conclusion can be drawn from this?

If, for example, it turns out that 70% of the crashes occurred on wet road surface, specific questions are:

- Is that number larger than can be expected, based on the dry-wet road surface-time relation?
- Does this serve as a basis for formulating a hypotheses regarding possible crash cause?

3.4.3. Formulating hypotheses

Based on the “in office” analysis, hypotheses regarding the possible crash causes should be formulated. This should be done for each dominant crash type or characteristic separately.

It is important for various conclusions from the crash analysis to be compared and put together as a puzzle. They can be either contradictory or even complementary to each other.

Additionally various types of crashes sometimes have same cause.

The hypotheses regarding possible crash cause should be formulated for each individual dominant type of characteristic, based on the total picture of the crash analysis.

3.4.4. On site investigation - Collecting and processing of crash data

When the “in office” crash analysis has been carried out, each of the sites will require a site investigation. A site survey should be carried out in order to add more details and to "test" the hypotheses. The assumptions as regards the possible causes should be examined as careful as possible to determine the accuracy.

The road and traffic situation at the location should be examined using the results of the crash analysis as the starting point. The investigation has to take into consideration the **triggers** of the driver's reactions and patterns of behaviour, which may result in an crash.

In the application of the Human Factors concept to traffic accidents, the road safety expert asks for the reasons that led to a driver’s **operational error**, which finally resulted in an crash. This approach is not very new in road construction. In the 1930s, basic ideas from the Human Factors concept were taken into account in planning major roads and highways.

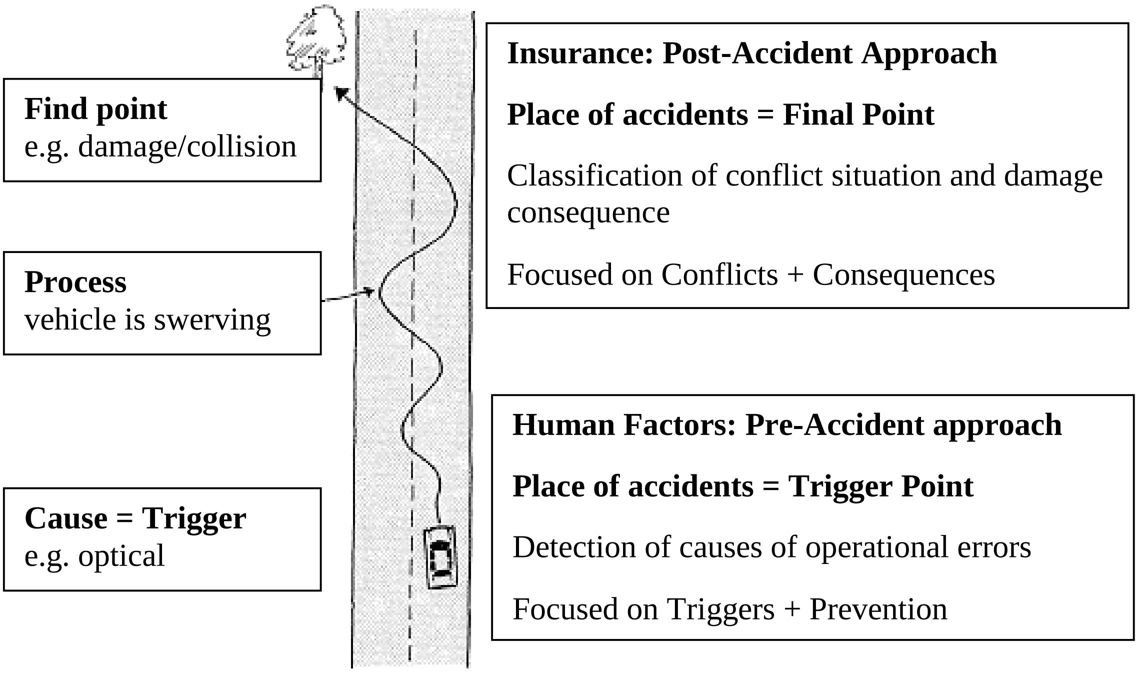

Fig. 1: Post-Crash and Pre-Crash approach [15]

The Human Factors concept considers the driver's operational error as the first step in a chain of events that may lead eventually to a crash. Many of the often-observed operational errors result from the direct interaction between the road and the driver's reaction characteristics. Road features determine driver behaviour. Since the driver's reaction characteristics cannot be changed, attention should be focused on the road characteristics. This deduction makes it possible and obligatory to take into consideration the human limitations of drivers' perception, information processing and action and must be taken into account when roads are planned and constructed.

It is the aim of the Human Factors concept to reduce the probability of operational errors and ultimately to reduce the probability of driving errors by a user-friendly and self-explanatory road design. This means that the road has to be constructed clearly, so the driver has clear information to enable safe driving. This required that dangerous points have to be designed so as to be easily understood, perceptible and recognisable. The road user should be neither confused nor invited to take risks. The goal of the notion of "self- explanatory road design" is to increase the unmistakable interpretation of road features. Such a user-friendly, self-explanatory road design should directly result in a decrease in the frequency of crashes. (see more in PIARC Human Factors Guideline).

There are a number of parameters which can be collected on site and which can substantially improve the understanding of the cause of crashes. The most important ones are: number of vehicles and average speed in at the location being analysed and the road situation as well as information regarding cross fall, skid resistance etc.

Traffic counting

Traffic counting is a procedure which enable crashes counting of road users (vehicles, pedestrians, ...) which are passing through a certain point in the road network (a section, intersection, etc.). In traffic counting road users can be sorted by category (e.g. motorized traffic, non-motorized traffic, pedestrian traffic, etc.), and by time of day. The results of traffic counts are entered in pre-prepared forms, so that those counting should only count vehicles that are passed through their location.

The methodology of traffic counting is well developed and widely accepted and already used in all TRACECA Countries, so the procedure and methods of traffic counting will not be explained any more.

An output of traffic counting should be diagram, which shows traffic load of road, intersection legs, some location, etc. Counting could also provide information on traffic composition (percentage of different types of vehicles in traffic flow). These outputs can contribute for the better understanding of the existing road situation and improve the hypotheses and decision-making about which counter measures should be taken at Black Spots.

Vehicle speed measurement

Vehicles speed is usually one of the main factors which increases the risk of road crashes. Often, speed is a direct cause of a traffic crash, and more often it has a direct contribution to the severity of consequences. According to available information, speed measurement of vehicles on the road network and statistical analysis of speed has not so far been carried out in systematically way in TRACECA Countries. Therefore, method of speed recording will be more explained.

Exceeding the maximum permitted speed limit on the roads is one of the most important risk factors and acute problem of traffic safety in each country. Modest experience, collected inside field trips and researches of Black Spots in different TRACECA Countries, shows that speeds at the observed locations were often above the permitted speed limits. This clearly indicates the need of speed analysis at each Black Spot location.

Speed measurement should be done at the same period of day as when the biggest number of crashes happen.

Speed measurement of the vehicle can be implemented manually or with automated devices. In the case of usage of automatic devices for speed recording (inductive loops or modern laser devices / video / ultra-red / microwave detectors) the speed of vehicles can be recorded over longer periods of time.

Speed measurement results should be used for getting data about average speed of vehicles, standard deviation, the percentage of drivers which exceed the maximum allowable speed, speed of 85% of the vehicles in flow, the percentage of slow vehicles, etc.

Previous analysis will enable good understanding of driver behaviour and speed influence on Black Spot location.

Traffic conflict techniques

For crash analysis researchers usually use the information contained on crash reports to identify and understand failures of the road system and then to propose appropriate treatments. Sometimes, data from crash reports are not enough and need to be complemented by field observations in order to improve the accuracy of safety diagnoses.

Over the years, different tools have been proposed to assist safety analysts in making field observations. One of most useful formalized techniques for recognizing the risks at analysed location is traffic conflict techniques.

In a traffic conflict technique, trained observers watch the traffic and note the frequency and types of conflicts that occur at a specific location. Since conflict studies imply direct observations of road users' behaviour, they help in identifying manoeuvres that are particularly hazardous, and that can easily became the real crashes if someone did not react quickly enough.

A well-accepted definition of traffic conflict is: “An observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged”.

For successfully implementation of traffic conflict techniques the following conditions are needed:

- Recorders must be trained to recognize and capture the conflicts,
- If more than one recorder is using, they all should apply the same criteria for identifying the conflicts, as well as severity of conflicts and
- Conflict recording period should correspond to the time when most of crashes have happened.

One of most used models for traffic conflict technique is the so called “Swedish model” or “Swedish conflict technique”. According to this model, a dangerous place is the place where are three conflicts recorded in the period of 60 min.

As a help, recorders could use predefined form. An example of a typical form is shown at Figure 3.4.4.1.

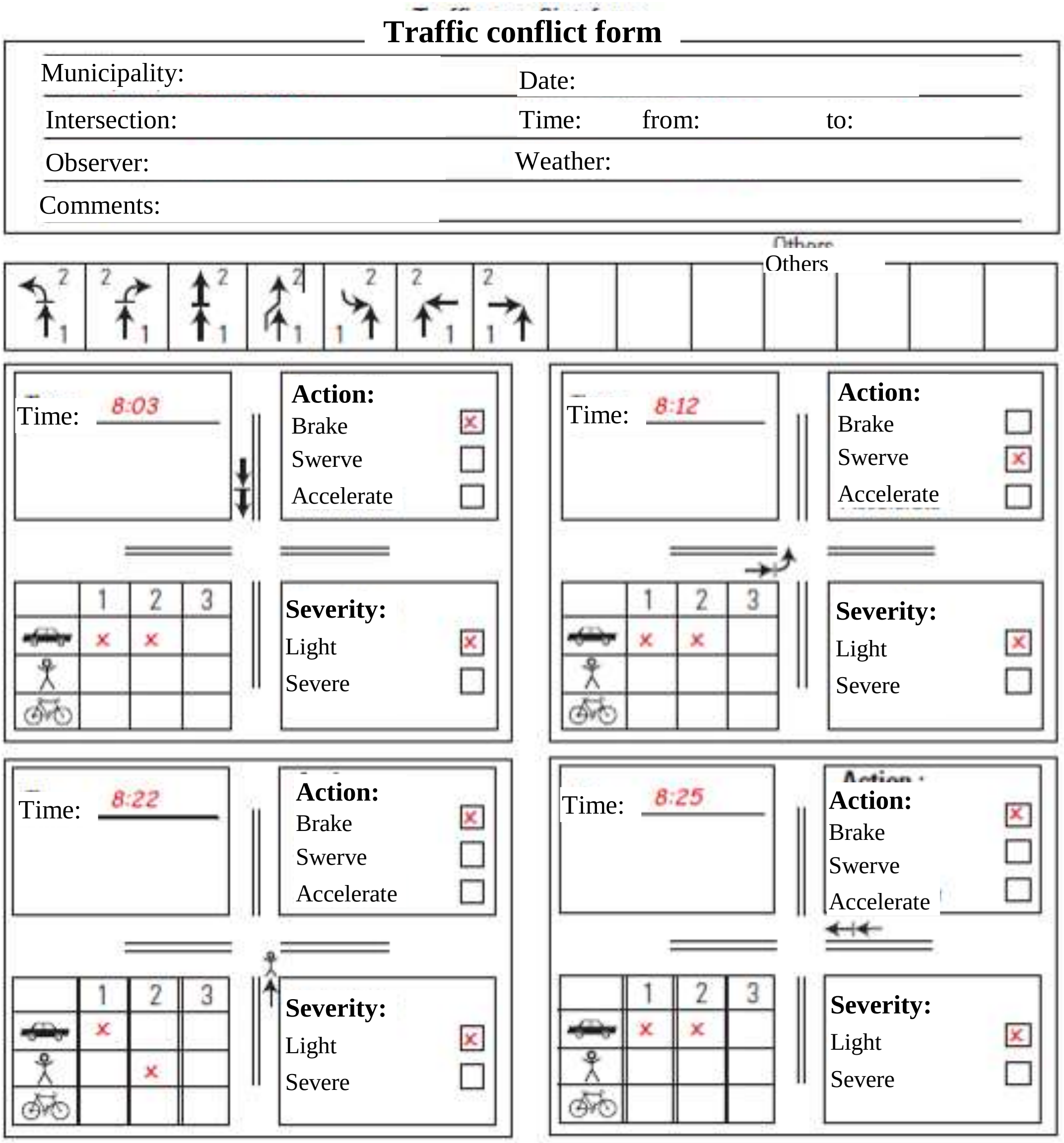

Figure 3.4.4.1. Possible look of Traffic conflict form

Beside, previously mentioned methods and techniques for field analysis, the following recommendations should be followed:

- The investigator should put himself, as best as possible, in the crash situation. The location should be approached a number of times with the "dominant" mode of vehicle from the relevant direction. Attention should also be given the route leading to the location.
- The field analysis should be carried out, as much as possible, under the circumstances similar to those prevailing at the time of the crash (time, light, weather conditions, etc.).
- It is sensible to make a list of points of attention per hypothesis for the site investigation beforehand, based on the crash analysis.
- The traffic behaviour at the intersection or road section should be observed. Entrance behaviour, observation situation, functioning of priority regulation, crossing behaviour and complexity of the manoeuvre should be studied carefully.
- Possible causes, not found during the crash analysis, may be found during the site investigation. It could be useful to take photos or video in order to enable assessment of

the situation afterwards. The recording should preferably be made from position of the parties involved (location and eye level).

- Always take good time for the site investigation. Talking to people living nearby could generate useful supplementary information.
- Try to find the relation between the crash pattern and the road/road environment.

3.4.5. Determine the cause of crash

If the site investigation provides sufficient evidence for the hypotheses, then the probable crash causes can be determined for each dominant crash type.

It is important to compare the various findings from the site investigation. They can be complementary but can also sometimes be contradictory. Different types of crashes can sometime have the same cause.

Based on the findings, the hypotheses could be confirmed or rejected for each dominant type of crash characteristic. The dominant cause of crash should be determined in order to guide the decision about countermeasures proposed.

3.5. Determination of Black Spot Treatment

When the causes of each dominant crash type have been established, the results should be discussed among concerned stakeholders. Next, the objectives and solutions have to be defined and decided on.

The countermeasures

The countermeasures should eliminate the main causes of crashes. The various counter measures for preventing the various dominant types of crashes should form a unified whole solution. If the research brings deficiencies in the existing design to light, the design has to be adjusted. Some of typical black Spots and preventive countermeasures and potential crash savings are presented in Chapter 4 and 5.

If the cause of crashes lies in the use of infrastructure and little can be done through infrastructural measures, or only at extraordinarily high cost, then activities such as traffic safety education, media campaign and strong law enforcement are more suitable. However, much can also be done to improve road user behaviour through improved traffic signing, speed limits and warnings.

All proposed measures should be oriented towards problem solving. It should be noted that combating against one kind of crash might, after all, lead to generation of another crash type or transference of the crashes to another place. For example, a speed limiting measure such as a speed hump in an intersection can have a beneficial effect on the number of give-way crashes. When the same measure is applied to a main road, with high traffic volumes and speed over 50 km/h (where such measure not expected by drivers), this measure can lead to a worse situation than the original problem.

When countermeasures proposal consists of structural measures special attention should be given to potential side effects, and especially to the measures which may influencing traffic circulation.

In the process of determination of the Black Spot treatments priority should be given to the, so called, "low cost" solutions. Low cost does not mean low quality. This means low capital cost and therefore rapid implementation by upgrading road infrastructure in as many as possible Black Spots which will lead to the decreasing the number of crashes. Better delineation, installation of guardrails, use of "speed bumps", improving of lighting, use of traffic signs with high retro reflection and high quality line markings and reflective signing are typical low cost measure which are often all that is needed at many rural Black Spots in TRACECA Countries to improve their level of safety.

When proposing measures, several alternatives or a combination of measures may be suggested. The output from this step is expected to be the proposal of Black Spot treatment with preferably application of high effective and low cost measures. The final choice of measure will be made upon cost/benefit analysis.

Until TRACECA Countries develop their own experiences in countermeasure effectiveness, World Road Association - PIARC Catalogue of design safety problems and potential countermeasures (2009) can be used. This catalogue was prepared by a team of experts drawn from the roads authorities around the world.

Estimation of crash reduction

Until now in TRACECA Region there are not too many documented experiences about the effects of implemented road safety countermeasures.

Chapter 5 contained a list of evaluated countermeasures from different courtiers, which can be used until the regions own experiences is collected. A set of expected reduction factors is given in the list where all measures are accompanied with the expected percentage of crash reduction. This list is made as a result on different case studies and research work. Usually, the analysis of road crashes is done before and after the implementation of the particular countermeasures and effects were recorded.

The expected road crash reduction factors can be used to estimate the potential crash reductions for selected countermeasures. Crash reduction factors can be also used for estimating the economic worth of projects and prioritization.

In time, crash reduction factors for each TRACECA Country will be developed, and these will allow more accurate estimates of benefits to be made.

3.6. Ranking (Priority listing upon cost/benefit analysis)

In the early years of BSM usage, ranking was pretty simple and based on number of crashes (primarily on crashes with fatality). In this way, a ranking list of Black Spots was prepared focusing only on total number of fatal crashes. Even with usage of a weighted index proposed model is pretty simple for usage.

Soon, in the process of BSM (especially in the part of determining treatment measures for improving the road safety), the following question arises: “What profits the investment into various measures (solutions) will bring in return?” To answer this question, the effect of the treatment must be related to their costs. Methods being used for this purpose are generally known as cost/benefit analysis.

The characteristics of cost/benefit analysis are that it relates the effects and cost of implemented measures.

The purpose of cost/benefit analysis is to determine priorities of measures (ranking). The determination of priorities can be used in two ways:

1. To identify the most effective measures within a determined budget.
2. To calculate the budget required for the best effect.

In most cases the first aim prevails, as the budgets are always limited.

The required information or input to carry out the cost benefit is:

1. A working list of Black Spots locations.
2. Design and cost estimates of proposed measures.

Procedure of cost benefit analysis is:

1. Calculate the annual cost per measure,
2. Estimate the number of prevented crashes,
3. Calculate the cost-benefit ratio of measures and
4. Determine priorities of measures.

Simplified method of calculating Fatality Cost Ratio (FCR):

In order to accurately determine the benefits which society will have after treatment of Black Spot, it is necessary to know the value of human life. It is normal to calculate the economic value of human life a value and calculate the amount of money that society will save by preventing fatalities by implementing proposed measures.

A detailed calculation model for "cost/benefit calculations" can be used in future, but simplified calculation model has been accepted and used for some years.

Even that value of human life has not yet been officially established in most of TRACECA Countries, for the purpose of presentation of the proposed model, crash costs from a previous Study undertaken in one of TRACECA Countries was used. So, for the purpose of testing the model, human life value will be set to **290 652** Euro.

FCR - Fatality Cost Ratio = (fatalities per year * 290 652) / cost of countermeasures

The above formula, presents a simplified calculation model where the number of fatalities at a Black Spot per year is taken from historical records, multiplied by adopted value of fatal crashes and divided by the cost of relevant countermeasures. This formula can be also be used where fatalities are substituted by casualties. Casualties in this case mean the total of any fatal crashes and any injury crashes.

For example, let us assume that a particular Black Spot has 4 recorded fatalities over a three year period (an average of 1.33 fatalities per year). After a site investigation and assessment of crash report data, it is calculated that the cost of countermeasures are about 30000 Euro.

The Fatality Cost Ratio then becomes:

FCR 1 = (1,33 * 290652)/ 30000
FCR 1 = 386567.16/ 30000
FCR 1 = 12,88:1

Now let’s say, that another Black Spot site has the average of 3 fatalities per year, and after the site investigation it is shown that the cost of countermeasures comes to 20000 Euro.

The Fatality Cost Ratio then becomes:

FCR 2 = (3 * 290652)/ 20000
FCR 2 = 871956/ 20000
FCR 2 = 43,59:1

This shows that the second site, with a FCR 2 of 43,59:1, gives almost four time more benefit than the first site which only gave an FCR of 12:88:1 so site 2 should be given more propriety for implementation. This systematic, scientific approach enables more rational decision-making and more effective use of the limited funds available for road safety.

This is a very simple technique for prioritising which shows which Black Spot treatments give society the best return on investment.

Priority list based on Fatality Cost Ratio:

The ranking list of remedial measures should be made on the basis of the FCR. From this list measures may be ranked in order of priority for implementation.

Some other factors should be also considered before the final priority list is created. These factors could be implementation problems (physical, legal, ecological, etc.), limited funds available for investment, other consequences for the transport system (such as costs of congestion, etc.) and others. Experience shows, that plans based only on effective but unpopular counter measures may end up not being implemented. However, if the final decision differs from the ranking order, such deviation from procedure should be clearly pointed out in order to present leading and justification to that decision.

Prioritized treatment measures should be put into the annual Business or Action program (plan) of the Road Authority as a separate and transparent parts of the plans. If there are not enough funds in the eventual annual budget, some of proposed Black Spots could be rescheduled for the following year.

3.7. Programming, Budget and Financing

After the Black Spots are prioritized the next step is making a National (Country) Program (NP) for their treatment (implementation of measures). A national medium or long term road safety Program is a prerequisite for achieving sustainable improvements in road safety and improvement of Black Spots. The NP should set measurable mid/long term road safety targets.

The most urgent remedial measures, ranked according priority, have to be put into the priority Business/Action Plan and a basic system or standard institutional implementation procedure for effective Black Spot treatment should be established.

The main objective of the NP should be to reduce the social and economic costs of road crashes and trauma by:

- cost effective treatment of locations with a history of fatality crashes,
- placing significant focus on the need to reduce road trauma,
- coordinating and strengthening the activities of all the key road safety stakeholders who can influence on road safety and
- allocate adequate funds to treat selected locations.

Under the NP, implementation of the priority Action Plan should be undertaken for the implementation of program. In most cases, the Action Plan for Black Spot treatment incorporated into Road Authority activities and take a transparent place in their annual business and budgeting plans. The number of annually treated locations should be in accordance with available budget of Road Authority for BSM. It is likely that the number of Black Spot will be bigger than the available annual budget; NP should be made for three years.

A time scale of three year is suggested, because it allows implementation of measures for a reasonable number of Black Spots. External specialist road safety advisory input might be required for this purpose.

As the Black Spot treatment NP usually will cover a period of 3-5 years (with annul revisions), a long term sustainable funding (financing) is required to cover the implementation.

In order to achieve the benefits of a Black Spot program, it has to be systematically implemented over a period of time. Equally important is the evaluation of effects from the program implemented.

3.8. Implementation of Treatment measures

The Road Authority is responsible for initiating, coordinating and overseeing project implementation, including procurement, financial management, project monitoring and reporting, and the day-to-day supervision of project activities.

The main objectives of Road Authority are:

- To provide leadership and framework for effective implementation of road safety measures and
- High standard of road safety during implementation.

3.9. Design and Construction

Depending on to the character and the size of the construction work on Black Spot locations the Road Authority could either use the internal or external design capacity and maintenance department or external contractor for the design or work implementation.

It is the responsibility of the Road Authority (or delegated organization) to ensure safety at road works. The work site should be properly signed with temporary signalization during road works period. Risks for the road workers as well as for the road users must be avoided.

In addition any delays of construction work which can cause discomfort for the road users or neighbourhoods and should be minimized.

3.10. Follow up and Evaluation

When a period of time (1-2 years) has elapsed and the road users are familiar with the new traffic situation some after-research should be carried out in order to evaluate the effects of the implemented counter measures. This could be done by Road Authority (Road Safety Unit if such exists).

Evaluation is the permanent monitoring of the effects of measures implemented, followed by the comparison with the goals set. Monitoring means collection of traffic data and crash data, complaints and general views on the situation. Experience shows that implemented measures sometime do not immediately lead to an improvement of the situation.

Comparison with the goals set. This means: an answer to the question whether results are as expected (do the results comply with the goals) or not.

An evaluation period of 1-2 years (sometimes even 3 years) is generally used in many countries before any definite conclusions can be made. If the effects are not satisfactory, then analysis should be repeated and corrected or new measure should be introduced.

The “after-data” should be documented together with “before-data” and used as an experience bank (Catalogue of road safety countermeasures) for the future.

For example, "before and after" crash levels at the Black Spot site should be monitored. Part of this analysis includes using the database to make sure that there has been a significant reduction in the number of crashes at a Black Spot site. The results are used to create a new entries to the list with data about reduction of crashes (Chapter 5).

The crash analysis experts should analyse the “after studies”, because it is important to fully understand the effect of the Black Spot measures and Program and eventually if necessary make adjustments.

3.11. Documentation

It is important that all technical and financial documentation of Black Spot Management is saved and available for future users. To determine the actual effect of countermeasures actual effect on fatal crashes, independent evaluation of the project may be conducted from time to time. Road Authority should maintain all the adequate documents and records for the whole process so that appropriate data will be available for this purpose.

Documentation is also a valuable tool for education and training of people involved in the Black Spot remedial process. To learn from successful and less successful countermeasures is essential. Also, data from documentation could be used for adding the information in Catalogue of countermeasures.

4. TYPICAL BLACK SPOTS

According to international best practice, there are some types of typical dangerous places on roads in TRACECA region.

Surveys of Black Spots in some of TRACECA Countries and examination of the road networks, were used for preparation of this chapter of Guidelines. BSM surveys were done in combination of office and field work.

After detailed analysis of investigated locations (Black Spots or Black Sections), as well as survey of other parts of the road network (Project team have had an opportunity to examine more than 5000 km of major roads in different TRACECA Countries), the following typical locations/problems can be pointed out, as more dangerous than others:

Figure 4.1. Typical black spots and countermeasures

Black spot description / Typical countermeasures	**Illustrations**
<u>- Roads passing through towns</u> (too many access roads, mixed traffic, high speeds, illegal parking of vehicles, pedestrians, insufficient visibility, street markets, ...).	 
- access control (closing of illegal access roads) - separation of shoulders by barriers - traffic calming (signs, physical obstruction, road surface and larger schemes) - construction of foot pass - construction of pedestrian crossing help - new signing and marking - installation of artificial lighting - add specific (UN-standard) signs - ...	

<u>- Intersections</u> **<u>Problems</u>** (dangerous types such as “Y” intersections, dangerous roundabouts with inadequate deflection, bad design or intersections without enough visibility, with inadequate	

signing and marking, problems with pedestrians, ...).

Possible solutions

- reconstruction of intersection (adding of channelization islands, improving of visibility, ...)
- improving of signings and markings (clear wait and right of way)
- installation of artificial lighting
- add specific (UN-standard) signs
- ...

- Dangerous curves

Problems

(curve with the lack of visibility, too small radius for the road range, inadequate cross-slope, without the necessary signing and marking, ...).

Possible solutions

- improving of geometry (increase the curve radius if necessary)
- improving of visibility (signings and markings, adding of rumble strips, etc.)
- additional vertical signalization (warning signs, chevron signs)
- add built-in asphalt markers
- add guardrails
- add specific (UN-standard) signs
- ...

- Road narrowing

Problems

(at bridges and culverts, with the traffic conditions that compromise road safety, with inadequate signs and markings, ...).

<u>Possible solutions</u>

- widening of the narrow section
- improving of signings and markings
- additional vertical signalization
- add built-in asphalt markers
- add guardrails
- add specific (UN-standard) signs
- ...

<u>- Bridges *(Tunnels)*</u>

<u>Problems</u>

(objects on the road usually between two curves, lack of visibility, without adequate traffic signing and marking, mostly without vehicle guardrails, ...).

<u>Possible solutions</u>

- improving of signings and markings
- additional vertical signalization
- add built in asphalt markers
- add guardrails against EN 1317
- usage of tunnel safety standards and norms
- adding of artificial lightening
- add specific (UN-standard) signs
- ...

<u>- Pedestrian crossing</u>

<u>Problems</u>

(Inadequately designed, signed and marked, poorly visible, without the necessary traffic equipment in areas of intense movement of children, with no lighting).

<table>
<tr>
<td><u>Possible solutions</u>
- improving of design and signings and markings
- traffic calming (signs, physical obstruction, road surface and larger schemes, especially usage of humps and rumble strips
- construction of pedestrian crossing help (refugee islands, pedestrian guard rails,)
- adding of pedestrian fences
- installation of artificial lighting
- add specific (UN-standard) signs
- ...</td>
<td>
</td>
</tr>
<tr>
<td><u>- Railway crossings</u>
<u>Problems</u>
(Crossing of road and rail at small angle, lack of transparency and visibility, inadequately secured and marked places, ...).</td>
<td rowspan="2">
</td>
</tr>
<tr>
<td><u>Possible solutions</u>
- improving of signings and markings
- additional vertical signalization
- add built-in asphalt markers
- add specific (UN -standard) signs
- ...</td>
</tr>
</table>

Apart from typical dangerous places (Black Spots), there are usually a few systemic deficiencies of active and passive road safety, such as:

- absence of UN compliant road signings and markings,
- low quality of passive road elements (guardrails are not in accordance with road range or not made upon adequate specification),
- a large number of commercial activities and stalls are too close to the state roads, especially on the sections of roads where they pass through populated places (cities),
- a large number of unregulated (illegal) access roads, etc.

Understanding the most typical occasion, which produces the Black Spots, is as important as desire to be active and to prevent them. The causes of Black Spots could be removed in the design phase, construction works and road maintenance.

It can be concluded that in almost all locations, there is a lack of signings and markings, to provide adequate guidance and information to its driver, as well as missing guardrails to protect them even if they make a mistake.

One suggestion could be, that all identified Black Spots should be marked with non-standard traffic signs. With this, the dangerous locations will be easily recognized by road users (mostly drivers), and they will adjust their behaviour (speed) to local road conditions. These signs will be removed after improvement (reconstruction, rehabilitation or else) at that location.

Proposed countermeasures and ways of signing the Black Spots are based on the experiences of developed countries and international associations (IRF, ERF, PIARC, PRI, WB, OECD, ECMT, etc.) Thus, provide an effective and uniform management system of Black Spots on the entire network of State roads.

5. POTENTIAL CRASH SAVINGS

For any kind of countermeasure proposal it is necessary to know crash reduction potential. Therefore a list is proposed of the most usual low cost countermeasures with their expected effects.

The following table is collated from results of different international research projects and case studies and can be use for understanding the potential crash savings of different countermeasures. Table 5.1. presents each different proposed countermeasure (treatment) and its potential crash reduction as a percentage. Usually, minimum and maximum effects are presented.

Table 5.1. Efficiency (crash reduction) of different countermeasures

Treatment	Potential crash reduction [%]
Road Standard	
Improve to higher standard	19-33
Increase number of lanes	22-32
Lane widening 0,3 – 0,6 m	5-12
Paved shoulder widening 0,3 - 1 m	4-12
Add median strip	40
Bridge widened or modified	25
Widen shoulder	10
Overtaking lane	20
Right turn lane	40
Left turn lane	15
Pedestrian overpass	10
Side slope flattening from: 2:1	
to 4:1 ... 7:1 or flatter	6 ... 15
Side slope flattening from: 4:1	
to 5:1 ... 7:1 or flatter	3 ... 11
Service roads	20-40
Traffic calming	12-60
Speed reduction from 70 km/h to 50 km/h	10-30
Speed reduction from 90 km/h to 60 km/h	17-40
Horizontal Alignment	
Improve geometry	20-80
Curvature: improving radius	33-50
Vertical Alignment	
Gradient / removing crest	12-56
Super elevation improvement/introduction	50
Passing lane	11-43
Climbing lane	10-40
Road Structure	

Lane widening	12-47
Skid resistance improvement	18-74
Shoulder widening	10-40
Shoulder sealed	22-50
Road verge widening	13-44
Junction Design	
Staggered (from straight) crossroads	40-95
T-junctions (from Y-junctions)	15-50
Fully controlled right turn phase	45
Roundabouts (from uncontrolled)	25-81
Roundabouts (from traffic signals)	25-50
Mini roundabouts (from uncontrolled)	40-47
Turning lanes	10-60
Traffic islands	39
Sheltered turn lanes (urban)	30
Sheltered turn lanes (rural)	45
Additional lane at intersection	20
Skid resistant overlay	20
Red light camera	10
Law enforcement by the Police	7-25
Traffic Control	
Regulatory signs at junctions	22-48
Guidance/directional signs at junction	14-58
Overhead lane signs	15
Side road signs	19-24
Brighter signs and markings	24-92
Signs and delineation	29-37
Bend warning signs	20-57
Stop ahead sign	47
Speed advisory sign	23-36
Warning/advisory signs	20
Speed limit lowering - & sign	16-19
Yield/Give Way	59-80
Stop sign	33-90
Signals from uncontrolled	15-32
Signals - modified	13-85
Junction channelization	10-51
Remove parking from road side	10-25
Visibility	
Lane markings	14-19
Edge markings	8-35
Yellow bar markings	24-52
Raised reflective pavement marking	6-18
Delineator posts	2-47
Flashing beacons	5-75

Lighting installations	6-75
Sightline distance improvement	28
Channelization medians	22-50
Crash Amelioration	
Median barrier	14-27
Side barriers	15-60
Frangible signs	30
Tree removal (rural)	10
Pole removal (lighting poles, urban)	20
Embankment treatment	40
Guardrail for bridge end post	20
Impact absorber	20
Pedestrian Facilities	
Pedestrian walkways	33-44
Pedestrian zebra crossings	13-34
Raised zebra crossings	5-50
Pelican crossings	21-83
Marking at zebra crossing	-5-14
Pedestrian refuges	56-87
Footbridges	39-90
Pedestrian fencing	10-35
Cycling Facilities	
Cycle schemes	33-56
Marked cycle crossing at signals	10-15
Cyclist advanced stop line at junctions	35
Rail Crossings	
Flashing signals	73-91
Automatic gates	81-93
Traffic Calming	
30 km/h zones (inc. humps, chicanes etc.)	10-80
Rumble Strips	27-50
Rumble Strips and Bumps	20-80

NOTES:

1. Crash Reductions are NOT ADDITIVE, use highest value if multiple treatments are proposed for a particular location.
2. Reductions apply to all crashes within single intersections or single midblock that contain the treatment.

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