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Ranking of High Accident Concentration Sections and Network Safety Ranking

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Title:	**Ranking of High Accident Concentration Sections and Network Safety Ranking**
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Ranking of High Accident Concentration Sections and Network Safety Ranking

Keywords:

Network safety ranking; high accident concentration sections; hazardous road section; homogenous road sections and junctions; accident rate; injury accidents; traffic volume; expected number of accidents.

Abstract:

Safety performance of existing roads should be raised by targeting investments to the road sections with the highest accident concentration and/or the highest accident reduction potential.

“Network safety ranking” (NSR) means a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings. “Ranking of high accident concentration sections” means a method to identify, analyse and rank sections of the road network which have been in operation for $3-5$ years and upon which a large number of fatal/injury accidents in proportion to the traffic flow or compared to respective conditions have occurred.

This report provides detailed recommendations on implementation and execution of “Road network safety ranking and ranking of high accident concentration sections” procedures.

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Definitions

Hazardous road sections - is any section on the road network that has a higher expected number and severity of accidents than other similar road sections as a result of local and section based accident and injury factors. Hazardous road sections are also referred to as dangerous roads, problem roads, accident prone locations, roads for safety investigation, roads with safety potential or promising roads (Sørensen and Elvik 2008).

Accident rate – number of fatal or injury accidents per vehicle mileage (often expressed as accidents/100 million vehicle kilometers).

Expert – natural or legal person, other organization established in the European Union member state and in other states of European economic space or a subdivision of legal persons or other organizations of those states that has entered into a contract with the road owner (manager) on rendering services of the in office analysis of hazardous road sections and junctions and on-site observations of road-user behaviour.

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Content

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Summary

Directive 2008/96/EC on road infrastructure safety management requires the establishment and implementation of procedures relating to road safety impact assessments, road safety audits, ranking of high accident concentration sections and network safety ranking and road safety inspections. This Directive shall apply to roads which are part of the trans-European road network, whether they are at the design stage, under construction or in operation.

Member States may also apply the provisions of this Directive, as a set of good practices, to national road transport infrastructure, not included in the trans-European road network.

This report provides detailed recommendations on implementation and execution of "Road network safety ranking and ranking of high accident concentration sections" procedures for the trans-European road network. Prepared report is applicable and for all road network, i.e. rural roads and roads which goes through urban area (other streets are excluded).

To make the division of the road system into clearly defined road groups and homogeneous road sections, it is necessary that the road authorities collect data about traffic volume, road design and the surrounding environment. These data have to be unambiguously located on the road network by use of for example stationing along all roads in the road network. In addition, the data have to be immediately interoperable with each other and the accident data collected by the police, so that it is possible in the identification stage to make an analysis of the correlation between the different data (Elvik 2007).

The identification of hazardous road sections should rely on a more or less advanced model based method, ideally speaking the empirical Bayes method. The argument for this is that model based methods are the best to make reliable identification of sites with local risk factors related to road design and traffic control, because systematic variation and partially random fluctuations are taken into consideration.

The hazardous road section analysis stage should consist of a general accident analysis, a collision diagram, a road inspection and relevant traffic and road analyses.

After the described methods have been implemented by the road authority it is very important that the data and methods are being maintained and updated. An essential part of the implementation of the recommended methods is to make a procedure for maintenance. A typical problem is that there are no resources allotted for the maintaining and updating of the data and methods. A part of making the procedure for maintaining is therefore to secure money, time and personnel for the continuous maintaining and updating.

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1. Scope of Road Network Safety Ranking and Ranking of High Accident Concentration Sections

Network safety ranking (NSR) means a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings (Directive ... 2008). This method is used for identifying, investigating and classifying the road network sections in operation for 3 – 5 last years and on which, the largest number of fatal/injury accidents in proportion to the traffic flow or compared to respective conditions have occurred. When ranking the road sections of high accident concentration one takes into consideration the existing traffic volume in a certain unit of road section length or in the junction, as well as traffic composition, data of fatal and injury accidents. Network safety ranking is periodical procedure which should be performed yearly considering to the at least 3 – 5 last years data about traffic volume, accidents, road infrastructure changes etc.

Road Network Safety Ranking and Ranking of High Accident Concentration Sections procedures are very topical since **having properly processed the available data, having divided road network into homogenous sections and having assessed their safety performance it would be possible to more accurately allocate current funds**, to implement cost-effective safety measures and to perform an evaluation of their effect.

Safety performance of existing roads should be raised by targeting investments to the road sections with the highest accident concentration and/or the highest accident reduction potential. To be able to adapt their behaviour and increase compliance with traffic rules, in particular speed limits, drivers should be made aware of road sections with a high accident concentration (Directive ... 2008).

Network safety ranking has a high potential immediately after its implementation. Once road sections with a high accident concentration have been treated and remedial measures have been taken, safety inspections as a preventive measure should assume a more important role. Regular inspections are an essential tool for preventing possible dangers for all road users, including vulnerable users, and also in case of roadworks (Directive ... 2008).

The identification of sections for analysis in network safety ranking takes into account their potential savings in accident costs. Road sections shall be classified into groups. For each group of roads, road sections shall be analysed and ranked according to safety-related factors, such as accidents concentration, traffic volume and traffic characteristics such as speed limit. For each

road group, network safety ranking shall result in a priority list of road sections where an improvement of the infrastructure is expected to be highly effective.

The conception of road network safety and high accident concentration sections ranking is to use the accident history and general expected number of accidents to identify locations with local risk factors that are related to the local detailed road layout.

A central question in relation to application of NSR is how the road system should be divided into smaller road sections and how long these sections should be. The road system should be divided into road sections with variable length so they are homogeneous with regard to the parameters.

The road sections have to be homogeneous in order to make a model based identification, but how can the road system be divided into homogeneous sections in practice? Division can be done by relying on the following four principles (Sørensen and Elvik 2008):

1. Section based principle

2. Point based principle

3. Accident based principle

4. Combination

The two first principles can be characterized as road and traffic based division principles. In the first principle, the road system is divided into sections that are homogeneous with regard to selected traffic and road design parameters that have significant influence on the number of accidents.

The second principle is a point based principle, where intersections, towns or other “points” are used as division points.

The third principle is based on registered accidents in the identification period. Either there has to be a certain number of accidents on each road section or there has to be a uniform accident concentration or pattern on each road section.

The last principle is to combine the previously described principles. An obvious opportunity is to combine the first two principles. The two principles differ a lot from each other, but in practice, they will result in more or less the same division and can therefore advantageously be combined. The reason that the two principles approximately give the same result is that major changes in road design and traffic obviously coincide with larger intersections and towns.

To ensure reliable identifications and a potential for reducing the number of accidents the first two principles can be combined with the last principle that each road section has to have a certain number of accidents.

It is recommended that the road and traffic based division principles are used. The argument is that these principles can be used together with the model based identification method, where it is essential to have homogeneous road sections for the estimation of the general expected number of accidents. In addition, the advantage is that the principles more or less will result in the same division of the road system for different time periods, which makes it possible to compare the accident level for different time periods for each road section. Finally, the advantage of the point based principle is that it gives a rational, easy and natural division.

2. The process of Road Network Safety Ranking and Ranking of High Accident Concentration Sections

Network safety ranking and ranking of high accident concentration sections is performed on the basis of injury accident records (accidents with material damage only are excluded) and inspections of the road sections with a large number of fatal and severe accidents. Its organisational costs can be therefore assumed comparable to costs of routine road safety inspections. Road safety inspections shall be carried out pursuant to "Procedures for Road Safety Inspection". As results of the inspections, remedial measures for realisation shall be ranked based on their benefit/cost ratios for prioritisation for implementation. Evaluation of the effects of the treatment should be carried out pursuant to "Procedures for Road Safety Impact Assessment". Therefore, only safety measures showing the highest benefit-cost ratios shall then be implemented. This guarantees that costs increases due to the measures selected for implementation will be offset within a short while due to reduced number and cost of accidents.

Determination of safety levels of road network is organized by the institution implementing the owner's rights and duties of the state road maintenance enterprises.

Road network safety and high accident concentration sections ranking procedures can be divided into 5 stages (table 1).

Table 1. Typical stages in road network safety and high accident concentration sections ranking

1. Data collection	Collection of data on roads, traffic and accidents

2. Definition	Definition of road groups and junction groups
3. Dividing	Dividing the road network into homogenous road sections and junctions
4. Identification	Road network safety ranking and identification of hazardous road sections
5. Analysis	In office analysis of hazardous road sections and junctions and on-site observations of road-user behaviour

2.1 Data collection

Data collection is a very important part of the implementation of the guidelines. The necessary data is as follows:

Injury accidents (location of the accident, date and hour of accident, accident type, accident severity, including number of fatalities and injured persons, characteristics of the persons involved such as age, sex, nationality, alcohol level, use of safety equipment or not, data on the vehicles involved (type, age, country, safety equipment if any, date of last periodical technical check according to applicable legislation), accident data such as collision type, vehicle and driver manoeuvre, road surface and weather conditions, whenever possible, information on the time elapsed between the time of the accident and the recording of the accident, or the arrival of the emergency services, pictures and/or diagrams of the accident site),

Traffic volume (Annual average daily traffic (AADT), proportion of light and heavy vehicle),

Road parameters (road status or function, road significance (type), road category, cross section including number of lanes, lane width, shoulder and the presence of bicycle lanes and side strips, possibility for oncoming traffic, speed limit, lighting, markings, alignment, roadside obstacles, number and design of intersections and access roads, junction type including signalling).

The surrounding environment (rural or urban area).

Those data have to be relatively easily located and be immediately interoperable with each other.

2.2 Definition of road groups and junction groups

The trans-European road network should be divided into sections that are homogeneous with regard to selected traffic and road design parameters, but how should these parameters be chosen? The groups of road sections and the groups of junctions are formed separately (European … 2011). Member States may also apply the provisions of this procedure to all national road network, not included in the trans-European road network (Directive ... 2008).

The groups of road sections are formed according to the following parameters:

- road type and category;
- surrounding environment (rural or urban area);
- cross section;
- speed limit;
- traffic volume.

Figure 1 and Table 2 give a scheme for dividing roads into groups and subgroups based on 4 criteria:

- By the first criterion **"road type, category, surrounding environment (rural or urban area)"** four large road groups are distinguished, i.e. motorways, main roads, national and regional roads, urban roads.

- By the second criterion **"cross-section"** the subgroups are distinguished: roads with median and roads of different width of carriageway without median.

- By the third criteria "**speed limit"** the subgroups are divided into smaller subgroups: roads with a speed limit of 50km/h, 70 km/h, 80 km/h, 90, km/h, 100 km/h, 110 km/h, 130 km/h.

- By the fourth criteria "**traffic volume**" the subgroups are divided into more smaller subgroups: roads with different traffic volume.

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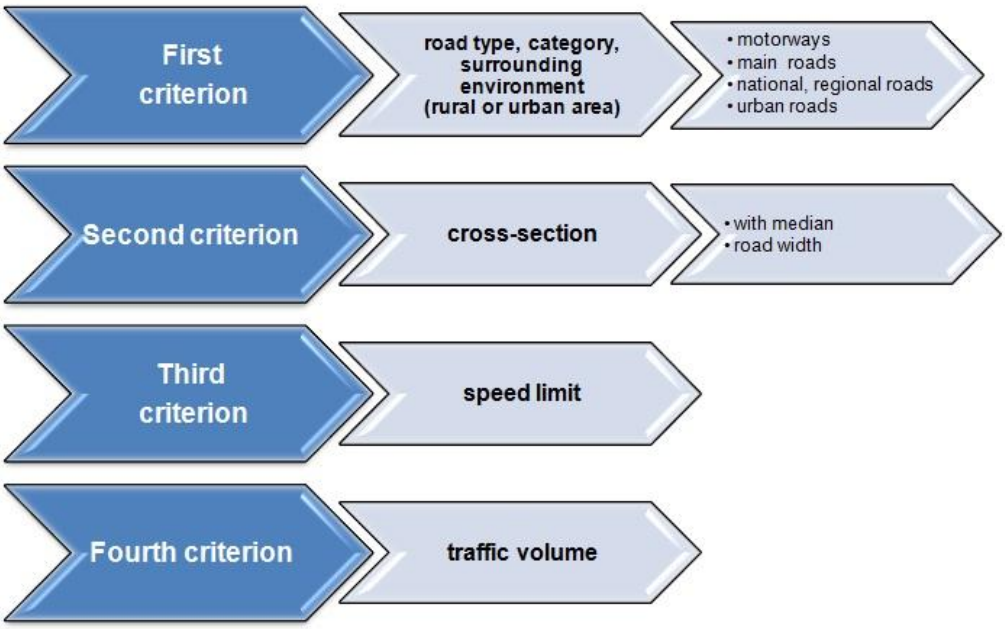

Fig. 1. Dividing process of the all road network into road groups and subgroups

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Table 2. Road network division into road groups and subgroups (proposal)

	Road groups and subgroups	AADT, veh./day
1. Separated driving directions:		
	1.1. Motorways	< 9000 9000 – 12000 ≥ 12000
	1.2. Four lanes with median 90 km/h	
	1.3. Four lanes with median 100 km/h	
	1.4. Four lanes with median 110 km/h	
2. Main roads, rural:		
	2.1. Main roads, ≥ 9m	<3000 3000 – 6000 ≥ 6000
	2.2. Main roads, ≤8m	
3. Minor roads, rural:		
	3.1. Minor roads, ≥ 9 m	<1500 1500 – 4500 ≥ 4500
	3.2. Minor roads, 8 m	
	3.3. Minor roads, 7 m	
	3.4. Minor roads, ≤ 6 m	
	3.5. Gravel roads	<150 150 – 300 ≥ 300
4. Urban roads:		
	4.1. Urban roads, 50 km/h	<3000 3000 – 6000 ≥ 6000
	4.2. Urban roads, 70 km/h	
	4.3. Urban roads, 80 km/h	

Junction groups and subgroups are formed taking into account two criteria:

- junction type (level crossing T, level crossing X, roundabouts and grade separated crossing);
- traffic volume for level crossings (according to the proportion of the incoming traffic from the minor road).

Junction zone is called an area (address) of the junction and its approaches, i.e. 200 m on both sides of a crossing point of road axes on major road and 150 m on both sides of a crossing point of road axes on minor road (Lithuanian … 2011).

Figure 2 and Table 3 give junction groups and subgroups based on two criteria.

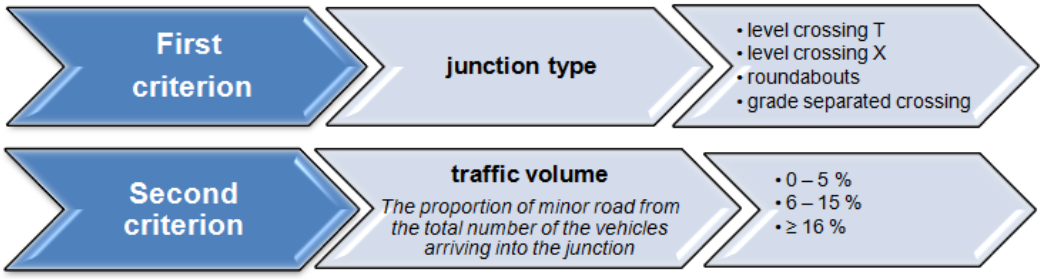

Fig. 2. Dividing process of the junctions into junctions groups and subgroups

Table 3. Junction groups and subgroups (proposal)

Junction groups and subgroups	Minor road traffic volume proportion *
1. Level crossing T	
	0 – 5 % 6 – 15 % ≥ 16 %
2. Level crossing X	
	0 – 5 % 6 – 15 % ≥ 16 %
3. Roundabouts:	
	0 – 5 % 6 – 15 % ≥ 16 %
4. Grade-separated crossing	
** - The proportion of minor road from the total number of the vehicles arriving into the junction*	

2.3 Dividing the road network into homogeneous road sections and junctions

The road network, based on the above formed road and junction groups (see chapter *"2. Definition of road groups and junction groups")* is divided into homogeneous road sections and homogeneous road junctions. For dividing road network into homogeneous sections data of the surrounding environment, road parameters and traffic volume of at least 3 **last** calendar years is used, described in *"1. Data collection"* chapter.

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2.4 Road network safety ranking and identification of hazardous road sections

Having divided the road network into homogeneous road sections and junctions the road network safety levels are identified. Road sections and junctions get into the groups of road sections and the group of junctions with their own accident data.

First stage. Network safety ranking in the road and junction groups

To distinguish the road network safety levels it is necessary to determine the total accident level in each road group or junction group, i.e. to calculate accident rate in each road or junction group. When calculating accident rate the accident severity shall be taken into consideration. For road links accident rate *AR* shows the number of weighted accidents per vehicle mileage (The Ministry ... 2011):

$$AR = \frac{A \cdot 10^6}{365 \cdot N \cdot L \cdot m} \quad (1)$$

$$A = (A_k \cdot x_k) + (A_{si} \cdot x_{si}) + (A_{li} \cdot x_{li}) \quad (2)$$

where: A – number of road accidents in the studied road group in years m, calculated by the formula (2);

N –annual average daily traffic in the studied road group, veh./day;

L – total length of homogeneous road sections in the studied road group, km;

m – number of years, i.e. of how many years data is used ($m \geq 3$).

A_k – number of road accidents where at least one person was killed;

A_{si} – number of road accidents where at least one person injured undergoes in-patient treatment;

A_{li} – number of road accidents where people injured undergo out-patient treatment;

x_k, x_{si}, x_{li} – weight coefficients of accident severity.

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For junctions accident rate is calculated respectively, however the rate is calculated per millions of vehicles arriving into the junction. So instead of $N \times L$, the number of vehicles arriving into the junction is used (calculated by AADT's of the legs in the studied junction, veh./day).

Weighted evaluation of accident severity is of two options (Sørensen and Elvik 2008):

- based on injury cost: weighted value is calculated on a basis of socio-economical evaluation of injuries.
- agreed: weighted value is assigned in a way of agreement, e.g. taking into account political objectives.

It is recommended that the weighted value is calculated based on the first option, i.e. to use monetary expression in different severity levels of the average number of people injured, this is a more objective and reliable method than agreed/political determination of values.

Having calculated *AR* for each road group or junction group the safety levels of the road network are obtained, i. e. from the total road network the group of roads or junctions having the largest accident level is distinguished.

After implementation of this stage, **the current network safety level** is obtained in each road group or junction group.

Hazardous road sections should be identified in terms of the expected number of accidents. For this purpose it is necessary to determine general expected number of accidents in each road group or junction group using accident prediction models (European ... 2011).

Second stage. Safety ranking in the homogenous road sections and junctions

Hazardous road sections or junctions is any section on the road network that has a higher expected number and severity of accidents than other similar road sections or junctions as a result of local and section based accident and injury factors. Hazardous road sections are also referred to as dangerous roads, problem roads, accident prone locations. The expected number of accidents is estimated by using the empirical Bayes method (Elvik 2007).

An accident prediction model gives an estimate of the expected number of accidents for a roadway element that has a certain combination of traits. In most models, these include traffic volume, characteristics of highway geometry and type of traffic control. Most accident prediction models will not include all factors that produce systematic variation in accident counts. Hence, estimates of the expected number of accidents derived from accident prediction models are mean values for

units that have a given combination of traits. The expected number of accidents for a specific unit will normally differ from the mean value for units that have similar general traits.

According to the empirical Bayes method, the best estimate of safety is obtained by combining two sources of information:

- the accident record for a given site, and
- an accident prediction model, showing how various factors affect accident occurrence.

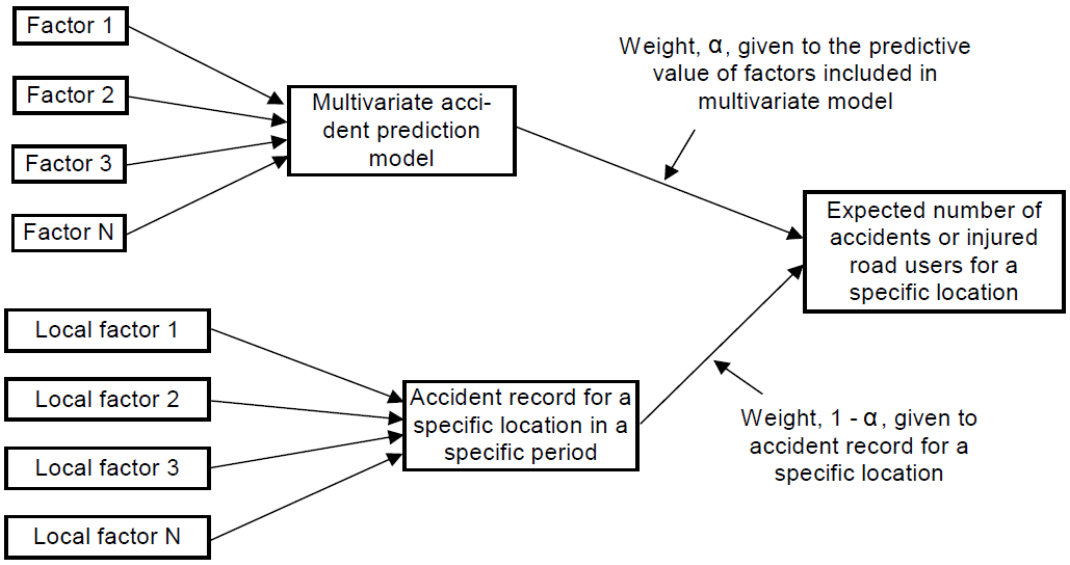

Fig. 3. Illustration of the empirical Bayes method, where information about the normal and registered number of accidents is combined for estimation the local expected number of accident for a specific location (Sørensen and Elvik 2008)

In the empirical Bayes method, the expected number of accidents on a road section is estimated by weighting the registered number of accidents on the road section or junction and the general expected number of accidents for road group or junctions group (similar sites) estimated by accident prediction models. This method is illustrated in figure 3 and in the following formula (Sørensen and Elvik 2008):

$$E(\lambda / A) = \alpha \cdot \lambda + (1 - \alpha) \cdot A \tag{3}$$

$$\alpha = \frac{1}{1 + \lambda / k} \tag{4}$$

where: $E(\lambda/A)$ – the local expected number of accidents on a road section/junction;

λ – the general expected number of accidents estimated by accident models;

A – the registered number of accidents on the road section/junction;

k – the inverse value of the overdispersion parameter.

The parameter α determines the weight given to the estimated normal number of accidents for road group or junctions group (similar sites) when combining it with the recorded number of accidents in order to estimate the expected number of accidents for a particular site.

Having calculated the local expected number of accidents for each homogeneous road section or junction, they are listed in a decreasing order of the local expected number of accidents value. **The higher position of the road section or junction in the list the more hazardous it is compared to the other sections of the same group.** For further evaluation those homogeneous road sections or junctions are selected **which in their group are characterized by a higher than the average accident probability**.

Making the list of the most hazardous road sections or junctions **of all road network** it is necessary implement Third stage below.

Third stage. Listing of hazardous road sections

The list of the most hazardous road sections or junctions of all road network includes those sections which are distinguished in their group by a higher expected number of accidents than the average of that road or junction group (see Second stage). Having the total list of hazardous road sections we rank it once again. The road sections at the top of the list are more hazardous than those listed below.

All the identified most hazardous road sections or junctions must be analyzed and subjected to special-purpose inspections (see Chapter *"5. In-office analysis of accidents and on-site observations of road-user behaviour"*).

2.5 In-office analysis of hazardous road sections and junctions and on-site observations of road-user behaviour

In office analysis

In-office analysis shall be carried out by at least 2 road safety experts having a special qualification in the field of road design, road safety engineering and accident analysis, or having

experience of investigating hazardous road sections or implementating road safety audits (Lithuanian ... 2011).

In office analyses are carried out pursuant to "Procedures for Road Safety Inspection", however, the below information shall be evaluated:

1. a description of the road section or juction:
   - which group;
   - groups safety level;
2. A reference to possible previous reports on the same road section (if there was any report made before).
3. The analysis of available accident reports (data of at least 3 **last** calendar years is used):

   - precise as possible location of the accident;
   - pictures and/or diagrams of the accident site;
   - date and hour of accident;
   - accident data such as accident type, collision type, vehicle and driver manoeuvre;
   - accident severity, including number of fatalities and injured persons;
   - characteristics of the persons involved such as age, sex, nationality, alcohol level, use of safety equipment or not;
   - data on the vehicles involved (type, age, country, safety equipment if any, date of last periodical technical check according to applicable legislation);
   - information on the road such as area type, road type, junction type including signalling, number of lanes, markings, road surface, lighting and weather conditions, speed limit, roadside obstacles;
   - whenever possible, information on the time elapsed between the time of the accident and the recording of the accident, or the arrival of the emergency services.

On-site observations

On-site observations of hazardous road sections or junctions are carried out pursuant to "Procedures for Road Safety Inspection".

Conclusions

Traffic accidents have to be registered continuously, but it is also important that information about traffic volume, road design and surrounding environment are maintained and updated all the time

because both traffic and roads change over time for example as a result of traffic safety engineering.

It is important that this information is updated, because it is used as input to the road classification, the division of the road system into road sections, in the making of accident prediction models and in the comparison of hazardous locations and safe locations or the normal accident pattern.

When a location is changed, it is also important to record when the reconstruction is made, because this information should be used in the comparison of different locations, calculation of the normal accident pattern and possibly in a before-after evaluation.

The general safety level changes over time. The accident prediction models should also be re-estimated continuously. It should not be done every year, but it is recommended that it be done in a 3 – 5 years cycle.

The updating is especially needed if the police recorded accidents in the accident database are supplemented with hospital recorded traffic accidents as recommended (Elvik 2007).

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